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Abbreviations

APX	Amsterdam Power eXchange
BEMI	Bi-directional Energy Management Interface
BRP	Balance Responsible Party
CHP, μ-CHP	Combined heat and power plant, micro (very small) combined heat and power plant
CMS	Congestion management system
CSI	Customer site integration
DER	Distributed energy resource (may be generation or flexible demand)
DG	Distributed generation
DR	Demand response
DSL	Digital Subscriber Line
EEX	European Energy Exchange
EMS	Energy Management System
FPS	Fixed Program Shift
HEM	Home Energy Management
HTSO	Hellenic Transmission System Operator
ICT	Information and Communication Technologies
IMS	Imbalance Management System
IT	Information technologies
PnP	Plug-and-Play
PPC	Public Power Corporation
	Price-Power Control
RAE	Regulatory Authority for Energy
RES	Renewable energy source
SOC	State of charge
TSO	Transmission System Operator
UPS	Uninterruptible power supplies
VPP	Virtual power plant

1. Status of the Energy Market Environment of Wholesale Electricity Trading and Grid Balancing

The relevant short-term electricity markets in the three countries in which field tests are carried out within the SmartHouse/SmartGrid project are briefly summarized in the following sections.

1.1. The Netherlands

Starting with the Energy Act in 1998, that implemented the EU Energy Directive on market liberalization, The Netherlands have completed a full liberalization of the electricity market for end consumers since 2004. At this moment over 20 suppliers are registered, some of them aiming at special markets such as green energy. Nevertheless three large companies, NUON, Essent and Eneco, dominate the market. Although some energy suppliers generate the largest part of their electricity themselves, production is decoupled from supply. Electricity is traded on several markets: the bilateral Over the Counter (OTC) market, the Amsterdam Power eXchange (APX) day-ahead market, and, since September 2006, the APX intra-day market. Furthermore TenneT, the Dutch Transmission System Operator, operates a balance market that handles deviations between actual demand and projected demand.

The APX operates the main power exchange. Trade volumes at the Dutch APX accounted for 16 TWh in 2006, which corresponds to about 14% of the total electricity consumed in The Netherlands. In the last years a volume growth has been reached of 15-20% per year. The APX is based on a so-called 36/24 scheme. At 12:00 pm all parties have to deliver their final bids to the market for the next day, starting at 00:00 hr. Since 2006 an intra-day market has been established on which traders can optimize their position to reduce imbalance risks until 2 hours before delivery.

In November 2006 the Trilateral Market Coupling (TLC) was launched, which coupled the power exchanges in The Netherlands, Belgium (Belpex) and France (PowerNext). Price differences between the three markets decreased significantly and prices were identical during 65% of the time, averaging the last two years. Also the APX showed a significant reduction in price volatility. In the summer of 2008 also a 700 MW interconnector linking The Netherlands and Norway (the NorNed cable) is in operation. The first half-year turnover for this cable already is more than double the expected figure.

It is noteworthy that smaller industrial production units are taking part on the APX market, mostly through intermediate aggregators. Especially in agriculture the operation of Combined Heat and Power (CHP) in combination with large heat buffers can be optimized based on the market price for electricity (and gas). On the other hand, for intermittent generation the position on the APX is less favorable, since intermittent production is confronted with large imbalance cost.

TenneT, which is 100% state owned, serves as the national Transmission System Operator (TSO), and manages the transmission grid and the trans-border interconnector capacity, and safeguards the reliability and continuity of the Dutch electricity supply. Tennet also stimulates transparent electricity markets and as such is also the largest shareholder of the APX B.V.

One of the main responsibilities for TenneT is the operation of the balancing market for regulating power. Hereto the TSO contracts generation capacity for primary, secondary and emergency reserve. Production sites of a certain capacity are obliged to make available a predefined portion of their capacity to the TSO. This offer is done in the form of a bid. In case of (smaller or bigger) system-wide imbalance, the TSO calls off the reserves available in the order of their bid prices, in order to restore the instantaneous system balance. The actual costs for the upward and downward regulation are charged to those Balance Responsible Parties that had deviations from their energy programs. These charges are referred to as imbalance costs. More on this subject can be found in several of the business cases in chapter 2.

In The Netherlands traditionally the electricity supply chain has been organized in vertical companies taking care of production, supply and distribution. Today the process of a complete separation of distribution system companies and commercial companies involved in production, trade and supply is almost finished.

This legal unbundling has recently led to new network companies such as Alliander, Enexis and Stedin (formerly having a close relationship with resp. energy companies Nuon, Essent and Eneco).

The electricity market is overseen by the Dutch electricity regulator, DTe. The DTe regulates network tariffs and has to guarantee nondiscriminatory access to the grid for generators. Grid access has been the topic of discussion in the last years as a shortage in connection capacity threatens investment in agricultural CHP and the construction of new electricity plants (Maasvlakte en Eemshaven). Also it is still under discussion who should pay for connection capacity for large-scale offshore wind.

1.2. Germany

In Germany, the Energy Industry Act [Energiewirtschaftsgesetz, EnW2005] regulates the electricity sector and defines the rules of operation and competition for all firms and organizations engaged in power generation, transportation and supply. Although generation, transmission, distribution and retail supply have been separated, the incumbent firms operating in the German electricity industry are active in several or all of these fields, i.e. they are vertically integrated. In Germany, the four transmission system operators (TSOs) are vertically integrated with power generation and retail firms belonging to the same trust. At the same time, these four large companies are the dominant players in power generation; together, they operate approximately 80% of the total installed generation capacity.

The European Energy Exchange AG (EEX) operates the main power exchange. Trade volumes at the EEX spot market accounted for 123.7 TWh in 2007, which corresponds to more than 23% of the total amount of electricity consumed in Germany in the same year. With this, the EEX is one of the largest and most important power exchanges in Europe; clearing prices resulting at the EEX markets are also used as reference prices for other power contracts in Germany and elsewhere in Europe. The most important short-term marketplace is the *spot market*, where contracts that entail physical electricity delivery at specified hours or blocks on the following day are traded. This marketplace offers both continuous trading and a call market. In the latter market, price determination begins at 12:00 pm. On the very short term, generators may want to sell spare capacity or purchase additional electric energy in order to be able to react to the actual supply and demand situation after closure of the day-ahead market. Since September 2006, the EEX intra-day market allows trades in power contracts for delivery on the same or the following day. These can be accomplished until 75 minutes before physical delivery. Intra-day trading takes the form of a continuous double-auction with an open order book, where anonymous buying and selling bids can be entered at any time. Traded volumes are, however, low on this market, but display an upward trend (1.4 TWh in 2007, 1.8 TWh in 2008 until mid-October).

Processing of electricity deliveries or trading transactions through the transmission lines is effected within balance agreements between the affected transmission system operator (TSO) and the trader. The EEX day-ahead market distinguishes six places of delivery, which correspond to the control zones of the four German TSOs, and the Austrian and Swiss TSOs. The are four control zones in Germany are operated by the four transmission system operators E.ON Netz GmbH, RWE Transportnetz Strom GmbH, Vattenfall Europe Transmission GmbH and EnBW Transportnetze AG (see Figure 1). Every trader who wants to buy or sell electricity at the wholesale level in one of the four control zones has to have a balancing area within this zone. The person in charge for the balance area, i.e. the Balance Responsible Party (BRP, *Bilanzkreisverantwortlicher*), has to ensure that the sum of power feed-in into the balance area equals the sum of power withdrawal from it throughout all 15 minute periods. The BRPs' obligation is to plan or forecast the production and consumption in their portfolio and to notify this plan to the TSO who manages the corresponding control zone. The notification has to be done before 14:30 pm on the day before the settlement period.

The TSOs ensure stable grid operation at the extra high voltage level. The technical procedures of frequency control are defined through the security and reliability standards issued by Union for the Co-ordination of Transmission of Electricity [UCTE 2006] and the German TransmissionCode [VDN 2007]. The TSO contracts generation capacity for primary, secondary and tertiary reserve in order to accomplish his task of ensuring grid stability. The necessary capacity for the three balancing qualities is procured separately by means of auctions. The costs arising from primary control and from holding secondary and tertiary control capacity in reserve are constituent of the transmission system usage fee. At the settlement stage, the costs for the deployment of electric work from secondary control or minute reserve (tertiary control) plants are charged as *imbalance costs* to the account of the balance areas that had deviations from their energy programs. The legal framework for these procedures of balancing power procurement and billing are set by the Energy Industry Act [EnWG 2005], and by two other more specific provisions of law: *Stromnetzentgeltverordnung* [StromNEV 2005] and *Stromnetzzugangsverordnung* (StromNZV 2006). Primary and secondary reserve capacity is procured twice per year for six-month periods, whereas minute reserve auctions take place on a daily basis. The four German TSOs are required to procure their balancing power demand in a joint Internet-based auction [Bundesnetzagentur 2006]. The daily procurement auctions for minute reserve have to take place at 10:00 am and must be settled before 11:00, i.e. before EEX spot market clearing, in order to allow for greater liquidity on the balancing power markets.

Figure 1: Control zones in Germany[4]

1.3. Greece

At present, the electricity sector operates within the framework set by Law 2773/1999 "Liberalization of the electricity market regulation of energy policy issues and other provisions [Official Gazette A 286] enacted for the transposition of Directive 96/92/EC for the liberalization of the electricity market [OJ L27/ 30.1.1997] as it was revised by Law 3175/2003 "*Exploitation of the geothermal potential, district heating and other provisions*" [Government Gazette A 207].

The Public Power Corporation (PPC) was established in 1950, on a monopolistic basis, having as a main target the production and transmission of electric power. According to the new law PPC has been transformed into a private company owned by the state. Furthermore certain private producers have been established also.

The electricity consumption at October 2007 was estimated to be 38.1 TWh, with an installed capacity of 12,500 MW of PPC-operated plants5 and 1,400 MW of auto-producers, conventional power and renewable energy sources generators. The transmission lines in the interconnected system have a length that exceeds 12,000 km whereas the distribution lines exceed 200,000 km. The number of customers served is some seven million.

[4] [VDN 2002]

Competent authorities

- Regulatory authority for energy (RAE)

  The regulatory authority for energy (RAE) is basically responsible for the energy planning of the country. RAE was established as an independent public agency entrusted with the task of monitoring and controlling the electricity market and the delivery of opinions regarding the observance of the rules of genuine competition and the protection of consumers.

  In addition, RAE formulates proposals to the minister of development with regard to the issue of power generation authorizations and there after monitors the implementation progress of the RES projects through quarterly reports and recommends the removal of those investors who exhibit unjustifiable delays. Also, RAE recommends legislative measures for the further deregulation of the electricity market within which critical RES issues can be addressed (as is the case of hybrid plants).

- System operator

  The creation of a system operator was provided for in article 14 of Law 2773/1999 and it was set up by virtue of Presidential Decree 328/2000 "Establishment and statutes of the Societe Anonyme Hellenic Electric Power Transmission System Operator S.A." [Government Gazette A 268]. Its task is the operation, maintenance and development of the electric power transmission system throughout the whole country, as well as, of its interconnections with other systems, in order to secure Greece's electric power supply in a sufficient, safe, cost effective and reliable way. The transmission system operator (DESMIE S.A) assumed the commercial management of the renewable energy plants of the interconnected system in October 2002.

The Hellenic transmission system operator is currently operating a mandatory day-ahead market and is calculating the system marginal price based on hourly bids of market participants. Besides operating the spot market, HTSO is dispatching generators real time to meet real time load on the system. This occurs throughout every dispatch hour on the dispatch day and determines the actual quantities of energy traded.

HTSO has to verify and finalize metering quantities. The ex post SMPs, at which the energy quantities in the dispatch hours are traded are then determined using actual unit availability and system load. The calculated ex post SMP is then settled with the market participants. Therefore HTSO has to verify and finalize the settlement amounts, determine penalties and other charges and has to perform the monthly settlement and billing activities.

HTSO has contracts with certain generators to have reserve power and capacity available for balancing the system. For the availability HTSO pays a fixed monthly fee, which is passed through to the users of the system.

The Public Power Corporation is a dominant company at both production and supply of electricity. PPC has the ability to exercise market power available due to both the mix of technologies and fuels in the production and on the other hand the existing client base which includes practical all electricity consumers.

Market Model

There are practically two markets:

- The capacity assurance market

  For the capacity assurance mechanism, suppliers would be obliged to secure contracts (capacity availability contracts) with producers sufficient to meet their expected load, plus a security excess that reflects a prescribed capacity margin, while producers in order to enter into contracts with suppliers are obliged to have sufficient capacity (capacity availability tickets) by commissioning new generators to deliver the contracted power.

  When capacity shortages are foreseen – and not covered by new generation units – HTSO can proceed for a tender for the pre-purchase of the so called CACs. The purchase is made by HTSO with the purpose of transferring them by an auction to suppliers in the future. The generation capacity of dispatchable units is reflected by CATs which are issued by the producers annually.

- The wholesale energy market

  In this market there are several market participants, selling and purchasing to/from the pool. These are:
  - Producers, production license holders from generation units registered with the generating unit register;
  - Suppliers, supply license holders; and
  - Eligible customers who choose to be supplied with energy through the energy transactions system for their own exclusive use (hereinafter referred to as self-supplying customers).

Market clearing function modes (wholesale market)

- Day-ahead scheduling mode

  The wholesale energy market is a day-ahead mandatory pool scheme that provides a day ahead firm price based upon the supply/demand balance that ensures efficient short term dispatch taking into account generation unit constraints (technical minimum, ramp rate, etc.), reserve requirements and a simplified transmission system zonal constraint mechanism. The day-ahead procedure (day-ahead market clearing) produces a single SMP (system marginal price) for each settlement period (one hour) and a 24 hour production (MW) schedule for each unit.

- Day-ahead / intra-day dispatching scheduling mode

  The object of the dispatch procedure is to schedule the operation of dispatchable units, contracted units, emergency imports, and cold reserve units, as well as to issue the relevant dispatch instructions in real time by the HTSO, so that, in accordance with the HTSO's forecasts and measurements, the total energy absorption by the system is effected under conditions of good and reliable system operation, ease of facing contingencies in the system and the units, quality load supply, and maximizing the objective function.

  In that context, the HTSO shall prepare the dispatch schedule and issue the dispatch instructions to dispatchable units for the injection of energy into the system and the provision of ancillary services to contracted units for ancillary services for the provision of ancillary services and the injection of energy into the system, and to contracted units for supplementary system energy and cold reserve units for the provision of supplementary system energy and ancillary services, also in accordance with the terms of the relevant contracts.

- Real-time mode

  Real time dispatch deals with the problem of clearing offers for the physical market as a constrained linear optimization problem in real time. The optimization consists of an objective function (operational cost minimization), a set of decision variables (quantity to be allocated for each offer), and a set of linear constraints (equality or inequality constraints).

- Ex-post imbalance pricing mpde

  The electricity market in Greece does not include a separate balancing market. HTSO provides only an ex-post administrative settlement of imbalances among the market participants. This concept might be altered in the future, depending on the development of competition on the supply side. Today the settlement is performed daily and the billing activities are performed monthly.

Imbalances would be specified at a unit level for producers while for suppliers would be specified at a meter category level to ensure an accurate allocation of deviations between the day ahead and actual dispatch. The general rule that is applied is that the creator of the imbalance has to pay on the base of the imbalance marginal price.

2. Business Cases for SmartHouse and SmartGrid Integration

Business case scenario descriptions form a first step towards the architectural design of complex ICT systems. This is a proposal to describe a number of key scenarios of the SmartHouse/SmartGrid functionality in a common format as part of the requirements engineering phase of WP1. The business case scenarios should be described such that:

- Their essentials are understandable by everyone, also by stakeholders outside the project.
- They provide a simple, but shared information basis and reference point within the project, in a uniform format.
- They provide baseline information for further requirements and development work.
- They are compatible with architecture, system, and development international standards (to be) adopted by SmartHouse/SmartGrid.
- They have a limited size (document of about ten pages), and are no more than three work days to develop (e.g. one workshop / brainstorming meeting, two structured write-up).

2.1. Structure for Business Case Description

The business cases described in this document follow a uniform structure which is summarized in the following. A short summary of each business case (1.) is described in this section of the deliverable. All further information characterizing the business case (2.-10.) is provided in the Appendix.

1. **Summary of key idea:** What is the key idea both from business and technical perspectives? Why is it valuable or of interest to consider? The value driver is described as precisely as possible.
2. **Actors and goals:** Who are the actors in the scenario and what are their role/responsibilities and goals?
3. **Context and scope:** Covers issues such as
   - What is the business context (e.g. market type)?
   - What is the technical context (e.g. network configuration)?
   - What is the scope of the scenario (especially what are the system boundaries, what is considered and what not)?
   - What are important (pre-)conditions that must be or are assumed to be satisfied for the scenario (e.g. certain characteristics from the regulatory framework or industry / market organization, or key technological enablers).
4. **Technology infrastructure:** What technologies and/or technology components (systems, communications, control, etc.) must be (made) available in order for the scenario to work?
5. **Business case scenario script:** Describes the central storyline showing the event-state chain of the network or of the actors. The main scenario is given in a limited number of steps of the following type:
   <actor1> <(inter)action> <actor2>
   or:
   <system1> <(inter)action> <system2>.
   The main scenario is described, not all possible sub-scenarios.
6. **Sustainability and grid efficiency effects:** Description of (side) effects (positive or negative) for sustainability and grid operational efficiency. Sustainability effects include enhanced accommodation capability for renewable electricity sources, or reduction of generation from inefficient peak-load generators. Grid efficiency effects include increased load factors, or enhanced security of supply.
7. **Interaction and communication:** Further script information is provided in the form of UML sequence, state or activity diagrams. This gives some info about dynamics, interaction and control flows.

8. **Value model:** Describes the value exchanges between the actors. In this document, it has been decided to use the *e³-value* methodology, which has been developed by Jaap Gordijn and Hans Akkermans and is used in several energy-related projects for describing the value of business cases.
9. **Cost considerations:** Identifies the associated costs (operational, investment, development, in/outsource) for the technology infrastructure and components. Who carries these costs?
10. **Success measure:** A business case is successful if it meets its objective(s) and if it is economically viable. Technology acceptance, for instance, or fault-free technical functioning of the necessary hardware are important prerequisite for a business case success. Success can also be expressed by the achievement of a significant load shift (and a corresponding reduction in peak consumption), or an overall electricity consumption decrease. The "degree" of success is reflected by meeting the qualitative or quantitative targets set beforehand.

From these business case scenarios, the key requirements are derived and presented in a so-called MoSCoW structure (Must have, Should have, Could have, Won't have). This is supposed to be a starting point for further architecture design, and system and component development (see Section 3).

2.2. Summaries of Business Cases

Nine business cases have been defined within the scope of the SmartHouse/SmartGrid project. A short description of each case is provided in the following subsections. A more detailed description of the aspects named above for each case is given in the Appendix.

2.2.1. Aggregation of Houses as Intelligently Networked Collaborations

SmartHouse/SmartGrid concepts will exploit the potential that is created when homes, offices and commercial buildings are treated as intelligently networked collaborations. When SmartHouses are able to communicate, interact and negotiate with both customers and energy devices in the local grid, the electricity system can be operated more efficiently, because consumption can be better adapted to the available energy supply, even when the proportion of variable renewable generation is high. A commercial aggregator could exercise the task of jointly coordinating the energy use of the smart houses or commercial consumers that have a contract with him.

The joint management of a collection of houses and commercial sites can be done in two ways. The aggregator might directly control one or several participating devices (e.g. deep freezers, air conditioning); this would require the end-users to allow direct access to the control of these appliances. Another way is that an aggregator can only provide incentives to the participating devices, so that they will behave in the desired way with a high probability, but not with certainty. The second option leaves the power of control to the end-user, i.e. the owner of the appliances, and might thus be more acceptable, and also easier to implement from a legal perspective.

One important concern in the aggregation of smart houses as intelligently networked collaborations is to avoid tipping effects in a mass application scenario: if all customers are controlled in a uniform way or all customers are given the same incentive at the same time, the overall system might destabilize by the sum of all reactions. This would compromise the objective behind the coordinated control, i.e. a more efficient operation of the energy system. Therefore, solutions for aggregating and jointly controlling smart houses have to deal with the implications of a mass use scenario and avoid tipping effects.

2.2.2. Real-Time Imbalance Reduction of a Retail Portfolio

This business case is rooted in the balancing mechanism as used by TSOs throughout the world. The European variant of this mechanism is part of the ETSO Scheduling System (ESS) and is widely implemented by European TSOs. In this context, an actor that is responsible for a balanced energy volume position is called balance responsible party (BRP). The balancing mechanism consists roughly of three parts:

1. **Balancing responsibility:** the obligation of BRPs to plan or forecast the production and consumption in their portfolio and to notify this plan to the TSO. The granularity of notified plan is given by the *settlement period* length, typically 30 or 15 minutes. The notification is done before some *gate-closure time*, a predefined period ahead of the start of the settlement period.
2. **Reserves for frequency response:** the TSO contracts generation capacity for primary, secondary and emergency reserve. Production sites of a certain capacity are obliged to make available a predefined portion of their capacity to the TSO. This offer is done in the form of a bid. In case of (smaller or bigger) system-wide imbalance, the TSO calls off the reserves available in the order of their bid prices, in order to restore the instantaneous system balance.
3. **Settlement of imbalance costs with the balancing responsible parties:** in a later stage, the TSO charges the actual costs for the used reserve and emergency capacity to those BRPs that had deviations from their energy programs. These charges are referred to as *imbalance costs*.

Depending on the nation-specific regulations, the plan notified to the TSO is valid for a certain grid area, referred to as a *control zone*. The BRP is obliged to provide a plan for each control zone it has contracted generation or load in, and needs to follow the plan for each zone individually. So, a BRP is allowed to compensate for an imbalance in one part of a control zone using units in another part of the same zone. Typically, control zones cover a large geographical area: The Netherlands, for instance, is one control zone, while the UK is divided in 14 of such zones.

As imbalance prices are very volatile, the system of balancing responsibility imposes imbalance risks to market parties. Among BRPs, this risk will vary with the predictability of the total portfolio of the BRP. BRPs with low portfolio predictability are faced with higher imbalance risks. For instance, parties with a high share of wind energy in their portfolio are faced with higher imbalance costs.

To manage imbalance risk, market participants undertake balancing activities. These activities can both take place before gate closure as well as in the settlement period itself:

- **Pre gate closure:** Typically, balancing activities before gate closure occur in the power exchanges. Market parties fine tune their positions close to real time by contracting with generators or suppliers to adapt their position according to short-term load forecasts.
- **Within the settlement period:** After gate closure each BRP is on its own: each trade with other market parties cannot be notified to the TSO and, thus, will contribute to the BRP’s imbalance. The BRP can only influence the producing and consuming units in its own portfolio to achieve in real-time the desired net physical energy exchange with the network for each control zone.

This business case scenario focuses on the balancing actions by a BRP during the settlement period. Traditionally, these real-time balancing actions are performed by traditional power plants within the BRP’s portfolio. The key-idea of this business case is the utilization of real-time flexibility of end-user customers to balance the BRP portfolio. For each control zone, the BRP aggregates all its contracted flexible distributed generation and responsive loads in a *virtual power plant* (VPP). The BRP uses the VPP for its real-time balancing actions.

2.2.3. Offering (Secondary) Reserve Capacity to the TSO

This business case is rooted in the ancillary services as initiated by TSOs throughout the world. This business case will be based on the Dutch grid management concept as described by Tennet, the Dutch TSO[6]. The scenario described is an enhancement of the business case “Real-time Imbalance Reduction of a Retail Portfolio” (described in 2.2.2).

