Distributed Renewable resources Exploitation in electric grids through Advanced heterarchical Management

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**ABSTRACT:**

This document describes the drivers for DREAM adoption and main scientific and practical barriers for DREAM framework development and implementation. There is an explanation on market and regulatory differences and relevant technological aspects. Finally, DREAM approach to overtake the identified barriers is described.

¹ PU = Public; PP = Restricted to other program participants (including the EC services); CO = Confidential, only for members of the Consortium (including the EC services); RE = Restricted to a group specified by the Consortium (including the EC services).
² R = Report; R+O = Report plus Other. Note: all “O” deliverables must be accompanied by a deliverable report.
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³ Refer to the DREAM Management Handbook for more details on the IR Process and roles of contributors.
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# TABLE OF CONTENTS

Executive Summary.......................................................................................................................... 5
List of Figures ........................................................................................................................................ 6
List of Tables ....................................................................................................................................... 6
List of acronyms / abbreviations used in this document.............................................................. 7
Glossary of terms used in this document ...................................................................................... 7

1. Introduction.............................................................................................................................. 8
   1.1 Public drivers .................................................................................................................... 8
   1.2 Economic drivers .......................................................................................................... 11
   1.3 Technical drivers ......................................................................................................... 14
   1.4 Perspectives and barriers .......................................................................................... 15
       1.4.1 Summary table .................................................................................................... 17

2 Prosumer motivation .................................................................................................................. 18
   2.1 Description of barrier ................................................................................................... 18
   2.2 State of the art and best practice learnings ................................................................. 20
   2.3 DREAM approach ....................................................................................................... 22

3 Heterogeneity of European energy markets / National regulation ............................................. 24
   3.1 Description of barrier ................................................................................................... 24
       3.1.1 Different distribution of DG/RES and regulation for smart grid infrastructure ...... 24
       3.1.2 Different taxes and electricity prices ...................................................................... 27
       3.1.3 Regulatory impediments for market actors ............................................................ 29
   3.2 State of the art and best practice learnings ................................................................. 30
   3.3 DREAM approach ....................................................................................................... 30

4 EU regulation ............................................................................................................................ 32
   4.1 Description of barrier ................................................................................................... 32
   4.2 State of the art and best practice learnings ................................................................. 33
   4.3 DREAM approach ....................................................................................................... 33

5 Insufficient possibilities for use and adoption of ICT ............................................................... 34
   5.1 Description of barrier ................................................................................................... 34
   5.2 State of the art and best practice learnings ................................................................. 34
       5.2.1 Consumer/producer/prosumer segment ............................................................. 34
       5.2.2 ICT for distribution system operation ................................................................. 35
       5.2.3 Smart metering .................................................................................................... 35
       5.2.4 The ICT-sector point of view ............................................................................. 36
**Executive Summary**

In this study on drivers and barriers for DREAM project, it is possible to find the description of the barriers, possible solutions and scientific advances and enablers for DREAM framework validation and implementation, describing the drivers to overcome the barriers detected. Social concern on energy costs, ecology and safety are expected to play a key role for public drivers to support new business models requiring more real time information on how the energy was produced and delivered. While economical and technical drivers are related to system stability and improving operation efficiency, which is expected to result on cost reduction for system operators.

![Figure 1-1 Top-down and distributed in-feed of electricity](image)

Another important role is played by public regulators and regional, national and EU governments. While analyzing the barriers detected, most of them are all related to motivation, technology and implantation.

In the case of prosumers and DSOs, motivation will be supported by the economical and ecological aspects. According to several studies, it is expected a general interest in new market options because of possible cost reduction, especially if they are considered green initiatives.

From DSO’s point of view, interests are focused in increasing renewable penetration preserving system stability, thus enabling demand response prosumers participation and providing flexibility.

Regarding market and regulation, existing heterogeneity is expected to be one of the most important barriers for DREAM framework implementation. Despite the effort for regulation convergence, it is still difficult to provide a single general solution, since this solutions will not only need to be flexible enough for scalability and different production and distribution scenarios, but also to satisfy local regulation. Taking into account long-term national and EU policy regardless of the existing regulatory environment and keeping in mind diverse EU scenarios and cooperation regulatory groups is needed for success.

Regarding technological barriers, existing infrastructures and proprietary solutions are delaying new ICT solutions making extensive use of ubiquitous information.
List of Figures

Figure 1-1 Top-down and distributed in-feed of electricity ................................................................. 5
Figure 1-1 Top-down and distributed in-feed of electricity ................................................................. 9
Figure 1-2 Energy dashboard for PowerMatchingCity phase 2 ........................................................... 11
Figure 1-3 Hydraulics system analogy of electricity markets ............................................................. 13
Figure 1-4 Real-time and loosely-coupled coordination ..................................................................... 14
Figure 2-1 Feed-in compensation in Germany 2012 – 2014 (Test.de) ................................................. 19
Figure 2-2 Customer decisions for demand-side management ............................................................ 20
Figure 2-3 Factors affecting customer decisions regarding demand response .................................. 20
Figure 3-1 Share of renewable energy in gross final energy consumption in 2012 - own figure, based on (Eurostat, 2014) ........................................................................................................... 24
Figure 3-2 Share of renewable energy in electricity in 2012 - own figure, based on (Eurostat, 2014) .. 25
Figure 3-3 Smart-metering CBA outcomes and roll-out plans as of July 2013 (EC 2014b) ............... 26
Figure 3-4 Summary of deployment arrangements for electricity smart metering (own figure, based on EC 2014b) ......................................................................................................................... 27
Figure 3-5 Household electricity prices (2nd semester 2012, including taxes) (EC 2013) .............. 28
Figure 3-6 Demand response in today’s market design (ex. Germany). Source Entelios (SEDC, 2013) 29
Figure 3-7 Demand Response in today’s market design (under experimentation, ex. Germany). Source: Energy Pool (SEDC, 2013) ..................................................................................................................... 30
Figure 3-8 Demand response in today’s market design (ex. UK). Source: Enernoc (SEDC, 2013) ......... 30
Figure 6-1 Business Model Canvas overview; following (Osterwalder & Pigneur, 2010) .............. 43
Figure 7-1 ICT vs SCADA CIA pyramid priority comparison (INTECO, 2012) ....................................... 47
Figure 8-1 Current market design of energy value chain including interactions ............................... 50
Figure 8-2 DREAM market design of the energy supply chain including interactions ..................... 51

List of Tables

Table 1-1 Acronims ................................................................................................................................... 7
Table 1-2 Glossary of terms ...................................................................................................................... 7
Table 1-1 Summary table ......................................................................................................................... 17
Table 8-1 Explanation of interactions in electricity markets ................................................................. 53
List of acronyms / abbreviations used in this document

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT</td>
<td>Information and Communication Technologies</td>
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<td>Distribution System Operator</td>
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<td>TSO</td>
<td>Transmission System Operator</td>
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<td>IoT</td>
<td>Internet of Things</td>
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<td>DDS</td>
<td>Data Distribution Service</td>
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<td>OMG</td>
<td>Object Management Group</td>
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<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
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<td>OPEX</td>
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<td>ESCo</td>
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</tbody>
</table>

Table 1-1 Acronyms

Glossary of terms used in this document

<table>
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<tr>
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</tr>
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<tbody>
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<td>Aggregator</td>
<td>A professional broker who acts as a commercial entity, aggregating flexibility of the prosumers and DERs and selling the aggregated flexibility to the highest possible bidder on the electricity markets</td>
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<tr>
<td>Internet of Things</td>
<td>Interconnection of uniquely identifiable electronic devices in an internet-like structure as basis for automation in a plethora of fields, especially enabling advanced applications like a Smart Grid.</td>
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Table 1-2 Glossary of terms
1. Introduction

Active and intelligent energy infrastructures empowered by ICT, fit in new ‘holistic’ whole system approaches for designing and developing new infrastructures like smart cities. In these concepts, ubiquitous information and communication technology assists the inhabitants and, so, also the producers and consumers of energy, to configure their energy management systems depending on their individual comfort, cost and renewability preferences. They also can join forces with other users to reach common objectives forming virtual communities using social networks empowered by ICT.

Apart from these longer term developments, already now, these developments play a role for the electricity infrastructure and especially for the distribution networks. Already now, the introduction of DG-RES and electrification of HVAC as an energy efficient way for heating and cooling well-insulated houses in certain ‘hotspot’-regions in Europe drives distribution system operators to the limit to keep their grids stable. Examples of this situation emerging can be found in Germany and Spain.

On the national scale, high levels of DG-RES can be seen to be disruptive to existing electricity markets. Future electric mobility, with highly simultaneous loads at peak hours in the network, is also expected to add to the demand for intelligent coordination on the DSO and market level. In the following sections the drivers for the public, economic and technical perspective and the required scientific developments are discussed.

1.1 Public drivers

In nearly all countries of the European Union the fraction of nuclear electricity production is diminishing due to phase-out of nuclear power plants after the Fukushima incident. Climate change and environmental concerns on emissions lead to an increasing concern on the effects of the application of gas or coal-fired carbon-rich emissions of electrical production facilities. Finally, fuel prices have increased during the last decade and geopolitical developments no longer guarantee a long term secured supply of energy. These factors lead to higher costs for the total energy supply with a concomitant societal desire for less environmental effects of energy production. The EU has defined an upgrade of the 20-20-20 strategy; most countries are currently in line with these projected targets. On the levels of government, individual countries, regions and of municipalities, additional sub-targets are set to increase the proportion of renewable energy resources for carbon dioxide emission reduction in the design and operational phase of building areas, building refurbishment and energy consuming processes and installations.

In the realisation process of the 2020 targets, the last decade has seen the advent of renewable electricity resources like wind turbines and solar electricity. More energy efficient energy usage through electrification by substitution of traditional fossil fuels in mobility (EV with electricity storage) and heating/cooling systems using electricity lead to an increase in the interest and engagement of the general public. Distributed generation, especially wind and CHP in countries like Denmark and the Netherlands, has been around since the end of the 1980s. Distributed generation now also has
protruded to the LV-levels significantly. Also in other countries, electricity as an energy carrier no longer is solely produced centrally and fed-in at the HV-level but also fed-in from the MV and increasingly from the LV grids.

