# MIRACLE

## Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution

Specific Targeted Research Project: 248195

## D1.1 State-of-the-art report and initial draft of the role model

## Work package 1

Leading partners: SAP, INEA

June, 2010

Version 1.0

| **DOCUMENT INFORMATION** | |
|---|---|
| **ID** | D1.1 State-of-the-art report and initial draft of the role model |
| **Work Package(s)** | WP1 Architecture and process model |
| **Type** | Report |
| **Dissemination** | Public |
| **Version** | Version 1.0 |
| **Date** | June 30th 2010 |
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# Table of Contents

# 1 Summary

The energy sector is in transition. Firstly, the deregulation process forces companies to restructure their value chain in order to increase their market efficiency. Secondly, in order to reduce carbon emissions, the use of renewable energy sources is enforced by national and international regulations. Thirdly, smart metering is being widely adopted. The main goal of the MIRACLE project is to develop an ICT system that fits the future deregulated energy sector and enables the integration of a higher rate of distributed and renewable energy sources into the electricity grid. We will explore a micro-request-based approach for demand side management in which electricity producers and consumers issue micro-requests indicating flexibilities in time and amount of the electricity profiles. These requests will be processed by our system in order to balance electricity supply and demand in near real-time.

In this deliverable, we describe the conceptual architecture of the energy data management system (EDMS) developed in the MIRACLE project. The architecture reflects the hierarchical organization of the energy domain in balance groups and market balance areas. The requirements for the system are derived from the project goals and an estimation of the volume and number of messages exchanged within the EDMS and the volume of the data to be stored persistently in the EDMS.

A major prerequisite to design the EDMS in a way that it will be applicable to the future deregulated energy sector is to understand the current situation of the energy sector in different European countries and foresee its future structure. We therefore describe the current national electricity markets for some European countries in detail and compare the national roles to the roles defined in the ETSO harmonized model. We then describe characteristics of the MIRACLE system and based on that we specify three use cases that represent these characteristics. The processes associated with the use cases, the ETSO roles involved in them and the base processes identified are described and listed. The description of the MIRACLE role model reflects the status of the current discussion within the MIRACLE team. The final specification of the MIRACLE roles and processes is planned for the next deliverable (D1.2 Final role model and process specification).

# 2 Conceptual Architecture and Requirements

## 2.1 Conceptual Architecture

In MIRACLE, we manage two types of electricity data which are “schedulable” requests for electricity demand and supply and “continuous”, non-schedulable electricity demand and supply. Examples of schedulable demand and supply are combined generation of heat and power (supply) and appliances such as washing machine, dryer, fridge, dish washer, electric car (demand). Examples of continuous electricity are lighting (demand) and renewable electricity sources that use wind or solar energy (supply)

The MIRACLE energy data management system (EDMS) is organized in a multi-level hierarchy of local energy data management systems (LEDMS) (see Figure 1). Each LEDMS in this hierarchy communicates with systems on the next lower level (if there are some) and the system on the next higher level (if there is one). The levels correspond to different areas in the European energy system. The consumers and producers that issue requests and consume and/or supply electricity are actors on level 1, the prosumer level. An LEDMS on level 1 communicates with smart meters. A smart meter measures energy consumption or production. Balance responsible parties (BRPs) and balance suppliers are actors on level 2, the balance group level. Transmission system operators (TSOs) act on level 3, the market balance area. There might be an additional European level.

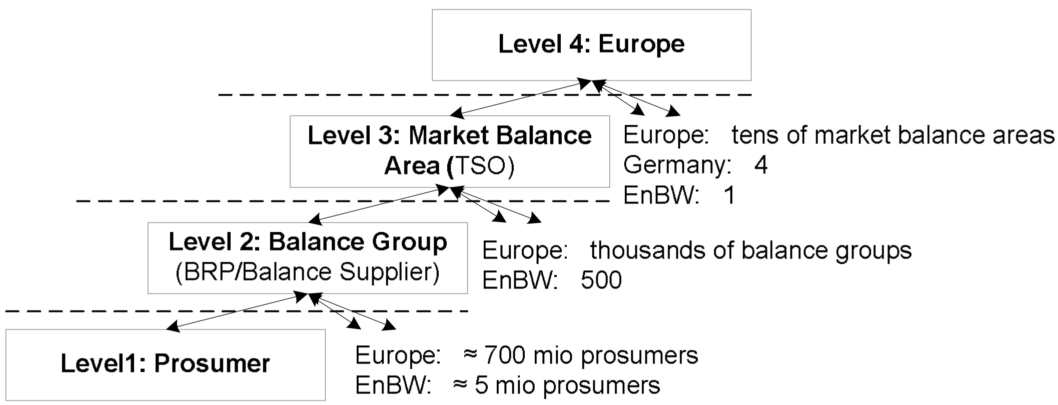


**Figure 1: Hierarchical architecture of energy data management systems**

Each LEDMS has the same conceptual architecture (see Figure 2). It has a persistence layer, an analytics layer and a user interface. The analytics layer processes incoming messages and stores/retrieves data from the persistence layer. It applies functionalities such as aggregation, forecasting, and scheduling on the electricity data. It furthermore prepares data for the presentation at the user interface. The user interface comprises means to monitor current and forecasted demand and supply, to view requests and their scheduled starting times, and to analyze requests, forecasts, as well as “real” electricity demand, supply, and costs.

The communication between LEDMs on different layers in the overall EDMS can be divided according to the types of electricity (schedulable vs. continuous).

The communication for schedulable electricity is shown in Figure 3. A request is sent to an LEDMS on the next higher level (Request). After a price setting phase which is based e.g. on pricing models or auctions, an assignment is sent back (Assignment). The price-setting and negotiation process and the messages depend on the applied technique. An overview about negotiation and price setting is given in the deliverable D5.1 State-of-the-art report on scheduling and negotiation approaches.

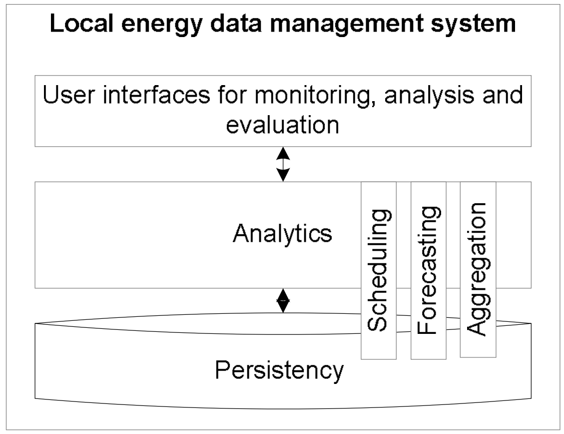


**Figure 2: Architecture of a local energy data management system**

Initially, a micro-request is specified by a prosumer at an LEDMS of level 1. In order to compute the high amount of lower level requests, they are aggregated to macro-requests with a higher energy volume on the LEDMSs of the next levels. So the number of requests that has to be managed on each level of the system is comparable but the energy volume per request increases at higher levels.

Within an LEDMS, requests are locally stored and at a certain point in time, they are retrieved, aggregated and scheduled. Macro-requests are also stored in the persistence layer. A new incoming request is integrated into a macro-request and depending on the characteristics of the resulting schedule, macro-requests are re-scheduled. The goal of the aggregation is to reduce the number of requests for further processing. A macro-request should keep as much flexibility provided by the lower level requests as possible. The goal of request scheduling is to enable the use of more renewable energy. Scheduling is used by the actors to balance demand and supply (TSO, BRP), to minimize the cost of electricity which must be bought (BRP) or to maximize the profit of electricity which can be sold (BRP). An overview about scheduling techniques is given in the deliverable D5.1 State-of-the-art report on scheduling and negotiation approaches.

Before a macro-request is executed, it is disaggregated and for each single request, a message with the concrete scheduled time is sent to the lower-level LDMS (ScheduledTime).

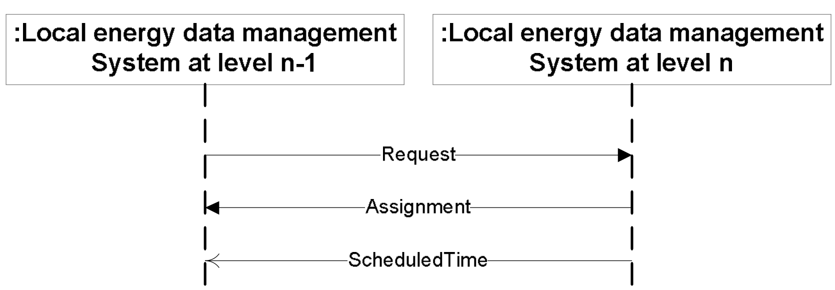


**Figure 3: Message exchange for requests**

The messages that are exchanged to handle continuous energy demand and supply are shown in Figure 4.

A weather forecast of a weather forecast service (WeatherForecast) is used by an LEDMS besides other information such as locally available histories to forecast the future continuous electricity demand and supply. The forecast model and its parameters or the forecasted values are stored in the persistence layer. The forecasted demand and supply (Forecast) are then sent to the LEDMS of the next higher level.
After each measuring period of electricity consumption and production, the measured values are sent to the LEDMS on the next higher level (Measure). Furthermore, the forecasting component analyzes the measures locally and adapts the forecast. If the new forecast deviates from the previous one to a certain degree, an update is sent to the LEDMS on the higher level as well (ForecastUpdate).
The LEDMS on the next higher level aggregates the incoming measured values and the forecast updates. It updates the current forecast e.g. when the difference to the current forecast exceeds a threshold. The concrete update process depends on the developed forecast approach.
The forecasting process and the messages depend on the applied forecasting technique. An overview about forecasting approaches is given in Deliverable D4.1 State-of-the-art report on forecasting.

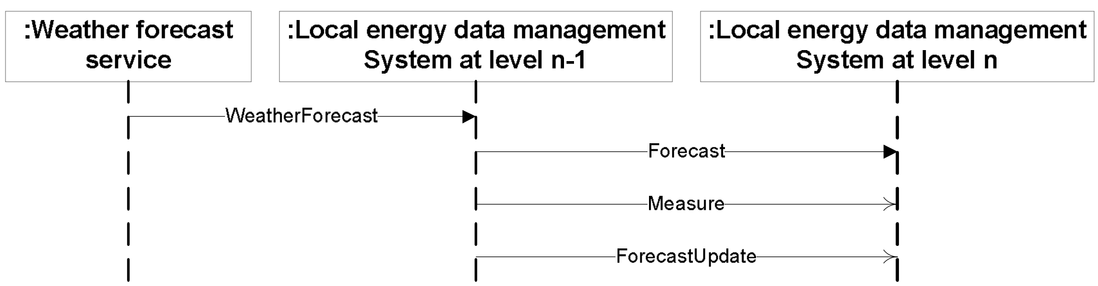


**Figure 4: Message exchange for continuous demand and supply**

## 2.2 Estimation of data sizes

In this section we will estimate the sizes of the persistent data, the messages and the schedulable electricity in order to evaluate different data management architectures in the following section. We specify data structures that are stored and managed by LEDMSs and messages that are exchanged between LEDMS nodes. We furthermore specify a set of parameters for the estimation and present parameter settings for some scenarios. The data and message specification is preliminary. The specification will be developed in WP2 Data specification.