If a balance responsible party balances its own portfolio, it may reduce its imbalance cost. If the imbalance of the portfolio is in the same direction as the system imbalance, balancing costs are indeed reduced by the

[6] See http://www.tennet.org/english/images/Bedrijfsvoeringsconcept%20UK_tcm43-12801.pdf

imbalance reduction. If the balance is totally restored within the portfolio and the BRP has extra flexibility in its portfolio, it may be used to further support the TSO in its upward or downward regulation. On the other side, if the imbalance of the portfolio is in the opposite direction from the system imbalance, the BRP would be adding imbalance in the system if it reduces its own imbalance. The BRP may even use its flexibility to create more portfolio imbalance in order to support the TSO. The only way to do this properly is to let the market decide. Therefore, the BRP should be able to offer its flexible demand and supply on the reserve market.

The current reserve market operation consists roughly of three steps:

1. **Contracting of reserves for frequency response:** The TSO contracts generation capacity for primary, secondary and emergency reserve. Production sites of a certain capacity are obliged to make available a predefined portion of their capacity to the TSO. This offer is done in the form of a bid, using a bid ladder. The gate closure of the reserve market typically is in the order of one hour ahead.
2. **System Balancing:** In case of (smaller or bigger) system-wide imbalance, the TSO calls upon the reserves available in the order of their bid prices, in order to restore the instantaneous system balance. There are constraints in requirements for the call time (response time plus time for reserve to be up and running) for primary, secondary and emergency reserve.
3. **Determination of imbalance costs:** Based on the bid prices in the reserve market and the contracted volumes, the TSO determines the actual cost for real-time balancing of the system. These costs are imposed on those BRPs that had deviations from their original energy programs. These charges are referred to as *imbalance costs*.

The BRP offering reserve capacity submits its bid before gate closure of the power exchange market, simultaneous with its energy program. These bids can be revised (both in capacity and price) intra-day, until an hour ahead before implementation. At realization, bids are called on in order of the bid prices. Calls on reserve power always applies for at least one program time unit (PTU; in The Netherlands, one PTU equals 15 minutes).

In order to enable BRPs to offer flexible demand and supply on the reserve market, their bids have to fit into the above market structure. One way is to make a forecast of the flexibility in the portfolio one hour ahead, and base a bid on the forecast. This imposes new uncertainties for the BRP. Therefore, in this scenario we propose an extension on the market structure to allow participation on the reserve market for flexible demand and supply with real-time bids.

This business case scenario thus focuses on the participation of parties, having flexible production and consumption, in ancillary markets during the settlement period. Traditionally, these real-time balancing actions are performed by contracted reserve capacity. The key-idea of this business case is the utilization of real-time flexibility of end-users (prosumers) in balancing a control zone. For each control zone, market parties aggregate these flexible distributed generation and responsive loads in a *virtual power plant* (VPP). The TSO contracts in real-time part of these flexible loads for its real-time balancing actions.

2.2.4. Distribution System Congestion Management

This business case aims at deferral of grid reinforcements and enhancement of network utilization. The need clearly arises in areas with a large amount of distributed generation near one location or in areas evolving into a so-called all-electric society, e.g. by introducing electric heating (heat pumps) or electric mobility. Non-coordinated control of these new devices may lead to a sharp rise in needed capacity on lines and transformers. By coordination of these devices, they can be allocated timeslots for operation that are spread out over time. Furthermore, coordination can increase the simultaneousness of local supply and demand in case local generation is integrated.

Congestion management as a service can be aimed at different beneficiaries. In residential houses, it can be used to get a better match in own production and consumption, thereby decreasing the energy bills (difference between buying and selling prices of electricity and reduction of distribution cost and tax payment). The same holds for large apartment buildings / offices / industrial sites, but there it can also be used to lower the connection capacity cost to the external grid. Distribution System Operators (DSO) may be interested in improvement of the quality of supply in areas with restricted capacity in lines and transformers. Within the SmartHouse/SmartGrid project, the focus will be placed on that latter scenario.

The application of this business case is a low voltage cell with residential houses having flexible demand and supply, e.g. heat pumps, μ-CHP, cooling, storage, etc. The DSO is interested in keeping a stable load profile at the transformer station, avoiding peak loads. Therefore, a substation agent measures the load flow at the transformer station. Whenever the load flow becomes critical, the substation agent creates a market signal that encourages the flexible supply and demand to react accordingly. The market signals and the interaction of the flexible supply and demand with the congestion management system could be, for instance, based on the PowerMatcher protocol (or on similar systems allowing real-time control of flexible loads and generators).

2.2.5. Variable Tariff-Based Load and Generation Shifting

The overall load patterns of electricity consumption are quite well predictable. Characteristic peaks occur at some time intervals (e.g. at noon or at 19:00 in mid-European winter days) and other time intervals are characterized by low consumption, especially during night-time. Also, the availability of renewable energy resources can be predicted with certain accuracy, giving an indication of probable situations in the electricity system for the next day. In well-functioning and liquid markets, the expectations of all market participants about the generation and consumption situation of the next day are well reflected in day-ahead power exchange prices, e.g. on the EEX or APX (see Sections 1.1 and 1.2). If these wholesale prices are passed over to the end-users (directly or in a modified way), the end-users have incentives to shift loads from high-price times to times of lower prices, which would be beneficial for the retailer and for the overall system.

The key idea of the business case is, thus, to provide the customer with a variable price profile on the day before power delivery. This profile, calculated by the retailer, should be fixed once it has been communicated to the customer, so that the latter can rely on it for his further planning of generation and consumption. The price profile can look different for each day, however, to reflect market conditions that also vary from day to day. These variations will likely increase with increasing generation from fluctuating sources like wind and solar energy.

The price profiles could be based on the wholesale prices that the retailer faces when procuring the energy amounts he sells to the customer. The exact relation between the spot market prices and the variable tariff profiles sent to the smart customer can be determined flexibly. The possibilities range from a direct adoption of the spot-prices (plus grid costs, taxes etc.) to more complex contractual relations specifying maximum price and average price levels of the customer. Moreover, in order to make the flexible tariff model more acceptable for the end-user, a “maximum average cost per kWh” could be guaranteed by the retailer, protecting the customer from unintended very high energy bills. It has to be noted, however, that each guarantee for prices decreases the customer’s financial incentive to shift his consumption and generation in the desired way, thus weakening the demand response.

At the customer’s premise, an energy management system should receive the price signal and determine the optimal timing for the energy consumption of those appliances that can be shifted in time (e.g. washing machines or dishwashers) or that have a storage characteristic (such as fridges or deep-freezers). The same applies for generation units, such as μ-CHP plants – these are scheduled to run at those time intervals when prices are highest. The automated energy management frees the customer from the burden to monitor prices every day in order to save money, and it guarantees that possible load and generation shifts occur in an optimal way.

It may be part of the business model that the retailer receives feedback from the customers after the publication of the price curve and during the day of delivery on their automatically planned / predicted load and generation profiles. So the retailer can optimize his portfolio by trading on intraday electricity markets.

It is also possible, however, to rely solely on a prediction model of customer behavior. As a further option, it would be possible that in exchange for an additional financial incentive, customers might be willing to accept adaptations of the price profile during the day of delivery reflecting changes in the retailer portfolio that come up during the day and also to reduce imbalance in his portfolio.

The main value driver from the customers' perspective is to receive a tariff and a technology which reduce their energy bills. The value driver from the retailer's perspective is the opportunity to attract new customers and reduce his costs when buying from wholesale power markets.

2.2.6. Energy Usage Monitoring and Optimization Services for End-Consumers

In her „Action Plan for Energy Efficiency", the European Commission estimates the EU-wide energy savings potential of households at around 27% (European Commission 2006). As one important measure for realizing this potential, the action plan states that awareness must be increased in order to stimulate behavioral changes. A study for the German Ministry of Economic Affairs [BMWi 2006] estimates the potential for energy savings through a timely display of energy consumption at a minimum of 9.5 TWh per year (this corresponds to 1.5% of the total energy consumption in Germany in 2006). Personalized and well targeted advice on how to save energy can help further exploit the savings potential.

When detailed metering data is collected on a large scale, valuable information can be extracted from the data pool, which can help end-consumers to achieve the desired reduction in energy consumption. For example, through comparing one's own consumption pattern with average load profiles of comparable households, an end-consumer can become better aware of his energy usage. Or, if the place of energy consumption is made visible in a comprehensible manner, the end-consumer is able to find out how much energy is spent by which appliances, and can identify the greatest potential for a reduction of energy consumption. A portal or display that combines information about present and past consumption, comparisons to average consumption patterns, and precise suggestions how to further lower consumption which are tailored personally to the customer is probably the most effective way of realizing the possible increase in households' energy efficiency. It should therefore be tested within the SmartHouse/SmartGrid project.

The business concept of services that comprise average consumption patterns could rely on the principle of reciprocity: those customers who contribute to the data set by allowing metering data to be read by the service provider can also access average data. This concept gives an incentive for the end-users to reveal their data, under the condition that it is not accessible by unauthorized parties.

The additional value to the customer provided by the described information services can either be remunerated through additional fees or through enhanced customer loyalty. A combination of both is also conceivable. If neither positive impacts from increased customer loyalty, nor a customer's willingness to pay for the information service are given, this business case risks being not viable. A retailer usually makes more profit if he sells more products, and if the energy consumption feedback leads to lower energy consumption, sales volumes would decrease for the retailer. Either the energy feedback has a value in itself for the customer (this valuation could also be exploited through higher average tariffs or through advertisement), or other measures, for example through subsidies or tax relief, have to compensate for the losses in sales volumes to make this a viable business case.

2.2.7. Distribution Grid Cell Islanding in Case of Higher-System Instability

The key idea of this business case is to allow the operation of a grid cell in island mode in case of higher-system instability in a market environment. This business cases considers that the islanding procedure is performed automatically. The scenario has two main steps: the first step takes place before the event that may occur and the second step is the steady islanded operation.

During the first step, the system should monitor both the available distributed generation (DG) units and the loads, and should forecast the consumption as well the available power and energy in the next hours. A load shedding schedule should be created based on to the criticality of the consumption loads and on the customers' willingness to pay for running the appliance during the island mode.

In the first minutes after the event, the DSO allows the operation according to the criticality. If there is enough power to the islanded grid, no load shedding will take place. When balance and stability has been ensured the system decides how to manage the energy within the network.

As mentioned before, the transition to the island mode is automatic and neither end-users nor the aggregator interferes with it. The system manages the energy generation and consumption within the island system and it is assumed that all nodes within the islanded grid participate in the system.

Grid cell islanding is of value to the DSO. If instabilities occur in the distribution grid, it is the DSO's task to restore stability as quickly as possible and with the lowest possible number of affected customers. Through islanding, the DSO can reduce the number of connected customers that are negatively affected by the higher-system instability. Islanding also helps the DSO to quickly restore system stability within his grid area. The service of grid-cell islanding can be provided by a commercial aggregator who installs the necessary control equipment in contracted households and then performs the islanding upon request by the DSO in case of a higher-system instability.

2.2.8. Black-Start Support from Smart Houses

The key idea of this business case is to support the black-start operation of the main grid. It considers that after a black-out, the local grid is also out of operation and the main goal is to start up quickly in island mode and then to reconnect with the upstream network in order to provide energy to the system.

The scenario has four main steps: the first step is before the event that may occur, the second step is just after the event, the third step is the steady islanded operation and the final step is the reconnection to the main grid.

The first two steps of the black-start support resemble the operation as described for the grid cell islanding case (see Section 2.2.7). When the system is in a safe state, it will try to reconnect in order to provide power to the grid; the goal is to provide as much energy and power as possible.

Black-start support is of value both to the DSO and the consumer. If a black-out occurs in the DSO's grid area, it is his responsibility to restore system stability as quickly as possible. Flexible demand helps him to perform this task. Black-start support could be provided by a commercial aggregator who installs the necessary control equipment in contracted households and then performs black-start support upon request by the DSO in case of a black-out. This service could be coupled with the grid cell islanding service, and could be provided by the same aggregator. Similarly to the previous business case depends on the market structure and the benefit depends on who is responsible to pay for the possible load shedding and how much the customers are willing to pay for quick power restoration.

2.2.9. Integration of Forecasting Techniques and Tools for Convenient Participation in a Common Energy Market Platform

The volatility of the production level of distributed energy resources (DER) makes forecasting a necessary tool for market participation. The actor with the lowest forecasting error will have the most efficient market participation. Moreover, the usage of intelligent management tools for handling the information about the uncertainties of wind generation will improve the operational costs, fuel savings and CO_2 savings regarding to the present decentralized energy management technology. However any good forecasting tool usually requires accurate data collection.

Currently, wind energy represents an important percentage in the electricity generation of several European countries, such as Germany, Denmark, Spain, Portugal or in some Greek islands. The high amounts of wind generation in autonomous or interconnected electrical systems cause several difficulties in the operation and management of a power system. This is mainly due to the intermittent nature of the wind resource, which acts as a limiting factor for wind power integration.

This business case provides benefit for both the consumer and the aggregator. The aggregator has the ability to participate accurately in the wholesale market and gain by reducing the uncertainties. The consumer benefits from lower prices. However, this business case requires the participation of the consumers, since an accurate forecast requires online monitoring of the DER and not simply reading from the smart meter.

Forecasts are needed by following actors of the energy market:

- Energy supplier (balancing responsible party)
  - Customer load forecast
- Energy trader
  - Energy price forecast
- Distribution system operator (DSO)
  - Distribution grid load forecast including intermittent sources
- Transmission system operator (TSO)
  - Transmission grid load forecast including intermittent sources

The benefits of high quality forecasts are:

- Energy supplier (balancing responsible party)
  - Reduced balancing power costs
- Energy trader
  - Reduced energy trading costs through optimized energy retail portfolio
- Distribution system operator (DSO)
  - Reduced network losses through optimal power flow
  - Reduced balancing power costs (e.g. DSO is BRP for loss energy)
  - Optimized network operation
- Transmission system operator (TSO)
  - Reduced network losses trough optimal power flow
  - Reduced reserve capacity auction costs
  - Optimized network operation

The data collection for all these different forecasts is very similar (e.g. every load and price prediction is influenced by wind generation, outdoor temperature prediction, etc.). Every actor needs data from according data collection service providers.

So the business case “Integration of Forecasting Techniques and Tools for Convenient Participation in a Common Energy Market Platform” has two main parts. The first part is the data collection which is the most critical part that may lead to a correct forecast. Data collection is part of the business model since data typically is not freely available and sometimes confidential. The second part is the data evaluation and processing, e.g. for extracting a wind power prediction valid for a certain region. The third part is the distribution of results to the different customers that may also be competitors. It can be expected that the more fluctuating generation is to be integrated into grid, the higher the importance of forecasting services will be. Because of vital interest many actors of the energy market even already today use the forecasts of more than one service provider to improve the quality of their own forecasts.

3. Business Case Evaluation Approach

In the course of the SmartHouse/SmartGrid project, it should be tested how the business cases described in this document can contribute to the realization of the overall objectives as formulated in the description of work. Therefore, it has to be defined how the measurement of these given objectives (A, B, C, and D) can be done in terms of quantification and comparability.

It should be noted that this document describes possible measurement in general terms, not reflecting the constraints of the field trials to be carried out within the project. These may limit the possibility to carry out specific measurements. The analyses and measurements actually planned for the field trials (work package 3) are specified in more detail in Deliverable D3.2; the scenario simulation carried out in work package 4 will be described in Deliverable D4.1.

3.1. Measurable Objective A

Objective content: **The developed ICT technical functionality works under real-life field conditions.**

The measurable objective is subdivided into several objectives that are investigated within the SmartHouse/SmartGrid projects. These are specified in Sections 3.1.1, 3.1.2 and 3.1.3.

3.1.1. Objective A.1

Objective content	Relevant for business cases	Measurable in field trial
Scalability	**2, 3, 4, 7 and 8**	**A**

Under scalability of the intelligent communication and negotiation architecture, it is understood that the system is able to handle on the order of many thousands up to 1 million of energy devices simultaneously. A scalable energy balancing system also ensures that it reacts within an acceptable time frame if millions of users are connected via the proposed architecture (with multiple concentrator levels).

The scalability – and, thus, the reaction speed – of the device-to-device communication and electronic market negotiation technology and architecture is especially relevant for those business cases that consider real-time control of loads and generation units, i.e. business cases 2, 3, 4, 7 and 8. For day-ahead planning or for consumption feedback, such as necessary in business cases 5, 6 and 9, data exchange is neither "heavy"(only one price curve, forecast or consumption curve is sent), nor time-critical, so scalability is less an issue for these business cases.

The objective can be measured by increasing, stepwise, the number of users linked to the balancing system (e.g. PowerMatcher) and measuring if the desired reaction in generation or consumption takes place in a given reaction time interval. Large-scale scenario simulations can help evaluating this measurable objective.

The business case "Real-Time Imbalance Reduction of a Retail Portfolio" utilises smart houses at a mass scale. The aggregation of houses, together forming a virtual power plant (VPP), is considered the equivalent of a conventional power plant. The main requirements for such a power plant in the context of a balancing responsible party are:

- The knowledge of the current state of the smart house aggregation (=VPP), the potential power and the cost of ramping up and ramping down

  → In an ever changing distributed environment where the operation of millions of devices is determined by their process state, it is unrealistic to expect a perfect knowledge of the state of the smart house aggregation. The main goal is that the known state not significantly deviates from the real state.

- The ability to handle large numbers of events in the system

  → In a system of event driven near real-time coordination a large number of events will expectedly occur in short timeframes. Since minor changes in the system (e.g. several kW deviation on a scale of MW at the top level) will not affect the overall goal of the VPP control, filtering the events (i.e. the demand and supply bids) by their significance for the sub-cluster as a whole can be done on every concentrator level. The significance can be assessed on load change or on price change, or both. Also, time delays can be built in such that only aggregated events over a certain time frame are sent by each concentrator to the level above.

- The ability to response at short notice.

  → The short notice has to be seen in the light of the business case, e.g. a program time unit (PTU) that is the basis of the balancing services and that is used to calculate the imbalance penalties by the system operator (the PTU is 15 minutes in many European countries). In order to be of value to balancing services, the smart houses should be able to react within these 15 minutes, preferably even within 5 minutes. This is a hard scalability requirement especially for business case 2.

For the real-time energy control in business cases 2, 3, 4, 7 and 8 we state the following scalability measure:

- Scalability_0.9 measures the time needed for attaining a response of 90% of the addressed power (or 90% of the involved agents)
- Scalability_0.95 measures the time needed for attaining a response of 95% of the addressed power (or 95% of the involved agents)
- Scalability_1.0 measures the time needed for attaining a response of 100% of the addressed power (or 100% of the involved agents)

Figure 2 visualises possible scalability measurements to be carried out via simulations. In practical operations of the field trials, the number of agents reached within a certain time is easier to determine; the amount of power addressed can then be estimated based on this number.

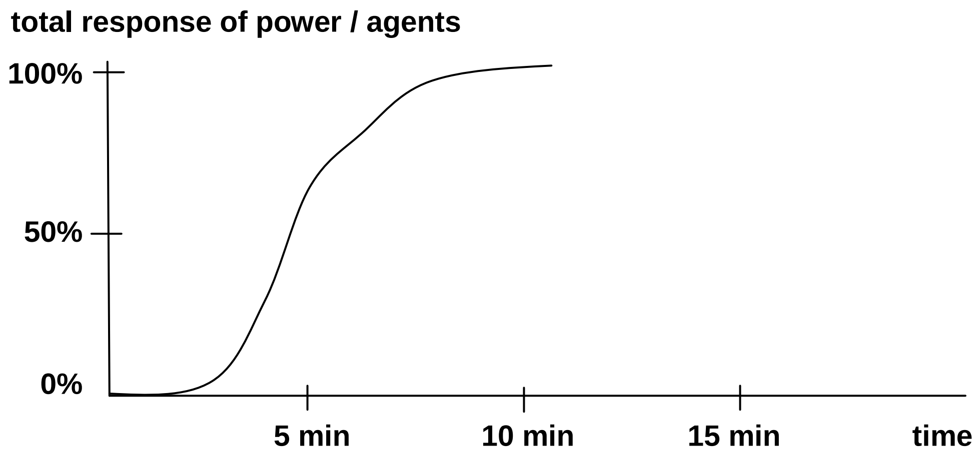

Figure 2: Reaction time to address 0.1 MW, 1 MW and 10 MW for a virtual power plant containing 10,000, 100,000 and 1,000,000 agents, respectively

It should be noted that the device ramping up/down time should not be taken into account in this objective, since this depends on the device characteristics, which is not part of SmartHouse/SmartGrid field trials or simulations. However, it shows that the characterisation of a cluster of devices based on ramping up/down is an important issue.

As the business cases 2, 3, 4, 7 and 8 require smart metering, scalability should also be considered for the meter readings. However, these can be done on a daily basis (or even less frequently) and are not time-critical. Therefore, the scalability of the meter and price readings is measured in terms of # of messages exchanged, total data transfer volumes, and storage requirements for persistent data storage in the retailer's database.

3.1.2. Objective A.2

Objective content	Relevant for business cases	Measurable in field trial
Ease of use and responsiveness to end users	**2-8, especially 6**	**B**

The ease of use and responsiveness objective is concerned with the question how end-users react to the energy management or other systems installed in their house. An energy management system should require as few user interactions as possible, as users don't want to be bothered too much with their electricity consumption. However, some interaction is necessary as users must reveal their preferences in some cases (e.g. they have to specify at what time a washing machine should have finished), so it is important to make these interactions as easy as possible.

The ease of use and responsiveness to end users can mainly be verified using surveys and interviews of involved customers. Methods from socio-scientific disciplines, such as structured or unstructured interviews, questionnaires, observations or experiments help to measure the ease of use and responsiveness of the end users. It should be noted, however, that these types of studies have not been foreseen in the SmartHouse/SmartGrid project. However, surveys and further socio-scientific studies will be carried out in complimentary projects that run in parallel to field trials A and B; the SmartHouse/SmartGrid project will have access to the collected data and may use it as additional input for drawing conclusions.

Besides socio-scientific studies, the response from customers in respect to questions, help needed for handling, complaints as well as positive feedback during a field trial is documented, giving an indication about the ease of use and responsiveness. The number and content of incoming calls in a call-center for smart house customers is a good indication for ease of use and should be well documented.

Moreover, web interfaces use by smart house customers (especially as envisaged in business case 6) can be assessed automatically through keeping log files of customer intervention, e.g.

- How many days per week the customer logs on to the web interface
- How often the customer clicked on different items or sub-pages
- How often the customer provided restriction information to the energy management system (e.g. not to wash later than 22:00)
- How often the customer downloaded user data from the web interface (e.g. load profiles)

3.1.3. Objective A.3

Objective content	Relevant for business cases	Measurable in field trial
Real-time control flexibility and optimality	**2, 3, 4, 7 and 8**	**A and C (and B, for optimality)**

The concept of optimality has several aspects. The first aspect considers that for a given set of cost functions (for the generation side) and valuations (for the consumption side), the optimal solution of which appliance to turn on or off should be found; this can be proven mathematically. Another aspect of optimality is that the selected policy by the agents fulfils the customer's consumption (generation) preferences / requirements at the lowest (highest) possible price, given the market price or variable tariff.

As no participant in a SmartHouse/SmartGrid system has knowledge of the cost functions and valuations of all participating generation and consumption devices, the overall optimum cannot be determined in the field. Optimality can only be tested through experiments / simulations of scenarios for which all relevant parameters of generation and consumption are known; it can then be evaluated whether the energy management system reaches the optimum that is calculated analytically. In the field, qualitative analyses can be done that check whether flexible generation devices tend to operate in high-price times and flexible consumption appliances tend to operate at low-price times. This can give an indication of the effectiveness of the decentralized energy management, but it cannot give a quantitative figure of how close the outcome is to the optimal outcome.

For the near real-time coordination, a main indicator will be the amount of flexible power over time that can be utilized in a virtual power plant. This flexibility depends on the type of devices involved. Earlier research work within the CRISP project[7] identified a potential of 40% imbalance reduction of a wind portfolio if the total of flexible power and the total of wind power are of comparable scale. The optimality criterion from the view of a balancing responsible party lies not so much in imbalance reduction, but in the reduction of the cost of imbalance. Imbalance reduction during low cost periods will not lead to optimal utilisation of the VPP if it hinders (e.g. by exhaustion of the flexible power in the cluster) imbalance reduction during high imbalance cost periods. For market-based real-time coordination, such as with the PowerMatcher, the aggregated demand/supply function is a good indicator of the available flexible power in the VPP.