![Diagram](image.png)

**Figure 1-1** Top-down and distributed in-feed of electricity

**Figure 1-1** illustrates the top-down in-feed and the bidirectional power flows leading to more heterogeneous distribution networks and partly non-monitored power flows in the LV-networks out-of-reach of the monitoring tools of the DSOs. Apart from investors in large generation capacity, traditional consumers and retail customers have invested in the electric power generation infrastructure. Average end customer price (net system price) for rooftop PV solar systems with rated power of up to 10 kWp have steadily decreased to values close to 1 Euro/Wp (Wirth, 2014). The 20-year guaranteed feed-in tariff for households in Germany in 2006 amounted to 54 ct/kWh and has decreased sharply to 18 ct/kWh in 2013, while the retail electricity price has increased from 18 to 28 ct/kWh in the same period in Germany, as the feed-in tariff is paid from an increment to the distribution tariff. A result of this development is that the electrical utility sector, after restructuring during liberalisation, is in the process of additional restructuring to satisfy these new requirements. This pertains to the generation side, where profit margins are decreasing, to the distribution side, where power system stability is at stake and asset investment schemes have to be made more malleable to tackle shorter investment horizons,
and to the retailers, that have to serve their customer with energy services outreaching the kWh-commodity.

Legislation for the electricity sector is currently driven by the important role electricity systems play in society. Long-term and short-term security of supply and quality-of-service have been the important parameters for defining regulation. Clear responsibilities of actors in the value chain are defined and non-discrimination is a pre-requisite; every producer and consumer has to be offered a connection on the same conditions. In most European countries, DSOs are not allowed to directly control loads or generation from the customer side. Small producers are not allowed to trade their generated electricity directly to others. Generally, electricity commodity tariffs per kWh, distribution charges and taxes increase with the total consumption of customers decreasing. Finally, governments tax energy and electricity at some delivery point. Distribution tariffs are mostly based on the highest load, the leftmost point of the load-duration curve, during a year, not taking into account energy transport components. The tariff classes mostly are optimized to diminish the number of these capacity steps.

The first experimental demand response mechanisms based on offering power control capabilities by small customers, where reserve power (demand or supply) is offered during a certain period, are currently in the evaluation phase (ELIA, 2014). The ownership of the energy in these mechanisms is not yet settled; energy consumption or production capacity is provided but only called upon at a certain statistical probability. Generally speaking, the mapping of market operation and distribution grid operation to the final financial cost of energy for end-users is based on the high level centralized model and on an aggregated approach treating all customer types and grid configurations equally.

Bringing in the DSO in the coordination loop and involving the flexibility in demand and supply requires a more accurate real-world mapping of the individual actors and redesigning the policy, institutional, allocation and technical models of the electricity system as a whole in a societal context (Hakvoort & Huijgen, 2012). Dispatch of production according to the merit order has to take into account local distribution network utilisation. The network operator no longer follows and facilitates the market, but operates active distribution grids including flexibility. In the implementation of European energy efficiency directives article 15.8 (ACER, 2014), these policy guidelines are contained to match these requirements with respect to the role of demand side resources in the distribution network and on the market. Suppliers and demanders become more active in this approach and supply and demand flexibility is assigned an important role. A yearly settlement of electricity usage via a bill based on two readings then will be replaced by more frequent bills based on multiple micro-transactions. The settlement will be based not only looking at what energy was consumed or produced as a function of time, but also on time dependent capacity tariffs and verification of requested responses by system operators and capability payments. The application of information and communication technology plays a key role in improving this mapping by providing the next generation of smart meters enabling this functionality and enabling these service models and services.

For parts of the small and commercial customer segment of retail electricity segment, the electricity commodity electricity is changing from a dissatisfier to an element, that is part of a lifestyle. Utility
companies in a number of companies in Europe (Greeniant, 2014) and the US (OPOWER, 2014) now offer sets of energy gadgets and tools to monitor and control the energy and electricity usage.

![Energy dashboard for PowerMatchingCity phase 2](image)

**Figure 1-2 Energy dashboard for PowerMatchingCity phase 2**

In Figure 1-2 the energy dashboard as it is currently used by the households involved in the PowerMatchingCity-2 field test (PowerMatchingCity, 2014) is shown. The dashboard shows a total time-dependent energy picture also from individual devices including a gas fired heating systems.

### 1.2 Economic drivers

In value creation of electrical energy production several stakeholders are involved. Dependent on the electricity market design and the division of tasks and responsibilities by the regulator, the value of more intelligent usage of electricity has to be explicitly shared. Societal cost-benefit analyses for this multi-stakeholder system have been performed (CEDelft, 2012) showing positive business cases for Smart Grids. As already indicated, integration of the energy and electricity infrastructure in design and planning of Smart Cities is one of the key features in the future energy system. The integration leads to a shift of the total life cycle costs of energy from the OPEX to the CAPEX expenditures. This trend is leading to energy performance contracting of these infrastructures instead of an emphasis on energy cost contracting. The time horizon for the CAPEX expenditures also increases. The banking sector is now in the process to derive financial products for this changed setting.

From an energy sales perspective traditional B2B and retail customers segments are evolving to ‘prosumers’ with bidirectional energy flows. kWhs are no longer a commodity but also means for a retailer for attracting new types of customers and offering value-added services. For large generators and consumers, it is possible to map and adjust the behaviour of the primary process consuming
electricity to the market and grid events. Feedback and incentives based on real-time management of the portfolio position can be directly exerted. For smaller users the mapping of market actions now is via aggregation of supply and demand in fixed profiles, characteristic for a certain consumer category. Final settlements are based on a yearly meter reading even with the advent of smart meters currently occurring in Europe. With the advent of renewable energy resources and electricity based HVAC and EV-loads sometimes more than doubling or near-nullifying the electricity consumption, these consumer category averaged profile-based methods for reconciliation, are difficult to sustain. Smart meters were initially intended to automate the meter reading process and to enable utility companies to send more frequent feedback on the energy usage. Current smart meters, sampling at PTU intervals, enable the kWh-realisation pattern in time to be used for reconciliation. Data transfer of the smart meter data series (typically 96 readings per day for four registered values) takes place irregularly to minimize cost of the communication infrastructure. One step further is to use the output ports of the smart meter to read-out real-time realisations; with modern meters these are made available on the second scale. The measured individual patterns can be fed in to the home energy management system, which is then able to forecast the electricity consumption for the time periods used in operation of the market. By individualizing the forecast and not only taking the time dependent price, but also the deviation of the realisations from the forecast as measure for reconciliation, proper incentives to small customers can be given. This smart meter allocation mechanism currently is introduced in Finland.

From a wholesale supply-side perspective, electricity generation companies, owning large power plants, have to compete with subsidized, priority in-feed of DG-RES of traditional consumers investing in distributed or dispersed electricity production systems. In several European countries this has led to lower electricity prices, a lower number of production hours for facilities and lower profit margins. Balance Responsible Parties and wholesale electricity traders trade each kWh delivered. Finally the original produced kWh changes 2 to 3 times owner as compared to the initial planning phase of production. Trade continues until the last quarter of an hour before delivery. The mechanism of matching supply and demand analogous like a hydraulic system is depicted in Figure 13.
Traders base their strategy on historic and real-time information on supply and demand in their portfolio. Information on real-time supply and demand matching, aggregated at the right level, is of prime importance for traders. Apart from wholesale markets, participation of more types of users in imbalance and spinning reserve markets is expected.

From the power (kW) perspective, transmission and distribution system operators are obliged to embed the distributed and dispersed ‘negative’ demand in a power system originally designed for top-down distribution of electricity. In view of the increase in the future overall and peak demand and the uncertainty in DG-RES supply over the day as well as from a planning perspective over the next years, this asset management driven sector, traditionally having investment horizons over 30 years, needs more malleable investment horizons. Furthermore, security-of-supply and stability are important key performance indicators in the distribution sector. Monitoring and metering infrastructures extend to the MV-LV level via SCADA systems; There is no information as to the LV power flows e.g. from local producers to consumers in the same LV segment leading to cable overloads; furthermore short-circuiting paths and fault-detection with local small generation systems may provide problems.

From a commercial and end-user consumer perspective, having own production facilities increases the awareness on energy and electricity usage. This awareness is increased by modern ICT systems, giving instantaneous feedback on the energy efficiency performance. ICT also allows joining forces with other prosumers to increase the value of aggregated production and aggregated information. In the commercial large user segment, the added value of aggregating and of sharing information already is used extensively. An example in the Netherlands is combining the sum of the generation pattern of a
number of wind parks across the country in a portfolio to decrease the deviation from the forecasted pattern of such a total portfolio. Between near real-time coordination and yearly reconciliation, ICT enables more close to real-time feedback mechanisms as depicted in Figure 1-4 and new market designs.

![Figure 1-4 Real-time and loosely-coupled coordination](image)

A real-time layer is used to coordinate supply and demand following forecasted production and consumption in the portfolio; a delayed loosely coupled ICT-layer enables adjustment and shorter cycle billing, reconciliation and updating incentives to steer demand and supply aggregates using virtual power plants.

### 1.3 Technical drivers

As already stated, massive introduction of small generation systems and new electrified energy consumption processes lead to a need for DSOs to get more information about what is happening in their distribution systems. The level to which the grids are monitored at the SCADA-level is expected to go one level deeper. Data storage and handling is expected to become a bottle neck for advanced added value services, since current SCADA, EMS and DMS systems were not designed for such a big amount of real time data. Currently, most EMS and DMS are proprietary and also the communication channels use wired, proprietary infrastructures of the DSOs using IEEE and IEC standards within their RTUs. Existing communication infrastructures and protocols used will also need to be updated, since they could also collapse under the new management circumstances.
Apart from centralized control approaches, agent-based coordination and control algorithms are currently increasingly used. Topologies, where message exchanges take place are hierarchic, peer-to-peer and publish-subscription mechanisms, allowing for hybrid implementations of control logic. These types of dynamic federations and emergent aggregation are also used extensively in modern ICT and internet protocols.

1.4 Perspectives and barriers

Resuming, scientific research how to realize smart power systems according to the requirements for the new infrastructures, new markets and the new types of users has to be formulated. The flexibility of design and usage of infrastructure components has to be increased. A higher response to realize the dynamics of the system from an asset management and an operational perspective has to be realized. Market mechanisms suitable for also realizing active and incentivising participation of DG-RES in energy systems are necessary. In these market mechanisms reconciliation and billing mechanisms for simultaneously serving the market and also grid-friendliness are mandatory. The coordination mechanism should be changeable on-the-fly depending on the current status of the network. The role of the consumers/producers has to be automated as much as possible according to their individual preferences. ICT and data collected should increase the awareness of individual appliances on total network operation. Distribution of these data is not only required for DSO-operation but also for the other stakeholders to be used for evaluation of VPP-operation and forecasting. In this way direct coordination of Virtual Power Plants as services to satisfy grid objectives comes within reach.