### 2.2.1 Specification of the Data Structures in the Persistence Layer

The persistence layer of an LEDMS on level n contains data about requests of level n-1 and macro-requests of level n (see Figure 5). Each request has a unique identifier *request_id,* an *actor_id* and an associated profile. The *actor_id* of Request_n contains the id of the actor on level n+1 while the *actor_id* of Request_n-1 contains the id of the actor on level n-1. The profile is a list of profile intervals. The attribute *interval_no* specifies the order of the profile intervals. The attribute *amount* specifies the amount of demand or supply in this interval. The flexibility in time of a request is specified by the earliest starting time *start_time* and the latest starting time *end_time*. The time for which the request is scheduled *at_time* is updated by the message ScheduledTime. Each request contains the times when the request was *sent, updated*, and *contracted*, the maximal price

specified when the request was issued (*max_price*) and the contracted price (*contracted_price*).
The data about the continuous demand and supply is captured in the data structure Continuous_Demand_Supply (see Figure 5). Continuous demand and supply is measured and forecasted in time intervals. The timestamp for the end time of an interval (*interval_end_time*) specifies the interval. The amount of energy is forecasted for each time interval and stored in *amount_forecast*. The timestamp of the last forecast is stored in the *forecast_from* field. The length of the time interval is specified within two communicating LEMSs. The measured amount of electricity consumed or supplied is stored in *amount_measured*. The unit for the amount fields is kWh.

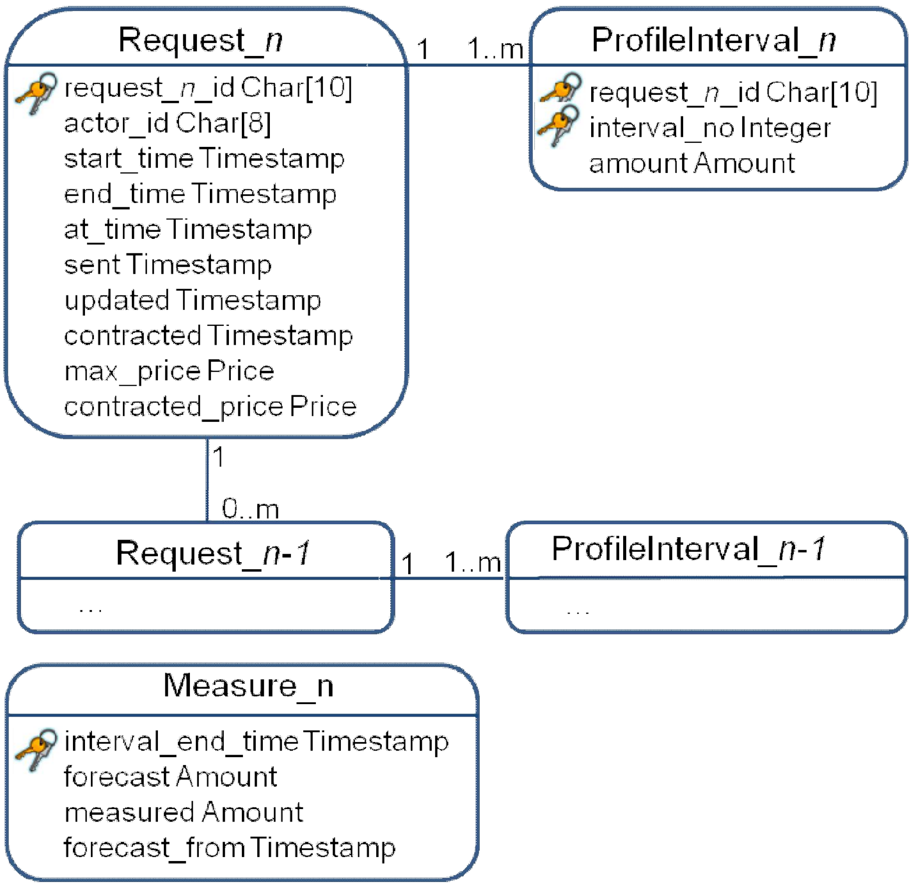


**Figure 5: Data structures in the persistence layer**

### 2.2.2 Specification of Messages Exchanged Between Energy Data Systems

We distinguish messages that are related to requests and continuous demand and supply. The messages related to continuous demand and supply are visualized in Figure 6. Figure 7 shows the messages related to requests.

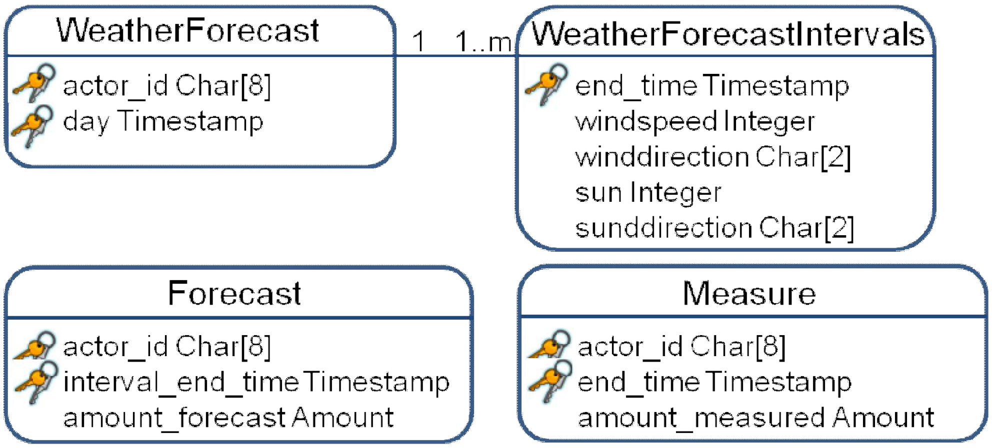


**Figure 6: Continuous demand/supply messages**

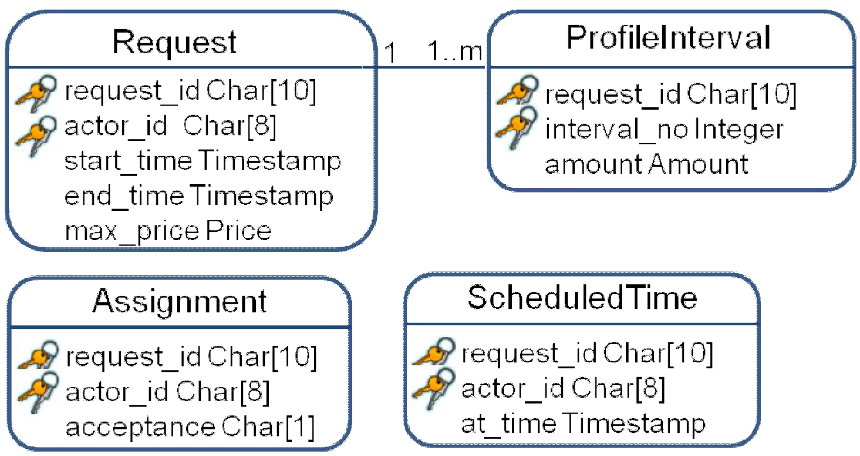


**Figure 7: Request messages**

### 2.2.3 Estimation of Data Sizes

The data types in the data structures above are mapped to Java data types and their associated size as shown in Table 1.

| Data type | Java data type | Size in Byte |
| --- | --- | --- |
| Char[x] | char[x-1] | x*2 |
| Timestamp | long | 8 |
| Amount | double | 8 |
| Price | double | 8 |
| Integer | int | 4 |

**Table 1: Mapping of data types to java data types and size in byte**

We assume that we have 10 % overhead in size of each data structure. This overhead comprises meta-data related to persistency and message transfer. Depending on the chosen storage and communication technology, the overhead might be different. The resulting sizes of the data structures are listed in Table 2.

| Data structures | Size in Byte |
|---|---|
| Request_n | 110 |
| Profile_Interval_n | 36 |
| Measure_n | 36 |
| WeatherForecast | 27 |
| WeatherForecastIntervals | 27 |
| Forecast | 36 |
| Measure | 36 |
| Request | 66 |
| ProfileInterval | 36 |
| Assignment | 42 |
| ScheduledTime | 49 |

**Table 2: Size of the data structures**

We will use the parameters listed in Table 3 for the estimation. Parameter settings for the use cases BRP, Germany and Europe are also shown in Table 3. The parameter settings vary in the number of actors on each level (parameter N1 to N4). The formulas for the calculation of the data volume of messages and persistency are listed in Table 4. The results for the three scenarios are shown in Table 5.

| Parameter / Scenario | BRP | Germany | Europe |
|---|---|---|---|
| **R** :Average number of requests issued for the next day per prosumer | 6 | 6 | 6 |
| **E**: Average number of requests issued within the day per prosumer | 6 | 6 | 6 |
| **i**: Size of the interval in mins | 15 | 15 | 15 |
| **I**: Number of intervals per day | 96 | 96 | 96 |
| **D**: Average number of request intervals | 6 | 6 | 6 |
| **N1**: Number of prosumers at level 1 | 5000000 | 80000000 | 700000000 |
| **N2**: Number of actors at level 2 | 500 | 1000 | 3000 |
| **N3**: Number of actors at level 3 | 1 | 4 | 30 |
| **N4**: Number of actors at level 4 | 1 | 1 | 1 |
| **U**: Average forecast update within the day | 4 | 4 | 4 |
| **H**: Years of storage for historical data | 1.5 | 1.5 | 1.5 |
| **A1**: Request aggregation rate of level 1 | 1/500 | 1/500 | 1/500 |
| **A2**: Request aggregation rate of level 2 | 1/10 | 1/10 | 1/10 |
| **A3**: Request aggregation rate of level 3 | 1/5 | 1/5 | 1/5 |
| **C**: Rate of combined consumers and producers | 1/3 | 1/3 | 1/3 |
| **S:** Average size of a request in kWh | 0.8 | 0.8 | 0.8 |