The quality of variable tariff-based load-shifting (such as with the BEMI) can be measured by comparing the managed load profile with a reference load profile. The latter should be a realistic profile for the case of no energy management for the same household and can be based on:

- Historic measurements of the test customers without energy management, e.g. before the field trial starts (calculation of seasonal corrections might be necessary)
- Standard load profiles for residential customers, as usually used by electricity providers as a basis for their internal load prediction (only valid for aggregated customers)
- Measurements of a group of customers (without energy management) on a common connection point (e.g. transformer station), best in parallel to the field trial, otherwise calculation of seasonal corrections of the load curves might be necessary
- Load curves gathered within other R&D projects with variable tariffs (but without energy management), if such data is available

If the variable tariff sent to the customer is based on spot market prices, the goal is that customers avoid consuming (generating) high (low) price times and thus minimize the procurement costs for the retailer. The quality of the customers' reactions to these price signals can be calculated by the following formula:

$$MLPQ_a = \frac{\sum_{h=1}^{24} RLP_h \cdot SP_h - MLP_h \cdot SP_h}{\sum_{h=1}^{24} RLP_h \cdot SP_h} \quad ; \quad MLPQ = \frac{\sum_a \sum_{h=1}^{24} RLP_{a,h} \cdot SP_h - MLP_{a,h} \cdot SP_h}{\sum_a \sum_{h=1}^{24} RLP_h \cdot SP_h} \qquad (1)$$

MLPQ	Managed Load Profile Quality [%]	RLP	(Hourly) Reference Load Profile [MW]
MLP	(Hourly) Managed Load Profile [MW]	SP	(Hourly) Spot Market Price [€/MWh]
Indices: h	Hour	a	Agent / Customer

[7] http://www.crisp.ecn.nl/

MLPQ has a positive value if cost savings for the retailer occur and a negative value if the costs increase in the managed load case; the higher the absolute value, the larger is the difference between the managed and reference case. The MLPQ value does not give an indication to what extent other goals of variable tariff-based energy management, such as increased renewable energy integration (and, thus, CO_2 reduction) have occurred.

When SmartHouse/SmartGrid solutions are used for stabilizing the grid, as envisaged in field trial C, the time that the cluster of smart houses stays in island mode before reconnecting to the grid is measured for different algorithms. It is a good measure for real-time flexibility / optimality, as a short reconnection signifies high flexibility, whereas longer islanding times means that the cluster cannot react quickly to critical situations.

3.2. Measurable Objective B

Objective content: **The developed ICT technology is affordable.**

The measurable objective is subdivided into several objectives that are investigated within the SmartHouse/SmartGrid projects. These are specified in Sections 3.2.1 and 3.2.2.

3.2.1. Objective B.1

Objective content	Relevant for business cases	Measurable in field trial
The developed technology is affordable in terms of the knowledge and time resources required from end users.	**1-8**	**A, B and C**

There are a number of processes in the household that provide flexibility of the consumption or production of electricity. For each of these processes the way of control will change in a smart grid environment. In some cases this control can be kept fully automated without any change for the user. Many heating and cooling processes already are controlled by thermostats. Smart control can change the way of control of a thermostat by making smart use of the already existing temperature range. This approach has been followed in an earlier field trial in the Netherlands without any user complaints [Warmer et al. 2008]. Other processes may require new, intuitive and personalized interfaces to the end users. As an example not everyone will allow his washing to be done in the morning and letting wet goods in the machine until evening when he returns home.

Whether the end-user is capable of coping with the energy management system deployed in his household can be verified by an appropriate customer feed-back (e.g. surveys). Automated analyses of log files installed within the tools might give hints on how users can cope with the functionalities delivered by the tools. This survey can be carried out together with the ease of use analysis, as it addresses related issues.

It should be mentioned that different energy management systems require different user interaction. The common goal of all approaches analyzed in the SmartHouse/SmartGrid project is that the number and complexity of user interactions should be minimized. Also, the effort of installing the necessary hardware and software at home should require as few steps as possible.

The evaluation of objective B.1 can be done by naming all necessary steps that the user herself has to carry out, and specifying what knowledge is necessary for doing it. In the field trials, the best way of measuring the necessary time for each step is to observe the customer while she carries out the steps. With given time constraints and a likely unwillingness of the customer to be observed during installation, the necessary time resources could be estimated based on answers stated by the users in questionnaires.

An example of such evaluation is given in Table 1. The necessary steps and required time and knowledge resources should be surveyed separately for each energy management system considered, as the technology also differs. Based on the gathered data, some conclusions on average total time investments and minimum skill levels can be derived. This also allows comparing the three approaches PowerMatcher, BEMI and Magic, giving additional insights about the future potential of each of the three technologies.

No	Task	Required knowledge	Assistance & collaboration	Ø time needed	Re-occur-rence
When using the PowerMatcher approach					
1	Installing the PM concentrator	Functioning of a router,…	Technician	10 min	Once
2	Setting device preferences	Knowledge of own consumption patterns,…	Call center	1 hour	Once + changes
3	Integrating a new device	Basics of IP technology,…	Call center	30 min	Several times
…	…	…	…	…	
When using the BEMI approach					
1	Setting preferences for user-programmed devices (e.g. washing machines)	Knowledge of variable tariff	None	5 min	Several times
2	Integrating a new device	Functioning of integration process	Call center	10 min	Several times
3	Set-up of personal computer for web portal access	Basics of IP technology	Call center	10 min	Once
…	…	…	…	…	…
When using the Magic approach					
1	Installing the Magic controller	Communication network, electrical installation	Technician	1-2h	Once
2	Setting device settings	Knowledge of own consumption patterns,…	Remotely	1 hour	Once + changes
…	…	…	…	…	…

Table 1: Example of valuation table for objective B.1 – necessary time and knowledge resources

3.2.2. Objective B.2

Objective content	Relevant for business cases	Measurable in field trial
The developed technology is affordable in terms of financial investment and operational costs.	**all**	**(A, B and C) WP 4**

Evaluating objective B.2 requires the detailed list of costs that are generated to install the required infrastructure. The costs should be split into investment costs to enable a household to participate in the smart grid and into operational costs to run the smart grid. The first part includes costs for smart meters, smart devices, installations and communication / wiring. The second part is the more difficult part as it includes costs for systems that match demand and supply, as well as operational costs for the enterprises, like maintenance and also the additional cost of billing of consumption with variable prices.

The SmartHouse/SmartGrid field trials give some indications of the cost of the energy management system hardware (BEMI, PowerMatcher or Magic). However, as the hardware for the project prototypes are not produced in large batches, it doesn't allow direct declarations about the hardware costs that would apply in a mass-scale scenario. This can only be estimated based on cost developments of comparable components and on discussions with the hardware suppliers and will be done within work package 4 of the SmartHouse/SmartGrid project.

There are two main actors in getting a household using an energy management system such as the BEMI, PowerMatcher or Magic system: The energy supplier (or DSO or aggregator) on the one hand and the household customer on the other hand. One of the most important incentives for both sides is cost savings. If the costs for financial investments are affordable for any market participant depends mainly on the savings that can be achieved in the long-run. The field trials therefore need to demonstrate the savings for each actor. Two scenarios are perceivable for determining if costs are in an acceptable relation to benefits:

- The retailer or any other commercial players invest into the energy management hardware: in this case, the acceptable hardware costs are closely related to the cost savings that this player can realize through the deployment of the energy management system. The savings for the energy retailer are determined by the reduction of its operating cost, which includes less required balancing energy or a better position on the wholesale market by avoiding buying expensive peak power. The actual costs and cost savings have to be evaluated based on the estimated hardware costs (as described here) and on the evaluation of objective C.2.
- The customer invests into the energy management hardware: the customer will probably mainly be motivated by cost savings resulting from lower tariffs at low-demand times. It has to be analyzed whether the expected savings justify the investment. The customer could, however, also be motivated by other factors, for example if she is particularly interested in new technology of if she is specifically concerned for environment / climate protection.

The amount customers would be willing to pay for an energy management system can be verified by an appropriate customer feed-back (e.g. survey) after carrying out the field trial. The behavior of the customer (e.g. her usage of the information and infrastructure in order to deploy energy more efficiently) should be analyzed in relation to her personal savings. It is important to know if the active participation of the customer depends on the money she can save, or on other criteria. Therefore, the effects should be determined and displayed not only in terms of cost savings, but also in terms of CO_2 savings or renewable integration effects.

One important goal of the field trials, in particular of field trial B is to contribute to a least-cost equipment, installation and operation of the energy management system incl. all data transfer, and to show that the customer can in reality handle all additional incentives for price and energy savings. Assuming a life time of up to ten years for all equipment plus mostly cost-efficient maintenance (best through external access via modem to read and modify software from outside if needed), then the cost savings per year should be at least 10% of the total equipment, installation, maintenance and operations costs. In practice, all efforts should rather pay back earlier, e.g. within five years or less.

3.3. Measurable Objective C

Objective content: **The developed technology has significant potential for mass application across Europe.**

Mass application requires the adoption of the technology by a significant number of energy suppliers, homes, manufacturers of devices and other market participants. Objective C.1 measures the adoption potential, while C.2 considers the motivation of the energy suppliers to use the new technology. These are specified in Sections 3.3.1 and 3.3.2, respectively.

3.3.1. Objective C.1

Objective content	Relevant for business cases	Measurable in field trial
Low entry barriers regarding adoption and diffusion of the technology	**all**	**B, Market and competition analysis**

When measuring the potential of the technology, there are three aspects important for adoption and diffusion of the technology: adaptability, availability and usability.

To allow the users to adapt the technology to their needs, it has to be based on international standards recognized by organisation such as the World Wide Web Consortium (W3C). The technology must not require too high investments for the development of new software to use it (consider also objective B.1 and B.2 for that aspect). The standardization activities in the fields relevant to SmartHouse/SmartGrid are monitored (and documented in D1.2 and its update) and also actively conducted via the OGEMA activities.

As for availability, the technology should be offered by different service providers or by a non-profit-organization. This avoids a monopoly, which would make availability much harder. The installation and usage of the technology should also be made as easy as possible, with a minimum requirement of documentation on all aspects of the technology. Deliverable D5.3 covers a market analysis regarding relevant products and vendors in order to understand the availability of needed products to set up SmartHouse/SmartGrid scenarios. The outcome of that market analysis will be used to measure the availability factor.

The usability of the technology has to be excellent for all roles accessing it (consider also objective A.2 for that aspect). For measuring that, various usability metrics are available. The Single Usability Metric (SUM) combines task completion rates, task time, satisfaction and error counts [Kindlund/Sauro 2005]. The result of the SUM analysis is a percentage value between 0 and 100 %, with 100% indicating perfect usability.

The objective C.1 can, thus, be evaluated with a combination of the standardization analysis conducted in Deliverable D1.2, the availability analysis conducted in Deliverable D5.3, and through surveys carried out in accordance of usability evaluation methods such as proposed by [Kindlund/Sauro 2005].

3.3.2. Objective C.2

Objective content	Relevant for business cases	Measurable in field trial
There is a solid business case for energy utilities and energy service providers to step into ICT-enabled energy efficiency technology.	**all**	**WP 4**

Measuring the adaptation of the new technology into energy supplier's business cases is rather difficult. It requires the new business cases to be of interest to the supplier and for the technology to be able to enhance the existing business cases.

One way to measure that effect could be to interview energy service providers. The survey should investigate what the current business cases are, whether the energy provider can profit from the new technology for these cases and whether he regards the new business cases as solid and would adopt them. The survey should include different kinds of providers (public or private sector, different sizes) to give a representative picture of the adoption potential. Of course, the financial aspects that are covered in objective B are also crucial to the adoption potential.

Care has to be taken to possible changes in the availability / prices of energy resources, possible changes in the legal aspects of energy markets in the future, or new consumption technologies such as electric cars. These aspects may, in fact, lead to a whole new market environment that will change the business cases for energy suppliers. They are also constantly monitored throughout the project, and documented in the next update of this Deliverables D1.1 and D1.2.

These legal and economic framework factors are also taken into account in the simulations conducted within the scenario analyses of WP 4, where the potential of ICT-enabled energy efficiency technology is assessed for the case of a whole country or all Europe. In these scenarios, the costs and benefits of all business cases presented in this document will be assessed based on simulations.

It should be mentioned here that surveys with energy experts are not foreseen in the SmartHouse/SmartGrid project. However, three smaller studies (Master's theses) that add to this question and that involve interviews with energy experts regarding viability of business cases have been carried out at IWES, ECN and SAP. The outcomes of these studies can be reported in the objective analysis of C.2.

3.4. Measurable Objective D

Objective content: **The developed technology is able to achieve aggregate energy efficiency gains >20%.**

Energy efficiency increases through SmartHouse/SmartGrid concepts can result from different sources that will be elaborated separately in the following paragraphs. The optimized operation of devices, both from behavioral changes based on consumption feedback (Section 3.4.1) and on automated energy management (Section 3.4.2), less grid losses (Section 3.4.3) and a higher accommodation ceiling for sustainable decentralized generation (Section 3.4.4) all lead to an increase in overall energy efficiency.

3.4.1. Objective D.1

Objective content	Relevant for business cases	Measurable in field trial
Efficiency gains through interactive feedback to users on optimal energy use (approx. 10%).	**6**	**B**

The split of the efficiency gain into gains caused by behavioral change of energy usage by the users and gains as a result of automated energy management of devices or reduction of grid losses can be done on the basis of customer feed-back (through interviews or standardized questionnaires). Customer surveys can help to understand if the information provided to the customer initiated any change in her energy usage behavior. The condition of active customer involvement and any feedback about consumption and prices is the basis for business case 6 "Energy Usage Monitoring and Optimization Services for End-Consumers".

As a means for simplification, in the SmartHouse/SmartGrid measurements we assume that the energy efficiency gains based on an optimized energy management of devices does not lead to a decrease in overall consumption, but only in changes of the timing of consumption. Therefore, all decreases in overall energy consumption can be allocated to the behavioral changes based on consumer feedback. This can simply be calculated on the basis of the total consumption compared to a reference case. Consequently, the evaluation of the energy efficiency gains based on field trial operations require a suitable reference case that the SmartHouse/SmartGrid case can be compared to. Basically, two different comparison options are conceivable to measure objective D.1 and other objectives in category D:

1. Comparison of the consumption (and generation, if applicable) in test period with the consumption of the same customer group in a comparable period of the previous year(s)
2. Comparison of consumption (and generation, if applicable) of field trial participants with consumption of non-participants (control group) within the test period

The total consumption *D* of all participants of the smart grid field trial will be measured and provided as the sum of total consumption in kWh per month *m* in year *t*, $D_{m,t}$.

Following comparison pattern 1, the consumption of each month of the previous year for those customers that participate in the smart grid field trial needs to be calculated on basis of the measurements done in the previous year $D_{m,t-1}$. If the consumption was not measured on a monthly basis, the total consumption is split to the single months based on the common weighting procedure that is also used for prepayments of electricity consumptions. The total energy savings *S* for any month can be determined as follows, where positive values represent savings and negative numbers represent an increase in consumption:

$$S_{m,t} = \frac{D_{m,t-1} - D_{m,t}}{D_{m,t-1}} \quad (2)$$

The challenge of this comparison pattern 2 is the determination of a representative and comparable control group. At first, the control group should be sized in the same way as the smart grid participants:

- Same number of households
- Same consumption pattern (synthetic profile & period consumption)

Following comparison pattern 2, the consumption of the control group (not participating in the SmartHouse/SmartGrid trial) $D_{nonSHSG,m,t}$ needs to be measured and compared to the consumption of the field trial group $D_{SHSG,m,t}$. Again, the total consumption is split to the single months based on the common weighting procedure that is also used for prepayments of electricity consumptions in the case that the consumption was not measured on a monthly basis. The total energy savings for any month can then be determined as follows:

$$S_{m,t} = \frac{D_{nonSHSG,m,t} - D_{SHSG,m,t}}{D_{nonSHSG,m,t}} \quad (3)$$

Energy efficiency is determined as a relation between input and output of energy. Energy input is considered here as kWh of energy consumed, while the output is the effective (useful) energy that arrives in the household (light, heat, mechanical work etc.). In the project, we only consider the input of electrical energy. We also assume that field trial participants do not narrow their comfort and living quality as a reaction to consumption feedback; energy savings are assumed to be a result of reduced wastage. Consequently, we can also consider the (relevant) output as constant across measurements. Thus, the energy savings as defined by (3) are a complete proxy for the efficiency gains.

3.4.2. Objective D.2

Objective content	Relevant for business cases	Measurable in field trial
Gains as a result of optimized energy management of devices	**1-5, 7, 8**	**A, B and C WP 4**

The calculation of energy efficiency gains due to the implementation of the smart grid is more complex than the calculation of the mere energy savings. In addition to the total energy consumption per month, also the total energy generation per month $G_{SHSG,m,t}$ needs to be measured and taken into account. The energy efficiency gain that can be expected from SmartHouse/SmartGrid concepts is that generation from distributed renewable sources and from distributed “high-efficiency generation” (such as combined heat and power) is used immediately in the neighborhood of that generation. Moreover, the direct use of centralized renewable energy generation, such as power output of large wind farms, is facilitated by SmartHouse/SmartGrid technologies.

For determining the efficiency gain through optimized device operation, the generation efficiency has to be determined separately for each time interval considered (i.e. 15 minutes intervals or at least hourly intervals). One difficulty of this approach is that a comparison of efficiency factors between fossil/nuclear and renewable electricity generation does not lead to meaningful results. As most renewable generation does not require any material input for generation, its efficiency should be assumed as 100%; this applies to solar, wind and hydroelectric generation. Biomass and biogas generation, as controllable thermal processes, are considered with their usual efficiency factors.

Another aspect should be considered in the efficiency calculations: with μCHP plants, the heat can also be used locally, thus raising the overall energy efficiency of this generation option. When calculating the efficiency of power generation, this effect is not taken into account. In this case, the overall energy efficiency (around 80-90% for combined heat and power) should be taken as the value for the calculations to this objective, although this is a simplification.

With this knowledge and with the information of how much consumption and generation has been shifted due to SmartHouse/SmartGrid technology intervention, the gain in terms of energy efficiency and also in terms of saved CO_2 emissions and nuclear waste can be determined in scenario analyses.

In this objective, there is no distinction between a shift of consumption from low price to high price hours that occurs due to active customer behavior or due to automated device control (i.e. through PowerMatcher, BEMI or Magic). Whether a customer monitors current prices and actively shifts certain activities that require some amounts of electricity (e.g. ironing, baking,…) into times of lower prices can only be detected by interviewing the customers. These kinds of interviews, however, are not foreseen in the SmartHouse/ SmartGrid project.

3.4.3. Objective D.3

Objective content	Relevant for business cases	Measurable in field trial
Reduction of power grid losses by increasing local sustainable demand and supply solutions (4-8%).	**1-5, 7, 8**	**(A, B and C) WP 4**

Grid losses are defined as the difference between the electricity generated in the power plants and the generation consumed at the end users’ sites. In central Europe, the grid losses at the high-voltage transmission level are around 1% per 100 km. In contrast, grid losses at the low and medium voltage level are higher and should, thus, be restricted to short distances. Besides, losses occur during the transformation between voltage levels. The average grid losses over all voltage levels are around 6% per 100 km in central Europe.

A higher share of distributed generation has two trends that go in opposite directions: first, the average distance between generation and consumption is decreased, which also decreases the need for electricity transportation. But second, generation is fed into the grid at a medium or low voltage level, where grid losses are higher than on the high voltage level. The second aspect can even lead to higher grid losses. The simultaneous impact of these effects suggests that the share of distributed generation that minimizes power grid losses is somewhere in between a very low and very high share, as visualized in Figure 3.

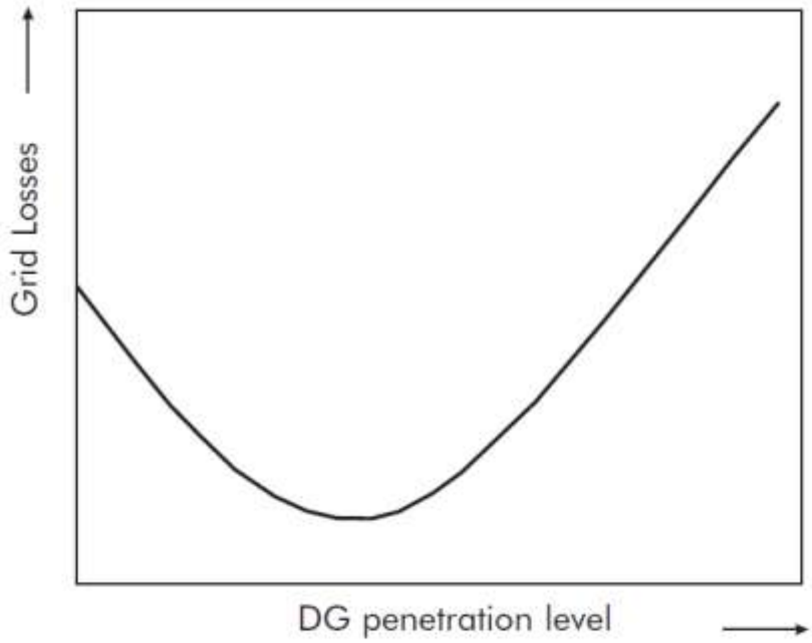

Figure 3: Grid losses related to the penetration of distributed generation[8]

In the SmartHouse/SmartGrid world, the physical transmission and distribution system itself is not analyzed and regarded as given. The grid loss reductions resulting from SmartHouse/SmartGrid concepts are due to the better integration of local generation, including generation from renewable sources. For the field trials in tightly inter-meshed grid areas, such as the planned project trials, reduced grid losses can only be inferred from lower shares of "imported" electricity into one considered (physical) grid area. Less imports lead to less needs for transmission of power to the distribution grid location, and thus to lower grid losses. The grid losses within the distribution grid zone under analysis can only be estimated roughly, and is not subject of analyses within the SmartHouse/SmartGrid project.

With this reasoning, we can define the efficiency gains as the difference between local generation P_{local} and "imported" generation P_{import} for the distribution grid area under analysis (1) for the ordinary operation case, indexed with *nonSHSG*, and (2) for the SmartHouse/SmartGrid case, indexed *SHSG*. The distribution grid area can also defined virtually, as an aggregation of smart houses that belong to one retailer; in this case, all power delivered to theses houses and the distributed generation within the houses is calculated.

$$EE = \frac{G_{import,nonSHSG} - G_{local,nonSHSG}}{G_{import,SHSG} - G_{local,SHSG}} \quad (4)$$

The field trials can give some indication of how much demand and supply flexibility the aggregations of smart houses can help to better use the local generation locally (as it is also measured in Objectives A.3, D.1 and D.2). If the share of distributed generation is low in comparison for the "imports" from traditional supply sources, it is possible that Equation (4), if applied on the field trial data, does not deliver meaningful results, as the small amounts of distributed generation are consumed directly anyway. In order to estimate how SmartHouse/SmartGrid concepts can help to better integrate local generation in the case that this generation has a much higher share of total consumption than today, complementary scenario analyses and simulations have to be carried out. This will be done in the framework of work package 4.

[8] [van Gerwen 2006]

3.4.4. Objective D.4

Objective content	Relevant for business cases	Measurable in field trial
Gains through raising the accommodation ceiling of local networks for integration of local generation.	**1-5, 7, 8**	**WP 4**

The energy efficiency gains from raising the accommodation ceiling of local networks for the integration of local generation is difficult to be determined in any field trial. Here again, the field trials can give some indication of how much demand and supply flexibility the aggregations of smart houses can actually deliver (as it is measured in Objectives A.3, D.1 and D.2). In order to determine how much local generation from small generation units can be accommodated by the grid, or for example whether a self-sufficient operation of a neighbourhood would be possible at adequate costs and at an acceptable comfort level for the inhabitants can more precisely be determined through dedicated scenario runs and analytical analyses. These are foreseen to be conducted within the tasks of work package 4.