In this chapter barriers for work package 2 (“DREAM energy distribution marketplace”) of the DREAM project are outlined. This section briefly introduces the six barriers that will be described in greater detail according to a common structure in the following sections.

(1) An important change in the European energy markets is the increasing number of prosumers. But there is still a vast number of consumers, who could generate energy and provide it to the market or could consume power in a flexible way, but are not willing and planning to do it. This is a barrier for the DREAM approach, which has to be addressed first. An increasing number of energy prosumers is a big driver for bringing smart grid concepts and technologies into the markets. They are the main means to ensure stability and flexibility of the European energy grids.

(2) The second barrier is related to the diversity of national regulations and laws of the European states. This includes the different taxes on retail electricity prices within the member states. Different market designs and market role characteristics make an implementation of a Europe-wide new market model and energy grid administration very difficult. Within the DREAM approach, the barrier of heterogeneity of the European markets has to be taken into account to enable an implementation of new solutions.

(3) Besides national regulation, the DREAM approach also has to be aware of the regulations and guidelines originating from pan-European level, which will be developed in the next years by the European Agency for the Cooperation of Energy Regulators (ACER). The background is
that the work of ACER could lead into new barriers which may prevent implementations of new smart grid approaches like DREAM.

(4) Next to regulatory barriers the insufficient use of modern (IT) technology makes it hard to implement a new energy grid and energy market solutions. This situation can be found in every European state and is not limited to some regions and countries. Especially DSOs have a big potential to implement and use modern technologies. Therefore, this barrier is a constraint and has to be addressed within the DREAM project. Without a better acceptance of modern – mostly computer and IT – technologies, new active and intelligent energy infrastructures will be hard to manage. This situation is not new and the costs of updating the IT infrastructure are rapidly increasing due to omissions in the past.

(5) Furthermore, it is difficult to determine the viability of the various electricity market actors’ (DSO, TSO, consumers, ESCO) business models due to the abundance of design options and influencing factors between them. The barrier here is to evaluate the economic viability in an easily comprehensible manner due to the large number of options and influencing factors. For instance, it is hard to assess the business model of one actor without considering the other electricity market actors. At least, the influential factors have to be identified and suitable assumptions about these factors have to be made. These issues have to be addressed within DREAM because the illustration of business model practicality is necessary to promote Europe-wide implementation.

(6) A new approach for smart energy grids requires also new solutions/concepts for system security and cyber security to prevent a system manipulation and disturbance to any IT and physical related issues and influence initiated by a third party. Also data privacy has to be considered by any new approach. Both should also lead to a new regulation, which defines the security and privacy level for all actors, their systems and the energy market in general. Security and privacy are very important, but should not influence negatively the new market approach and the usability.

In summary, work package 2 of the DREAM project will focus on addressing barriers, which currently complicate a Europe-wide implementation of new smart grid approaches. These include the heterogeneity of national regulations and laws besides the reluctance towards modern technology adoption and the current economic viability of the new approaches.

Limited predictability of power generation and dealing with this situation on electricity markets is another barrier. Prediction of power generation is more and more difficult because of increasing amounts of renewable energy fed into power grids. In this context also transient peaks in distribution energy may occur that lead to energy losses. Energy losses could be compensated by making available energy storages within power grids for short time storage of energy. DREAM will not solve the problem of renewable energy predictability per se, but proposes a near real time marketplace that enables market actors to react to unforeseen deviations from forecasts and ensure grid stability. This issue is covered in work package 4 (“real time operation of distribution grid”).

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### 1.4.1 Summary table

<table>
<thead>
<tr>
<th>Barrier Name</th>
<th>Short Description</th>
<th>Chapter</th>
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<td>Challenges in incentivizing consumers to become prosumers.</td>
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<tr>
<td>Heterogeneity of European markets</td>
<td>Different national regulation within the EU member states.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>• Different distribution of DG/RES and regulation for smart grid infrastructure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Different taxes for the energy market within the EU member states.</td>
<td></td>
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<tr>
<td></td>
<td>• Different market design and different market role assignments within the EU member states.</td>
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</tr>
<tr>
<td>EU regulation</td>
<td>EU regulation and planned EU regulations</td>
<td>4</td>
</tr>
<tr>
<td>Insufficient use of modern technology</td>
<td>Lagging awareness of modern technologies in energy markets.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>• Lagging modern technologies adoption in energy market.</td>
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<tr>
<td></td>
<td>• Reluctance of adopting new technologies especially by DSOs.</td>
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<tr>
<td></td>
<td>• Costs of required ICT infrastructure</td>
<td></td>
</tr>
<tr>
<td>DSO motivation and economic viability</td>
<td>It is difficult to determine business models for DSOs and assess their economic viability due to the large amounts of design options and influencing factors between electricity market actors (DSO, TSO, consumers, ESCO, etc.).</td>
<td>6</td>
</tr>
<tr>
<td>Security and Privacy</td>
<td>New solutions for system security and cyber security besides data privacy have to be part of the DREAM approach</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 1-1 Summary table
2 Prosumer motivation

2.1 Description of barrier

One barrier for widespread diffusion of smart grid solutions in the distribution market is the lacking motivation of consumers to participate in such initiatives (given that the proposed smart grid solution is not enacted by regulators). As DREAM assumes the existence of "energy boxes" (extended smart metering devices that manage all communication between the customer’s manageable load, storage, and production devices and the aggregator) in all households, the question of how to implement these boxes and encourage customers to become prosumers is central to DREAM’s success. Besides the smart meters, DREAM and the EU energy directives build on growing adoption of distributed energy resources, which require substantial prosumer motivation to invest as well. The barrier has both economic as well as social aspects. The main problems that equally apply to smart metering and DER investments are that customers fail to see the advantages of the smart grid initiatives, fear of comfort loss, and privacy concerns (in case of smart metering).

On the other hand, studies about consumer motivation regarding private smart grid activities (to use smart meters or to invest in renewables) show that a bundle of motives are relevant that can positively influence customers to participate (Stamminger & Anstett, 2013). The three main motives are:

1) To reduce the electricity bill and earn money
2) To become energy-self-sufficient
3) To act environmentally friendly

Personal preferences and regulatory circumstances determine which motive is most important to which consumer. Despite the importance from an overall societal and economical perspective, consumers do not think they should play a role in ensuring grid expansion or stability of service and are therefore not willing to pay more to ensure this kind of service.

Regarding 1), two important influencing factors are consumer electricity prices as well as smart grid devices purchasing prices, which tend to be highly volatile due to regulatory developments and technical advances. The example of Germany shows how fast the regulatory environment can shift dimensions of monetary incentives to participate in renewables. As shown in Figure 2 1, German feed-in compensation was almost cut in half over the last two years, clearly reducing the attractiveness for end consumers to invest in DG/RES such as solar arrays. Considering that private business cases on solar array investments will plan to depreciate the investments over a time horizon of several years up to two decades, such unforeseen policy shifts can render investments economically infeasible. This increases the importance of the intangible motives (self-sufficiency and a “green energy” contribution) for smart grid participants.
The consumer’s decision for participating in flexibility programs is made in two stages (Figure 2-2): the decision of whether or not to sign up for a voluntary program or tariff precedes the decision of whether or not to respond to events or to adjust the energy consumption in response to price signals (Energy, February 2006).

Consumer’s behavior at each decision stage is greatly affected and determined by a variety of factors (Figure 2-3). The decision of the first stage is based on the evaluation of the expected benefits accruing from participating in such programs. After enrolling to such programs, implementation of DR strategies is dependent on the actual measurable benefits from the incentive payment offered, on the availability of the load, on the duration of the event, on the valuation given to the discomfort posed by the DR strategy, on opportunity costs, etc.

It is to be expected that uncertainty in any form will discourage the customers from participating in such programs, since it involves high risks, posing a significant hindrance in the widespread adoption and implementation of load response strategies.

Furthermore, lack of customer education and engagement affects the customers’ decisions. (FERC, October 2013)
2.2 State of the art and best practice learnings

Existing smart grid initiatives and research studies all over the world offer insights on solutions to the prosumer motivation problem. Focusing on the smart meter adoption aspect, research on recruitment incentives shows that "opt-out" framed participation contracts are more likely to motivate prosumers to participate in smart grid initiatives (such as the instalment of smart meters) than "opt-in" contracts (Bremdal, 2013). This means that consumers are more likely to accept a smart meter installation if this is presented as the default choice. Studies also show that an emphasis on the societal and environmental benefits of smart grid initiatives may have a positive impact on consumer willingness to participate, which is in line with participation motives 2) and 3).
Generally, customer acceptance and trust should be gained by making the smart meter’s data collection and additional functions explicit. It must be made clear that smart meter data will not be used by unauthorized bodies and not for any purposes other than agreed with the customer, because such concerns may prevent smart meter adoption. In contrast, the advantages from smart metering for customers should be emphasized. The European Smart Metering Alliance (ESMA) assembled a list of smart metering advantages for customers which is reproduced here (ESMA, 2010):

- The end of estimated bills: the benefit of more frequent bills based on real consumption and without waiting for a meter reader, will certainly appeal to most consumers’ imagination. On the other hand, accurate bills mean that energy costs can also rise strongly in certain periods of the year, which could be hard to bear for the most disadvantaged in society.
- The provision of historical data on bills to show how energy consumption compares with the same billing period of the previous year.
- The possibility to become more aware of household energy consumption and the ability to better manage energy consumption, resulting in savings on energy bills.
- The ability to switch more easily between energy suppliers.
- The ability to adapt energy consumption patterns to take advantage of time of use tariffs and hence lower costs.
- The ability to install micro generation measures without new metering arrangements.

A study conducted by the University of St. Gallen with about 500 participants in the DACH region (Germany, Switzerland, Austria) in 2011 assessed consumer opinions regarding smart metering. They found that about 40% of the respondents can be regarded as “Supporters” of smart metering, believing that the advantages clearly outweigh the drawbacks. Roughly half of this group stated that they would be willing to pay for new smart metering equipment. About 30% of all respondents were classified as “Ambiguous”, meaning that benefits and concerns were roughly evaluated equal. Only about 25% of the respondents were “Skeptics” with dominating concerns (Curtius, Künzel, & Loock, 2012). A larger international study by IBM from 2008 found that slightly more than 20% of consumers are willing to become active and invest in better energy management (Valocchi, Juliano, & Schurr, 2009). These numbers show that there is a promising potential customer base for smart grid adoption, which needs to be motivated by the right means. Experience also shows that energy feedback can indeed lead to changed customer behavior resulting in reduced energy consumption at peak hours (Stamminger & Anstett, 2013). To make this happen energy feedback must be made available to the customer in useful intervals and in an easily understandable way.