**Table 3: Parameters for the estimation and use cases**

| | |
|---|---|
| NR1: Number of requests at level 1 per day | N1*(1+C)*(R+E) |
| NR2: Number of requests at level 2 per day | N1*(1+C)*(R+E)*A1 |
| NR3: Number of requests at level 3 per day | N1*(1+C)*(R+E)*A1*A2 |
| NR4: Number of requests at level 4 per day | N1*(1+C)*(R+E)*A1*A2*A3 |
| Persistency Prosumer | (R+E) * H* 365 * (Size (Request_n) + D * Size(Profile_Interval_n)) + H* 365 * I * Size (Measure_n) |
| Persistency of an actor on level 2 | (NR1+NR2)/N2*H*365*(Size(Request_n)+ D*Size(Profile_Interval_n))+ H*365*I*2*Size(Measure_n) |
| Persistency of an actor at level 3 | (NR2+NR3)/N3*H*365*(Size(Request_n)+ D*Size(Profile_Interval_n))+ H*365*I*2*Size(Measure_n) |
| Persistency of an actor at level 4 | (NR3+NR4)/N4*H*365*(Size(Request_n)+ D*Size(Profile_Interval_n))+ H*365*I*2*Size(Measure_n) |
| Message volume per Prosumer per day | Size(WeatherForecast)+I*Size(WeatherForecastIntervals) + (R+E)* (Size (Request) + Size (Assignment)) + (1 + U/2) * I * Size (Forecast) + I * Size(Measure) + (R+E) * Size(ScheduledTime) |
| Message volume per actor on level 2 per day | Size(WeatherForecast)+I*Size(WeatherForecastIntervals) + (NR1* (Size (Request) + Size (Assignment)) + N1 * (1+C)* (1 + U/2) * I * Size (Forecast) + N1 * (1+C) * I * Size(Measure) + N1 * (1+C) * (R+E) * Size(ScheduledTime))/N2 |
| Message volume per actor on level 3 per day | Size(WeatherForecast)+I*Size(WeatherForecastIntervals) + (NR2* (Size (Request) + Size (Assignment)) + N2 * 2* (1 + U/2) * I * Size (Forecast) + N2 * 2* I * Size(Measure) + N2 *2* (R+E) * Size(ScheduledTime))/N3 |
| Message volume per actor on level 4 per day | Size(WeatherForecast)+I*Size(WeatherForecastIntevals) + (NR3* (Size (Request) + Size (Assignment)) + N3* 2* (1 + U/2) * I * Size (Forecast) + N3 * 2* I * Size(Measure) + N3 *2* (R+E) * Size(ScheduledTime))/N4 |
| Amount of schedulable electricity | NR1*S |

**Table 4: Calculation of the data sizes**

| Size | Scenario BRP | Scenario Germany | Scenario Europe |
|---|---|---|---|
| Persistency of a prosumer | 24.2 MB | 24.2 MB | 24.2 MB |
| Persistency of an actor on level 2 | 26.7 GB | 213.2 GB | 621.9 GB |
| Persistency of an actor on level 3 | 29.3 GB | 117.1 GB | 136.6 GB |
| Persistency of an actor on level 4 | 3.2 GB | 51.1 GB | 446.9 GB |
| Message volume of a prosumer | 2.8 GB | 43.8 GB | 383.4 GB |
| Message volume of an actor on level 2 | 203.1 MB | 1.6GB | 4.6 GB |
| Message volume of an actor on level 3 | 200.0 MB | 1.6 GB | 558.8 MB |
| Message volume of an actor on level 4 | 130.5 MB | 2.1 GB | 17.3 GB |
| Amount of schedulable electricity | 64 GWh | 1 TWh | 9 TWh |

**Table 5: Size of required data storage and message volume**

# 3 State-of-the-art in data management and data exchange systems

In this section, we summarize the requirements to the energy data management system and then review data models and applications. The state-of-the-art description of architectures of data management and exchange systems is divided into three parts. One part is devoted to architectures of data management systems for local energy data management systems. In a second part, architectures of message exchange systems are reviewed. Finally, architectures of integrated distributed systems are described that relate to the energy data management system as a whole. The last section summarizes the evaluation of the previously mentioned systems and architectures.
The D3.1 State-of-the-art report on data collection and analysis focuses on data processing and querying that depend strongly on data management architectures. It is therefore closely related to this section. We will refer in some sections to this deliverable.

## 3.1 Requirements

The following general properties are important for the data management architecture to be developed:

- Scalability
  The architecture has to be *scalable* in order to be able to process growing data loads from the mass of households.
  It has to scale up to the level of a continent (e.g., Europe) and handle requests from LEDMSs of every prosumer within. Hence, it must be efficient enough to handle up to a billion connections from LMSs simultaneously and process up to few billions of micro-requests from LEDMS per day (see scenario 3 in Table 5).
  Furthermore, it has to store historical electricity consumption and production data (i.e. measures) in various granularities for certain time period, e.g. 1.5 year, resulting in approx. 25MB of data per consumer and up to 400 GB of data per actor on a higher level (see scenario 3 in Table 5).

- Performance
  Since the EDMS will be applied for operational control of energy use, it has to satisfy various time constraints. In particular, it has to provide a time guaranties for prosumers from issuing a request until the assignment Furthermore, to enable a BRP or TSO to operatively react on changing conditions e.g. concerning the production of renewable energy, near real-time rescheduling and forecasting are essential and these operations need fast data access and fast data processing.

- Decentralization and autonomy
  The system is decentralized because participants are supposed to act to a great extent independently.

- Distribution & Data integration
  The architecture has to be distributed because of the inherently distributed nature of the problem domain which involves multiple actors maintaining their own computing infrastructure. The messages of lower level LEDMSs have to be integrated into LEDMSs on the next higher level. The messages include discrete

requests and forecasts as well as continuous flows of measures. In addition, external data such as weather forecasts have to be integrated.

- Operations
  The architecture has to support both *transactional* and *analytical* operations on data (i.e. OLTP and OLAP workload). Transactional operations are needed to process and store incoming data. Aggregation, forecasting and other complex data processing tasks require analytical operations. The operations must be able to deal with uncertain data that result e.g. from forecasting.

### 3.2 Data Models and Applications

To satisfy the requirements to the architecture and develop an appropriate system design, it is necessary to study currently existing data processing and storage technologies. There are many different dimensions along which various storage solutions can be classified. One general dimension is to classify databases and data models depending on the *abstraction level* they support.

- Models which are intended for describing how data is really stored are referred to as *physical models*. Physical models are very important for the overall system performance and depending on the task it is necessary to choose a system with an appropriate physical storage format. For example, a table can be stored physically as (i) a number of columns (column-store), (ii) a number of rows (row-store), (iii) a number of attribute-value pairs (key-value store). There are also various options and optimizations used at the level of physical models: distributed storage, replication, partitioning, compression, cache-consciousness.
- *Logical models* are intended for describing a data model in platform-independent terms. There exist many different logical models which are designed for specific tasks and specific views of data. For example, the relational model is very convenient for describing transactional applications, multidimensional models are more appropriate for analytical applications and XML format is appropriate for representing structured documents.
- *Conceptual models* are intended for describing rich domain-specific structure and properties of data. These models are very convenient for the problem domain analysis and documenting purposes. To create a database such a model has to be translated into a lower level model.

The second dimension classifies databases and data models depending on the main application type they support:

- *Transactional applications* (OLTP) are aimed at storing and retrieving relatively small sets of data items. An example of such application is flight booking or online shop. Transactional applications are usually modeled using the relational model of data at logical level and row-stores at physical level. Yet, contemporary applications tend to rely on cloud-stores with key-value data format which have a number of advantages over traditional architecture including higher scalability and reliability.

- *Analytical applications* (OLAP) support data analysis operations like grouping and aggregation. An example of such an application is analysis of sales depending on product type and country. Analytical applications are usually described by means of a multidimensional model at logical level using column-store at physical level (with compression and cache-conscious processing algorithms for processing).
- *Batch processing* applications are intended for reading large amounts of data, processing it and then writing the results back to the database or returning it to the client. An example of such application is log file analysis for generating access statistics for a web site or finding frequent patterns in purchase data. A typical design pattern for batch processing is the use of key-value format as storage in combination with map-reduce approach for data access.

In the next sections we describe technologies for data management in more detail.

## 3.3 Architectures of data management systems

In this section we will describe traditional databases, in-memory databases, data stream systems, and cloud computing architectures that can serve as a data management system for a LEDMS in the context of the MIRACLE project.

### 3.3.1 Traditional Databases

The early hierarchical and network databases had one serious drawback – they assumed a strong dependence between the database and the application that used it. In particular, the application had to know how data is represented by using some kind of physical handle to access data items. One of the main purposes of the relational model [C70] was to remove the need in having physical navigation through the data items so that databases and applications become more independent from one another. A relational database is a number of relational tables consisting of rows which in turn consist of attribute values. Relational databases have been dominating among other databases for more than 30 years and they are currently used as a basis for providing many other data representation and analysis methods. In this sense, contemporary relational databases are normally hybrid systems which are based on a relational kernel by extending it with additional operators.

Most traditional relational databases were designed for OLTP applications where data is supposed to be manipulated by appending, removing or updating relatively small groups of records. However, these databases are not very suitable for OLAP applications the main purpose of which is analyzing large quantities of data with the use of grouping and aggregation operations. Such functionality is provided by data warehouses [BS97] which use multidimensional data model (see next section for more details).

One problem in using relational databases is that their data organization principles are quite different from data organization in applications which normally use object-oriented approach. To eliminate or at least decrease the so-called object-relational impedance mismatch a new type of database were developed, called object-relational systems [SM96]. Such databases provide support for user-defined types and type hierarchies described using inheritance relation as it is done in the object-oriented approach. It is assumed that there is one common type system within the database and the application. In addition, these databases support references and dotted notation at the level of DDL and DML. An example of an object-relational database is PostgreSQL [Pgres].

Databases can be also classified according to their application and type of data: spatial databases, time-series databases, document-oriented databases, bibliographic databases, multimedia databases, XML databases and others. Frequently, the type of application influences the choice of the data model and technology behind the database system.

Traditional DBMSs may have very high performance especially for transactional operations which is a natural consequence of their centralized architecture. However, they have a rather low scalability and increasing performance is normally reduced to changing the available hardware. It is not only an inflexible and expensive approach but also has a hard limit in the form of the best hardware currently available. Although traditional database provide support for basic analytical operations, there are not optimized for this type of workload and therefore their performance is low. For these reasons, the potential use of this technology within MIRACLE is limited by the part of the system architecture that deals with data collection.

### 3.3.2 In-Memory Databases

In-memory database technology assumes that all data is stored in main memory where it can be processed much faster in comparison with traditional approaches where data is stored on disk. Strictly speaking, in-memory technology is orthogonal to the type of data model used to represent data which means that various approaches to data organization can benefit from this technology. For example, currently there exist in-memory column-stores, in-memory row-stores and in-memory key-value stores. However, in-memory technology is especially suitable for implementing column-stores in the context of analytical applications.