3.5. Problems in Measuring the Objectives

When determining differences between status quo operations and the case deploying SmartHouse/ SmartGrid technologies in the field trials, there are some general problems that may limit the significance of the findings. These should be discussed here:

- Length of the testing period

  In order to retain a meaningful result, the length of the testing period is crucial. From previous tests and experiences, it is known that the consumers' motivation to contribute to the success of a smart grid changes during the first month; it either remains high or it sharply decreases and consumers go back to normal operations without smart grid concepts. Therefore, it is helpful to have a test period as long as possible. Even during summer and winter times, the energy demand is quite different and the energy production by wind, CHP and photovoltaic varies. A test period of at least an entire year is desirable to receive well grounded results.

- Number of customers

  Even the number of customers is crucial, because the ability to shift demands is increasing by the number of customers.

- Smart grid independent energy savings or spending

  Consumption comparison of the previous year with the current year (the smart grid year) can be influenced by certain ordinary changes within the households that cannot be respected or discovered in a field trial. For example, purchasing of additional devices can cause higher consumption, or purchasing of energy efficient devices can cause lower consumption. Those events are not respected in the measurements.

- Rebound effects

  The rebound effect describes the effect that consumers who invest into energy efficient devices (e.g. replacing traditional light bulbs by energy saving lamps) are inclined to compensate the efficiency gain by consuming more units of the good in question (e.g. turning more lights on and not switching them off while not in the room). This phenomenon has been observed especially in the car business, where the energy efficiency gains through more efficient motors is offset by a higher number of energy consuming appliances on board that raise overall energy consumption. The rebound effect can even turn negative, expressing that the efficiency gain is more than compensated through higher consumption. This risk is especially obvious if more computing devices are run in for observing or controlling energy consumption, where the computer itself consumes electricity that would not have been consumed if energy monitoring or energy management was not in place.

4. Requirements Catalogue

The three categories of general and functional requirements and (non-functional) quality attributes are differentiated in the following. Before, the general preconditions for realizing the business cases are listed.

4.1. Common Preconditions for Realizing the Business Cases

In order to realize the business cases specified in this document, some preconditions have to be met. The requirements named in the following sections define additional needed functionality of a SmartHouse/SmartGrid system that built on top of the preconditions listed in Table 2.

Prerequisite	**Description**
Smart Metering: Metering Intervals	The realization of the business cases 1-5 and 7-8 assumes that participating households offer some kind of day-ahead or real-time demand and supply flexibility. Customers only have the incentive to provide this flexibility if they can take advantage of low (high) prices to which they preferably shift their demand (generation). This requires fine-grained metering of demand and feed-in from all households. As a minimum time interval for metering, we define 15 minutes periods.
Smart Metering: Meter Data Access	The smart meter should also allow the metering data to be displayed on an external device in real-time. The real-time metering data could, for example, be displayed on a monitor that is installed in a part of the house that the inhabitants visit frequently (in opposition to the places where meters are usually installed nowadays), or it could be imported via a web browser-based customer portal.
Billing	Along with the fine-grained metering, the energy amounts actually consumed and produced in these time intervals of course have to be billed to the customer accordingly, so that he benefits from consuming (generating) in low-price (high-price) times and has an incentive to avoid consuming (generating) in high-price (low-price) times. The billing system has to be able to calculate the due amount based on the smallest metered time interval (here 15 minutes) for each customer. The invoice should give the customer a qualified feed-back about his consumption and generation so that the incentive to behave in a way that is beneficial for the overall system remains active.
Smart Appliances	The business cases 1-5 and 7-8 use the demand and supply flexibility that smart houses can offer. This requires that houses are equipped with smart appliances that communicate with some sort of smart house gateway. The technical realization of this gateway is subject to developments within this project. A common requirement however, is that the communication between the smart house and the offering part (energy retailer, aggregator or DSO) is provided, e.g. via DSL or powerline communication. Accordingly, an in-house communication between the gateway and the appliances has to be assured. This implies that the appliances that offer flexibility are equipped with a communication device that is compatible with the smart house gateway. A soft requirement in this domain is also that the customer is willing to deliver the flexibility and that his appliances are equipped with the necessary advanced control functions.

Table 2: General requirements for realizing the business cases

4.2. General Requirements

The system SHOULD rely on publicly available standards wherever possible.			
Description			
To realize cost efficient communication, standards are decisive that define a common language between the communication partners. In this way effort for individual development and engineering is reduced to a minimum.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq1		Created in WP 1

The communication between home appliances and in-home energy management systems SHOULD rely on one uniform protocol.			
Description			
The protocol meant here is supposed to be the same across all field trials within the SmartHouse/SmartGrid project. This uniform protocol MUST allow mapping to home automation systems suitable for private customers and small businesses (including Z-Wave) and to building automation systems such as KNX and LON.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq2		Created in WP 1

The communication between the in-home energy management and external parties, i.e. the energy supplier, metering service provider and the DSO, SHOULD rely on one uniform protocol.			
Description			
The common protocol description will provide several applications… For an efficient implementation of device integration, existing protocols for communication and information exchange should be used or extended. Such support has implications regarding interoperability as it will ease the device integration and cooperation in a highly heterogeneous infrastructure. Example for protocols in that context are OASIS standards, the DPWS specification, OPC-UA, or the Business-to-Manufacturing Markup Language (B2MML), which is an implementation of the ISA-95 or IEC standards and IEC 61850-7-420. Especially the data models of IEC 61850-7-420 for energy management and access to distributed generation from outside the SmartHouse (if necessary) should be used.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq3		Created in WP 1

The architecture of the customer interface SHOULD make sure that components that several applications require are only implemented once and can be accessed in a uniform way.			
Description			
Components that are used by several applications are (e.g.): • User interface, data base • Access to loads and generators installed at the customer's site • Administration of hardware resources etc. • Protocol stacks for WAN communication • Access to weather forecast			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq4		Created in WP 1

Home energy management systems SHOULD support web services, and appliances within one smart house SHOULD support web services.			
Description			
Web services have emerged as the de facto standard for enterprise application integration, and are the common denominator that needs to be supported by all components participating in a service-oriented infrastructure, as the one envisioned in this project. Coupling web services with smart house appliances or other devices of the electricity system has the potential to increase the efficiency of power grid operation and allows for an overview of the network and interaction with its components. In this context, to improve the transparency of the connection between grid operation systems and smart houses, the devices should be able to expose their functionality as web services.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq5		Created in WP 1

The system MUST provide a service lifecycle management.			
Description			
Service lifecycle management deals with the administration of services during their entire lifecycle. It manages the deployment of new services, the update of existing services, the starting and stopping of services, and the configuration and parameterization of running services. A sophisticated service lifecycle management has the potential to increase the availability of enterprise systems as it extends the possibilities of changing grid operation processes without decreasing overall system efficiency.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq6		Created in WP 1

The system SHOULD provide eventing support.			
Description			
Thousands of events are generated in smart houses and in the grid during normal operation. Some of these events can provide an overview of the current status of the network while others can indicate unexpected problems. Therefore, eventing support is a requirement for smart grid applications to become deeply connected to the smart houses. Filtering (to select the messages that are of real interest to the smart grid), local processing, and evaluation are additional mechanisms that can enhance the performance and scalability of the eventing support.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq7		Created in WP 1

The system SHOULD provide an alerting handling system.			
Description			
Alerting could be supported especially for mission critical parts of the energy system. In a critical situation, messages have to be treated with high priority, and it might be inefficient to defer them to a higher level. Furthermore, the devices should get only the necessary decision-critical information and not get overwhelmed with all alerting data from the smart grid. Therefore, support for the exchange of emergency data and a common alerting protocol have to be in place, which will regulate the communication flow between the different architecture layers.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq8		Created in WP 1

The devices connected to the system SHOULD provide access to their status information.			
Description			
For the management of smart embedded devices, a rich interface to the device status is necessary, and options that can configure it or even allow code to be downloaded to the device are required. All devices should provide a standardized view of their capabilities according to a common ontology and scenario needs. Generally, devices should provide full real-time access to their status to any authorized entity. In case of gateways that control a couple of devices (like home energy management systems), several status reports can be aggregated to hide complexity and provide a comprehensive view.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq9		Created in WP 1

The in-house energy management system SHOULD have the ability to combine different business cases and participate in different market services.			
Description			
The market environment in which the in-house energy management system should operate is quiet complicate since it can directly sale energy or provide ancillary services. The system should have the ability to participate in different business cases and the selection should be made according to the price offered by the aggregator.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq10		Created in WP 1

The system MUST be able to handle potentially conflicting control incentives in different business cases.			
Description			
Incentives from different business cases can be conflicting. As an example market incentives at a global level can lead to peak load or peak generation in the distribution grid. This may lead to congestion due to restricted line or substation capacity. The overall system must provide a means to handle such conflicts, preferably with unbiased outcome for the different stakeholders. One of the consequences of this requirement might be that an energy service company may not exercise direct control of user appliances without some form of consent from the system operator (network constraints) or end-users (comfort degradation). Part of the conflicts may be solved by contractual rules; part will depend on the system state and may require interoperability between business cases.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq11		Created in WP 1

The system SHOULD not oppose liberalization of energy markets.			
Description			
A main issue is the freedom of choice for prosumers to take services from different market parties. Therefore prosumers should be able to connect to the service bundle of their choice.			
Target field trial	**Identifier**	**Relations**	**History**
All	GReq12		Created in WP 1

4.3. Functional Requirements

Message exchange between in-house energy management systems and external parties MUST be bi-directional.			
Description			
Communication both from the TSO or supplier to the customer, and from the customer to the TSO or supplier must be enabled.			
Target field trial	**Identifier**	**Relations**	**History**
All	FReq1		Created in WP 1

The system SHOULD provide for inclusion of information services that can be approached by other system components.			
Description			
Typical information services are forecasts of climate, external market prices, load profiles (generation and production). One of the main reasons why forecasting is required, is to enable local adaptive strategies for appliance control.			
Target field trial	**Identifier**	**Relations**	**History**
All	FReq2		Created in WP 1

The in-house energy management system SHOULD get market price, load and production forecast and SHOULD provide data to the aggregator.			
Description			
Forecasting services are complex and critical part of the system. In order to efficiently schedule the system behavior the local SmartHouse/SmartGrid system should have access to the forecasted values. On the other hand it is mandatory to provide local data in order to have an accurate forecast.			
Target field trial	**Identifier**	**Relations**	**History**
All	FReq3		Created in WP 1

The end-customer within a SmartHouse/SmartGrid system SHOULD get real-time feedback about her current electricity consumption and production.			
Description			
Experience has shown that the mere display of consumption already leads to a significant reduction of consumed electricity, because of the customer's increased energy awareness. This potential for energy savings should also be exploited within the SmartHouse/SmartGrid project.			
Target field trial	**Identifier**	**Relations**	**History**
A (The Netherlands) and B (Germany)	FReq4		Created in WP 1

The end-customer CAN receive information about average / best energy usage of comparable households (benchmarking), and CAN be provided energy saving suggestions.			
Description			
As data about the energy consumption of many households is available in a high-resolution in SmartHouse/SmartGrid scenarios, this data could be used for deriving information from it that helps end-consumers to compare their consumption patterns to that of similar households. Besides, the data delivers the basis for automatically generated energy savings suggestions that could also be made available to the end-consumers.			
Target field trial	**Identifier**	**Relations**	**History**
A (The Netherlands) and B (Germany)	FReq5		Created in WP 1

All devices connected to the system SHOULD have Plug-and-Play characteristics.			
Description			
Enhanced energy efficiency through SmartHouse/SmartGrid concepts can best be achieved in a mass deployment scenario. However, offering energy management systems to millions of users requires that installation and maintenance costs are low. Consequently, devices and energy management systems must be easy to install for anyone, so they must have PnP character. The PnP characteristic in the context of SmartHouse/SmartGrid concepts includes the feature that all devices that are connected to the grid or to an internal energy management system can automatically receive and install software updates if required.			
Target field trial	**Identifier**	**Relations**	**History**
All	FReq6		Created in WP 1

The system SHOULD provide tools for software maintainability.			
Description			
The main issue in software maintainability is version control. Similar solutions may be possible as the Microsoft Update service.			
Target field trial	**Identifier**	**Relations**	**History**
All	FReq7		Created in WP 1

4.4. Quality Attributes

All systems and devices that an end-user can interact with MUST be user-friendly.			
Description			
Intuitive use: "Computer literate" people must quickly understand how the systems / appliances work. Plug-and-Play functionality: End-users must be able to plug and install systems / appliances easily. Factory settings: Default values must be set to sensible values so that end-users who do not want to customize their devices can be sure that they function efficiently ("Plug-and-Play-and-Forget"). New appliances should not require any additional wiring. Users must be able to customize their devices at a convenient place and via an adequate interface (integrated displays / knobs for simple settings, web interfaces for more sophisticated settings).			
Target field trial	**Identifier**	**Relations**	**History**
All	QAtt1		Created in WP 1

Data processing and message exchange needs SHOULD use resources (processing capacity, memory, bandwidth, energy) as efficiently as possible.			
Description			
System should "sleep" when not in use, and wake up through events; lowest possible stand-by consumption; in-house energy management system should have a very low internal consumption			
Target field trial	**Identifier**	**Relations**	**History**
All	QAtt2		Created in WP 1

<table>
<tr><td colspan="4">All applicable law on data protection / obligation of secrecy MUST be complied with by all SmartHouse/SmartGrid system components.</td></tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">The acceptance of energy-related ICT in private households will rely to a large extent to the perceived data security and privacy it can provide. End-users become more and more sensitive towards data protection issues, so it should always be made sure that personal and behaviour-related data is only used by those parties that definitely need them for pursuing the system's goals. All other parties must be denied access to the end-user's data. End-users must be enabled to configure the kinds of data that is transmitted to any party, so that they can always influence the privacy level they want to have.</td></tr>
<tr><th>Target field trial</th><th>Identifier</th><th>Relations</th><th>History</th></tr>
<tr><td>All</td><td>QAtt3</td><td></td><td>Created in WP 1</td></tr>
</table>

<table>
<tr><td colspan="4">The system / network MUST be protected with respect to intrusion by non-certified parties.</td></tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">As with all privacy issues regarding data protection any control or information system will not be accepted by end-users nor by business operators if outsiders can connect to in-house systems resp. business platforms.</td></tr>
<tr><th>Target field trial</th><th>Identifier</th><th>Relations</th><th>History</th></tr>
<tr><td>All</td><td>QAtt4</td><td></td><td>Created in WP 1</td></tr>
</table>

<table>
<tr><td colspan="4">The deployment of SmartHouse/SmartGrid concepts MUST NOT degrade the electricity system's reliability.</td></tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">Electricity systems are already quite stable in most European countries. The current quality level of power supply (e.g. number and duration of outages, mean deviation from target voltage etc.) must be the benchmark for all further system developments.</td></tr>
<tr><th>Target field trial</th><th>Identifier</th><th>Relations</th><th>History</th></tr>
<tr><td>All</td><td>QAtt5</td><td></td><td>Created in WP 1</td></tr>
</table>

The system MUST allow several millions of end-consumers to be connected to it, without impairment of system functionality and reliability.			
Description			
SmartHouse/SmartGrid concepts should be designed for mass application scenarios. Data traffic must therefore be designed in a scalable way so that any number of participants can be connected to the system without reducing its overall performance.			
Target field trial	**Identifier**	**Relations**	**History**
All	QAtt6		Created in WP 1

The system SHOULD be extensible for the inclusion of future energy uses (e.g. electric cars).			
Description			
New electricity uses might gain importance that are not yet taken into consideration during the SmartHouse/SmartGrid project. An example for this is the increasing use of electric vehicles in many European countries. The systems developed should as much as possible have these kinds of future uses in mind and be designed in a way as flexible as possible to their integration into the system.			
Target field trial	**Identifier**	**Relations**	**History**
All	QAtt7		Created in WP 1

The deployment of SmartHouse/SmartGrid concepts MUST take into account future regulatory and market operation changes			
Description			
The legal and regulatory framework of energy market changes frequently and the system should be able to adapt with the minimum possible changes and software development.			
Target field trial	**Identifier**	**Relations**	**History**
All	QAtt8		Created in WP 1

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Appendix: Detailed Business Case Descriptions

1. Aggregation of Houses as Intelligent Networked Collaborations

1.1. Actors and Goals

Actor	Role description and goals
End users	Consumer of electricity who gives information about the operation of one or several dedicated home appliances and responds to price signals. He owns a home energy management system that allows operational flexibility and price responsiveness. The goal of the consumer is to save energy costs.
Aggregator	New player that manages the operation of a group of households in a way that is more efficient than if all households are operated individually.
DG owners	Small generator that gives information about or possibility to control the operation of one or several distributed generation units (e.g. μ-CHP). His goal is to sell his output most cost-effectively through preferably generating at times of high prices.

1.2. Context and Scope

Business context:

- The business context comprises a commercial aggregator or a comparable service provider who has a contract with several end-users residing in SmartHouses (residential or small commercial).
- The aggregator determines and delivers incentives to one or several appliances in each smart house in order to efficiently map supply and demand. As direct control of home appliances would presumably not be accepted by the customers, the form of influencing the operational mode of the appliances in a SmartHouse is through sending price information or other incentives that animate consumers to run appliances in the desired way.

Technical context:

- The participants of the aggregation are possibly, but not necessarily situated in a confined spatial region.
- The information or control signals are exchanged between the smart houses, the small generators and the aggregator via telecommunication, e.g. via Internet or powerline communication.

Scope:

- The timeframe of the business case is the near-real-time. The aggregator communicates with the SmartHouses frequently and on short notice. He sends price signals or other incentives that make the appliances increase or decrease load (or shift load in time) so as to balance the overall system.
- Energy supply from wholesale trading is considered as given in this business case, so no interaction between wholesale trading and coordinated control of SmartHouses is considered here.
- The environment of this business case can be seen as a variant, or also an enabler for delivering balancing power services to a transmission system operator (see description in 2.2.2 and 2 of this Appendix). In the business case described here, the focus is on efficient use of all available energy sources, such as renewable energy and μ-CHP, thereby minimizing overall cost of supply. In the balancing power services case, additional services can be derived from the intelligent coordinated control of several SmartHouses. Power delivery obligations from balancing power services are seen as an additional source of supply variance in this business case (e.g. variance of renewable energy supply).

Preconditions:

- Appropriate ICT infrastructure between the aggregator and the SmartHouses must be in place, and communication protocols must be agreed upon and must work reliably.
- A contract between the aggregator and the SmartHouses must specify how the communication between the two parties takes place and whether and how the aggregator can directly control dedicated appliances for balancing the system.
- Data exchange between the customers' smart meters must be made available to the aggregator, and appropriate privacy policies must be agreed upon.

1.3. The Technology Infrastructure

Required technical components and concepts:

- Appliances with shiftable loads or with buffering capabilities (e.g. containing a thermal or battery storage) must be controllable via a device which communicates with the aggregator.
- Distributed generation units must be able to communicate with the aggregator and must be controllable according to the system's needs.
- An in-house control unit (home energy management system) that communicates with appliances whose operation can be controlled in the framework of an intelligent collaborative network has to be in place. It has to be able to process price information provided by the aggregator, and propose meaningful appliance operation as a response to the price signals. Operation of the energy management system has to be done automatically, with settings defined by the customer (i.e. via a software agent).
- An aggregator must be able to read necessary metering data from the electricity meter inside the SmartHouse close to real-time so that he has up-to-date information about current grid operation.
- The aggregator must dispose of appropriate software that enables an intelligent collaborative operation of the sum of all SmartHouses that are under contract with him.
- The aggregator must have a billing system that is capable of correctly billing the energy fed into the system and withdrawn from the system, taking into account the according points in time and the time-variant prices applicable to each consumption / production.
- The computation required for this business case should be processed within web services wherever possible, in order to enhance interoperability.

1.4. Business Case Scenario Script

The daily operation within an intelligent network of collaborative smart houses can comprise of the following steps:

1. The aggregator forecasts the probable output of the variable renewable generation units that are part of his network.
2. The aggregator estimates the heating needs of the houses that have a μ-CHP plant or that are part of a local heat network.
3. The aggregator calculates the best operation of μ-CHP plants and of other controllable appliances (consuming devices that can shift their load in time or that have an integrated thermal or battery storage) for maximum energy efficiency within the intelligent collaborative network.
4. The aggregator can send this information to the consumers and small producers in order to make them aware of how their appliances are best operated according to the current situation.
5. When approaching real-time operation, the aggregator refines forecasts according to latest available information (e.g. about the weather) for his intelligent collaborative network.

6. In real-time, the aggregator either directly controls the appliances that he is allowed to control (distributed / renewable plants) or sends information / incentives to the customers' home energy management systems that make them operate the devices in a way that is desirable for overall system efficiency.
7. Every day, the aggregator can send information about system operation to the customers so that they can gain experience of the system behavior.
8. Once per month the aggregator bills the electricity produced, considering the applicable tariffs at the times of consumption, and creates a bill for the customer.

1.5. Sustainability and Grid Efficiency Effects

Possible sustainability effects:

- The imbalance risk for output of renewable generation units is reduced.
- Higher shares of renewable energy can be integrated into the grid and used efficiently, thus leading to reduced fossil fuel usage.

Grid efficiency effects:

- Energy is used efficiently within a locally confined area, so the need for grid reinforcement might become reduced.

1.6. Interaction and Communication

The interaction and communication structure within the current business case can be seen in Figure 4.

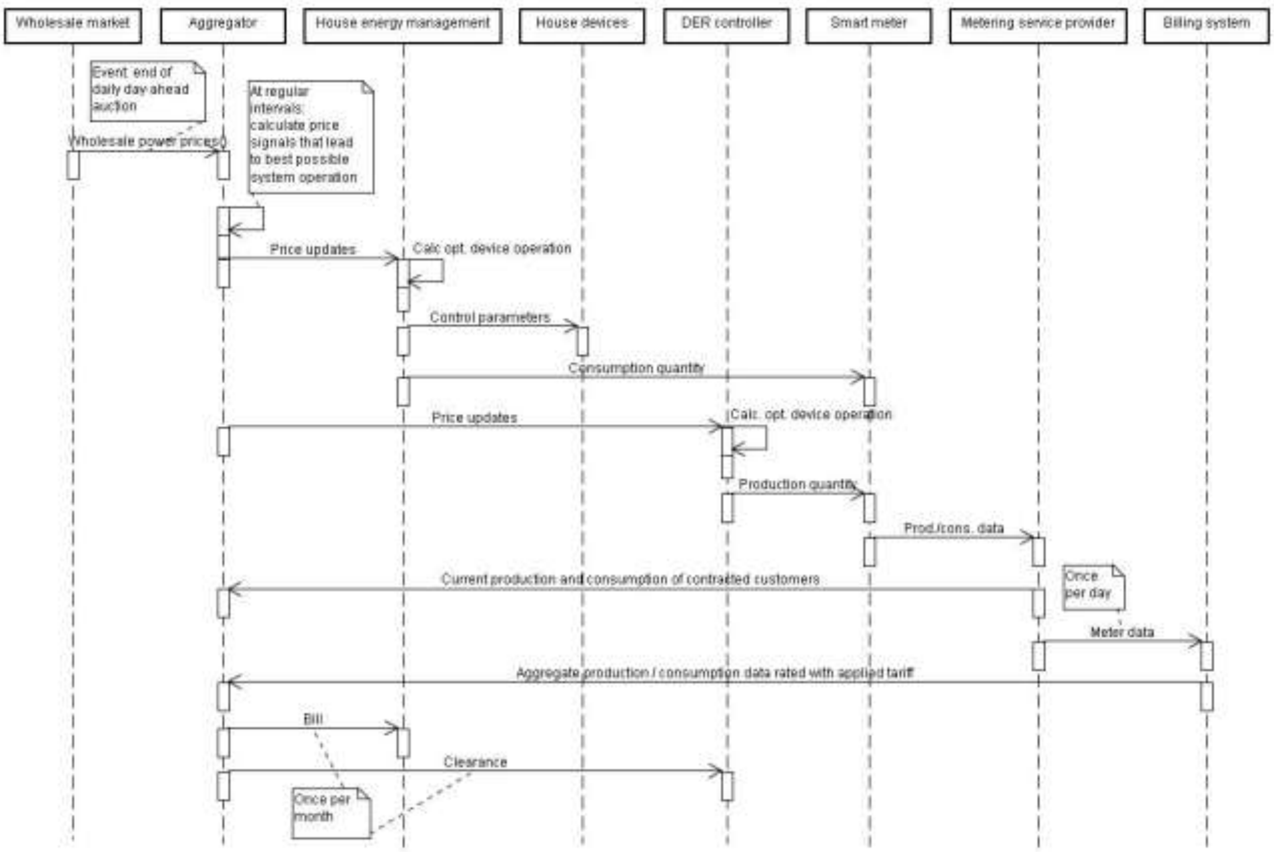

Figure 4: Interaction and communication in a network of intelligent collaborating smart houses

1.7. Value Model

The value driver of this business model is an improved mapping of variable power production and demand, which can lead to a decreased need for peak production and a more efficient local energy use. A service provider such as a commercial aggregator can reap part of the benefit from a better operation of the energy system when several SmartHouses coordinate their loads jointly. On the other hand, the end-users can save money by using electricity at times when it is cheap due to high availability. Owners of distributed generation can gain profits through an optimum operation of their plants. (N.B.: Within a legal framework in which producers of renewable energy are remunerated with a fixed feed-in tariff, they have no monetary advantage in this business case, as compared to current practice. However, in a scenario in which renewable energy production is also traded at markets, and the imbalance produced by variable production has to be set off by some party, this business case is attractive for operators of renewable power plants.) The value model of this business case is depicted in Figure 5.