Besides better customer information and user-friendly smart meters, regulatory means contribute to widespread smart meter and DER adoption. The European Directive 2006/32/EC holds that member states shall enable all consumers to have sufficient information about their actual energy usage to empower them to regulate their own energy consumption (European Parliament, 2006). This was confirmed in the newer Directive 2012/27/EU on energy efficiency (European Parliament, Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency,
amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC., 2012). Competitively priced smart meters shall be provided to consumers for this purpose, aiming at an adoption of at least 80% of consumers by 2020. Smart meters shall for example be built into all new buildings, whereas for other buildings implementation may be subject to technical and financial feasibility. The directive has been transferred to national law in most countries, which over time will naturally increase the number of smart meters available for new smart grid solutions like DREAM in the member states (for more information on smart meter roll-out, see the next chapter on the regulatory environment). Despite these regulatory efforts, the challenge remains to reach availability of smart meters with the desired functionality because more complex initiatives like DREAM need not only metering and communication functionalities, but also remote device management functionality.

Summarizing, evidence shows besides intrinsic customer motivation measures like information campaigns and advertising regarding DER and smart meter advantages, as well as regulatory efforts may help to increase consumer motivation to participate.

2.3 DREAM approach

In DREAM, the prosumer motivation barrier is relevant for two project phases: Firstly regarding prosumer recruitment for the DREAM field tests in the selected grid areas to ensure successful testing of the DREAM framework during the practical work packages, and secondly regarding the general motivation to participate in a DREAM-framework enabled scenario in real life in the long run.

As regards field test recruitment, DREAM faces the problem that hardly any benefits can be promised to consumers during initial tests. In the worst case, consumers may be forced to inject less electricity from their decentralized production devices than without DREAM interference, leading to lower feed-in revenues. This means that DREAM will mainly have to use non-monetary means to recruit prosumers. The planned strategy includes targeting prosumers with known attachment to the electricity system and “green energy”, which includes utility employees and customers with prior experience in smart grid initiatives which are expected to be more willing to participate. Due to limited project and technology maturity, customers cannot be “forced” to participate with an “opt-out” feature as suggested in the best practice section. If non-monetary arguments cannot convince a sufficient number of participants for the field tests, one DREAM participant suggested that participants could be compensated for lost revenues from potential less-than-optimal feed-in during the test phase, ensuring that they will not be worse off compared to the status quo.

Regarding the long-term realization of the DREAM concept, both monetary and non-monetary incentives are again relevant. Unless smart meters and the necessary management powers for DSOs are implemented extensively by law, consumers should be able to see real benefits from smart grid participation. It is thus the goal of DREAM’s future work to

- assess the magnitude of traded electricity on distribution level by the aggregation mechanisms and
- to evaluate possible business models for the actors
in order to determine DREAM’s potential value for consumers. Regarding monetary advantages, this will be practically assessed by an analysis of the different European countries’ electricity pricing levels. As explained above, consumers may also be financially compensated by DSOs for missed revenues in case of external interventions into their manageable devices in emergency situations, which will have to be evaluated further in future work on DREAM.

It is important to note that once this analysis has been conducted (given a positive result), there is a need for action from both regulators and DSOs to establish the required structures and offerings for consumers. This means that the barrier “prosumer motivation” does not only depend on convincing arguments for prosumers, but ultimately on the availability of attractive smart grid offers to give consumers a real choice to act, which need to be established by other actors. Similarly, a recent EURELECTRIC report notes that “the relevant signals for customer response are often missing: neither regulated retail prices nor largely volumetric network tariffs incentivize customers” (EURELECTRIC, 2013).
3 Heterogeneity of European energy markets / National regulation

3.1 Description of barrier

The European electricity markets are still shaped by national regulation. This section covers three aspects that are particularly relevant for the DREAM project:

1) Different Distribution of DG/RES and regulation for smart grid infrastructure
2) Different taxes and electricity prices
3) Regulatory impediments for market actors

3.1.1 Different distribution of DG/RES and regulation for smart grid infrastructure

The share of renewable energy sources differs across the European countries because of environmental policy and topography/geographical conditions. Similarly, smart grid infrastructure such as smart meters is also heterogeneously distributed across the markets. This is relevant for DREAM’s economic considerations because it complicates the assessment of the potential (and need) for aggregation in the distribution grid and the expected adoption in different countries. The following figures show the share of renewable energy and electricity and gross final energy consumption, respectively, of DREAM’s consortium participants in comparison to the EU 28 average.

Figure 3-1 Share of renewable energy in gross final energy consumption in 2012 - own figure, based on (Eurostat, 2014)
Share of renewable energy in electricity ranges from 10.5% in the Netherlands to 33.5% in Spain (top of the list lies Norway with 104.3%). These numbers give an indication of the size of the different markets targeted by DREAM. This heterogeneity is a potential barrier because countries are committed and able to develop towards more DG/RES to differing degrees.

The status of smart meter roll-outs, a critical prerequisite for DREAM, is summarized in recent reports from June 2014 from the European Commission (European Commission, Benchmarking smart metering deployment in the EU-27 with a focus on electricity, 2014)(European Commission, Cost-benefit analysis & state of play of smart metering deployment in the EU-27, 2014). The reports show the current progress of smart meter roll-outs in the member states and present the results of cost-benefit analyses (CBA) from all member states regarding smart metering. The Third Energy Package requires member states to ensure implementation of smart meters, but this implementation may be depending on a positive long-term CBA. About two thirds of the member states calculated positive CBAs (including France, Greece, Italy, Netherlands, and Spain), which will encourage increased roll-out speed in these markets until 2020 (European Commission, Benchmarking smart metering deployment in the EU-27 with a focus on electricity, 2014). Italy (together with Finland and Sweden) already has a close to 100% adoption rate, whereas most other countries plan to achieve a 80%-100% adoption rate by 2020. The results of the CBA and the resulting policy decisions are summarized in the following figure:
According to current estimations, smart metering systems will cost about 200 – 250 Euros on average per customer. Estimated costs per metering point range from below 100 Euros (Malta, Italy) to almost 800 Euros in the Czech Republic (European Commission, Benchmarking smart metering deployment in the EU-27 with a focus on electricity, 2014). Whereas these numbers are relatively encouraging, smart meter functionality is another critical point. A list of 10 minimum functional requirements for smart meters has been defined in the 2012/148/EU Recommendation, which are considered key for benefits realization for consumers and network operators (European Commission, Cost-benefit analysis & state of play of smart metering deployment in the EU-27, 2014). While these requirements do cover the main needs for DREAM, only very few member states have formalized these recommendations in legal guidelines for their national roll-out plans. It is therefore likely that not all functionalities will be available across the whole EU even when the 2020 roll-out goals are realized as planned.
Finally, smart meter roll-out responsibility is relevant for the DREAM economic assessment. The following table summarizes the planned responsibility of roll-outs in the DREAM consortium partners’ countries:

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</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>Regulated</td>
<td>Mandatory*</td>
<td>DSO*</td>
<td>DSO</td>
<td>N/A</td>
</tr>
<tr>
<td>Greece</td>
<td>Regulated</td>
<td>Mandatory</td>
<td>DSO</td>
<td>DSO</td>
<td>N/A</td>
</tr>
<tr>
<td>Italy</td>
<td>Regulated</td>
<td>Voluntary + Mandatory</td>
<td>DSO</td>
<td>DSO</td>
<td>DSO resources + network tariffs</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Regulated</td>
<td>Mandatory w/ opt-out</td>
<td>DSO</td>
<td>DSO</td>
<td>Network tariffs</td>
</tr>
<tr>
<td>Spain</td>
<td>Regulated</td>
<td>Mandatory</td>
<td>DSO</td>
<td>DSO</td>
<td>Network tariffs + SM rental</td>
</tr>
</tbody>
</table>

No wide-scale roll-out planned yet

| Germany                                                | Competitive     | N/A (no roll-out yet) | Meter Operator or DSO                         | Meter Operator or DSO                     | N/A                  |

*In France, meter ownership is retained by local municipalities, while DSO will operate them under a multi-annual concession. Furthermore, the ‘mandatory’ of the deployment applies to the DSO and not to the consumers.

Figure 3-4 Summary of deployment arrangements for electricity smart metering (own figure, based on EC 2014b)

Most countries (15 out of the 16 member states that proceed with the roll-out) view DSOs responsible for smart meter roll-out and plan a regulated metering market. In Germany, consumers should also be able to choose a meter operator instead of the DSO. Some countries (Denmark, Estonia, Poland, UK), provide for the possibility of a separate entity (a “central hub”) managing meter data in order to unbundle information management from device ownership (European Commission, Cost-benefit analysis & state of play of smart metering deployment in the EU-27, 2014). This model is attractive from a DREAM perspective because aggregation could be as well executed by a third party other than the DSO. Meter roll-out shall predominantly be financed via network tariffs. In Italy, where roll-out already took place, DSOs initiated the implementation and were able to recover incurred costs via a network tariff from 2004.

Summarizing, those aspects of national renewable energy market environments are prerequisite knowledge for reasonable economic assessments in DREAM. Although the general legislative commitment regarding smart metering deployment and renewables is encouraging, barriers to DREAM arise mainly from the complexity of varying electricity prices as well as smart adoption and functionality progress. This needs to be taken into account in DREAM’s economic analyses and may hinder viability of new business model suggestions.

3.1.2 Different taxes and electricity prices

The second main difficulty is the spread in electricity retail prices caused by “a range of different supply and demand conditions, including the geopolitical situation, import diversification, network costs, environmental protection costs, severe weather conditions, or levels of excise and taxation” (Eurostat,
The following figure shows the latest available data on retail electricity prices (including all taxes) in the EU for the second half of 2012.

Figure 3-5 Household electricity prices (2nd semester 2012, including taxes) (EC 2013)

This spread is largely caused by varying magnitudes of local taxes on energy. For example, in the UK, taxes account for 4.8% of the final retail price to household consumers, whereas in Denmark taxes and levies make up 57% of the final price (Eurostat, Share of renewable energy in gross final energy consumption., 2014). The large impact of taxes makes it extremely difficult to calculate the commercial attractiveness of any new kind of market mechanism that depends on retail prices for market parties across European countries. The magnitude of incentives to consumers which are derived from energy savings therefore vary across the markets. The DREAM focus must thus inevitably approach the question of industrial viability from a conceptual point of view, which should be valid for most markets, and then add country-specific considerations on a case-by-case basis, e.g. for DREAM’s technical test sites in the Netherlands, Spain, and Italy.