It is generally accepted that complex analytics workloads are best addressed by storing data by column rather than by row, thus needing to touch only the columns that were actually referenced in a given query. Thus, if a database is used to process queries involving aggregates over a large number of similar values then columnar organization will be more efficient just because less data needs to be loaded/processes and processing algorithms are simpler if the aggregated data is represented as one array. On the research side, we can mention C-Store [SAB+05] and MonetDB [BK95, BK99] as products in this space. Examples of commercial column-based stores include Vertica, Astoria, Exasol and Paraccel.

It should be noted however that column-stores are not necessarily faster than row-stores. In particular, column-stores are known to be less efficient in OLTP applications, particularly, when processing update and append queries. Thus, choosing between these two technologies is a trade-off where various factors influence the overall performance.

The following two technologies are especially interesting in the context of column-stores and in-memory databases: (i) Compression in data representation formats and (ii) Cache-conscious algorithms in data access.

Both of these technologies significantly improve disk and memory performance due to the fact that the speed of microprocessors increases faster than the speed of memory [Mow94]. This effect makes it difficult to efficiently use processor power because of the memory throughput and latency bottleneck. Another observation is that disk performance does not grow too much with respect to memory speed and therefore it is important to efficiently use the available memory. Compression and cache-consciousness are very efficient when applied to in-memory column stores which normally use various kinds of data compression and algorithms designed to efficiently use processor cache.

The main goal of compression techniques consists in decreasing the size of data being stored and transferred. The main challenge is to choose an appropriate compression algorithm which will provide high enough compression ratio being simultaneously computationally inexpensive. Another challenge is to minimize the number of compression/de-compression operations or even eliminate de-compressions completely by using operations which work directly on compressed data.

The main goal of cache-aware algorithms is to develop special *memory access patterns* which ensure high overall performance. The problem is that low latency is guaranteed only if the requested data is found in the cache – otherwise it is not possible to fully exploit the potential of modern hardware. The challenge here is to minimize cache-misses and column-based format is one way to achieve this goal. Normally, such algorithms take into account the size of the processor cache and try to arrange all operations to minimize cache-misses.
The main advantage of in-memory databases is their extremely high performance especially for analytical operations where they provide extremely fast response times with respect to traditional solutions. Since it is precisely what MIRACLE is focused on, they are a good choice for the analytical part of the project (aggregation, forecasting and scheduling).

### 3.3.3 Data Stream Management Systems

Data stream management systems (DSMS) [BBD+02] have been developed to process streams of data with a high data volume in near real-time. A data stream is a potentially unbounded sequence of tuples. Examples of data streams are sensor data coming for example from traffic control and transactional data such as phone calls.
A DSMS executes so-called standing queries on the continuous, conceptually infinite data streams. The mass of incoming data limits the per-tuple computation time. The conceptually infite number of tuples that are processed on finite resources does not allow to manage complete histories but only statistical summaries. Data stream queries have to be evaluated in one pass. Load shedding techniques [TCZ+03] are used to manage overload situations. Load shedding and limited resources lead to approximate query answers.
Aurora [CCC+02], STREAM [MWA+03], Gigascope [CJSS03], Hancock [CFP+00], IBM InfoSphere Streams [IBM] are examples of data stream systems.
DSMS are distributed and decentralized. They are optimized for a fast response time. The MIRACLE requests can be seen as a stream of data and the key functionalities forecasting, scheduling and aggregation could benefit from continuous near real-time query processing. However, data stream systems do not persist histories of measures and requests that are required by the MIRACLE core functionalities. Forecasting relies on histories of measures. Aggregation and scheduling functionalities need access to all requests. Furthermore, DSMS are not appropriate for transactional and exact analytical data processing because they delete data in overload situations.

### 3.3.4 Cloud Computing

According to [MG09a] “Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction.” From the point of view of businesses, one of the main features of cloud computing is the shift from fixed-price licenses and products to business models where users pay by usage. Cloud computing facilitates conversion of fixed costs into variable costs or costs which are volume-related, as for example in case of pay-per-use models. The business model behind cloud computing is to move costs from capital expenditures like buying new servers towards operating expenses. There exist the following three service models for delivering resources in cloud computing: (i) *infrastructure as a service* (IaaS) where computing hardware like servers, storage and network equipment is provided, (ii) *platform as a service* (PaaS) where run-time environment such persistent storage, application servers and middleware is provided, and (iii) *software as a service* (SaaS) where software and applications are provided like cloud-based calendar.

Depending on the scope of deployment, there exist four scenarios [MG09b]: (i) *private clouds*, which are operated by one organization like an enterprise, (ii) *community clouds*, which are shared by many organizations, (iii) *public clouds*, which are sold to the public, including multi-tenant mega-scale infrastructure, and (iv) *hybrid clouds*, which are compositions of two or more cloud deployment types

Technologically, the main purpose of cloud computing consists in providing access to shared data and computing services via the Internet without the need to build any infrastructure. This model is composed of the following essential characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity (=incremental scalability), measured service, failures as a norm with automatic handling (recovery), availability, scalability, distribution, partitioning and replication. Here are some examples of existing cloud infrastructures: Amazon EC2/S3, VMWare vCloud, Microsoft Azure, Rackspace, Google App Engine. Other examples of applications providing cloud portability, on demand scalability, self-healing and high-performance are the space-based computing platform XAP [Sha07] from GigaSpaces Technologies Ltd., or the cloud platform Open CirrusTM by Intel, HP and Yahoo [OCir].

Data modeling for cloud-based data storages has its own specific features: weaker schema constraints (no fixed table schema), weaker transaction constraints (no ACID guarantee) and relying on the BASE model [Prit08], weaker integrity constraints, key-value data representation, append only model and explicit version management. Operational key-value stores are good for web scale volume and availability but have limited query expressivity, eventual consistency and relaxed transaction semantics (NoSQL). In such applications one object at a time is assumed to be accessed by most applications. Such a design with no SQL, no transactions, no joins and primitive API contrasts with the traditional storage models with ACID guarantees and schemas.

Examples of cloud storages include: Google BigTable [CDG+06] which is a high performance large-scale DBMS (open sourced as HBase on top of Hadoop), Amazon Dynamo [DHJ+07] which is a highly available key-value store (open sourced as Voldemort), Cassandra which is a  peer-to-peer column-store based on Bigtable data model (open sourced) [LM09], Yahoo! PNUTS [CRS+08], OnScale Scalaris, Google Megastore (basis of App Engine).

Data analysis in the cloud requires special solutions which differ significantly from the traditional approaches. An example of such a solution is the MapReduce [DG04] framework developed by Google for processing huge amounts of data stored on a large number of computing nodes. The idea of this approach is that the Map-step breaks the input data into smaller sets and distributes these tasks among computing nodes. The computing nodes can further break their input into smaller tasks and send them for execution to other nodes. After a smaller task has been processed, the computing node sends the result back to the source node. At the Reduce-step all such partial results are collected by the master node which combines them to produce the solution of the original problem.

This approach requires that the mapping operations are independent and the partial results can be combined to produce the final answer. This algorithm is less efficient in comparison with traditional methods but its main advantage is very high scalability due its distributed nature. As a result, MapReduce is appropriate for processing very large data sets which cannot be handled by traditional algorithms.

Of course, cloud computing and analytical platforms like MapReduce do not provide a universal solution for all applications [Aba09] and therefore various hybrid solutions have been developed. In particular, Pig Latin language at Yahoo [ORS+08] and the SCOPE project at Microsoft [CJL+08] make focus on language and interface issues. Parallel applications on the cloud can be built using logic programming [ACC+09].

The main strong point of cloud computing with cloud storages is their extremely high scalability, elasticity and reliability. However, this technology is bad choice for real-time analytics which is in the focus of the MIRACLE architecture because general-purpose cloud-based solutions do not provide a fast enough response. Here the problem is not in the cloud computing as a paradigm but rather in the existing implementations which are aimed at two extremes: web-oriented applications providing their services to a huge number of users/applications, and analytical applications processing huge amounts of data. In the case of MIRACLE architecture, we need to achieve the same goals of high scalability, distribution and decentralization but retaining very fast response time for analytical operations. In this sense, MIRACLE architecture can be characterized as a cloud for real-time analytics and one possible solution is to use in-memory databases connected on the principles of cloud computing.

## 3.4 Systems and architectures for data exchange

Data exchange systems comprise ETL systems, Enterprise Application Integration systems, and also DSMS.

### 3.4.1 Data Stream Management Systems

A data stream management systems [BBD+02] that have been described in section 3.3.3 can also be used as a data exchange system. Data streams are the exchanged data. The data are processed during exchange.

### 3.4.2 ETL (Extraction Transformation Loading) Systems

ETL systems [KiCa04] allow the specification and execution of data flows that extract data from source systems, process the data, and then load the data to another system. On important aspect of the data processing is the cleaning of the data. Real-time ETL is a recent research direction to enable business intelligence on operational data. A detailed discussion of ETL systems can be found in section 4.3.1 of D3.1 State-of-the-art report on data collection and analysis.

The message exchange between LEDMSs in MIRACLE can be based on a real-time ETL system.

### 3.4.3 EAI (Enterprise Application Integration) Systems

EAI systems [Lint00] allow the integration of different applications and their common use in business processes. An important aspect is the integration of data of these different applications. A detailed discussion of ETL systems can be found in section 4.3.2 of D3.1 State-of-the-art report on data collection and analysis.

An EAI system on top of a fast or real-time communication infrastructure is applicable for the MIRACLE data exchange especially if the communication procedures are complex.

## 3.5 Distributed data management system and architectures

Distributed data management systems comprise local data management systems and the communication among them. In this section we will describe distributed databases and data warehouses. Cloud-based data management systems that rely on a cluster of computers are also distributed data management systems. They have been described in section 3.3.4.

### 3.5.1 Distributed databases

Research on distributed databases systems has a long history. Database architectures, partitioning of data, distributed query processing, distributed transactions and synchronization have been studied [OeVa97]. Distributed databases can be classified into parallel databases and multi databases.

A parallel database system is a database management system that can manage several physical nodes. The distribution is transparent to users; the system appears as one local system. It has been designed in a top-down fashion in order to enable load balancing.

A multi database consists of a number of local database management systems that are managed by a multi-database management system. Each local database system manages its own data. A global schema is maintained in the multi-database management system and global queries are decomposed into queries to the local systems. A federated database system manages partially autonomous local data management systems [SeLa90].