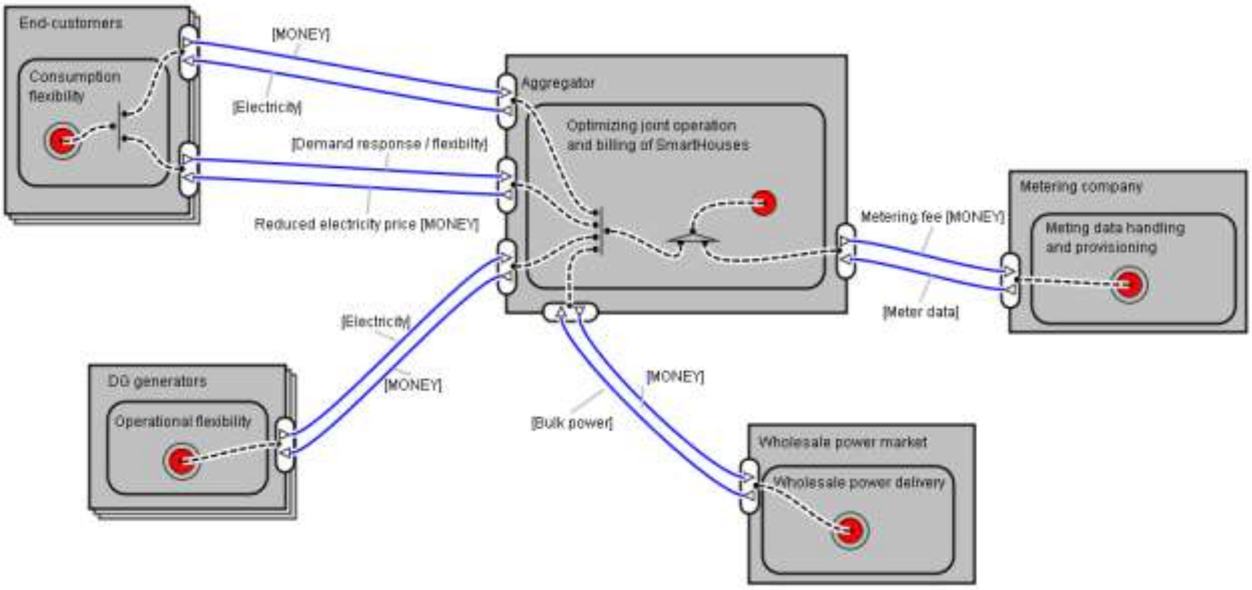

Figure 5: Value model smart houses operated as an intelligent networked collaboration

1.8. Cost Considerations

The business case of a network of intelligent collaborating devices is only viable if the return for the additional investment is interesting for the customers, for the DG operator and for the aggregator. Investment costs are mainly induced by setting up the infrastructure that allows an aggregator to communicate with the devices of the intelligent collaborative network. This also comprises obtaining appropriate software for exercising optimal network operation and for billing. For the customer, the investment in a smart meter and a control unit that switches the appliances has to be borne, if these are not taken over by the aggregator or the grid operator. On the operational side, costs related to data traffic, system maintenance and data processing will arise.

1.9. Success Measures

- Guiding evaluation question for efficiency of the overall system: can variable electricity generation from renewable sources and production from μ-CHP plants be better used even in a scenario with a high renewable share (e.g. derived from simulations of extreme scenarios)? → Objective D
- Guiding evaluation question for acceptability: how does the external control or influence by the aggregator influence the end-user’s convenience in energy consumption? → Objective A.2 and B.1

- Evaluation questions regarding economic performance: how much can be gained from possible business models of an aggregator? Does the end-consumer save money in this business case? → Objective B.2

The success of the aggregation of houses as intelligently networked collaborations can mainly be measured by applying the measurements of the objective D.2 – "Gains as a result of optimized energy management of devices". Objective D.2 is the most important objective to be used as a success measure of this business case, because the overall efficiency gain is the most important objective. Besides the overall efficiency gain, the individual costs savings of the different actors can be verified.

The following further aspects contribute to the success of this business case:

- The necessary technology needs to be affordable in terms of time and skills required by the end user (Objective B.1) and in terms of financial investment and operational costs (Objective B.2). The latter must be put in relation to the achievable cost savings
- Reduction of grid losses is a side effect of the business case and can be analyzed by measuring objective D.3 as described there.

2. Real-Time Imbalance Reduction of a Retail Portfolio

2.1. Actors and Goals

Actor	Role description & goals
BRP	Balancing Responsible Parties bear the imbalance risk of a portfolio of production and/or consumption units, including DER. The BRP aims at minimizing the imbalance risk in order to minimize his imbalance costs.
TSO	Performs system-wide real-time balancing of demand and supply by operating a real-time balancing market mechanism.
End user	Consumer, installs (or allows to install) a local system to deliver flexibility services to the BRP

2.2. Context and Scope

Business context:

- The business context is the balance responsible party and those end-customers within its contract portfolio that deliver flexibility services to the BRP.
- The market context is the Balancing Mechanism as described in subsection 2.2.2.

Technical context:

- The electricity infrastructure does play a minor role in this scenario as for the calculation of the imbalance costs for a particular control zone the location of individual units in that zone is irrelevant.
- The scenario describes the situation in one control zone. The scenario can be replicated for each control zone the BRP is actively involved in. After gate closure, there is no interaction possible between actions of VPP in different zones.

Scope:

- Deliverance of services by the end-user to the distribution grid operator is not being considered in this case description.
- The focus of the scenario is on the near-real-time, i.e.: utilizing flexibility during the settlement period, reaction to events occurring in the settlement period.
- Activities of wholesale market trading (futures, power exchange) are considered to be out of scope of this scenario. It is assumed that these activities have taken place before the scenario starts.
- The Reserve Market itself is out of scope as the BRP sees only the imbalance costs. Participation in the Reserve Capacity Markets by the BRP is not considered here.

Preconditions:

- The end-user contract must cover the deliverance of flexibility services.
- The customer has to be taken out of 'the profile', i.e. the BRP must carry the balance responsibility of the customer's connection in a direct way, not via a reconciliation process.
- There has to be an ICT infrastructure between the BRP and participating customers for control & metering data.
- The VPP must interface to the BRP enterprise systems: real-time dispatch system, billing system. The billing system must be capable of handling real-time tariffs.

There are no preconditions concerning the regulatory framework, as the case targets the current regulation and market mechanism.

2.3. Technology Infrastructure

Involved systems:

- Flexible DER: controllable distributed generator, controllable load or electricity storage device.
- HEM system: home energy management system, manages energy production and consumption within one smart house, communication gate way to external systems.
- DER agent: small-footprint software component associated with one flexible DER device. Is capable of sending control signals to the DER unit and of communicating with the HEM system.
- Dispatcher (system): human or system performing dispatch actions on the BRP level. Is capable of sending control signals to (virtual) power plants.
- VPP system: the virtual power plant, an ICT infrastructure towards a cluster of flexible DER units.
- VPP front-end agent: software component that presents the VPP to the dispatcher (system) in the form of a power plant control interface.
- Digital meter: automatically readable electricity meter at the grid connection point of the smart house.
- Metering data collection system: system for reading the digital meters of the smart houses.
- Billing system: the enterprise system the BRP uses for handling billing information and for creating bills.

The interactions of the VPP, the VPP front-end agent, the HEM system and the DER agents rely on a real-time energy management system such as the PowerMatcher protocol.

2.4. Business Case Scenario Script

Main scenario:

Smart house: Update of the real-time demand curve for the smart house:

1. Flexible DER agent system updates its demand curve whenever there is a reason to and sends the updated curve to the HEM system. The demand curve depends directly on the system state of the DER unit.
2. HEM system processes the update in its aggregated demand curve. When this curve is significantly changed compared to the last one sent, HEM sends the updated curve to the BRP VPP system.

BRP: Update of the real-time demand curve due to a dispatching action, i.e.: a change in the VPP setpoint:

3. Dispatcher (system) changes the setpoint for the VPP.
4. VPP front-end agent changes its demand curve to reflect the updated setpoint.

VPP operation:

5. VPP system processes each received update in its aggregated demand curve and determines the resulting price. When this price is significantly changed compared to the current real-time price, this price is communicated to all HEM systems and the BRP billing system.

Smart house: Receive a new price.

6. HEM system communicates the new price to all its DER Agents.
7. DER agent determines its operation point from the price and its last demand curve and adjusts the DER control parameters accordingly.

At the end of a settlement period:

8. Digital meter stores the energy exchanged during the period.

Once a day:

9. Metering data collection system reads a series of measurements out of the reader and sends the results to the BRP billing system.

Once a month:

10. BRP billings system processes metering data and real-time tariff and creates a bill for the customer.

2.5. Sustainability and Grid Efficiency Effects

Sustainability effects:

- **Enhanced accommodation capability for renewable electricity sources**: Balance responsible parties with lower over-all portfolio predictability face higher imbalance risks and, as a result, higher imbalance costs. This limits the accommodation capability of a BRP portfolio for renewables and lowers the market value of renewable electricity. This scenario increases the real-time controllability of a BRP portfolio and, thus, enhances the accommodation capability for renewable electricity sources.
- **Reduction of fossil fuel usage**: Real-time balancing actions from the virtual power plant are an alternative for those of traditional power plants. For the bigger part, VPP balancing actions are performed by shifting operations of DER devices, which does not increase the usage of primary energy. Moreover, balancing actions traditional power plants are carried out by inefficient and environmental unfriendly peak generation units, especially in on-peak hours of the day.

The scenario has no major effects on grid efficiency.

2.6. Interaction and Communication

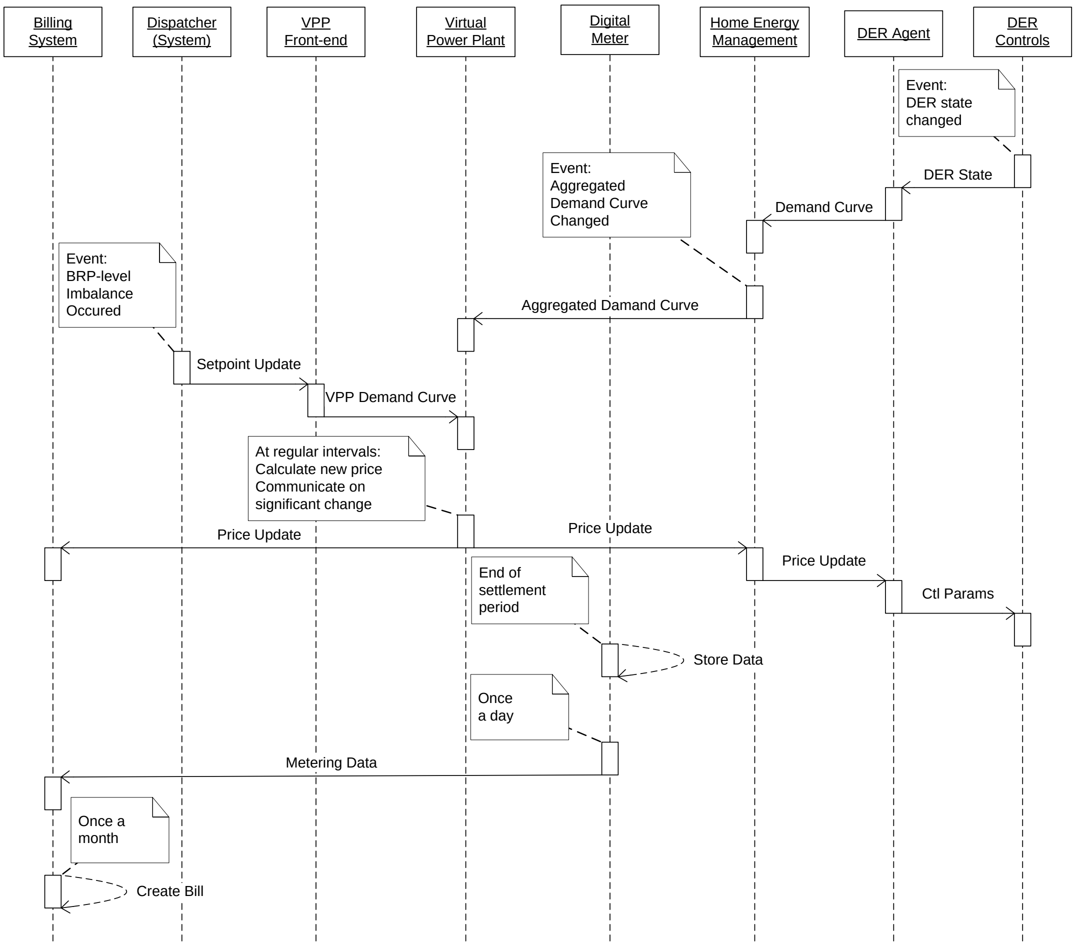

Figure 6: UML sequence diagram for the real-time imbalance reduction case

2.7. Value Model

Figure 7 gives a basic value model for the business case scenario. The BRP has a business need to reduce its real-time portfolio imbalance, indicated by a start stimulus. This need can be fulfilled either by the TSO (who the charges the BRP for the balancing service), or by flexible DER. In the latter case, the BRP must carry the balancing responsibility for the DER units involved. This means that the end-user is in the contract portfolio of the BRP.

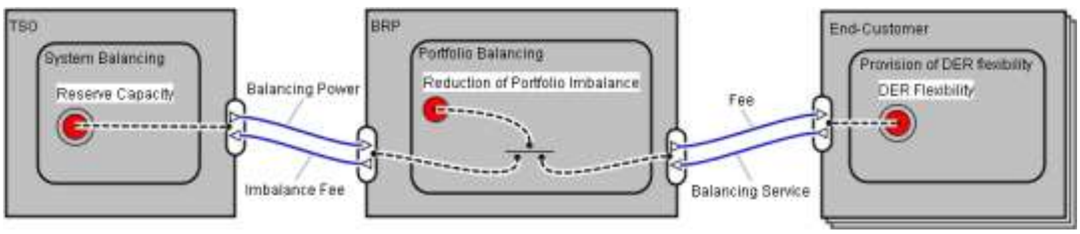

Figure 7: Basic value model for the real time imbalance reduction case

When the BRP carries the balance responsibility of one or more traditional power plants (either by owning or contracting), there is a real-time choice between regulating the VPP or the one of the traditional plants. In an economic dispatch process, this decision will be based on the momentary marginal production costs of all individual (virtual) plants. This case is depicted in Figure 8.

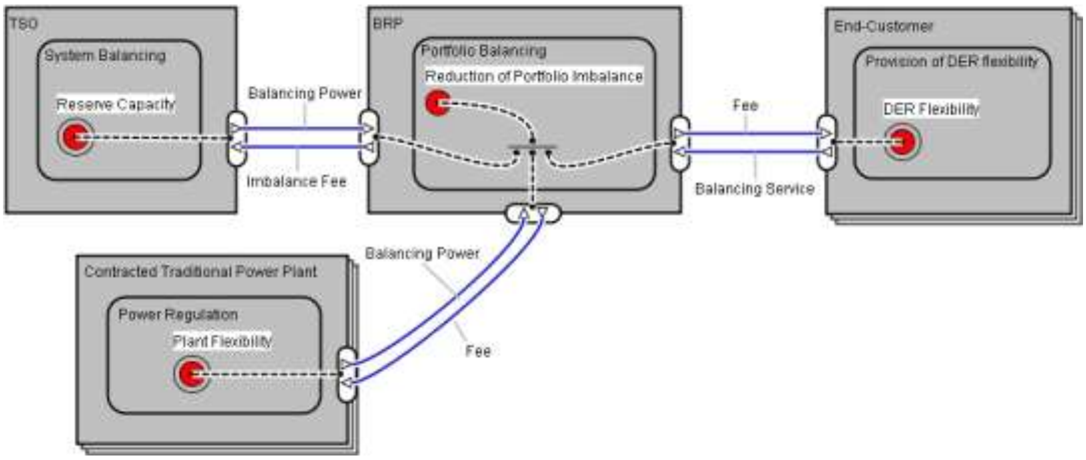

Figure 8: The basic value model extended with traditional power plants

A prerequisite for the scenario is the availability of metering data of sufficient resolution. When this data is provided by a separate company, the business model looks like the one in Figure 9. The BRP business need is now covered by the fulfillment of a combination of two sub needs (hence the 'and' fork): flexible power and metering data. The latter is bought from the Metering Company.

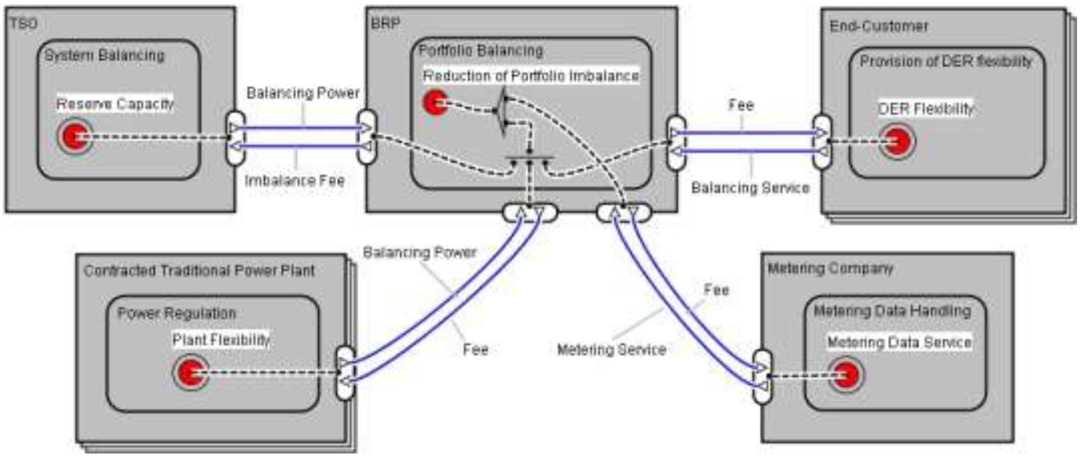

Figure 9: The model of Figure 8 extended with a metering company

2.8. Cost Considerations

Operational:

- IT-related costs for data connections, software licenses, maintenance, etc.
- Higher costs for billing data processing costs due to switch from flat fee to real-time tariff.
- The BRP has operational costs in the form of the fee paid to the end-customer in return of the delivered balancing service.

Investment:

- ICT Infrastructure: hardware, software
- Connection of the virtual power plant functionality to the existing enterprise systems for dispatch and billing.
- Marketing of the new business model to the customer & development of the contractual framework.

2.9. Success Measures

The business case is successful if it is financially viable for the involved parties. This especially involves avoided imbalance costs charged to the BRP. The success of the real-time imbalance reduction of a retailer portfolio can be measured by applying the measurements of the following objectives:

- Objective A1: Scalability

  Objective A1 is relevant to this business case, since balancing requires that the response time of participating devices is within the settlement period, which is 15 minutes in the Netherlands. The preferable time scale for device response will then be 5 minutes.

- Objective D.2 Gains as a result of optimized energy management of devices

  Objective D.2 is the most important objective to be used as a success measure of this business case, because any overall efficiency gain and therefore reducing load peaks is the most important objective

- Objective D.4: Gains through raising the accommodation ceiling of local networks for integration of local generation

  Besides the overall efficiency gain, the independence on balancing energy can be received by having a stand-alone grid in place, based on local generation.

3. Offering (Secondary) Reserve Capacity to the TSO

3.1. Actors and Goals

Actor	Role description & goals
BRP	Balance Responsible Party, operating aggregations of production and/or consumption units, including DER. The BRP aims at offering real-time flexible supply and demand to a system or network operator.
TSO	Ensures the stability of the grid by operating a real-time market-based balancing mechanism. Performs system-wide real-time balancing of demand and supply. The imbalance prices are determined in real-time on the reserve market. Using the mechanism of balancing responsibility, the TSO charges these costs to the Balancing Responsible Parties.
End user	Install (or allow to install) a local system to deliver flexibility services to the BRP.

3.2. Context and Scope

Business context:

- The business context is the BRP and those end-customers within its contract portfolio that deliver flexibility services to the TSO.
- The market context is the Ancillary Services mechanism as described in subsection 2.2.3. An extension of this market mechanism to real-time bidding is made.

Technical context:

- The electricity infrastructure does play a minor role in this scenario as for the calculation of the settlement prices for a particular control zone the location of individual units in that zone is irrelevant.
- The scenario describes the situation in one control zone. The scenario can be replicated for each control zone the TSO is actively involved in. After gate closure there is no interaction possible between actions of BRPs in different zones.

Scope:

- Deliverance of services by the end-user to the TSO is considered in this case description.
- The focus of the scenario is on the near-real-time, i.e.: utilizing flexibility during the settlement period, reaction to events occurring in the settlement period.
- Activities of wholesale market trading (futures, power exchange) are considered to be out of scope of this scenario. It is assumed that these activities have taken place before the scenario starts.
- Imbalance settlement with the BRP is not considered here. The outcome of the business case is the imbalance cost for each PTU.

Preconditions:

- The end-user contract must cover the deliverance of flexibility services.
- The customer has to be taken out of 'the profile', i.e. the BRP must carry the balance responsibility of the customer's connection in a direct way, not via a reconciliation process.

- There has to be an ICT infrastructure between the BRP and participating customers and between the BRP and the TSO for control & metering data.
- Both the TSO and the BRP must interface to their enterprise systems: real-time dispatch system, billing system. The billing system must be capable of handling real-time tariffs.

There is a precondition concerning the regulatory framework, since flexible production and consumption is currently not capable / allowed to participate in system balancing. However, the case may easily be incorporated in the current regulation and market mechanism.

3.3. Technology Infrastructure

Involved systems:

- Flexible DER: controllable distributed generator, controllable load or electricity storage device.
- HEM system: home energy management system, manages energy production and consumption within one smart house, communication gate way to external systems.
- DER agent: small-footprint software component associated with one flexible DER device. Is capable of sending control signals to the DER unit and of communicating with the HEM system.
- VPP system: the virtual power plant, an ICT infrastructure towards a cluster of flexible DER units.
- Dispatcher system: human or machine performing dispatch actions on the TSO level. Is capable of sending control signals to the IMS system.
- IMS system: imbalance management system of the TSO, capable of receiving bids from the VPP system and sending control signals to (virtual) power plants.
- IMS front-end agent: software component that is capable of sending bids to the TSO imbalance management system.
- Digital meter: automatically readable electricity meter at the grid connection point of the smart house.
- Metering data collection system: system for reading the digital meters of the smart houses.
- TSO billing system: the enterprise system the TSO uses for handling billing information and for creating bills for receiving reserve power from BRPs.
- BRP billing system: the enterprise system the BRP uses for handling billing information and for creating bills for the end user.