The large price differences are a major impediment for a realistic assessment of the economic viability of the DREAM framework and even for the evaluation for different actors’ business models. As the impact of the aggregated flexibility trade may only be very small for the executing actor, the question to be answered.
3.1.3 Regulatory impediments for market actors

Depending on national legislation, actors of the electricity grid have different rights and responsibilities. Whereas the core responsibilities for TSOs and DSOs, that is, operating the transmission and distribution system in given areas, respectively, are undisputed, subtle differences exist regarding the allocation of rights and responsibilities of DSOs and third parties like Suppliers, Retailers, or Aggregators. For DREAM, this is relevant when, for instance, third party Aggregators do not have access to wholesale markets or cannot get access to load profile data even if customers gave their consent (CEER, 2014), because this affects business model viability. On EU level, differences have been recognized and first recommendations have been given to open the energy market places for smaller players and to accommodate the changing requirements towards DSOs such as increased bilateral information flows with market partners (EC-TF SG, 2011).

Although first progress has certainly been made, especially Aggregators still face regulatory barriers in most European markets. For Demand Response (DR) to become successful, an Aggregator must be able to act in place of the customer and to market his aggregated pool of load as a single unit, which is not allowed in many member states. As explained by SEDC, fewer than 5 out of 27 EU member states have created regulatory and contractual structures that support aggregated DR. Those countries in formative stages of the process are Finland, Belgium, Austria, the UK, Ireland, and France (SEDC, 2013). The often complicated legal situation of Aggregators results in high overhead costs for contract negotiations that reduce Aggregator’s business model viability and create barriers for new market entrants. In Germany, for example, Aggregators must currently negotiate with six stakeholders before they can commercialize aggregated flexibilities. The following figures show Aggregator relationships in Germany, France, and the UK according to the current market designs.

Figure 3-6 Demand response in today’s market design (ex. Germany). Source Entelios (SEDC, 2013)
As long as these regulatory barriers on national level prevail, the momentum of distributed DR solutions like DREAM will remain limited.

### 3.2 State of the art and best practice learnings

_Not applicable for this barrier._

#### 3.3 DREAM approach

DREAM cannot directly influence those barriers stemming from regulatory differences while it is likely that they will prevail in the near future. To cope with them and achieve project success, the suggested approach is to be aware of those differences and explicitly state which assumptions will be taken for any economical (as well as technical) evaluation. This approach entails
• designing the DREAM framework and market mechanism in a “best possible way” that is desirable according to long-term national and EU policy regardless of the existing regulatory environment (meaning that existing barriers shall not limit solutions developed in DREAM, which instead fit more ambitious views of future electricity markets)
• presenting a number of realistic scenarios
• discussing the viability of results keeping the diverse EU situation in mind.

The goal is to make transparent for which type(s) of market the DREAM scenario is likely to be most valuable for member states and future research.
4 EU regulation

4.1 Description of barrier

The European electricity markets are not only shaped by national regulation (cf. section 3) but also underlie EU regulation. On 19th September 2007, the European Commission (EC) proposed the third package of legislative proposals for electricity and gas markets. The package was adopted by the European Parliament and the Council of the European Union in July 2009. The idea in European Union's third energy package is to establish a single market for gas & electricity.

As the EC states on its homepage, “progress has already been made: consumers can switch suppliers for gas and electricity, and suppliers must provide clear explanations of terms and conditions. Work still to be done includes aligning national market and network operation rules for gas and electricity as well as making cross-border investment in energy infrastructure easier.” (European Commission, Single market for gas & electricity).


1) Unbundling of energy production and supply interests
2) Installation of National Regulatory Authorities (NRAs) as independent market watchdogs for more effective regulatory oversight

Transmission networks are natural monopolies and therefore have to be regulated. To allow effective competition the Third Energy Package requires the TSOs to allow any electricity supplier non-discriminatory access to the transmission network to supply customers. The conditions of access to the networks are regulated by the NRAs.

An important prerequisite to not handicap third parties to access the transmission networks is the unbundling, i.e. the effective separation of activities of energy transmission from production and supply interests. There are three basic models for unbundling, where each member state can choose between one of three possible ways to unbundle (Ownership Unbundling (OU), Independent System Operator (ISO), Independent Transmission Operator (ITO)). Member States have to decide which one of them they want to transpose into national law. The unbundling rules had to be complied with by 3 March 2012. In case a transmission system is controlled by an entity from a Third country, the deadline for certification was 3rd March 2013.

One regulation of the third energy package established an Agency for the Cooperation of Energy Regulators (ACER) (European Parliament, 2009c). The purpose of the Agency includes the complementation and coordination of the work of national regulatory authorities (NRAs) and the participation in the creation of European network rules.

The Third Energy Package and its associated directives generally provide a promising environment for Smart Grid initiatives like DREAM. The energy efficiency directive also mentions new roles and responsibilities of market actors like DSOs and Aggregators, for instance in Article 15.8 regarding the...
encouragement of demand response providers (European Parliament, 2012): “Member States shall ensure that transmission system operators and distribution system operators, in meeting requirements for balancing and ancillary services, treat demand response providers, including aggregators, in a non-discriminatory manner, on the basis of their technical capabilities.”

However, as has been argued in the previous chapter, these provisions have not been overly successful in the member states as many barriers are still remaining. The Smart Energy Demand Coalition (SEDC) therefore demands from the EC to encourage member states more clearly to enable demand response and that “more clear and objective demand side targets” should be formulated (SEDC, 2013 p.7). The SEDC believes that for such targets to be realized on both national and European level “the Commission’s leadership will be essential” (SEDC, 2013, ibid).

Similarly, in a report from early 2014, EURELECTRIC calls for increased efforts from the European Commission to help accelerate the implementation of the Third Energy Package in the member states and to address areas that have so far not been sufficiently covered (EURELECTRIC, 2014). They stress that the energy market developments should occur in a cost-efficient and competitive manner, demanding a reduction of energy sector subsidies and regulated prices, which currently prohibit a fair EU-wide playing field. It can be argued that although the actual implementation naturally lies within the member states’ responsibility, the EC should perhaps be more precise in the implementation recommendations and focus not only on sketching ambitious goals for the new energy markets (the what), but also indicate which national regulatory decisions would run counter the overall targets (the how). The recent acceptance of the German revised Renewable Energies Directive (Federal Ministry for Economic Affairs and Energy, 2014) shows that this control mechanism is already in place, albeit with a success that is difficult to judge. Moreover, EURELECTRIC calls for a friendlier environment for innovation, in which investments should be driven by market signals instead of command and control.

Overall, DREAM is in accordance with several of the demands from EURELECTRIC, most notably in being a market-based framework that aims at empowering end users, DSOs, and new market partners to ensure security of service while at the same time promoting renewables.

4.2 State of the art and best practice learnings
Not applicable for this barrier.

4.3 DREAM approach
Conforming to approach described in chapter 3.
5 Insufficient possibilities for use and adoption of ICT

5.1 Description of barrier
Smart operation of electricity grids requires more active distribution grids. Distribution grids can be made more active, if they can consume or produce electricity in a more context aware fashion; e.g. an electricity consuming heat pump or an electric vehicle charging unit may sense a current or approaching congestion in the grid pre-emptively. The context awareness relates to perception of the current status of the grid from an electricity distribution perspective as well as from a market perspective. Agents, software programs interfaced to electricity demand and supply devices, operating in a distributed ICT network, can attribute to introducing the concept of more active distribution grids.
Life cycle periodicities of power systems components and ICT assets however are differing. From a distribution system perspective, investment decisions on ICT technology are relatively new as compared to investments in traditional power system components like cables and transformers. Also, DSOs, as owner of the most dependable infrastructure in society, focus on having proprietary communication and computing infrastructures, shielded from mainstream public communication networks.
From the larger consumer and producer segments there already is a lot of experience in applying ICT for intelligent electricity management. For the smaller consumer and producer (especially the prosumer) categories, the amount of possible ICT solutions, interfaces and technologies increases, but no technology is currently going to be mainstream to facilitate different energy management options.
As a critical public infrastructure with large revenue streams, accounted for by metering, security of operation and privacy in handling tax-comptable data are of high importance.

5.2 State of the art and best practice learnings

5.2.1 Consumer/producer/prosumer segment
Active and intelligent energy infrastructures empowered by ICT, fit in new ‘holistic’ whole system approaches for designing and developing new infrastructures like smart cities performing a key role in the projected energy transition from dependable geopolitically risk full to more local self-sufficient ecosystems. In these concepts, ubiquitous information and communication technology assists the inhabitants and, so, also the producers and consumers of energy, to configure their energy management systems depending on their individual comfort, cost and renewability preferences. They also can join forces with other users to reach common objectives forming virtual communities using social networks empowered by ICT. For parts of the small and commercial customer segment of the retail electricity segment, the electricity commodity electricity is changing from a dissatisfier to an element, which is part of a lifestyle. As it was mentioned in section 1, utility companies in a number of
companies in Europe (Greeniant, 2014) and the US (OPOWER, 2014) now offer sets of energy gadgets and tools to monitor and control the energy and electricity usage. Solutions can be realized with open-source off-the-shelf computing components and mainstream communication technologies. The first experimental demand response mechanisms based on offering power control capabilities by small customers, where reserve power (demand or supply) is offered during a certain period, are currently in the evaluation phase (ELIA, 2014). The ownership of the energy in these mechanisms is not yet settled; energy consumption or production capacity is provided but only called upon at a certain statistical probability. Generally speaking, the mapping of market operation and distribution grid operation to the final financial cost of energy for end-users is based on the high level centralized model and on an aggregated approach treating all customer types and grid configurations equally.

5.2.2 ICT for distribution system operation

The level to which the grids are monitored at the SCADA-level is expected to go one level deeper. Currently, traditional relational databases such as SQL are serving the needs of DSOs up to this level. Only DSOs use the information for monitoring and controlling at the MV-segment level for stable grid operation via SCADA. Some distribution companies already have large difficulties in managing and archiving the amount of data currently generated in SCADA-systems and are searching for a better alignment of their business processes to their ICT systems. Information systems like Energy Management Systems and Distribution Management Systems are mostly proprietary systems; also the communication channels use wired, DSO-owned infrastructures of the DSOs increasingly using IEEE and IEC standards within their RTUs; if wireless technology is used, mostly a dedicated shielded frequency band is reserved for private use. Part of the information system base in the power industry also still are using low frequency Power Line Communication for communicating control and measuring.