The relationship between consistency, availability and partitioning in distributed systems is shown in [GiLy02]. A comparison of parallel databases and map-reduce-based data processing has been discussed recently [SAD+10].

Distributed databases are virtually integrated systems i.e. they do not duplicate data. A detailed discussion of virtually integrated systems can be found in section 4.1 of D3.1 State-of-the-art report on data collection and analysis.

Parallel and multi databases are distributed database systems. Parallel database systems are centralized. Federated and multi databases have a centralized data management system that offers a global view on the data and partially manage the underlying local database management systems. A parallel database system is scalable. It partitions the data and balances the load. A multi database system is designed to integrate a number of local database systems. Data and queries cannot be placed freely in order to balance the load. So, typically these systems are not scalable. Parallel and multi databases are optimized for transactional operations. Therefore their response times are not fast enough for interactive data analysis and near real-time data processing.

### 3.5.2 Data Warehouses

A Data Warehouse (DW) integrates data and organizes them in a multidimensional data model with the goal to analyze them in a fast and timely fashion. In typical DW architectures [Inmo05, KRTM08], data are extracted from the data sources and then prepared for the DW through an ETL (*Extraction, Transformation, Loading*) process. Ongoing research is directed towards living or real-time data warehouses [Brt08], where changes in the source data are very quickly propagated to the data warehouse, which thus contains current data.

A data warehouse architecture comprises typically a single data warehouse and a number of source systems. The data of the source systems are copied to the data warehouse system and analyzed centrally. Distributed data warehouses have been discussed rarely [Inmo02, GoMa04]. A discussion of data warehouses can also be found in section 4.2 of D3.1 State-of-the-art report on data collection and analysis.

DWs are scalable but the scalability is bounded to the processing capacities of the underlying hardware. Main-memory DWs store all data in main memory and can therefore analyze the data fast. Traditional DWs store the data on disk and use pre-calculated data to achieve fast response time for the typical analytical operations. Main-memory DWs are discussed in the section about main-memory databases. DW systems are optimized for fast analysis and their support for transactional operations is relatively weak or absent.

## 3.6 Evaluation of Technologies for the MIRACLE Architecture

In this section we will summarize the evaluation of the data management technologies regarding the requirements to the energy data management system developed in MIRACLE listed in section 3.1 and derive conclusions.

Integrated systems such as distributed databases are closely coupled and not specialized for OLTP workload. Data warehouses are only specialized in analytical operations but do not guarantee acceptable response times. However, current research on real-time data warehousing will influence the MIRACLE architecture. A mapping of the complete hierarchical EDMS onto a cloud-based data management infrastructure suffers from performance and autonomy of the subsystems.

As a base for a data management system used in a LEDMS, we have presented traditional databases, in-memory databases, DSMS and cloud systems. Traditional databases do not support analytical operations. The performance of analytical operations on top of them depends on the implemented physical design. Main-memory database systems have advantages in the performance. However, the mix of analytical and transactional operations will degrade their performance. DSMS do not provide scalability in terms of persistency of histories. Current cloud-based systems do not fulfill the performance requirement.

Depending on the complexity of processes that are required for the communication between LEDMSs, DSMS, ETL or EAI systems on top of a fast communication infrastructure can be used. Simple communication patterns can be realized in messaging middleware.

In conclusion, there is no data management infrastructure that matches all requirements. However there are many approaches and techniques implemented in existing systems that can be applied to the MIRACLE system. In particular, main-memory database systems will be used as a central element of the architecture mainly aimed at analytical tasks (aggregation, scheduling, forecasting). These nodes will be connected via message exchange systems into a decentralized distributed infrastructure with a topology reflecting the structure of the energy system.

# 4 Current national role models

## 4.1 A view on different energy markets

The vision and initiative to start treating energy as a marketable product and thus bring into the electricity supply systems the concept of market has generated a process of transformation of electricity generation and supply systems around the world. The process was accompanied by a steady stream of publications, papers and policy-stating documents by various stakeholders and independent researchers ever since. A fair representation of this process can be inferred from the list in Table 7.

| Year | Subject | Document/ stakeholder's level | Document title or description | Ref. |
|---|---|---|---|---|
| 2009 | model for structuring of the energy market | European - ebIX | UMM 2 Business Requirements View for structuring of the European energy market | [EBIX09] |
| 2009 | European roles model | European - ENTSO-E, (+EFET, ebIX) | The Harmonized Electricity Market Role Model version 2009-01 | [ENTS09] |
| 2009 | European roles model – Implementation guide | European - ENTSO-E, (+EFET, ebIX) | Collection of documents collectively called Implementation guide (for the Harmonized Electricity market Role model) | [ENTS09a] |
| 2009 | Market model | Alliance of TSO's (interest group) | The European Electricity Grid Initiative (EEGI): a joint TSO-DSO contribution to the European Industrial Initiative (EII) on Electricity Networks, Public version, The Contribution of Network Operators to the European Industrial Initiative on Electricity Grids, September 18th 2009 | [EEGI09] |
| 2009 | Baltic Market model | Inter-national, EC DG TREN | Market Design, Present Regulatory and Legal Framework, Existing Barriers in the Baltic Member States of Estonia, Latvia and Lithuania – Roadmap towards an integrated power market between the Baltic Member States and the Nordic Countries, CESI Report, 8.5.2009 (report on contract for DG E & T) | [CESI09] |
| 2009 | Austrian current market model and players | National, APCS – imbalance settlement responsible p | Rules and regulations, Balance group model, Market actors, Balancing energy market, Clearing (http://en.apcs.at/rules_regulations/new_version/ | [APCS] |
| 2008 | European roles model | European - ETSO | The Harmonized Electricity Market Role Model, Version: 2008-01, 1.7.2008 | [ETSO08] |

| | | | | |
|---|---|---|---|---|
| 2007 | Danish Role model | TSO - national | The Danish role model, Energinet.dk, January 2007, Rev. 1, Regulation F: EDI communication, Appendix report 3 | [Ener07] |
| 2006 | Inter-national market model | Nordic Energy regulators (interest group) | THE INTEGRATED NORDIC END-USER ELECTRICITY MARKET – Feasibility and identified obstacles, Report 2/2006, Nordic Energy Regulators (NordREG) | [Nord06] |
| 2006 | Market model | Electric industry in Europe (interest group) | The Role of Retail Competition in Developing the European Electricity Market, TF Linking Wholesale & Retail Market, Union of the Electricity Industry–EURELECTRIC, EURELECTRIC's Position Paper, November 2006 | [EURE06] |
| 2004 | CEE Electricity market models | national independent | A comparison of electricity market models of CEE new member states, by Péter Kaderják, Regional Centre for Energy Policy Research at the Corvinus, University of Budapest. (Czech Republic, Hungary, Poland, Slovak Republic and Slovenia) | [Kade04] |
| 2000 | Eurostat information requirements | national | Electricity Market Restructuring and Statistical Data Collection Note by Prof. P. Capros, May 5, 2000 | [Capr00] |
| 1998 | Spanish Market model | national | Liberalization of the Spanish Electricity Sector: An Advanced Model, 1998, Elsevier Science Inc., 1040-6190/98/$19.00 PII S1040-6190(98)00047-5, June 1998 | [Urza98] |

**Table 6: Documents on Electricity market and roles & process models**

In this process, due to various local initial conditions and regulatory policies in different countries around the world, several types of emergent electricity market concepts were attempted. However, out of these there soon emerged two main types of market organization, (i) Power Pools or centralized markets and (ii) Bilateral Contracts Model or decentralized markets. Most electricity markets can be classified as of being of type (i), (ii) or its variants. Both types are present also on European territory and are of relevance as the technology framework for Miracle technology of micro-request based trading. For this reason, we shall represent their basic traits as described in a Cigre paper in 2005 [Cigr05]. For veracity purposes, the relevant passages are taken as summary from the paper.

### 4.1.1 Power Pools

In a power pool, all producers offer price-quantity pairs for the supply of electricity. This forms an aggregated supply curve. The offered prices can be based on predetermined variable costs or the producers can be free to offer any price they like. On the demand side, the market operator may forecast demand and dispatch generating units against this. This is called a *one-sided pool*. In more sophisticated pools (*two-sided pools*), the market operator may dispatch on the basis of a demand curve created from price-quantity bids made by the buyers on the market, such as distribution companies and eligible consumers (Figure 8).

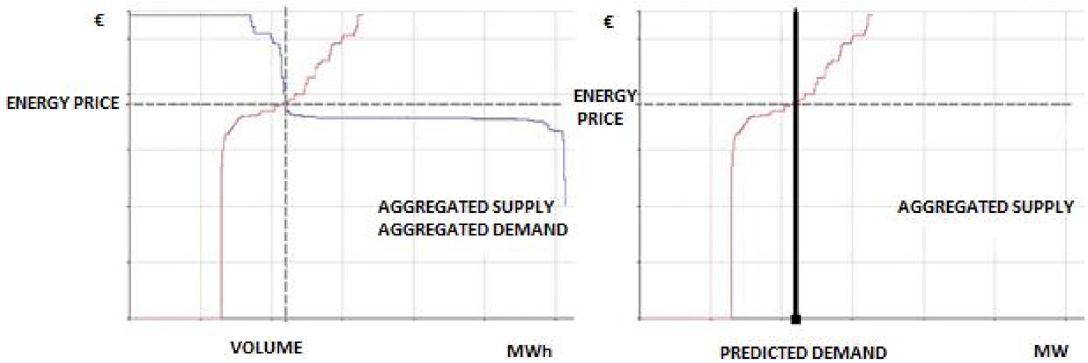


**Figure 8: Price discovery - either at the intersection of demand and supply, two-sided pool (left) or supply and predicted demand, one-sided pool (right)[BCGP]**

A pool can operate a day-ahead market or a close to real-time market (e.g. five minutes-ahead). There can also be a combination of several markets (day-ahead, intra-day and five minutes-ahead). Where a five-minutes-ahead market is operated, other sessions can still be run on the basis of non-firm offers and bids. Such sessions are used to create a forecast of the market prices as an indication for the market participants. Such price seeking sessions are based on non-firm offers and bids and are important to allow for non-dispatched demand side response in case of high market prices. One of the main advantages of a pool model is that it allows for Locational Marginal Pricing (LMP). LMP is based on the marginal cost of supplying the next increment of electric energy demand at a specific location in the electric power network accounting for both generation and network characteristics.

### 4.1.2 Bilateral Contracts Model

The alternative to a power pool model is a market mechanism based on physical *bilateral contracts*. This means that sellers and buyers freely enter into bilateral contracts for power supply. These types of transactions are referred to as Over the Counter (OTC).