The interactions of the VPP, the VPP front-end agent, the HEM system and the DER agents rely on a real-time energy management system such as the PowerMatcher protocol.

3.4. Business Case Scenario Script

Main scenario:

Smart House: Update of the real-time demand curve for the Smart House:

1. Flexible DER agent system updates its demand curve whenever there is a reason to and sends the updated curve to the HEM system. The demand curve depends directly on the system state of the DER unit.
2. HEM system processes the update in its aggregated demand curve. When this curve is significantly changed compared to the last one sent, HEM sends the updated curve to the BRP VPP system.

BRP: Update of the real-time demand curve for the VPP:

3. VPP system updates its aggregated demand curve and when this curve is significantly changed compared to the last one sent, VPP sends the updated curve to the IMS system. The demand curve depends directly on the system state of all underlying DER unit.

TSO: Update of the real-time demand curve due to a dispatching action, i.e.: a change in the IMS setpoint:

4. Dispatcher (system) changes the setpoint for the IMS.
5. IMS front-end agent changes its demand curve to reflect the updated setpoint.

IMS operation:

6. IMS system processes each received update in its aggregated demand curve and determines the resulting price. When this price is significantly changed compared to the current real-time price, this price is communicated to all VPP systems and the TSO billing system.

BRP: receive a new price.

7. VPP communicates the new price to all underlying HEM systems and the BRP billing system.

Smart House: Receive a new price.

8. HEM system communicates the new price to all its DER agents.
9. DER agent determines its operation point from the price and its last demand curve and adjusts the DER control parameters accordingly.

At the end of a settlement period:

10. Digital meter stores the energy exchanged during the period.

Once a day:

11. TSO billings system processes IMS outcome and real-time tariff and creates a bill for the BRP.
12. Metering data collection system reads a series of measurements out of the reader and sends the results to the BRP billing system.

Once a month:

13. BRP billings system processes metering data and real-time tariff and creates a bill for the customer.

3.5. Sustainability and Grid Efficiency Effects

Sustainability Effects:

- **Enhanced accommodation capability for renewable electricity sources**: Balance responsible parties can contribute to the accommodation and the market value of renewables outside of its own portfolio by adding flexible, and in most cases cheap, capacity to the current reserve market. Thus scenario increases the real-time controllability of a system imbalance and, thus, enhances the accommodation capability for renewable electricity sources.
- **Reduction of fossil fuel usage**: Real-time balancing actions from the virtual power plant are an alternative for those of traditional power plants. For the bigger part, VPP balancing actions are performed by shifting operations of DER devices, which does not increase the usage of primary energy. Moreover, balancing actions of traditional power plants are carried out by inefficient and environmental unfriendly peak generation units, especially in on-peak hours of the day.

The scenario has no major effects on grid efficiency.

3.6. Interaction and Communication

The interaction between actors in the 'delivery of reserve capacity ' case is basically the same as for the 'portfolio imbalance reduction' case. The main difference lies in the billing system. The prosumers do not pay their electricity bills to the TSO but to their utility. Shifting their supply or demand will not affect the total energy bill with their utility, but should be rewarded with lower demand cost or higher supply benefit, based on the profit the BRP gets from the TSO.

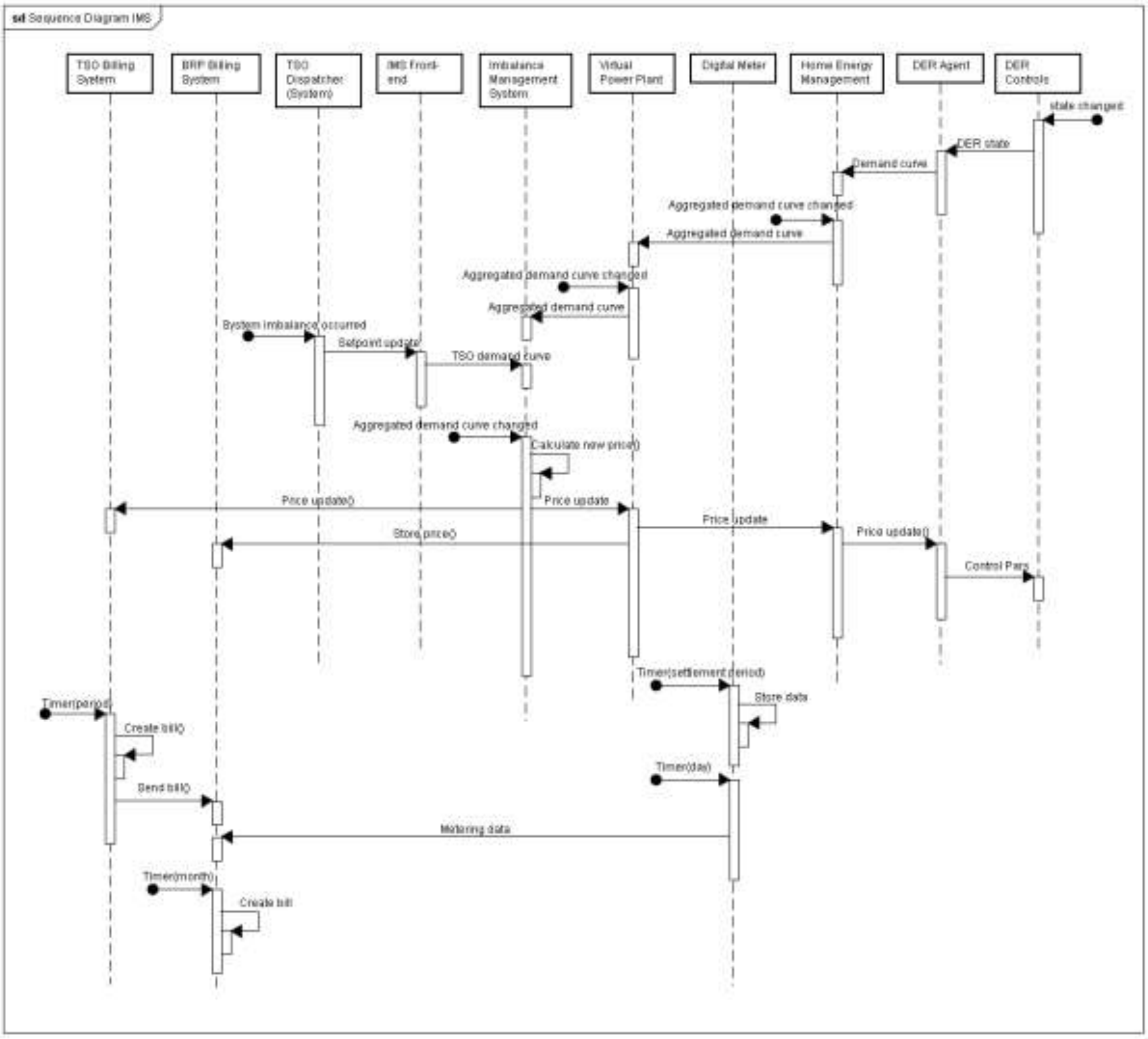

Figure 10: Sequence diagram for the business case "offering reserve capacity"

3.7. Value Model

The main value driver of this business model is the amount of reserve capacity offered to the DSO from the BRP. Furthermore the End Users interact with the BPR providing it capacity. The BRP tries to balances its own portfolio and the actions are performed by contracted reserve capacity.

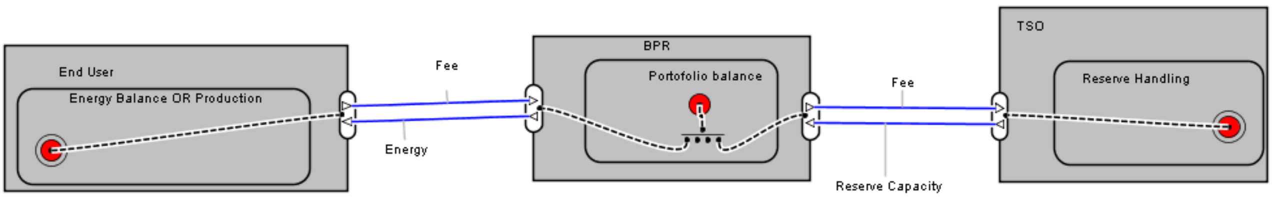

Figure 11: The basic value model for the "offering reserve capacity"

3.8. Cost Considerations

Operational:

- IT-related costs for data connections, software licenses, maintenance, etc.
- Higher costs billing data processing costs due to switch from flat fee to real-time tariff.
- The BRP has operational costs in the form of the fee paid to the end-customer in return of the delivered balancing service.

Investment:

- ICT Infrastructure: hardware, software
- Connection of the virtual power plant functionality to the existing BRP enterprise system for billing.
- Connection of the imbalance management system functionality to the existing TSO enterprise systems for dispatch and billing.
- Marketing of the new business model to the customer & development of the contractual framework.

3.9. Success Measures

The business case is successful if it is financially viable for the involved parties. This especially involves avoided use of stalled reserve capacity and hence reduction of energy and capital cost. The success of the offering (secondary) reserve capacity to the TSO can be measured by applying the measurements of the following objectives:

- Objective A1: Scalability

  Objective A1 is relevant to this business case, since balancing requires that the response time of participating devices is within the settlement period, which is 15 minutes in the Netherlands. The preferable time scale for device response will then be 5 minutes.

4. Distribution System Congestion Management

4.1. Actors and Goals

Actor	Role Description & Goals
Congestion manager	A congestion management party operates aggregations of production and/or consumption units, including DER. The he aims at offering congestion management services to a system or network operator.
DSO	Distribution System Operator ensures the stability of the distribution grid by avoiding congestions. As a main means the DSO detects overflow situations and relies on customer site response programs to tackle this. In time the DSO decides on grid reinforcements. The related investment costs are covered by the distribution fees per kWh as paid by the end users. His goal is to improve the grid quality to save the distribution fees and to postpone costly grid reinforcements.
End user	Install (or allow to install) a local system to deliver flexibility services to the DSO.

4.2. Context and Scope

Business context:

- The business context is congestion management by the DSO at a low voltage cell or by a dedicated service provider and those end-customers within the cell that are willing to participate in “customer site” services to the DSO.
- The market context is an extension of currently applied demand response programs towards real customer site integration (CSI).

Technical context:

- The electricity infrastructure at the low voltage grid is the main aim of the scenario, especially the transformer station. Line constraints are out of the scope of the scenario, but may be handled in a similar way. The location of individual units in the low voltage cell below the transformer is irrelevant.
- The scenario describes the situation within one low voltage cell below a transformer station. The scenario can be replicated for each transformer station the DSO is actively involved in. Interaction between transformer stations is not considered.

Scope:

- Deliverance of services by the end-user via the congestion manager to the DSO is considered in this case description.
- The focus of the scenario is on the near-real-time, i.e.: utilizing flexibility at real-time to reduce peak loads, reaction to events occurring real-time.
- Activities of wholesale market trading (futures, power exchange) are considered to be out of scope of this scenario.

Preconditions:

- The end-user contract must cover the deliverance of flexibility services.
- There has to be an ICT infrastructure between the congestion manager and participating customers and between him and the DSO operation for control and metering data.

- The congestion manager must interface to DSO enterprise systems: real-time dispatch system, billing system. The billing system must be capable of handling real-time distribution tariffs.

There is a precondition concerning the regulatory framework, since flexible production and consumption is currently not capable or allowed to participate in system balancing. However, the case may easily be incorporated in the current regulation and market mechanism.

4.3. Technology Infrastructure

Involved systems:

- Flexible DER: controllable distributed generator, controllable load or electricity storage device.
- HEM system: home energy management system, manages energy production and consumption within one smart house, communication gate way to external systems.
- DER agent: small-footprint software component associated with one flexible DER device. Is capable of sending control signals to the DER unit and of communicating with the HEM system.
- Substation monitoring and control system: is capable of measuring substation state, in particular substation load.
- Congestion management system (CMS) system: the congestion manager, an ICT infrastructure towards a cluster of flexible DER units. The CMS can be seen as the counterpart of the VPP in other business cases.
- CMS front-end agent: software component that presents the CMS to the dispatcher (system) in the form of a power plant control interface.
- Digital meter: automatically readable electricity meter at the grid connection point of the smart souse.
- Metering data collection system: system for reading the digital meters of the smart houses.
- Billing system: the enterprise system the DSO uses for handling billing information and for creating bills. The bills will be based on capacity and/or distribution cost, not on commodity cost.

The interactions of the CMS, the CMS front-end agent, the HEM system and the DER agents rely on a real-time energy management system such as the PowerMatcher protocol.

4.4. Business Case Scenario Script

Main scenario:

Smart house: Update of the real-time demand curve for the smart house:

1. Flexible DER agent system updates its demand curve whenever there is a reason to and sends the updated curve to the HEM system. The demand curve depends directly on the system state of the DER unit.
2. HEM system processes the update in its aggregated demand curve. When this curve is significantly changed compared to the last one sent, the HEM sends the updated curve to the CMS system.

DSO: Update of the real-time demand curve due to substation load change:

3. Substation monitoring and control reads out the substation load.
4. CMS front-end agent changes its demand curve to reflect the updated substation load. When this curve has changed significantly, the agent sends the updated curve to the CMS system.

CMS operation:

5. CMS system processes each received update in its aggregated demand curve and determines the resulting price. When this price is significantly changed compared to the current real-time price, this price is communicated to all HEM systems and the DSO billing system.

Smart house: Receive a new price.

6. HEM system communicates the new price to all its DER agents.
7. DER agent determines its operation point from the price and its last demand curve and adjusts the DER control parameters accordingly.

At the end of a settlement period:

8. Digital meter stores the energy exchanged during the period.

Once a day:

9. Metering data collection system reads a series of measurements out of the reader and sends the results to the DSO billing system.

Once a month:

10. DSO billings system processes metering data and real-time capacity / distribution tariff and creates a bill for the customer.

4.5. Sustainability and Grid Efficiency Effects

Sustainability effects:

- **Enhanced accommodation capability for renewable electricity sources:** Large scale introduction of renewables in the distribution grid may lead to less controllable energy flows, causing congestion problems. This scenario increases the real-time controllability of a distribution bottlenecks and, thus, enhances the accommodation capability for renewable electricity sources.
- **Enhanced accommodation for energy-efficient consuming devices and thus reduction of primary energy usage:** By controlling congestion problems in the distribution grid the introduction of all-electric solutions such as heat pumps and electrical vehicles at a large scale in the grid is supported. These all-electric solutions are more energy-efficient than their traditional counterparts and therefore the usage of primary energy is reduced.

The scenario also has major effects on grid efficiency, reducing grid losses.

4.6. Interaction and Communication

The interaction between actors in the “congestion management” case is basically the same as for the “portfolio imbalance reduction” case. The main difference lies in the actors: BRP is replaced by DSO, and the VPP dispatch system is replaced by a substation monitoring and control system. The billing system is driven by the DSO and either capacity or distribution costs are billed instead of commodity cost.

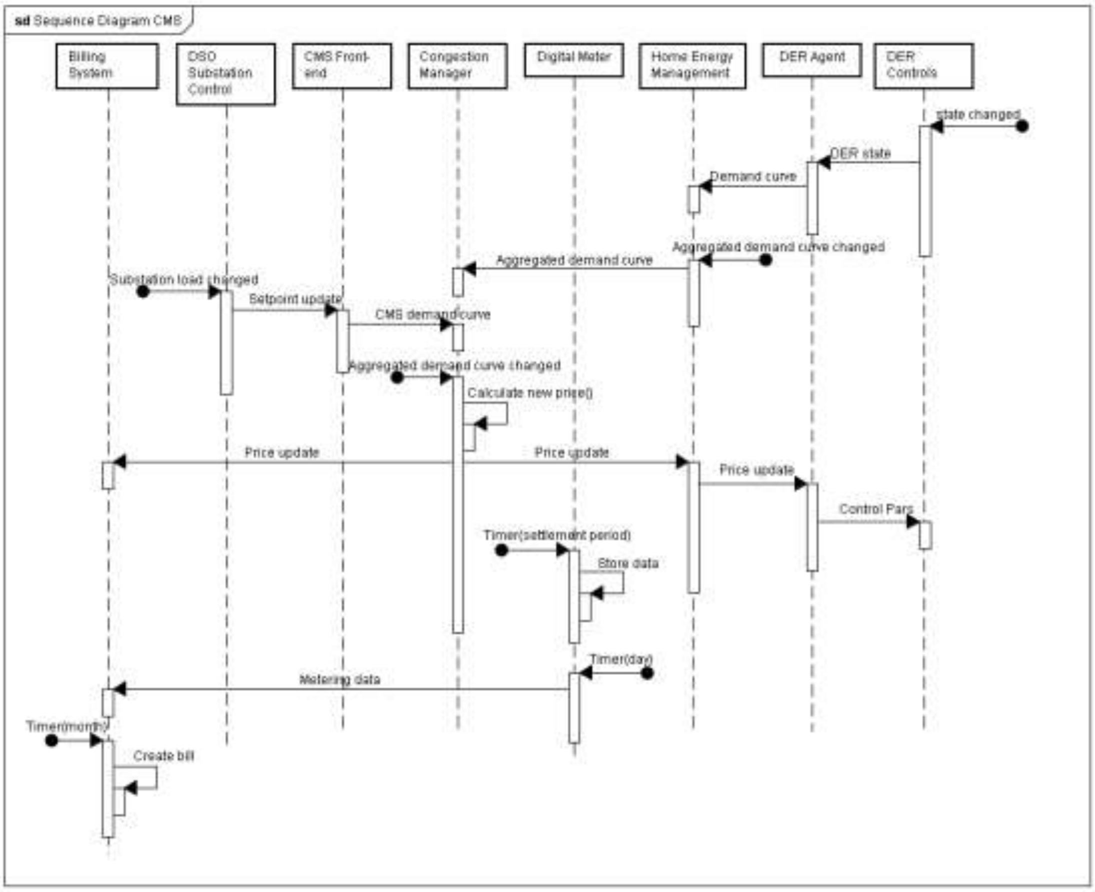

Figure 12: UML sequence diagram for the business case "congestion management"

4.7. Value Model

The main value driver of this business model is the amount of energy provided to the DSO from the CMS in order to have congestion relief. Furthermore the CMS interacts with the end-users providing them fee for the power produced or shed.

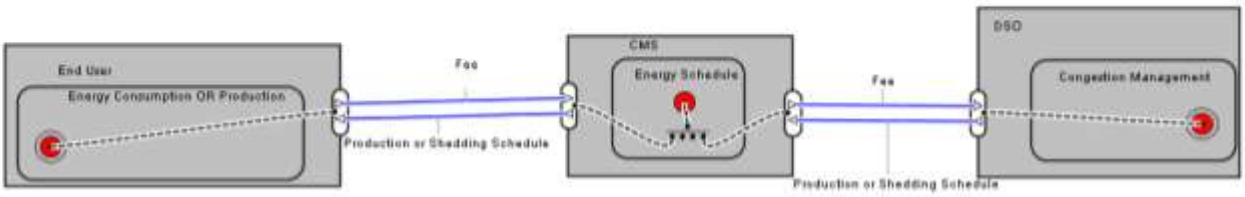

Figure 13: The basic value model for the "distribution system congestion management"

4.8. Cost Considerations

Operational:

- IT-related costs for data connections, software licenses, maintenance, etc.
- Higher costs billing data processing costs due to switch from flat fee to real-time tariff.
- The DSO has operational costs in the form of the fee paid to the end-customer in return of the delivered balancing service.

Investment:

- ICT Infrastructure: hardware, software
- Connection of the virtual power plant functionality to the existing enterprise systems for dispatch and billing.
- Marketing of the new business model to the customer and development of the contractual framework.

4.9. Success Measures

The business case is successful if it is financially viable for the involved parties. This especially involves a flattened load duration curve and reduction of peak loads at a transformer station, and hence a deferral of investment cost. It is important to assure that no decrease of comfort or functionality at the end-user site occurs. The success of the distribution congestion management can be measured by applying the measurements of the following objectives:

- Objective D.2 Gains as a result of optimized energy management of devices
- Objective D.2 is the most important objective to be used as an success measure of this business case, because any overall efficiency gain and therefore reducing load peaks is the most important objective
- Objective D.4: Gains through raising the accommodation ceiling of local networks for integration of local generation

Beside the overall efficiency gain the independence on balancing energy can be received by having a stand-alone grid in place based on local generation. Description

5. Variable Tariff-Based Load and Generation Shifting

5.1. Actors and Goals

Actor	Role description & goals
Energy supplier	The energy supplier (in his role as a retailer, an energy trader and the balancing responsible party) aims to minimize imbalance risks and purchasing costs.
End user	The end user (consumer) wants to reduce energy costs and agrees with the installation of technical load / generation shifting devices.

5.2. Context and Scope

Business context:

- A contract is made between energy supplier and end user regarding delivering electricity. The customer buys electricity from the supplier at a time-variable tariff. The contract must specify the exact rules regarding pricing, price guarantee, time of fixing and transmission of the price information etc.
- The basis for fixing the variable prices may be the corresponding prices at the day-ahead auction at large exchanges, such as EEX, because of price transparency and higher liquidity as compared to intra-day auctions.

Technical context:

- If a lot of customers that participate in variable tariff-based load shifting are connected to a single distribution grid, cooperation with the DSO may be necessary in order to avoid grid problems e.g. by avalanching effects
- See technology infrastructure, Section 5.3 of this Appendix

Scope:

- Delivery of services by the end user to the distribution grid operator is not being considered in this scenario.
- The focus is on day-ahead trading. The energy trader reduces his price risk when procuring on day-ahead markets by passing on some of the price fluctuations to the end customer.
- Reserve capacity markets are out of scope.

Preconditions:

- Smart metering and billing is a prerequisite of this business case. Load profile metering of the customer is assumed to be available.
- There are no preconditions concerning changes to the current regulatory framework (except for the availability of smart metering providing load profiles approved for billing and inclusion into the balancing profile of the retailer as a BRP)
- The end user has to be willing to engage in price-oriented load shifting for making this business case successful.