5.2.3 Smart metering

Telemetry and Smart Meter systems for customers typically only have one control signal to reduce the connection capacity or switch off customers in case of failing payments for electricity. Smart meters measure instantaneous power (kW) and integrate over a certain time period to get energy (kWh). For energy billing and reconciliation, this integration takes place typically on a 15 minute basis. Via special ports to the intelligent meter, integration readings up to 10 second time intervals can be realized for other purposes. Extending the scope of monitoring to the lower Voltage levels following a similar approach and using Smart Meters is beyond the reach of traditional database systems. These types of implementations would lead to a data storm (‘deluge’ or even a ‘tsunami’). Therefore, also initiated by Google, Amazon and Apple, alternative data storage approaches suitable for WEB-applications are to be used. In these techniques well-known collection framework classes like HashTables and SortedLists are implemented transparently in a distributed manner. So, apart from scalable intelligent coordination
perspective as well as from the scalable intelligent data storage a more distributed architecture is needed. Concluding, a bridge between the power sector specific ICT-systems available at higher Voltage levels and of the general purpose ICT systems has to be built. First RTUs using wireless technologies like WiFi are currently in development phase (Telvent, 2014).

5.2.4 The ICT-sector point of view

Mainstream ICT companies are more and more involved in the energy domain. After stopping the power meter initiative in 2011 (Google, 2011), Google still is trying to attain a position in energy management. Recently, in domestic settings, the company took over NEST (Google, 2014), a company designing intelligent thermostats and smoke detectors, for 3.2 billion dollar. Ubiquitous and pervasive information processing technology, since its inception in 1999 by Mark Weiser, has led to the development of the internet of things (IoT). The idea of IoT is to interconnect uniquely identifiable electronic devices in an internet-like structure. IoT refers to a wide variety of devices and protocols. This uncloses a broad range of application areas. The integration of different technologies to realize the concept of a smart power grid which is made up of networked embedded devices thus can be seen as an application of the IoT in the energy domain. In the IoT philosophy, the purpose of a computer is to help people by being a quiet, invisible servant. The more you can do by intuition the smarter you are able to operate; eventually, the computer should extend your unconscious. Technology should create calm. Using this technology, automating of energy efficiency and new energy management applications can be designed without placing end-users in the role of energy system operators of households.

There is quite a number of protocols and communication technologies that can potentially be used in IoT applications in the energy domain. For example, a comparison of wireless technologies is given in (Weyrich, Schmidt, & Ebert, 2014). Clearly, it does not make things easier if a plethora of different devices with different communication technologies and protocols want to be interconnected in the sense of IoT. Therefore, in the last time it can be observed that an increasing number of new IoT related standards is growing up (Networkworld, 2014). Although, it should be considered that smart grid operability can be allocated on different layers that can be grouped into technical, informational and organizational ones (NIST, 2010, p. 30). One example for an inter-process communication protocol that can be used in an IoT context is DDS (DDS, 2008), created by the Object Management Group (OMG); this standard now also is incorporated into Android, the operating system of most smartphones. Together with the OSG-I specification to connect to home gateways, a seamless integration with smart metering systems, smart devices and service applications is within reach. Within the EU, discussions have taken place on reserving part of the LTE-spectrum bandwidth for data communication serving critical infrastructures like the power sector; this would make satisfy the necessary required communication requirements. A similar broadband speed data collection infrastructure can be built on the basis of WiFi-hotspot networks. Currently, inverters of PV-systems are
connected to the Internet via a WiFi connection in the home and through a PC or a dedicated app give the owners feedback on the energy production.

Apart from centralized control approaches, agent-based coordination and control algorithms are currently increasingly used. Topologies, where message exchanges take place are hierarchic, peer-to-peer and twitter-like (with followers and optional retweets) allowing for hybrid implementations of control logic. These types of dynamic federations and emergent aggregation are also used extensively in bit-torrent like networks for fast data exchange.

5.3 DREAM approach

The DREAM packages target at realizing smart power systems according to the requirements for the new infrastructures, new markets and the new types of users in a possibly changing heterarchic context. The flexibility of design and usage of infrastructure components is increased within the DREAM framework. A higher response to realize the required dynamics of the power system from an asset management and an operational perspective then currently available can be realized. DREAM provides for a platform, that features a number of packages with each its own functionality. The granular and localized character of the DREAM framework allows the introduction of market mechanisms suitable for also realizing more localized and real-time active and incentivising participation of DG-RES in energy systems. In these market mechanisms for simultaneously serving the market and also grid-friendliness requirements are mandatory. The coordination mechanisms in DREAM are changeable on-the-fly depending on the current status of the electricity network. Via the agent mechanism DREAM allows the role of the consumers/producers to be automated as much as possible according to their individual preferences. ICT and data collected should increase the awareness of users for individual appliances on total network operation. Distribution of these data is not only required for DSO-operation but also for the other stakeholders to be used for evaluation of VPP-operation and forecasting. In this way direct coordination of Virtual Power Plants as services to satisfy grid objectives comes within reach. Due to the strong distributed nature of data storage the impact on security and privacy is more limited and responsibilities can be managed more easily.
### 6 DSO motivation

#### 6.1 Description of barrier

According to the article 2.6 of the electricity directive 2009/72/EC (European Parliament, 2009), a DSO is defined as “natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity”. Moreover, the DSO is responsible for regional grid access and grid stability, integration of renewables at the distribution level and regional load balancing, whereas the latter is done by a Balance Responsible Party in some countries (EC-TF SG, 2011).

These definitions already make obvious the fact that the activities done by DSOs and its interactions with the other participants of the electricity market are quite complex and in detail also differ between the single EU countries.

Looking at the Distribution System Operators (DSO) in context of their role in electricity markets, new challenges arise considering the current smart grid concepts and developments. The EU Commission Task Force for Smart Grids (EC-TF SG, 2011) has identified three key challenges for the DSOs:

- [C1] connecting additional generation from renewables
- [C2] enabling active demand/customer side participation in the market (this is also a key challenge for TSOs) and
- [C3] keeping the distribution grid stable and balanced by handling electric power flows in both directions

A central aspect regarding future developments of electricity grids and markets is the possibility of using flexibilities, which are enabled by [C2]. Grid users’ flexibility can be defined as “the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system. The parameters used to characterise flexibility include the amount of power modulation, the duration, the rate of change, the response time, the location etc.” (EURELECTRIC, 2014b).

Because from an economic perspective a DSO is a natural monopoly, distribution tariffs are regulated by the national regulatory authorities, who define or approve the level of tariffs and/or profits that distributors are allowed to set/make (EURELECTRIC, 2010). Besides keeping distribution grid stable and balanced (see [C3]), which is made more difficult because of increasing connection of renewables to the grid (see [C1]), the main motivation for the DSO to use flexibilities (which are enabled by [C2]) is the possibility of choosing a cheaper alternative than grid reinforcement: Buying flexibility services in hours of high load can be cheaper than upgrading highly loaded distributions grid feeders (Nordentoft, 2013). Consequently, to prove the viability of new business models for DSOs in the context of the challenges stated above it is necessary to show that the usage of flexibilities would help the DSO to

- avoid or delay distribution network reinforcement while
keeping the distribution grid stable and balanced.

**A barrier arises from the question** how to design new business models for DSOs and evaluate their economic viability on basis of new approaches developed in DREAM. It is difficult to determine business model viability for DSOs because of the plethora of design options and influencing factors between electricity market actors that affect the DSOs business model. The following questions make this clear:

- Which assumptions can be made regarding the flexibilities collected by an Aggregator⁸, i.e. to whom are the flexibilities sold?
- Which amount of flexibilities is sold to Day ahead/Intra-day markets and which amount is reserved for DSO to keep the distribution grid stable and balanced?
- What would be optimal solution for the business model of the Aggregator and what does this mean for the business model of the DSO?

These questions imply that it is hard to assess the business model of one actor without consideration of the other electricity market actors. At least, the influential factors have to be identified and suitable assumptions about these factors have to be made.

Another factor that is of paramount importance in proving the economic viability of flexibility initiatives is the exact valuation of the benefits and costs accruing from such services. Since these initiatives have at their core the modification of the behaviour of the consumers and the participating customers are remunerated according to the calculated changes from the baseline load, the selection of a truthful baseline load to be compared with the reshaped load curve is crucial.

Failure to establish an appropriate baseline curve may lead to undesirable situations in which either the consumers are over-compensated, thus leading to a negative evaluation of the initiative on the DSO’s side, or the consumers are not receiving enough compensation that would act as an incentive for participating, thus, leading to minor acceptance of the initiative on the consumers’ side.

### 6.2 State of the art and best practice learnings

For designing new business models for DSOs on basis of flexibilities it is crucial to identify the motivation of electricity market actors for using flexibilities and exploring how flexibilities can serve DSO’s demands. These aspects are treated in sections 6.2.1 and 6.2.2.

For evaluation of the economic viability of new business models it is interesting to look at methodologies that have been applied to perform cost-benefit analysis in the smart grid environment. This is covered in section 6.2.3.

#### 6.2.1 Motivation of electricity market actors for using flexibilities

If trade and usage of flexibilities shall be an element of the electricity market many actors will have to deal with this circumstance. It is not only important that advantages for the DSO can be identified but

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⁸ An Aggregator is a professional broker who acts as a commercial entity, aggregating flexibility of the prosumers and DERs and selling the aggregated flexibility to the highest possible bidder on the electricity markets.
also to identify motives for the other market actors to deal with flexibilities. Publications in this context agree on motivation factors that are summarized for the different electricity actors in the following.

**Consumer**
The consumer we know today more and more owns power generators like PV panels for his own use. From this arises the possibility to feed-out power to the electricity grid and by this means to become a prosumer. Moreover, consumers could flexibilize their power consumption shifting it to other day times (demand response). It may be expected that a consumer has no interest in time consuming active control of his consumption behaviour and may not have enough knowledge and interest in electricity markets. Therefore for consumers a professional broker would be of interest, i.e. an Aggregator that is able to sell consumers’ flexibility on electricity markets. Being paid by the amount of flexibilities delivered there is a clear motivation for consumers to sell their flexibilities.

**Balance Responsible Party (BRP)**
As a commercial actor the task of the BRP is to buy energy on electricity markets according to the estimated consumption profile of BRP’s customers, i.e. the market area the BRP is responsible for. The BRP can have the role of a supplier (retailer) who contracts with the end customers or act as wholesale supplier for the retailers. The BRPs could use flexibilities to lower imbalance risks by minimizing discrepancy between the traded energy volume and the real measured profile. I.e., flexibilities would allow the BRPs to perform balancing activities within the settlement period possibly by trading flexibilities on a new sort of near-realtime electricity market.

**Aggregator**
An Aggregator generates business by aggregating flexibilities of consumers and DERs and selling it to the highest possible bidder on electricity markets. By this means an Aggregator acts as a supplier by order of consumers and DERs.