In parallel to the bilateral contracts, a voluntary power exchange could be set up or could develop in the future on the initiative of the market participants. A power exchange could offer day-ahead and intra-day trade with the following benefits for the market participants:

- More price transparency,
- No counter party risk,
- Anonymous trading,
- Tool to optimize trading portfolio.

The power exchange will have no metered production or consumption and will therefore never have imbalances.

This model with bilateral contracts and a voluntary power exchange has been implemented in several European countries, with exchanges in the Netherlands (Amsterdam Power eXchange), France (Powernext), the Scandinavian countries (NordPool), Germany (EEX), Poland (PolPX) and Austria (EXAA). One can even have several competing exchanges in one country, as was the case in Germany (EEX and LPX) and England (UKPX , APX, PowerEX and IPE).

### 4.1.3 Comparison

The two models (pools and bilateral contracts) are equivalent in a world without transaction costs. In a world with transaction costs however, the bilateral contracts model may result in a sub-optimal outcome, where price and quantity do not reflect real time demand and supply. In a pool, prices and quantities should reflect actual demand and supply, more so depending on how far ahead of real time the trade occurs. Though prices in a pool may be more volatile than in a contracts market, there are hedging instruments available. In terms of institutional capacity, a simple contracts market is more straightforward and less expensive to set up than a power pool.

Both market models, pools and bilateral contracts, though so much different, can coexist. A pool could have bilateral contracts alongside of it and in a bilateral contacts mechanism a voluntary power exchange could be considered. Therefore, to better illustrate the difference between both, one can draw a line between markets with central dispatch of generating units and with self-dispatch. Generally speaking, central dispatch of all generating units is related to mandatory pools. Self-dispatch means that producers decide on the dispatch of their own generating units and this regime applies to bilateral contracts models.

## 4.2 Energy market models in various European countries and current state

As already mentioned, different electricity market models have been formulated in different European countries: Additionally, they are currently in various stages of implementation. In the next section, a representative selection of these markets is briefly discussed. The sample is based on the national mix of Miracle partners.

### 4.2.1 Denmark

#### 4.2.1.1 Description of physical grid

The Danish physical electricity system is divided into two electrically unsynchronized Western and Eastern parts [Energinet.dk, Villa07]. Each is distinct electricity transmission and distribution facility that operates at the 132 kV - 400 kV and 0.4 – 50/60 kV voltage level, respectively.

#### 4.2.1.2 Transmission systems

The Western Denmark electricity system is synchronised with the continental European system UCTE. Its topology is characterized by parallel lines at the 150 kV level and a combination of ring and radial connections at the 400 kV level (see [Ener07]). The system consists of interconnections to Germany, Sweden, and Norway. The interconnection to Germany consists of one 400kV, two 220kV, and one 150 kV AC connections with a total transmission capacity of 1500 MW. The interconnection to Sweden is the DC type and consists of two 250 kV connections with a total transmission capacity of 740MW. The interconnection to Norway consist of two 250kV and one 350kV DC connections with a total transmission capacity of 1040MW.

The electricity system in Eastern Denmark is synchronized with Nordel. It is composed of a radial grid at the 400kV level and a ring-connected grid at the 132kV level. The interconnection to Sweden is a link to the Nordic grid, and it consists of two 400 kV and two 132 kV AC cable connections with a total capacity of 1900MW. The interconnection to Germany, Kontek, is a 400kV DC connection with a transmission capacity of 600MW. A HVDC cable is now being established to connect the Eastern and Western Danish electricity systems. The cable is expected to be put into operation in 2010. Some of the Danish islands are not directly connected to these two power systems, but to other countries. An example is the Bornholm Island that is connected to Sweden at 60kV.

The transmission systems in Eastern and Western Denmark are owned, developed, and operated by Energinet.dk. This state-owned entity is the only Danish transmission system operator (also an operator of the natural gas system), and it is in charge of maintaining the market and the security of supply. Energinet.dk owns the 400kV installations and the international connections, as well as the 132kV grid in Northern Zealand (Eastern Denmark). However, the 150/132kV installations are owned by regional transmission companies that make them accessible to Energinet.dk.

#### 4.2.1.3 Distribution systems

The distribution network (60 kV or lower voltage levels) is owned and operated by more than 100 companies. A characteristic feature of the Danish electricity system is that, unlike in other countries, 40% of the total Danish generating capacity is connected to the distribution network [Dsup08]. This “distributed generation” mostly consists of decentralized (local) combined heat and power plants and wind turbines.

#### 4.2.1.4 Electricity generation

The total installed power capacity in both Eastern and Western Denmark is approx. 13 GW. The power capacities and the amounts of generated energy from different generation units in 2008 are presented in [Dsup08].

| **Generation unit** | **Capacity, MW** | **Production, GWh** |
| --- | --- | --- |
| Central power stations | 7, 217 | 20, 549 |
| Small local plants | 1, 829 | 4, 943 |
| Wind turbines | 3, 166 | 6, 928 |
| Others | 596 | 2, 317 |
| **Production total** | | **34, 736** |

**Table 7: Electricity generation and generating capacities in Denmark**

In 2008, 20% of the electricity generation in Denmark was produced from wind turbines, and 59% from the central generation plants. A large number of the plants in Denmark (including the central generation plants) are co-generating, i.e., they generate and supply both electricity and heat. In terms of fuel, the central generation plants use coal (76%), natural gas (13.4%), biomass (6.3%), and oil (4.3%).

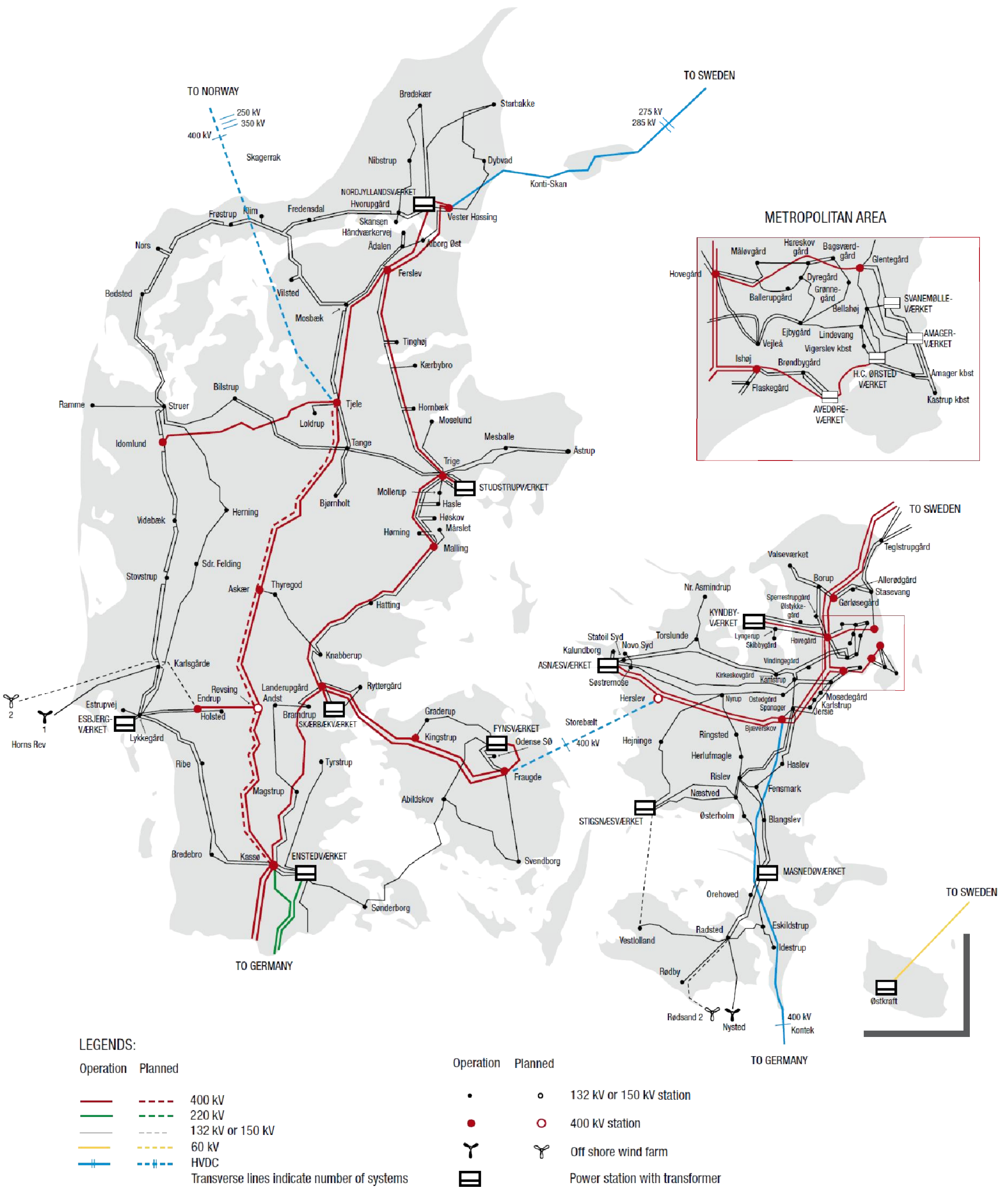


**Figure 9: High Voltage Network in Denmark [Dsup08]**

#### 4.2.1.5 Historical development

The key historical facts about the Danish electricity market are the following.

- In December 1997, with the Kyoto Protocol, Denmark committed itself to lower the $CO_2$ emissions with 21% by 2008-2012 from the 1990 levels.
- In 1999, the EU directive on the full liberalization of the electricity markets was adopted. This led to the unbundling of the transmission grid from the electricity generation in Denmark.
- In 1999-2000, Western Denmark (1999) and Eastern Denmark (2000) join the Nord Pool's Elspot and financial market areas.
- In January 2003, the full liberalization of the electricity market spurred the entire Danish electricity sector to cooperate on the laying down of rules and preparing performance requirements for the systems that manage the mutual relations between electricity traders, grid companies, system operators, and for handling the settlement between the market players.
- In 2004-2007, Eastern Denmark (August 2004) and Western Denmark (March 2007) joined the ELBAS market.

#### 4.2.1.6 The electricity market in Denmark

##### 4.2.1.6.1 Overview

Since January 2003, the Danish electricity market is a free market [Ener07] in which all electricity consumers are entitled to buy electricity from a supplier of their choice. The market was established in order to create competition.

##### 4.2.1.6.2 Market players

Several types of stakeholders are involved in the Danish electricity market. Specifically, central and local power plants sell electricity in the free market. Wind power producers, smaller local CHP plants, and industrial co-generating plants sell their electricity and also receive politically predetermined prices or subsidiaries for their generation. The distribution network/regional transmission network companies, in addition to their primary task of ensuring the security of supply, perform a number of customer-related services. Electricity trading companies in Denmark sell electricity to end-consumers based on the Danish Energy Regulatory Authority (DERA) regulated prices, and they are subject to mutual competition. The security of supply in the overall electricity system is ensured by Energinet.dk, which is also responsible for the drawing up of market rules that ensure a well-functioning electricity market.