5.3. Technology Infrastructure

Requirements:

- Load devices with communication interface (or with an external switch box)

1. Devices with thermal or battery storage, for which the state-of-charge (SOC) must be maintained within a certain range, e.g. warm water generation, air conditioning, ventilation or cogeneration devices.
2. Devices which carry out a fixed program with shiftable starting time (Fixed Program Shift - FPS); e.g. washing machines, dryers or dish washers
3. Devices which can reduce their power at high electricity prices (Price Power Control - PPC), e.g. dimmable lighting

- Controllable distributed generators with communication interface (e.g. CHP)
- Local energy management device (e.g. BEMI system)
  - Including smart metering (metering 15 minute periods of each integrated device)
  - Receiving price profiles
  - Calculating schedules for integrated devices and controlling these devices
- Communication system between the local energy management system and the devices that are controlled, as well as communication with the user interface (e.g. web portal or in-house display)
- Central energy management system (e.g. Pool BEMI)
  - Receiving price profile from energy exchange
  - Calculating price profile prediction
  - Calculating load profile prediction
  - Calculating individual price profile for each local energy management device / smart house (taking account of the avalanching problem)
  - Communicating with local energy management devices
  - Storing profile metering data of customers
  - Billing profile metering data
- Communication system between central energy management system and local energy management device
- High quality price profile predictions
- High quality load profile predictions
- Transparent price profile calculation achieving fair financial results for both actors (including financial risks and end user behavior)

5.4. Business Case Scenario Script

The following time-table describes how the business case could be put into practice step-by-step each day. The details are based on the German market, but could be adapted to other European markets easily:

1. Day-ahead delivery until 12:00 a.m.
   a) Price prediction spot-market for at least the next two days
   b) Price profile prediction for at least the next two days
   c) Load profile prediction (assumed that all customers get the before predicted price profile) for at least the next two days
2. Day-ahead delivery 7:30 – 12:00 a.m.
   d) Entering of bids at day-ahead auction (buy and sell)
3. Day-ahead delivery 12:15 – 12:45 a.m.
   e) Announcement of day-ahead market prices by exchange
   f) Announcement of realized contracts (MWh) by exchange

4. Day-ahead delivery from 12:45 a.m.
    g) Calculating price profile for at least the two next days
    h) Adapting load profile prediction for at least the next two days
5. Intraday until 75 minutes or less before delivery
    i) Energy supplier can trade for imbalance reduction of his portfolio (which has no relevance for customer prices)

5.5. Sustainability and Grid Efficiency Effects

Sustainability effects:

On first glance the scenario improves only the financial situation of both actors. But there is also a correlation between price and load profile. So these sustainability effects will be achieved indirectly:

- Enhanced accommodation capability for renewable electricity
- Reduction of fossil fuel usage
- Reduced operation of centralized peak power generation

Grid efficiency effects

- Deferral of grid reinforcement

5.6. Interaction and Communication

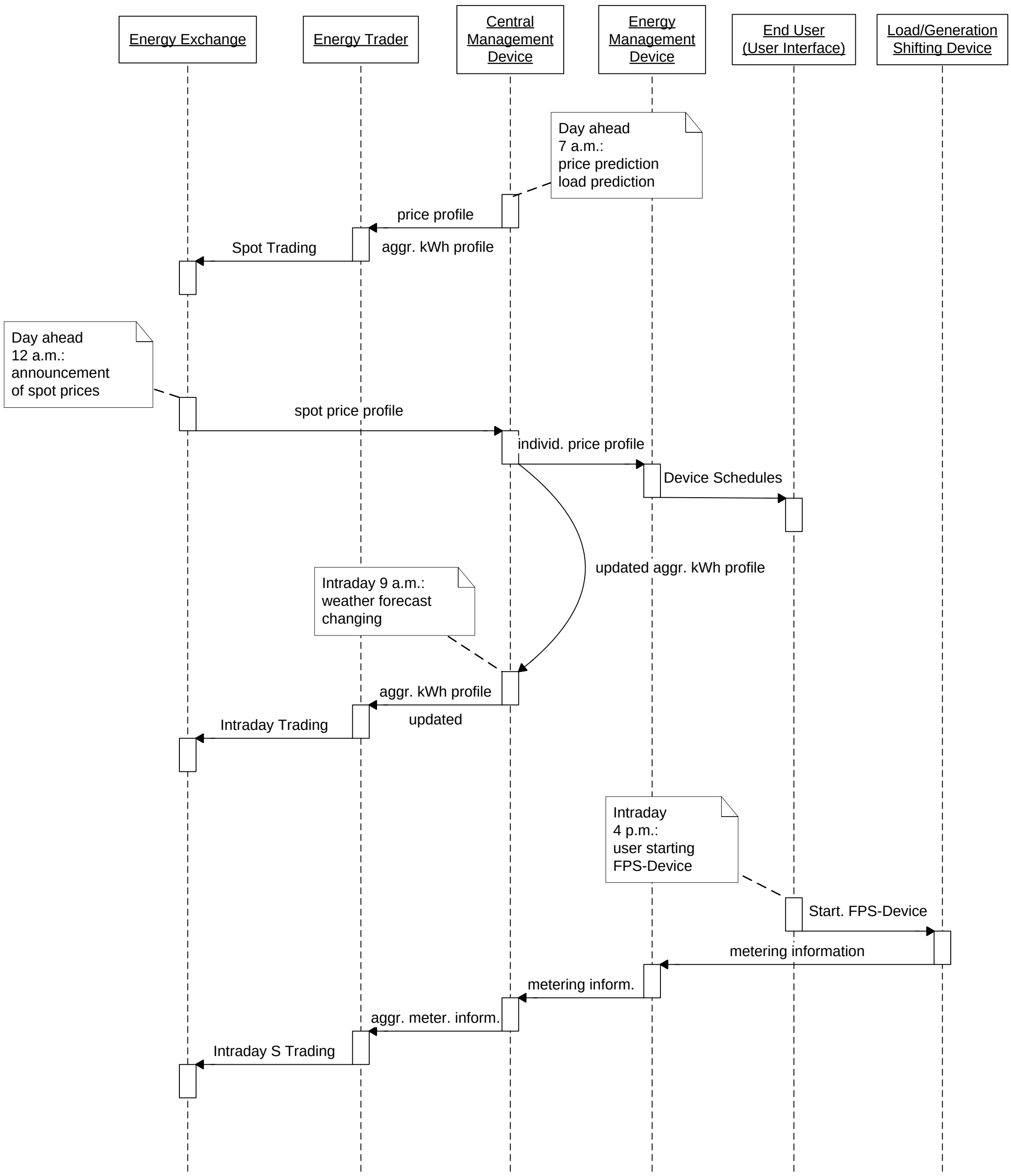

Figure 14: Exemplary UML sequence diagram for FPS device load shifting

The business case "Variable tariff-based load and generation shifting" creates a lot of different situations with different load devices and generation units also freely mixed with each other. So only an example is given in Figure 14.

5.7. Value Model

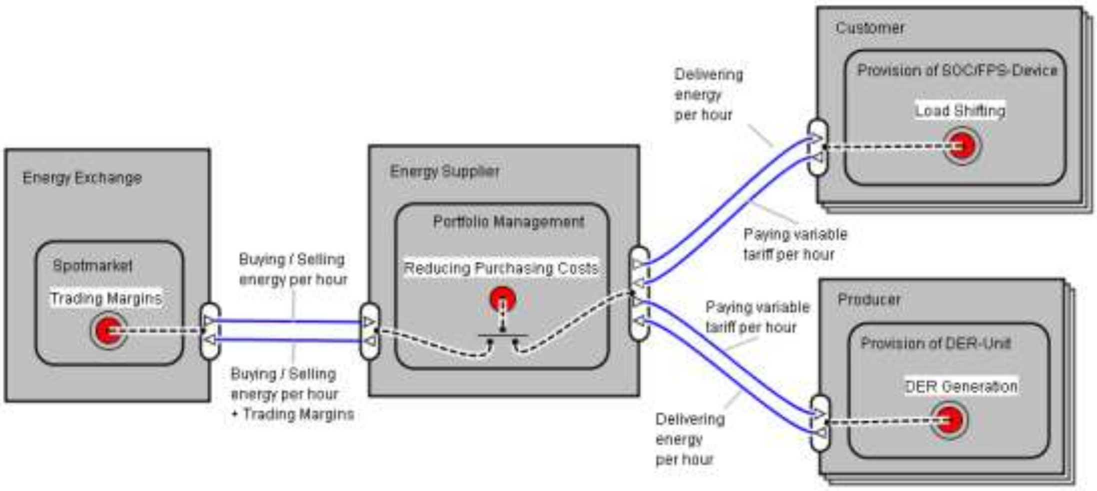

Figure 15: The basic value model for the "Variable tariff-based load and generation shifting"

Figure 15 shows the main actors of the business case "Variable tariff-based load and generation shifting". The energy supplier wants to reduce his energy purchasing costs. He has got the opportunity to trade (buy and sell) energy per hour at the spot market of the energy exchange. In lower and higher price areas the energy supplier has got the chance to offer interesting prices for customers and producers. To give a closer look next the creating of financial advantage for a SOC-Device is described in detail exemplary.

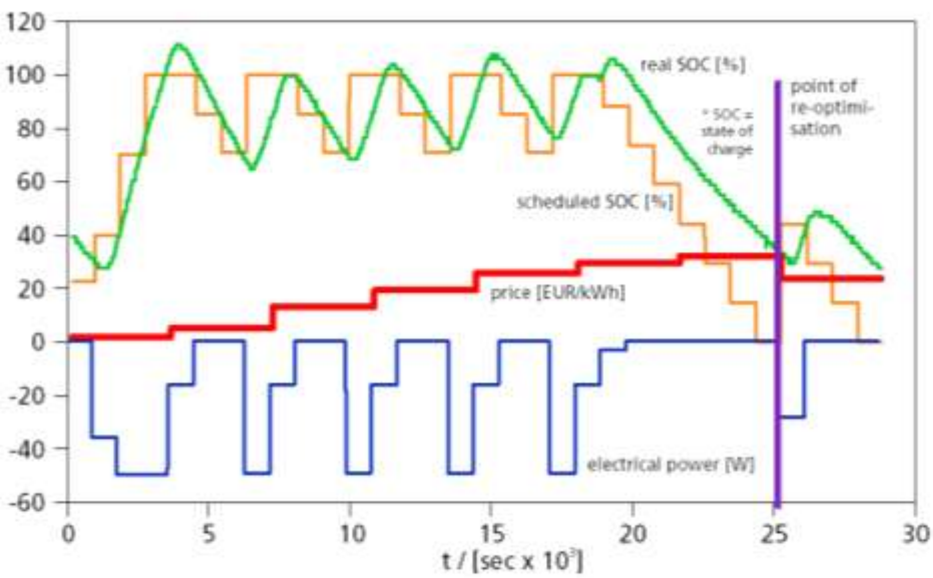

Figure 16: Management of a cooling device based on a variable tariff

Figure 16 illustrates that the SOC (state-of-charge) of a cooling device changes based on its operational state. When the device is in operation (i.e. when it draww power), the SOC increases. For economic efficiency, the SOC is held high during low price times. In high price times the device is turned off and the SOC decreases. This strategy generates a financial advantage.

The strategy of FPS devices is very similar (operating in low price times).

5.8. Cost Considerations

Operational:

- IT-related costs for data connections, software licenses, maintenance, etc.
- Higher billing data processing costs due to switch from fix price to variable based-tariff.
- Supplier face higher costs if end users shift load into higher price times

Investment:

- ICT Infrastructure: hardware, software
- Marketing of the new business model to the customer and development of the contractual framework.

5.9. Success Measures

- Reduced purchasing costs for the energy supplier
- Reduced energy costs for the consumer
- Fair distribution of financial advantages between both actors

The success of the variable tariff-based load and generation shifting can be measured by applying the measurements of the following objectives:

- Objective D.2 is the most important objective to be used as a success measure of this business case, because any overall efficiency gain is the most important objective.
- Objective D.1 can also be measured, because feed-back is given to the consumer about prices / tariffs and his consumption.

The following objectives can be contributing to the success factors of this business case:

- Objective B.3: The developed technology is affordable in terms of financial investment and operational costs

Beside, the overall efficiency gain the individual costs savings of the different actors can be verified.

- The success of the business case needs also the affordability consideration from the end user (Objective B.1).

6. Energy Usage Monitoring and Optimization Services for End-Consumers

6.1. Actors and Goals

Actor	Role description & goals
Energy service provider or supplier	Collects consumption data of his customers and aggregates them to form valuable information; makes the information available to the customer in a web portal or an in-house display.
End user	Allows the service provider / supplier to access detailed meter data; requests information services from the service provider in order to reduce his private energy consumption and costs.

6.2. Context and Scope

Business context:

- The business concept is that service providers offer information services to end customers that help the latter to reduce their private energy consumption.
- The service can either be offered by a supplier or an external partner.
- Remuneration of the service can be through direct payment of fees or through increased loyalty in case the supplier / service provider has further contractual relationships.

Technical context:

- The customers access the consumption data via a web browser or mobile device; the data is transmitted via internet protocol.
- More precise consumption data is stored directly on the smart meter and can be transmitted to the customer's PC or mobile device; aggregate data is exchanged with the service provider.

Scope:

- The service of energy consumption monitoring can, in principle, offered to any customer who has a smart meter that is able to send / receive metering data remotely.
- For determining comparable households, regional aspects should also be accounted for (e.g. a household's consumption in the north of Germany is not as much comparable to one in Greece).
- Energy monitoring can also be offered for small enterprises.
- The service aimed at in this business case can comprise automated advice for energy saving measures.

Preconditions:

- The participating customers have to be equipped with smart meters that communicate their consumption to the service provider.
- The infrastructure for communication with a remote server (e.g. via powerline or DSL) must be in place in the house of the participating customer.
- Legally compliant contracts that allow access to metering data must be in place, and privacy protection measures must be in place.

6.3. Technology Infrastructure

- Smart meter: metering device must be able to store data that can be downloaded within the LAN of the customer
- LAN and PC: the customer plugs the smart meter to his local area network and access the data directly from the meter
- WAN: the smart meter must be able to communicate with a remote server, and a service provider must be granted the right to access and process this data
- Meter data evaluation system: is capable of calculating all relevant data that the end-customer is interested in; can guess which sort of appliances are using how much power at which time, so that automated energy savings advice can be generated from the metering data

6.4. Business Case Scenario Script

1. The smart meter continuously tracks the customer's consumption and stores this data (e.g. in 1-sec steps)
2. In fixed intervals (e.g. every 15 minutes), the service provider requests aggregate consumption data from the customer's smart meter
3. The service provider processes the metered data of all his customers and calculates averages over various types of households
4. When a customer is interested in comparing his consumption with that of comparable households, he requests the according data from the service provider
5. The customer's metering data and data of comparable households is displayed in a comprehensible way in a portal that he has access to.

6.5. Sustainability and Grid Efficiency Effects

Sustainability effects:

- Due to an expected reduction in residential energy consumption from a timely display of information to the user, this business case contributes to achieving climate protection.

Grid efficiency effects:

- This business case does not interfere with the transmission or distribution systems and therefore has no grid efficiency effects; however, a general reduction of the end-users' energy consumption through the display of information can free capacity for other purposes.

6.6. Interaction and Communication

This business case is mainly described as a provision and processing / editing of data for the end-user, who can use the provided information for reducing consumption. Data update occurs frequently (i.e. every second for the data provided by the end-user's own meter, and 15 minutes for aggregate data of comparable households). The communication is done via a browser that could resemble to the GUI mockup displayed in Figure 17.

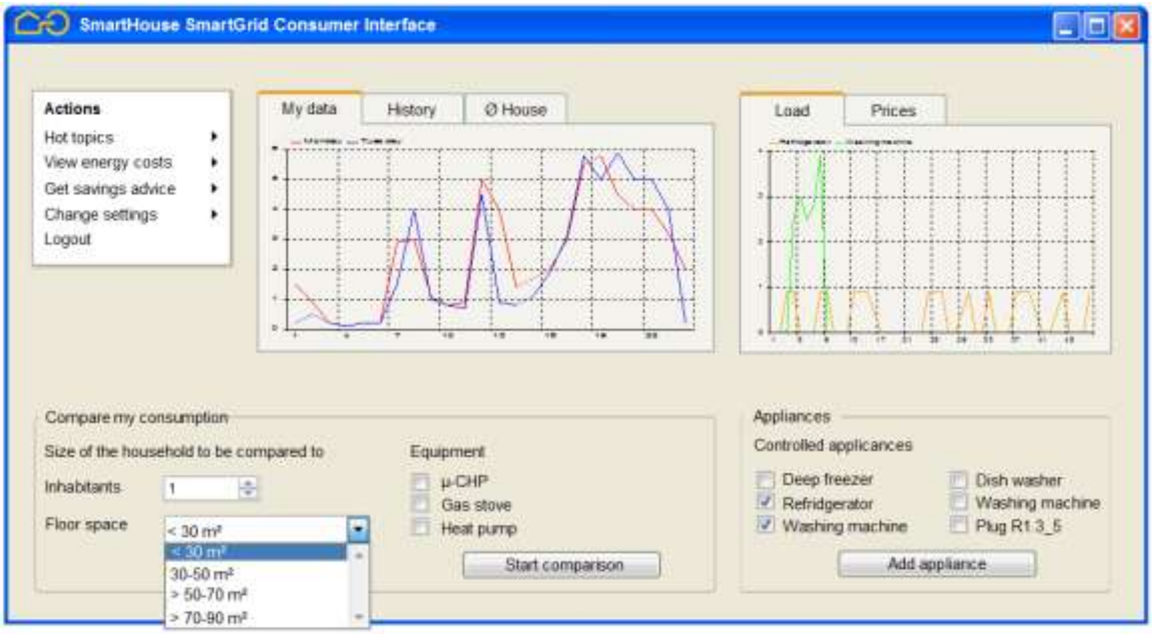

Figure 17: Possible functionality of a user interface for energy usage monitoring and optimization services

6.7. Value Model

Figure 18 gives a basic value model for the business case scenario for the case that the energy information service is provided by the supplier, who uses it as a customer retention measure; Figure 19 shows the same case in which the service is provided by a third service provider who charges a fee in return.

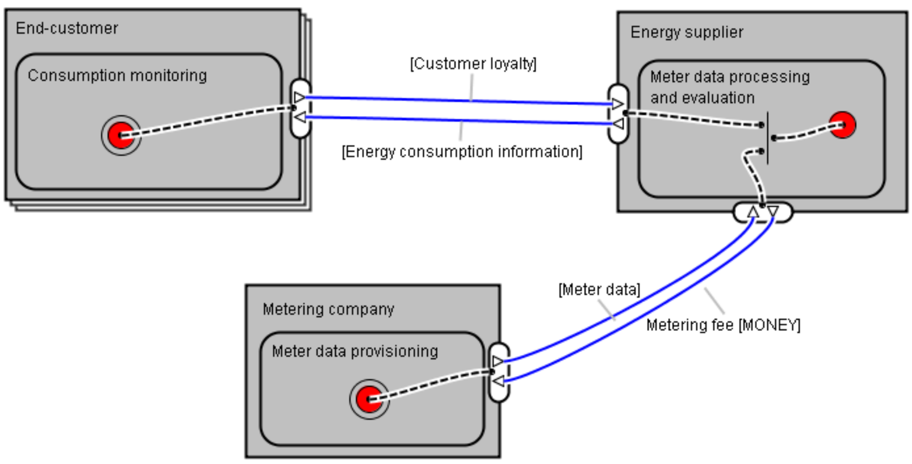

Figure 18: Value model of the energy usage monitoring and optimization services business case provided by the energy supplier

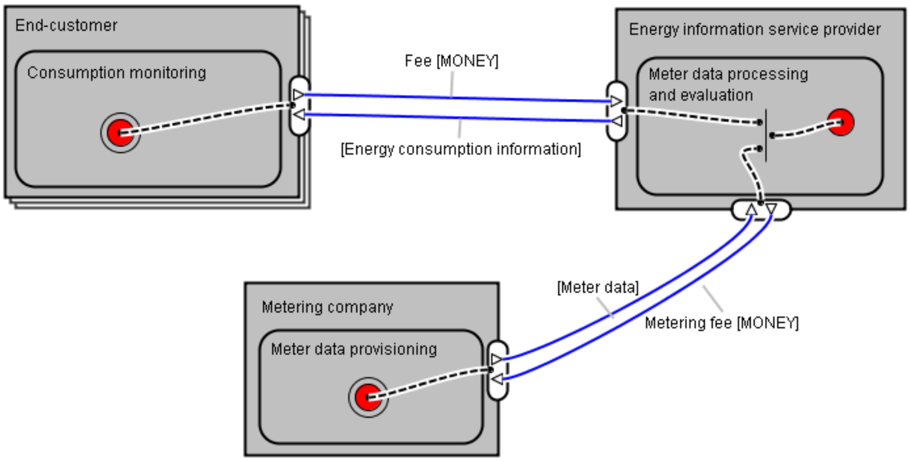

Figure 19: Value model of the energy usage monitoring and optimization services business case provided by a third service provider

6.8. Cost Considerations

Operational:

- Operational costs of the energy monitoring business case is rather low, as only information has to be exchanged and the graphical user interface has to be maintained so that it is always compliant to current software (browsers, mobile devices etc.).

Investment:

- Investment costs mainly arise from developing the user interface that displays consumption information to the customer. It should be assumed that the infrastructure allowing the meter to communicate with an external server, e.g. via powerline or DSL, is already available, so no extra investment occurs from this part of the technical requirements.

6.9. Success Measures

The success of the energy usage monitoring and optimization services for end-consumers can be measured by applying the measurements of the following objectives:

- Objective D.1 can be measured, because feed-back is given to the consumer about prices/tariffs and his consumption
- Objective B.3: The developed technology is affordable in terms of financial investment and operational costs

Beside the overall efficiency gain the individual costs savings of the different actors can be verified.

- The success of the business case needs also the affordability consideration from the end user (Objective B.1)

7. Distribution Grid Cell Islanding in Case of Higher-System Instability

7.1. Actors and Goals

Actor	Role description and goals
Consumers	Provides control of their load as well as metering data about their consumption
DSO	Manages the transition to island mode and allows the internal power management when it is considered as safe.
Aggregator	Monitors the system before the event that may lead to island mode and manages the operation of a group of consumers as well DG owners in an efficient way during the island mode.
DG owners	Provide information about their status and their production capabilities

7.2. Context and Scope

Business context:

- The business context comprises a commercial aggregator who has a contract with several consumers as well DG owners. The contractual agreements should be designed in cooperation with the DSO.
- The aggregator takes control over all appliances of each consumer, in order to map supply and demand. Based on information about future production capability as well on the overall load he creates a load shedding scheme.
- The consumers have a contract in which they have declared the amount of money they are willing to pay during the island mode as well the part of the load they allow to be controlled by the aggregator.

Technical context:

- The consumers and the DG owners should be situated in the same part of the network.
- The disconnection of the island is the DSO's responsibility.
- The information or control signals are exchanged between the smart houses and the aggregator via telecommunication, e.g. via internet or powerline communication.

Scope:

- The timeframe of the business case is the near-real-time. The aggregator communicates with the consumers, DSO and DGs frequently and on short notice.
- During the island mode, the system does not participate in wholesale market trading.

Preconditions:

- Appropriate ICT infrastructure between the aggregator, the consumers and the DG owners must be in place, and communication protocols must be agreed upon and must work reliably.
- A contract between the aggregator, the consumers and the DG owners must specify how the communication between the two parties takes place and whether and how the aggregator can directly control the consumers and the DG owners.
- Data exchange between the customers' smart meters must be made available to the aggregator, and appropriate privacy policies must be agreed upon.

7.3. Technology Infrastructure

Required technical components and concepts:

- Proper protection and electrical equipment in the network that will allow the transition to the island mode.
- Appliances and consumers must be controllable via a device which communicates with the aggregator.
- DG units must be able to communicate with the aggregator and must be controllable according to the system's needs.
- An aggregator must be able to read necessary metering data from the electricity meter in the consumer as well the DGs.
- The aggregator must dispose of appropriate software that enables an intelligent collaborative operation of the system.
- The aggregator must have a proper billing system that is capable of correctly billing the energy transaction during the islanded operation.

7.4. Business Case Scenario Script

The daily operation within an intelligent network of collaborative smart houses can comprise two main states:

- Before the island operation
    1. The aggregator monitors the production of the DG and estimates the production (power) capabilities as well the available energy within the network.
    2. The aggregator estimates the load demand and the amount of load that can be shed during the island operation
    3. The aggregator may send certain set points the DGs in order to ensure smooth islanded operation. For example it may ask from a battery to keep the state of charge above a certain level.
    4. The aggregator may send this information to the customers in order to make them aware of how their appliances will be operated during the island mode.
- After the island operation
    1. The aggregator stops the operation of certain load according to the load shedding scheme.
    2. The aggregator monitors the system and makes corrections to the load shedding scheme.
    3. The aggregator may sent signals to consumers about the load shedding scheme.
    4. The aggregator monitors the system operation in order to bill the energy produced and consumed within the island grid.

7.5. Sustainability and Grid Efficiency Effects

Sustainability and Grid efficiency Effects:

- In case of a black-out, all consumers and RES would be shut down. This business case allows continued device operation during the black-out state.

7.6. Interaction and Communication

Interaction and communication should be described here on a high level basis.