**TSO**
One essential task of the TSO is to balance frequency and power in its transmission electricity grid. It is expected that power generation from renewables will grow and classical power generation amount will shrink. The latter will have a negative influence on the price of reserves supplied by the classical power generation units (coal, oil, gas) and therefore TSOs will have to fall back on flexibilities offered by Aggregators.

**DSO**
The motivation for the DSO is to buy flexibilities offered by the Aggregator in order to avoid or delay investments into electricity distribution grid infrastructure. This aspect is treated in more detail in the next section.

### 6.2.2 DSO demands

A first step in designing new business models for DSOs is to be aware of their demands and how flexibilities can be used to serve these demands. The following enumeration shows some ideas about how flexibilities can be useful for DSOs (Nordentoft, 2013), (EURELECTRIC, 2013b):
• **Flattening the electricity consumption curve** to delay distribution network reinforcement necessary due to regular electricity consumption growth
  - flexibility services can be used to disperse load consumption and by this reduce peak loads (distribution grid has to be dimensioned on basis of expected peak loads)

• **Reducing the reserve capacity** in the distribution grid without running into problems in emergency situations
  - flexibility services can be used to secure the delivery of reserve supply when needed

• **Reducing high power flows** caused by activation of regulating power for the TSO
  - for example, flexibility services can be used to lower the base load while delivering control power

• **Reducing high power flows** caused by low electricity prices: In the future it must be assumed that consumers increasingly want to participate in low electricity prices as they are known on before-hand (i.e., closed day ahead market trades) and therefore consumers are willing to align their behavior in a way so that they will place more consumption in the low price hours
  - flexibility services can be used to ensure that grid capacity is taken into consideration

• **Tackling voltage level issues** caused by DG connected to local distribution grid (European standard EN 50160 requires that voltage regulation be within ± 10% of the rated voltage under normal operating conditions): Voltage increase (overvoltage) is the most common issue at the connection point for DG units and the relevant grid area. The more local production exceeds local demand, the stronger the impact on voltage profiles.
  - flexibility services can be used to help the DSO to serve each customer with electrical power within the voltage-limits in a sufficiently cheap, reliable and easy to carry-out way

• **Avoiding congestions** caused by DG connected to local distribution grid: When flows exceed the existing maximum capacity this may result in interruptions of generation feed-in or supply
  - flexibility services can be used to avoid maximum capacity overload

### 6.2.3 Approaches for quantitative economic analysis in the field of smart grids

Within the frame of “EPRI Smart Grid Demonstration Initiative” the Electric Power Research Institute (EPRI) contributed diverse reports on Cost/Benefit Analysis in the Smart Grid area. Before developing an own “Guidebook for Cost/Benefit Analysis of Smart Grid Demonstration Projects” (EPRI, 2013) there has been done an extensive review of existing studies about smart grid benefits and approaches that define and categorize Smart Grid benefits. The results of this summary are documented in (EPRI, 2010), chapter 2.1 where the interested reader is referred to. On the way to the guidebook for Cost/Benefit Analyses mentioned above there was published also a report about an approach to estimate the investment requirements and the resultant benefits of a fully functioning smart grid (EPRI, 2011).
6.3 DREAM approach

The DREAM approach for evaluation of economic viability of new approaches developed in DREAM consists of the following steps:

1. For every main actor in current electricity market design (producer, TSO, DSO, consumer, BRP/supplier, trader) a description of his business model will be provided using the Business Model Canvas (Osterwalder & Pigneur, 2010) as a description template. This template allows looking at the actor’s business models in a holistic way, also treating interactions between electricity market actors. An overview regarding the Business Model Canvas is provided in Error! Source du renvoi introuvable..

2. By contrasting DREAM solutions and DSOs demands, flexibility products will be identified that could be offered to the DSO by other market actors/third parties (especially Aggregators). For example, a flexibility product for load management could comprise a contract between DSO and Aggregator, where it is defined that on basis of a trigger signal from the DSO the Aggregator reduces his load in order to avoid a congestion situation.

3. For every flexibility product it will be analyzed which resources and activities have to be contributed by the DSO himself that are necessary to use the product (i.e., typically the flexibility products will need local network knowledge and network control capabilities which have to be provided by the DSO)\(^9\). It is worth to note that both the flexibility products (step 2) and the resources and activities that have to be rendered by the DSO are on the DSO’s cost side when utilizing flexibilities.

4. Business models for DSO are designed on basis of the usage of flexibility products identified in step 2 and with respect to results of step 3. The description of business models will follow the Business Model Canvas already used in step 1. This allows highlighting the differences between DSOs business model today and the future situation. Additionally, because the usage of flexibility products will raise the necessity of new electricity market mechanisms, DSO’s business model description will be extended with a description of new electricity market mechanisms. The latter will give a sort of frame/environment for the business model of the DSO.

5. Most promising DSO business models will be selected for further quantitative analysis that focuses on the DSO as an actor in the new electricity market. Performing a quantitative analysis will require
   a. Selection of a concrete use case
   b. Deployment of assumptions regarding circumventing electricity market actors
   c. Assumptions regarding network tariff structure design

\(^9\) An example here is the distinction between commercial and technical aspects regarding a Virtual Power Plant (VPP): In the FENIX project these aspects are associated with roles of Commercial VPP (CVPP) and Technical VPP (TVPP) [8].
d. Creation of an economic model that allows the investigation of the selected DSO business model by instantiation and variation of parameters

To examine if there will be a benefit for the DSO in the new business model on basis of flexibilities, the fact will be stressed that a price-cap for flexibility services to be consumed by the DSO is naturally given by the alternative costs of distribution grid reinforcement.

6. Quantitative analysis will allow to assess the economic viability of DREAM solutions concerning the DSO. This assessment is in focus of the last step to be performed. From the lessons learned in steps 1 to 5 recommendations for further developments on DSO business models in context of the smart grid developments will also be derived.

Figure 6-1 Business Model Canvas overview; following (Osterwalder & Pigneur, 2010)
7 Security and privacy

7.1 Description of the barrier
Deployment of new ICT infrastructures and systems are key enablers to provide the users and system administrators with advanced services. These advanced services can provide accurate operation forecast and diagnosis making use of precise real time information on system processes. However, when system processes are related to persons, information processing will entail certain risks and constraints that must be taken into account from the very beginning phases of system design. Some of them will be related to data validation and system security and some other will be related to data owner rights and personal data protection.

Regarding critical infrastructures, system safety and security is one of the cornerstones of system design and operation. On the other hand, data breaches are costly to respond to and quickly erode customer trust while data protection regulators enforcing best practices for personal data protection (Treacy, 2008). Taking this into account will make data protection another relevant system design criteria in next future.

7.2 State of the art and best practice learnings

7.2.1 Safety & Security
One of the emerging risks linked to data acquisition spreading and proximity to individual user interaction is the increasing complexity of system stability control and management. Malicious users or failing devices could mislead the system to instability or wrong operation conditions that should be avoided.

European regulation

(European Commission, 2004) regarding Critical Infrastructure Protection in the fight against terrorism includes energy installations and networks in the definition of critical infrastructures, to be specially protected.

(European Parliament, 2008) on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection.

In this directive it is defined that the final responsibility for Critical Infrastructure protection relies in member States and infrastructure operators. And defines a list of duties and actions to be taken, and included in national regulation.

According to this regulation framework, different local regulations have been defined for this purpose.
Standardization

There are also several international reference organizations related to critical infrastructures such as the Centre for the Protection of National Infrastructure (CPNI) in the UK, the European Network and Information Security Agency (ENISA) and the National Institute of Standards and Technology (NIST) or the North American Electric Reliability Corporation (NERC).

These organizations provide guides and standards for different safety and security aspects such as ANSI/ISA-99, ANSI/ISA-100 and IEC 62351.

The application of security standards available for IT systems and Industrial Automation Control Systems would be mandatory from the very conception of the systems for the deployment of devices and global systems.

7.2.2 Personal Data protection

In general, any business which collects and processes information about consumers will, in data protection terms, be processing “personal data” and is likely to be subject to data protection laws (Treacy, 2008).

European regulation

Data protection laws exist in many countries with different points of view. In some countries they focus on the right to determine who may use personal data for commercial purposes; in other countries, the laws may incorporate the human rights concept of “privacy”, as well as rights to information self-determination. In the European Union, data protection laws form a comprehensive legal framework.

However, computing power and data storage and transfer volumes are growing very fast and many data protection laws are expected to need complete revision to reflect technology advances and global networks.

Although the laws of individual EU jurisdictions differ, they rely on the EU Data Protection Directive (EC/95/46) and the European Privacy and Electronic Communications Directive (EC 2002/58), which is currently under revision – with the aim to make it technologically neutral.

Some key definitions related to data protection terminology (Treacy, 2008):

- “Processing” includes obtaining, recording, storing, amending, retrieving, disclosing and destroying the data. Even calling data up on a computer screen constitutes “processing”. In fact, it is difficult to envisage any use of personal data which would not amount to “processing” under the Directive.
- “Personal data” is any information which relates to an identified or identifiable natural person. “Sensitive personal data” consists of special categories of data such as data relating to a person’s racial or ethnic origin, religious beliefs or health, which are subject to additional safeguards.
The Directive imposes obligations on “data controllers” who are the individuals or entities which determine the purposes for which and the manner in which personal data and for how long the data is being processed. These directives, in a general context, do not impose a minimum or maximum retention period for personal data, but they try to ensure that sensitive information is not kept once the activity for which their retention was authorized is finished.

The role of a data controller is distinct from that of a “data processor” which processes data in accordance with the instructions of a data controller. Unlike the controller, the data processor does not have any obligations under the Directive, but will (or should) have contractual obligations imposed on it by the data controller.

The directive contains a set of data protection principles such as to require that personal data are:
- “processed only for the purposes specified to the individual” and only before this authorization expires.
- “not retained unnecessarily”
- “processed securely”

Data controllers must ensure that every use or processing is done according to them, by minimising data collecting and processing to the minimum required, limiting purposes of use and establishing appropriate security measures.

Best practice learnings

According to these principles, restrictions or networks operators to some categories of data is likely to prevent the full realisation of the expected network benefits of smart grid (ENA, 2011), such as more efficient and cost-effective operation, carbon dioxide emissions reductions due to energy consumption awareness, better renewable generation integration and greater up taking of micro-generation.

In (ENA, 2011), there is a report on privacy impact due to smart metering data use in GB. This document considers the benefits delivered when using data from smart meters, defines what data is required for that, and describes possible impact and risks once the main stakeholders for this process were consulted, including consumer organisations and privacy groups, network operators, energy suppliers and other.