There were 3.2 million electricity consumers (number of metering points), more than 36 trading companies with granted supply obligations, 12 regional transmission companies, and almost 90 distribution companies in Denmark by the end of 2009 [ReCh09].

##### 4.2.1.6.3 Market organization

The Danish electricity market is an integral part of the free Nordic electricity market [Energinet.dk, Nordpool.com], where exchange services are offered through Nord Pool ASA and Nord Pool Spot AS. Nord Pool Spot AS operates the physical electricity market and organizes the trade of electricity at Elspot (day-ahead) and Elbas (intra-day) market places. Nord Pool ASA, among other services, provides a marketplace where the exchange members can trade derivative contracts in the financial market. Figure 10 visualizes the concept of power exchange at Nord Pool. Here, financial (Nord Pool ASA), Elspot, and Elbas markets are handled by Nord Pool, and trades are executed prior to the physical delivery of electricity. The balancing of supply and demand is accomplished by national TSOs.

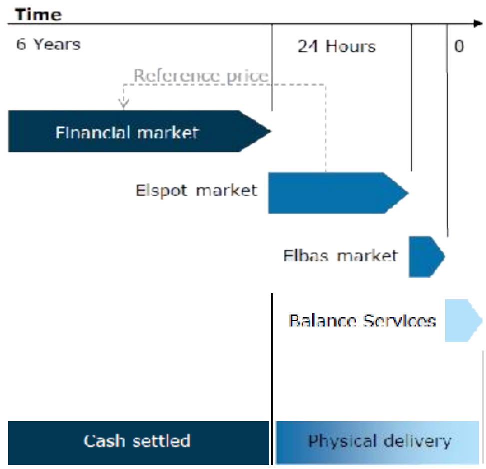


**Figure 10: Nord Pool power exchange concept**

#### 4.2.1.6.3.1 The Elspot market

On Elspot, hourly power contracts are traded daily for physical delivery during the next day's 24-hour period. Trade is based on the auction principle. The day-ahead prices are calculated based on the balance between electricity purchase and sale bids that are received from all market participants until the gate closure at 12.00 (noon). Three different bidding types are used: hourly bids, block bids, and flexible hourly bids that cover some or all of the 24 hours of the next day. All participants who meet the requirements set by Nord Pool Spot and have a balancing agreement with the respective transmission system operator (or through a third party) are given access to the Elspot market.

Due to the limited capacity of the connectors (bottlenecks) between/within the Nordic countries, the Nordic area is divided into a number of bidding areas. Denmark is treated as two different bidding areas: Eastern Denmark and Western Denmark. Two commercial participants separated by a bottleneck in the grid cannot trade physical energy (kWh) with each other. When a participant issues a bid, it must specify the bidding area the bid is issued from. Elspot then calculates a price for each bidding area for each hour of the following day.

The Elspot market also carries out day-ahead congestion management in the Nordic area. So-called market splitting and market coupling are used for congestion management through implicit capacity auctions. Here, Elspot (with other electricity exchanges in some cases) uses the available capacity for directing power to high price regions and extracting power from low price regions. Thereby, the prices in high price regions are reduced, whereas the prices in low price regions are raised. Currently, the market coupling is performed on the two interconnectors between Germany and Denmark and also on the Baltic cable between Sweden and Germany.

#### 4.2.1.6.3.2 The Elbas market

Elbas is a continuous cross border intra-day market where one-hour contracts are traded until one hour prior to delivery. Participants are allowed to trade on Elbas two hours after

Elspot is closed. Thus, they can obtain balance by making adjustments to trades done in the day-ahead market.

Elbas covers the Nordic countries and Germany. All trades done on Elbas are implicitly utilizing the available cross border capacity, which is updated after each executed trade. The participants of Elbas are power producers, consumers, and traders. They are obligated to report the trades done on Elbas to their local TSOs. Elbas provides the opportunity to sell power bought in the day-ahead market with a profit in the intraday market.

At 08:00 CET and 14:00 CET, the hour-contracts for the next day are opened for trade in Germany and the Nordic area (Finland, Sweden, Western Denmark, Eastern Denmark, Norway, and Estonia [from April 2010]), respectively. Because the capacities available for Elbas trading are published approximately at 14:00 CET, Germany is treated as a separate bidding area between 08:00 CET and approximately 14:00 CET.

#### 4.2.1.6.3.3 The Nord Pool ASA financial market

Nord Pool ASA is a marketplace where the exchange members trade contracts of power derivatives (financial contracts with a value linked to the expected future price) and emission derivatives (EUA emission allowances, and CER carbon credits) in the financial market.

The power derivatives are base and peak load futures and forwards, options, and contracts for difference. These derivatives are owned by Nord Pool ASA and they are used to guarantee prices and manage risk when a participant trades power. Nord Pool ASA offers contracts with a trading horizon of up to six years, which cover daily, weekly, monthly, quarterly, and annual contracts. The spot prices of the Elspot, EEX Phelix (Germany), and APX (Netherlands) markets are used as an underlying reference price for Nord Pool ASA contracts. There are more than 400 market participants from over 20 countries, and they include producers, retail companies, industrial companies, hedge funds, and professional traders. There is no physical electricity delivery of these financial market contracts.

The power and emission markets are open every day. For both markets, a participant's orders are binding until the end of the trading day, or until the member has changed or cancelled them and received a confirmation receipt. Once the market closes, written trade confirmations are made available for all participants. At a random time within the last 10 minutes of the trading day, closing prices for power and emission contracts, used for settlement and margin calculations, are determined. The randomization is used to prevent potential closing price manipulation. For contracts outside the buy and sell spread, or bid and offer price, or contracts that have not been traded, the closing price is defined as the average of the bid and offer, as specified by the rulebook for the financial power and emission market. Nord Pool ASA distributes closing prices to the market as soon as possible after the market closes.

Cash settlement is made throughout the trading and/or the delivery period, starting at the due date of each contact (depending on whether the product is a future or forward). The clearinghouse Nord Pool Clearing guarantees financial settlement.

#### 4.2.1.6.4 Balancing the production/consumption

The Nordic electricity market is divided into two balance areas [DesBa08], with Western Denmark being in the UCTE system and Eastern Denmark being in the *synchronous* part of Nordel. In Western Denmark, Energinet.dk is responsible for maintaining the balance between consumption and production in relation to the UCTE system. In the synchronous part of Nordel, Statnett and Svenska Kraftnät have a joint responsibility to maintain the balance between consumption and production using regulating resources from a joint

Nordic list. However, regulating resources from Denmark are co-ordinated via Energinet.dk.

The operational requirements for the Nordic power system includes an obligation to maintain sufficient operational reserves in the synchronous part of Nordel and to distribute the reserves between the subsystems (Denmark West has special conditions in relation to the UCTE system). Therefore, to ensure that sufficient reserve capacity is available, Energinet.dk makes reserve capacity agreements, according to which Energinet.dk pays participants a fixed amount for being available.

The operational reserves consist chiefly of frequency controlled reserves and fast reserves. Temporary peak load arrangements are used to balance regulation in special circumstances only. The frequency controlled reserves, specifically the *frequency controlled normal operation reserve* and the *frequency controlled disturbance reserve*, are activated automatically by frequency deviations. The fast reserves, specifically the *regulating bids* and *fast disturbance reserves*, are activated manually within 15 minutes, and they are based on trades in the regulating power market (RPM).

In RPM, balance responsible parties are allowed to trade by submitting regulating bids for upward or downward regulation to the local system operator. A bid may cover an entire day of operation, and it states the offered quantity (MWh) and price (DKK/MWh). The entered prices and volumes can be adjusted (by the bidder) until up to 45 minutes prior to the upcoming delivery hour. The system operators submit the regulating power bids to a 'coordinator' (Statnett) that compiles a joint list of all regulating power bids in the Nordic countries, sorted by price. If regulation of the frequency in the joint Nordic system is needed, the most advantageous regulating power bids on the joint list are activated, taking grid congestions into account. Not later than at 12:00 on the day after the day of operation, Energinet.dk sends the player a statement of the used regulated volume and the price involved.

All East Denmark regulating power bids are activated and settled by Energinet.dk. If a balance responsible party concludes a monthly reserve capacity agreement with Energinet.dk, it is committed to submitting bids to the regulating power market for each hour of the relevant month.

#### 4.2.1.7 End-user business relations

##### 4.2.1.7.1 Changing of the supplier

The Danish electricity retail customers are divided into two types [Dsup08, ReCh09]: template customers (primarily households and small business) and customers with hourly metering (electricity consumption is registered and settled per hour – mainly customers with an annual consumption of more than 100 MWh). All the customers have access to private contracts for energy supply on the retail market and may switch supplier free of charge. "Passive" template customers, i.e., customers who do not actively choose a supplier, are automatically supplied by the retailer company with the granted supply obligation for the consumers' geographical region ("default supplier"). However, medium and large customers with hourly metering must actively choose their supplier (no "default supply").

There is a 30 day notice period before a supplier switch takes effect [Ener07]. It also has to be done on the 1st day of the month. Customers have almost 90 suppliers to choose from. The process of supplier switching is web-based and it involves the following steps:

1. The customer inquires about a possible switch to the new supplier.
2. A contract is made and signed between the customer and the new supplier.
3. The new supplier announces the switch to the distribution system operator (DSO).
4. If the DSO approves the switch then it also notifies the old supplier.

5. The DSO informs the customer about the approved switch.

##### 4.2.1.7.2 Retail prices and tariff system

In accordance to Danish legislation, the regulation of energy prices for retailers with a supply obligation must reflect the wholesale market price levels [ReCh09]. Therefore, Danish Energy Regulatory Authority, DERA, sets a mark-up or gross margin for the competitive market by comparing non-regulated prices with Nord Pool Spot prices and taking profiling into consideration. This margin constitutes the cap of mark-ups of the "obligation to supply prices" of individual supply companies. If mark-ups exceed the cap, prices must be lowered accordingly. Every quarter, DERA calculates the tariff cap for all "obligation to supply" companies and publishes it on the website. Each supply company sets its own tarification and has to submit it to DERA each quarter. These are then published on the DERA website.
Retailers with a supply obligation offer several alternatives for their supply obligation products. Elpristavlen.dk shows all the alternatives. There are generally two categories of products. First, there are products with a variable price, where the consumer electricity price follows the developments in the wholesale market. Second, there are fixed-price products where the consumer electricity price is fixed for an agreed period (up to a maximum of six months). The suppliers of electricity also offer various other electricity products, e.g., "green products" pool electricity, and spot electricity.