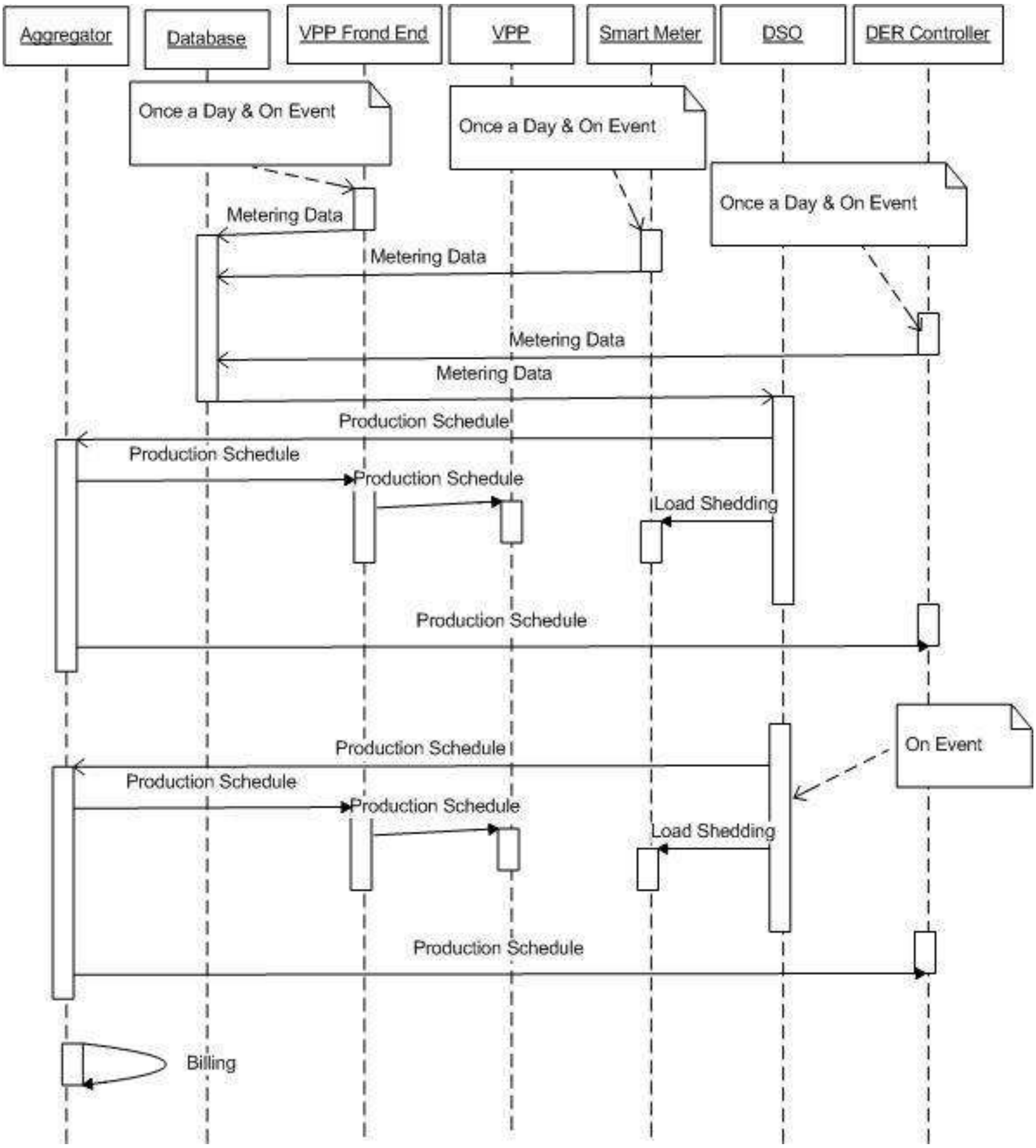

Figure 20: Exemplary UML sequence diagram intentional islanding business case

7.7. Value Model

The main value driver of this business model is to provide sufficient energy and power to the consumers that are willing to pay in case of instability and to allow the operation of the DGs during the island mode. The producers as well the consumers should take into account that without this service they would probably go into a black out. So they should compare the amount of money they would loose in case of no power supply.

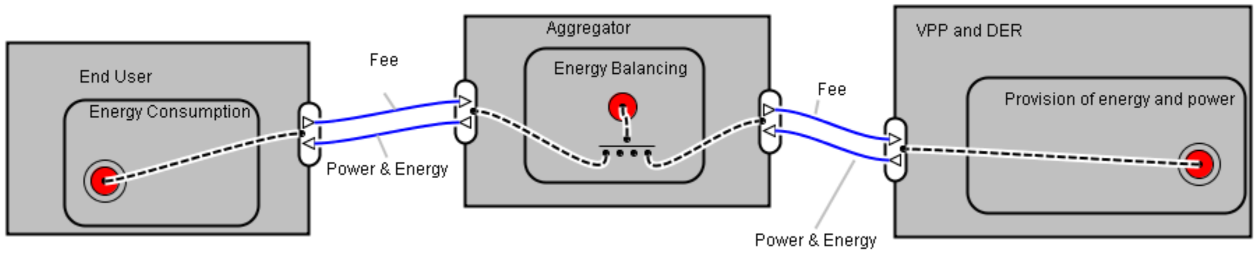

Figure 21: Value model of the island operation business case.

7.8. Cost Considerations

This business case requires sufficient monitor and control of all nodes in the related network. However part of the equipment, like monitor and control of the consumers, is considered as already installed. The main cost for this business case is the protection and electrical equipment that will allow the transition into island mode as well possible changes in the equipment of the DGs. Finally a significant cost is the development of the software that will allow the operation of the system.

7.9. Success Measures

Success measures of the business case are:

- Efficient power supply during the island mode.
- Increase of power quality and satisfaction of the consumers.
- The DG units are in operation during an instability, and can sell energy to the system.
- The main issue for this business scenario is the amount of money the consumers would like to pay is a case of islanded operation. This amount is determined by the local needs of each consumer.

The success of the business case "Distribution grid cell islanding in case of higher-system instability" can be measured by applying the measurements of the following objectives:

- Objective D2.4: Gains through raising the accommodation ceiling of local networks for integration of local generation.

The increase of consumers' satisfaction can be measured on the basis of the following objectives

- Objective B.3: The developed technology is affordable in terms of financial investment and operational costs
- Objective B.1: The developed technology is affordable in terms of knowledge and time resources required from end users

The success of the business case needs also the affordability consideration from the end user.

8. Black Start Support from Smart Houses

8.1. Actors and Goals

Actor	Role description and goals
Consumers	Provides control of their load as well as metering data about their consumption
DSO	Manages the transition to island mode and allows the internal power management when it is considered as safe.
Aggregator	Monitors the system before the event that may lead to island mode and manages the operation of a group of consumers as well DG owners in an efficient way during the island mode.
DG owners	Provide information about their status and their production capabilities

8.2. Comment

This business case technically is similar to the business case "Distribution Grid Cell Islanding in Case of Higher-System Instability" meaning that the procedure is similar. The only main difference is that in previous business case a static switch is mandatory. However, this is mentioned as a separate business case since some actors may participate in the black start support only, some other to islanding mode and some other in both. This requires the existence of separate monitoring, control and billing procedures.

8.3. Context and Scope

Business context:

- The consumers have a contract in which they have declared the amount of money they are willing to pay during the restoration process as well the part of the load they allow to be controlled.

Technical context:

- The black start operation is DSO's responsibility.
- The control system should be able to operate during a black-out.

Scope:

- During the black start operation the system does not participate in the wholesale market trading.

Preconditions:

- Appropriate ICT infrastructure between the aggregator, the consumers and the DG owners must be in place, and communication protocols must be agreed upon and must work reliably even during the black out.

All other specifications are equal to those in Business Case 7.

8.4. Technology Infrastructure

Required technical components and concepts:

- Proper protection and electrical equipment in the network that will allow the transition to the island mode and the black start.
- The aggregator must have a proper billing system that is capable of correctly billing the energy transaction during the black start.

All other required components and concepts are equal to those in Business Case 7.

8.5. Business Case Scenario Script

The daily operation within an intelligent network of collaborative smart houses can comprise two main states:

- Before the island operation

  Same as in Business Case 7

- After the black out

  1. The DSO set the system to island mode.
  2. The DSO sends a signal for the black start units to start (batteries, CHP, Diesel)
  3. The aggregator stops the operation of certain load according to the load shedding scheme.
  4. The aggregator monitors the system and makes corrections to the load shedding scheme.
  5. The aggregator may sent signals to consumers about the load shedding scheme.
  6. The aggregator monitors the system operation in order to bill the energy produced and consumed within the island grid.
  7. The DSO reconnects the system to the main grid when possible.

8.6. Sustainability and Grid Efficiency Effects

Same as in Business Case 7.

8.7. Interaction and Communication

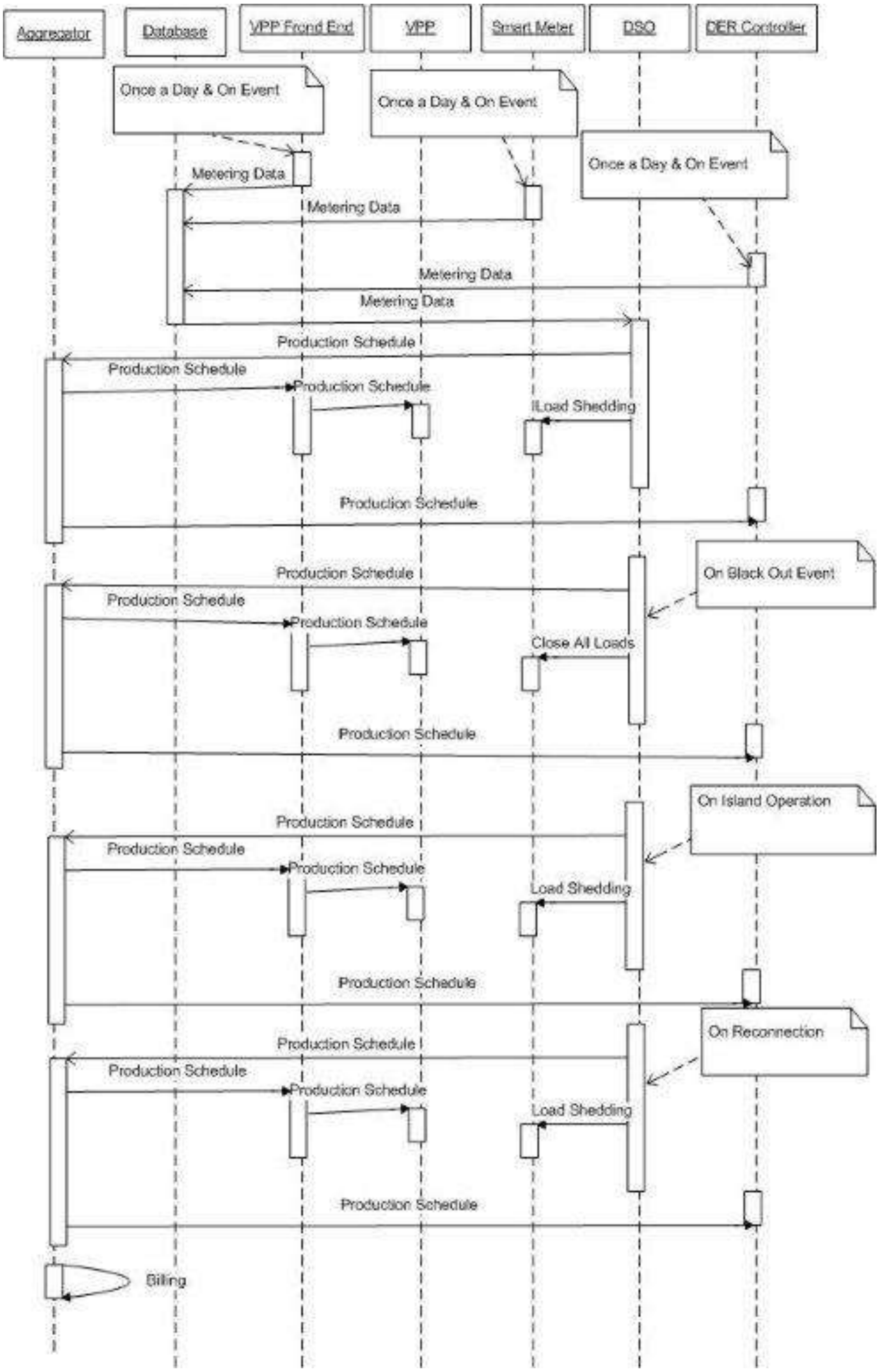

Figure 22: Exemplary UML sequence diagram black start support business case

8.8. Value Model

The main value driver of this business model is to provide sufficient energy to the consumers that are willing to pay in case of instability and to allow the operation of the DGs during the island mode. Furthermore the power producers offer power to the main grid in order to accelerate the black start process and the electrification of the grid users.

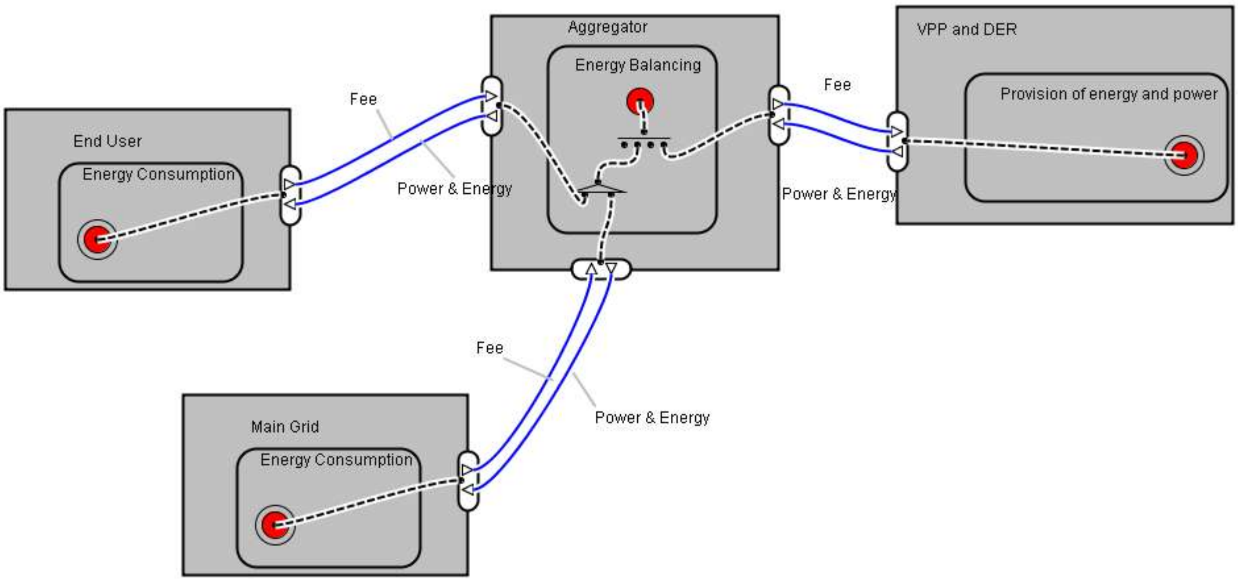

Figure 23: Value model of the black start business case

8.9. Cost Considerations

Same as in Business Case 7.

8.10. Success Measures

Success measures:

- Efficient power supply after the reconnection.
- Fast system restoration
- Increase of power quality and satisfaction of the consumers.
- The main issue for this business scenario is the amount of money the consumers would like to pay in order to support the black start operation. This amount is determined by the local needs of each consumer.

The success of the 'Black start support from smart houses' can be measured by applying the same measurements as for the Business Case 7.

9. Integration of Forecasting Techniques and Tools for Convenient Participation in a Common Energy Market Platform

9.1. Actors and Goals

Actor	Role description and goals
Consumers	Provide metering data about their consumption or DER production
DSO	Provides metering data about the network
Aggregator	Monitors the system and provides production schedules
DG owners	Provide information about their status and their production
Forecast service provider	Offers commercial forecasting services to the energy industry

9.2. Context and Scope

Business context:

- The business context comprises a commercial forecast service provider as well the DG owners.
- The accurate forecast allows the aggregator to participate efficiently in the energy market.

Technical context:

- The quality of measurement data is the most critical part in a forecast service.
- The calculation of the confidence intervals allows the minimization of the effects of the errors in the system.

Scope:

- The time horizon within this business case is a day-ahead schedule.
- Production profile metering of the customer is assumed to be available.

Preconditions:

- Smart metering and billing is a prerequisite of this business case
- Appropriate ICT infrastructure between the aggregator, the consumers and the DG owners must be in place, and communication protocols must be agreed upon and must work reliably.
- A contract between the aggregator, the consumers and the DG owners must specify how the communication between the two parties takes place and whether and how the aggregator can directly control the consumers and the DG owners.
- Data exchange between the customers' smart meters must be made available to the forecast service provider, and appropriate privacy policies must be agreed upon.

9.3. Technology Infrastructure

Required technical components and concepts:

- Communication and access to the metering data and the smart meters
- Communication and access to the DSO data
- Communication and access to the meteorological data

- Sophisticated software for the forecasts.
- Sufficient computer processor power in order to make the calculations

9.4. Business Case Scenario Script

The daily operation of a forecasting tool may have three steps:

A) Data collection

This part includes the collection of all necessary and available data needed for the forecast

B) Forecasting of consumption and production

C) Distribution of the forecast output

The module output will be delivered to the proper customer.

9.5. Sustainability and Grid Efficiency Effects

An accurate forecast will provide efficient usage of DER:

- Reduction of fossil fuel usage
- Increased usage of RES

Grid efficiency effect:

- Support of congestion management

9.6. Interaction and Communication

The order of events follows the scenario description is depicted in Figure 24.

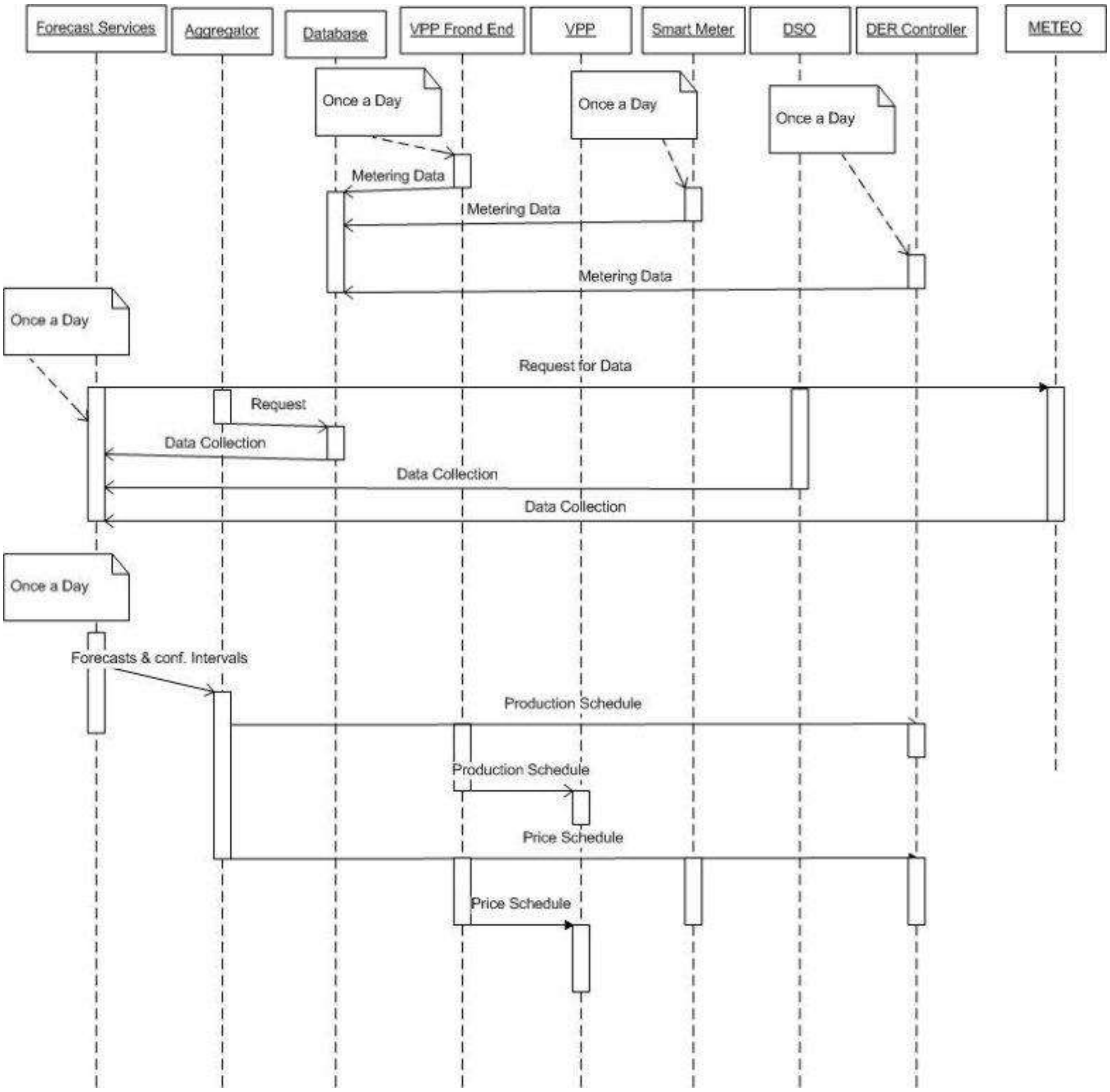

Figure 24: Communication and interaction model of this business case

9.7. Value Model

The main value driver of this business model is to provide accurate forecasts to the system which leads to accurate production schedules to the DER units. On the other hand the provision of metering data is critical in order to support the service.

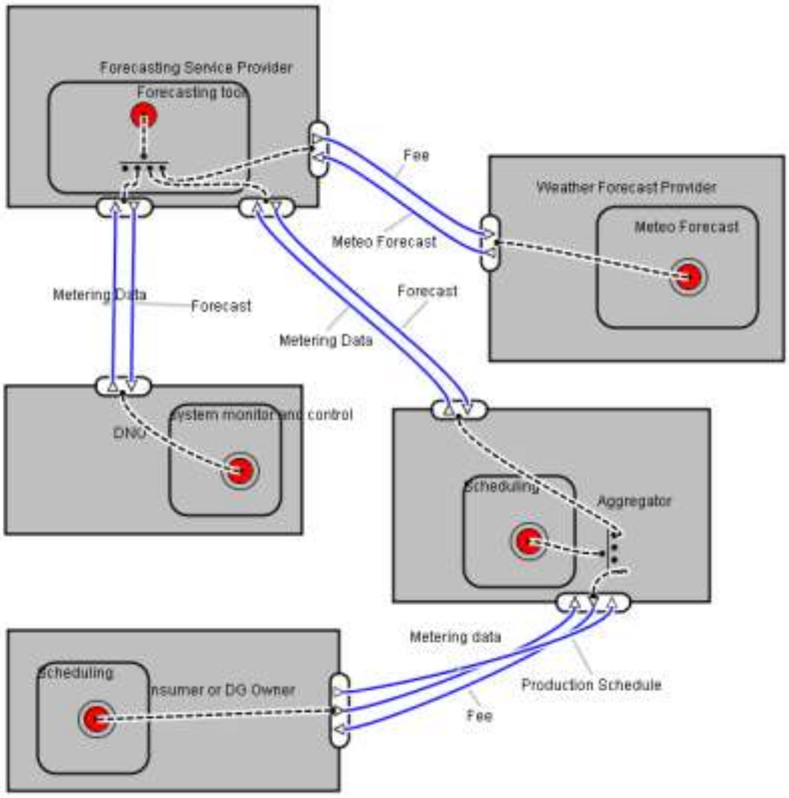

Figure 25: Basic value model for the integration of forecast techniques

9.8. Cost Considerations

This business case requires sufficient monitor of all DER in the related network. However most of the equipment is considered as already installed. The main cost for this business case is the licenses for the meteorological forecasts.

9.9. Success Measures

Success measures:

- Efficient DER energy usage
- Reduced penalties for power production deviations.
- Fair distribution of financial advantages between both actors