Concerning smart metering, the following data categories are considered to be needed for basic smart grid development according to this report.
- Active and Reactive Energy over half hour period.
- System Quality events, including half-hourly average of RMS value of the voltage, sags and swells detected and high or low voltage alarms.
- General events, such as unexpected loss of supply or any other event sometimes relating safety risks.
- Device configuration. Data showing how data acquisition devices are set up to measure the energy and how they should respond to particular events.
National or European regulation could prevent the complete development of Smart Grid functions due to data access or processing limitation.

Considering all the circumstances, it is considered that the aggregation of consumption or any other data related to consumer lifestyle or energy usage behaviour to levels where they cannot easily be attributable to an individual household. According to (ENA, 2011), initial stakeholder views are that grouping 10 or more households together would be sufficient to protect customers’ privacy. While network node-specific data such as network voltage levels and alarms are less sensitive in the sense that it conveys little information about consumer actions.

On the other hand, in the following diagram there is a comparison regarding CIA pyramid for typical ICT Systems and SCADAs. As it is shown, SCADAs, which are the typical solution for critical infrastructures operation control and monitoring have their own CIA pyramid, opposed to typical ICT systems, giving the maximum priority to system availability.

Figure 7-1 ICT vs SCADA CIA pyramid priority comparison (INTECO, 2012)

Regarding system architecture and data confidentiality, the needs for data aggregation and data collection minimisation, suggest the need of advanced or more intelligent devices for data generation, providing proper ICT style data management at the lower layers of data acquisition architecture.

### 7.3 DREAM approach

The DREAM approach for security and privacy could be described in two main aspects.

Regarding safety & security, DREAM solutions will make use of state of the art technologies and communication protocols, complying with the same security standards applied to standard control systems until the moment.

Acquired data will be processed and validated in order to ensure safe operation and the system will ask for DSO validation for every required operational change in the network. Regarding data manipulation or wrong acquisition, final solution validation will make sure that non fraudulent operations are carried out and modern and secure communication protocols will be used.

In terms of personal data protection, the flexibility provided by the heterarchical DREAM solution will be enough to adapt to available data for DREAM functions. All these functions will try to minimise non required data storage and will aggregate data when possible for statistical use or other inherently data storing functions to achieve personal data dissociation thus reducing or the time personal data is
retained in the system or even avoiding the use of this sensitive information, according to common personal data protection principles. Furthermore, data storage and systems will be protected with state of the art cryptographic functions complying with relevant standards in terms of IT systems security. Regarding data accessibility, the granularity provided by the heterarchical architecture will reduce personal data availability, since this kind of data can be immediately aggregated in the first node of acquisition and segregation will reduce the risk of big data leaks, which are much more probable and feasible under centralised acquisition systems.

On the other hand, implementing data protection policies in typical monitoring and control systems would have an impact in system availability, as it is shown in Figure 7 1.
8 Outlook on DREAM market design

8.1 Conceptual view on the new energy marketplace in DREAM: roles and interactions in the energy value chain

Most new concepts for demand response mechanisms follow the idea that in order to do this efficiently and in a market-oriented way, there is a need for a new “Aggregator” role in the market. This actor has both the resources and the incentives to bring “intelligence” to the distributed energy resources and offer their flexibilities, which have so far been unused, to other actors on the market. Although the approaches have this basic idea in common, the ways to implement it technically and commercially are different.

In DREAM, the so-called “Flexibility Aggregator” or in short “Aggregator” represents all the distributed resources connected to his portfolio on LV and/or MV levels. At this stage of the new market design, it is still open which legal entity(ies) will practically execute the role of the Aggregator. Three possible options would be an independent commercial entity, the DSO, or the electricity supplier/BRP, which will be evaluated in later project stages along with an analysis of the business models of the respective actors. Regardless of who will eventually impersonate the Aggregator, this role creates new interactions with the other market participants, which is illustrated in the following figures and explained in Table 1. These figures illustrate the changes in the market designs on a conceptual level. Thus, they do not aim to specify the nature of the commercial or commodity interactions or the time frames in which the interactions take place.

8.2 Current market design

The first figure shows the market participants in the current situation without demand response mechanisms and their basic interactions with each other and the energy markets. The DSO does not participate in the balancing market, because in the traditional market design balancing lies in the sole responsibility of the TSO. In this (already liberalized) market, independent suppliers source energy from the market and sell it to consumers. For the sake of simplicity, the “Supplier” and “BRP” roles are combined in one role because in reality they will often be united within a single market party. Theoretically, a supplier can of course delegate the BRP responsibility for his customers to another BRP, in which case he will no longer have a direct commercial interaction with the TSO, but instead with the BRP.

The interactions between the actors are explained in Figure 8-1
Figure 8-1 Current market design of energy value chain including interactions
8.3 New DREAM market design

Figure 8-2 DREAM market design of the energy supply chain including interactions

In this conceptual view on the new DREAM market design, the new actor “Aggregator” is introduced. The Consumer becomes a Prosumer and is assumed to possess manageable load, storage, and/or production devices. With the Aggregator’s participation in the market as mediator for flexibilities from Prosumers towards low voltage as well as higher grid levels, a new balancing market for the distribution level (involving DSOs and Aggregators) can be created next to the conventional balancing market with TSOs as core actor. Suppliers/BRPs can also acquire flexibilities for their own capacity planning and schedule optimization via the market from the Aggregator. The changed and new interactions in comparison to the original market design are also explained in
<table>
<thead>
<tr>
<th>No.</th>
<th>Interacting roles</th>
<th>Type of flow (E / C)</th>
<th><strong>Explanation valid for both scenarios when no difference exists, otherwise:</strong></th>
<th><strong>Explanation for current market design</strong></th>
<th><strong>Explanation for DREAM market design</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Producer – TSO</td>
<td>E</td>
<td>(Large) Power producer routes energy (kWh) to TSO as agreed upon in schedule.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TSO – DSO</td>
<td>E</td>
<td>TSO routes energy (kWh) from HV to MV/LV networks. Due to the growing amount of DC capacity, a local situation can occur in which supply exceeds demand. In this case, the surplus of electricity is fed upwards into the transmission grid, after which the TSO transports it to other distribution networks.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DSO – Consumer</td>
<td>E</td>
<td>DSO routes energy (kWh) on LV network to (small) Consumer.</td>
<td>DSO routes energy (kWh) on LV network to Prosumer. In turn, the prosumer may also provide energy to the grid.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TSO – Supplier/BRP</td>
<td>C</td>
<td>C: BRP tells TSO expected schedule in balance area. <em>Imbalance settlement after real time</em>: TSO charges BRP for imbalances.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Supplier/BRP – Consumer</td>
<td>C</td>
<td>C: Supplier sells energy (kWh) to Consumer.</td>
<td>Supplier sells energy (kWh) to prosumer. In turn, the Prosumer may also sell his energy to the Supplier.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Producer – Markets</td>
<td>C</td>
<td>Producer sells capacity (kW) via energy markets. This happens both on planning &amp; capacity allocation (wholesale) markets and – if required and if allowed to do so – on balancing market.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Trader – Markets</td>
<td>C</td>
<td>Trader trades capacity (kW) on planning &amp; capacity allocation market to profit from price variations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>TSO – Markets</td>
<td>C</td>
<td>TSO trades (buys and sells) energy (capacity) in the form of ancillary services on the balancing market to ensure real-time grid stability.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Supplier/BRP – Markets</td>
<td>C</td>
<td>BRP trades (buys and sells) energy (capacity) on energy markets. (a) Planning &amp; capacity allocation (wholesale) market: trading to balance supplies and consumptions in his balance area based on forecasts (portfolio optimization).</td>
<td>BRP trades (buys and sells) energy (capacity) on energy markets. (a) Planning &amp; capacity allocation (wholesale) market: trading to balance supplies and consumptions in his balance area based on forecasts (portfolio optimization). (b) Balancing market: participation in new (near-) real-time balancing market on distribution level by using the flexibility provided by the Aggregator.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Producer - DSO</td>
<td>E</td>
<td>DG (distributed generation) operators electricity is fed directly into the distribution network of DSO.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Supplier/BRP – DSO</td>
<td>C</td>
<td><em>interaction does not exist in current market design</em></td>
<td>DSO needs visibility of the planned actions in his grid to be able to check for network constraints. This is the same argumentation as for interaction No. 12, tbd. later if both are necessary and who will inform the DSO.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Aggregator – DSO</td>
<td>E &amp; C</td>
<td><em>interaction does not exist in current market design</em></td>
<td>E: Exchange of energy (kWh) between DSO and Aggregator as the Aggregator manages the</td>
<td></td>
</tr>
</tbody>
</table>

10 E = energy flow; C = commercial flow
The aggregator sells his flexibilities / capacities to the markets.

Table 8-1 Explanation of interactions in electricity markets

The interactions between the roles will be specified in more detail in upcoming phases of the project.
9 Conclusions

In this study on drivers and barriers for DREAM project it is possible to find the description of the barriers, possible solutions and scientific advances and enablers for DREAM framework validation and implementation.

Public, economical and technical drivers will be the key to find the way to overcome the barriers detected. In this point, increasing social concern for energy costs regarding economical, ecological and safety aspects will support new business models requiring more real time information on how the energy was produced and delivered. On the other hand, a more efficient and stable network will result on cost reductions for system operators.

Analysing the barriers detected, they are all related to three main aspects; motivation, implantation and technology barriers, and main identified actors are prosumers, DSOs and regulators.

In the case of prosumers and DSOs, motivation will be supported by the economical and ecological aspects. It is expected a general interest in new market options because of possible cost reduction, especially if they are considered green initiatives. From DSO’s point of view, increasing renewable penetration, enabling demand response participation and improving network stability are the main motivation for topologies and control mechanisms providing more flexibility.

The second group of barriers detected are related to market and regulation heterogeneity. Despite the effort for regulation convergence, it is still difficult to provide a single general solution, since they will not only need to be flexible enough for scalability and different production and distribution scenarios, but also to satisfy local regulation. Designing DREAM Framework and market mechanisms according to long-term national and EU policy regardless of the existing regulatory environment will produce a more realistic market approach, while the viability of results will need to keep diverse EU scenarios and cooperation regulatory groups in mind.

And for the last group of barriers, existing infrastructures and systems mainly based in proprietary solutions are delaying the irruption of new communication technologies, some of them based in open-source and off-the-shelf computing components that could provide the base for many added value services. The use of more information technologies making extensive use of ubiquitous information comes with some other counterparts, since the new solutions will need to take into account the existing regulation for information society protection and avoid common mode failure for the critical infrastructure protection.
10 References


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