#### 4.2.1.8 Summary of the role model

Stakeholders in the Danish electricity market are captured by the ebIX/ETSO methodology based role model [Energinet.dk]. The table below defines the players (i.e., the generalization of existing stakeholders) in the Danish electricity market, elaborating on the ebIX/ETSO roles they cover.

| Danish player | ETSO/ebIX roles | Comment |
|---|---|---|
| Electricity consumer | Consumer | |
| Electricity producer | Producer | |
| Balance responsible party (BRP) | Balance responsible party | Among the BRPs are production, consumption, and trading companies, including purchase organisations and traders. The BRPs have agreed with Energinet.dk to assume responsibility for a specific activity (production, consumption and/or trade). |
| BRP for production | Production responsible party | A balance responsible party has one or more types of duties and may cover one or more of the roles mentioned to the left. |
| BRP for consumption | Consumption responsible party | |
| BPR for trade | Trade responsible party | |
| Electricity supplier | Balance supplier | Electricity suppliers are responsible for servicing end users and enter into agreements on electricity supply. An electricity supplier must be approved by, |
| | Reconciliation accountable | |

| Danish player | ETSO/ebIX roles | Comment |
|---|---|---|
| | | or have made an agreement with, a BRP to be able to operate on the market. |
| Transmission company | Grid operator<br>Meter operator<br>Metered data collector<br>Metered data responsible<br>Transmission company<br>Metered data aggregator | A transmission company, as a player, is not responsible for system operation and has no direct customer connection. The player's responsibility is best compared to that of a grid company, yet without direct contact with the electricity consumer. |
| Transmission system operator<br>(TSO / Energinet.dk) | System operator<br>Responsible for balance settlement | The transmission system operator is also a *transmission company* and therefore has the same roles. |
| Grid company | Grid operator<br>Grid access provider<br>Metering point administrator<br>Meter operator<br>Metered data collector<br>Metered data responsible<br>Metered data aggregator<br>Reconciliation responsible | Grid companies are authorized to operate a distribution grid. All grid companies operate as monopolies with an obligation to ensure that registration equipment is installed and metered data supplied to all legitimate parties. Grid companies must also keep track of which BRP the end user has chosen. |
| Transmission capacity allocator (performed by E.ON – German TSO/transmission company south of the Danish-German border) | Transmission capacity allocator | |
| Meter operator (may be part of grid company) | Metered data collector<br>Metered data responsible<br>Meter operator<br>Metered data aggregator | In rare cases, some of the grid company's duties are delegated to a meter operator. In these cases, the meter operator's duties include collecting, storing, and qualifying metered data. The meter operator takes over the duties – responsibility remains with the |

| Danish player | ETSO/ebIX roles | Comment |
|---|---|---|
| | | responsible grid company. The ETSO/ebIX roles of the two players therefore overlap. |
| Public service obligation (PSO) company/ Electricity supplier (with special obligations). | Balance supplier | These companies are authorized to supply end-users who have not exercised their right to choose an electricity supplier. They have the same rights and obligations with regard to balance responsibility as do other market players with grid access. |

**Table 8: Danish electricity market players and their roles**

#### 4.2.1.9 Future actions on the market development

The Danish energy system is facing a paradigm shift [SysPl09]. Due to the recently adopted Climate and Energy Package in the EU, Denmark has to increase its share of renewable energy significantly, reduce greenhouse gas emissions, and carry out significant energy efficiency improvements. The Danish energy system has to be re-aligned and re-thought to allow large amounts of renewable energy to be efficiently integrated and used in the places where it is most valuable.
The most significant future development in the Danish electricity network includes increased integration of wind power into the power system, the intelligent application of electricity-based solutions in the heat and transport sectors, as well as significantly greater utilization of the potential for producing biogas.

### 4.2.2 Germany

#### 4.2.2.1 Description of physical grid

The German electricity grid has four voltage levels, which are operated by alternating current and connected by transformers with each other.
The extra high voltage level works with 220kV and 380kV and had in 2008 a length of 35.7 thousand kilometers. It forms the connection to European networks, but is used primarily for national distribution of electricity and to supply very large industrial firms. The high voltage level operates with 110kV and has a length about 76.3 thousand kilometers. It supplies larger businesses parks, industrial plants and railways.
The medium voltage level works with 20/10kV, has a length of about 507.2 thousand kilometers and supplies regional distribution networks as well as small and medium industrial companies. The low voltage grid supplies finally, with the known voltage of 230/400V, end users such as households, small commercial enterprises and agricultural enterprises.
The entire German power grid thus has a length of 1.78 million kilometers and requires about 566.200 transformers to supply the different voltage levels.

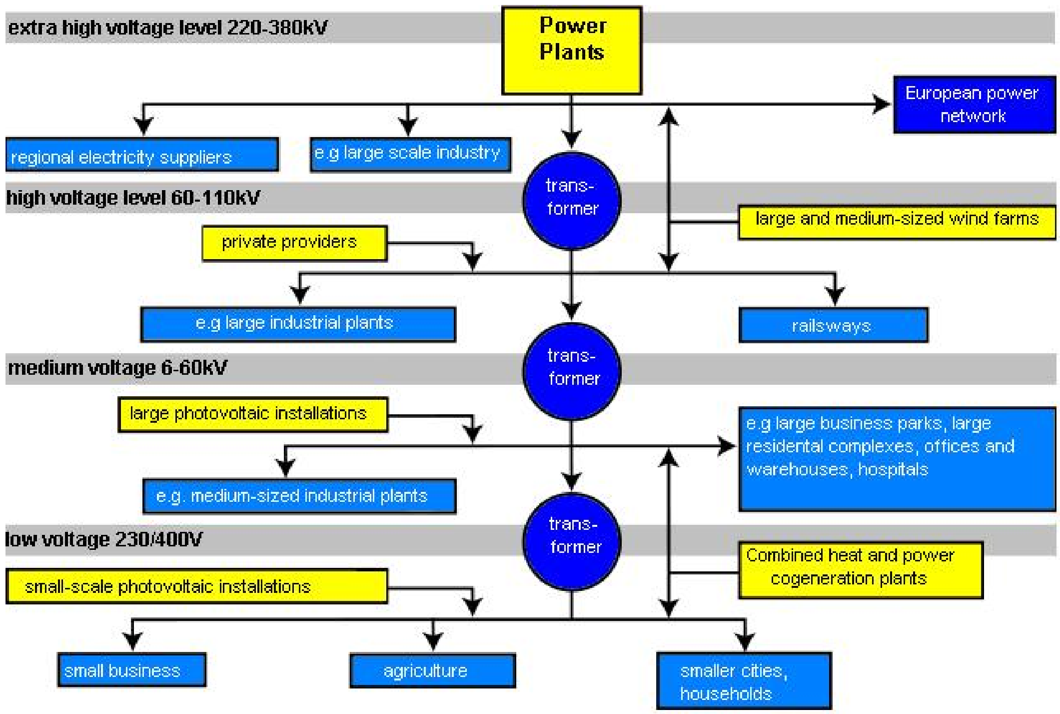


**Figure 11 : Structure of the German electricity market [Frie]**

In the regions of high voltage networks the grids of the different transmission system operators are connected with each other to a national integrated network.
Currently there are four transmission system operators in Germany:

- Amprion GmbH,
- EnBW Transportnetze AG,
- Transpower Stromübertragungs GmbH, and
- 50 Hertz Transmission.

In addition to these four operators, there are a variety of mostly local operators. In Germany, these are about 900 distribution system operators that operate on a regional level and provide the electricity to end customers. The grid operators do not receive their charge from the sale of electricity, but for the provision of networks. For that they receive from the power plant operator a network usage fee.
However, the interconnected system does not end at the German border. International tie-lines from Germany to neighbored foreign countries as well as tie-lines between foreign partners link the national subsystems to form a synchronous European extra-high-voltage system.

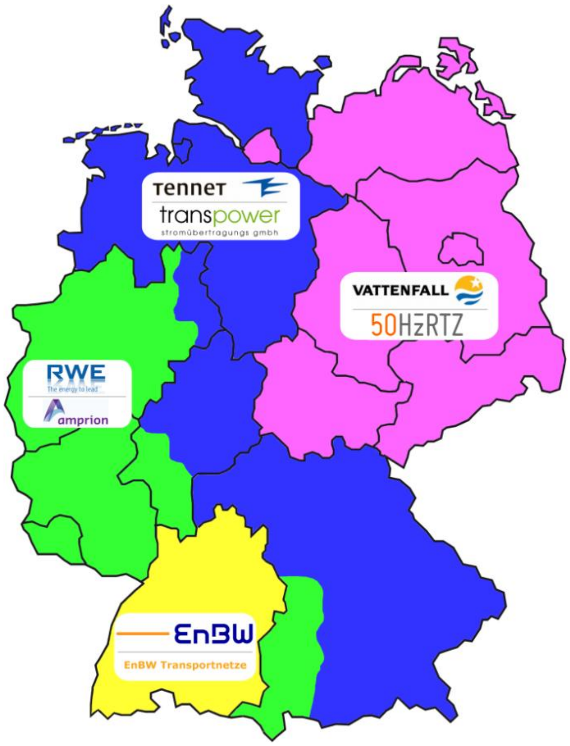


**Figure 12: Four control areas of the German TSOs [WPa]**

Today's extra-high-voltage system is strongly meshed. Electricity flows in the system based on the laws of physics described by Kirchhoff's or Ohm's Law. The current circuit arrangement in the system, also referred to as topology (lines switched on or off, transformer tap positions etc.), the local power output to subordinate distribution grids, delivery to large industrial customers as well as the current deployment of power plants determine how much electricity flows across individual lines. The transmission grid operator therefore only has limited control over physical load flows by changing the power plant deployment and by rearranging circuits in the system. This is why it is extremely important to monitor the flow of electricity as well as the loads on all the equipment in order to identify overloads and bottlenecks in the network soon enough and to be able to take corrective action. The systems of each energy utility were designed in such a way that demand in any utility's own control area can be met from its own power plant capacity without any bottlenecks arising in the system.

A major goal of interconnected operation in the electricity industry consists in exchanging electrical energy between the interconnected partners while maintaining security and availability. If more energy flows across national or international interconnection lines into a control zone than flows out of it, this difference constitutes the import of electrical energy. Conversely, if more energy flows out of the control zone than into it, electrical energy is exported.

Each control zone is lined up to the program value by means of load frequency control in order to be able to specifically influence and control export/import even in a highly meshed system. In its interaction with the primary-controlled power plants, load frequency control also maintains the network frequency (typically 50 Hz).

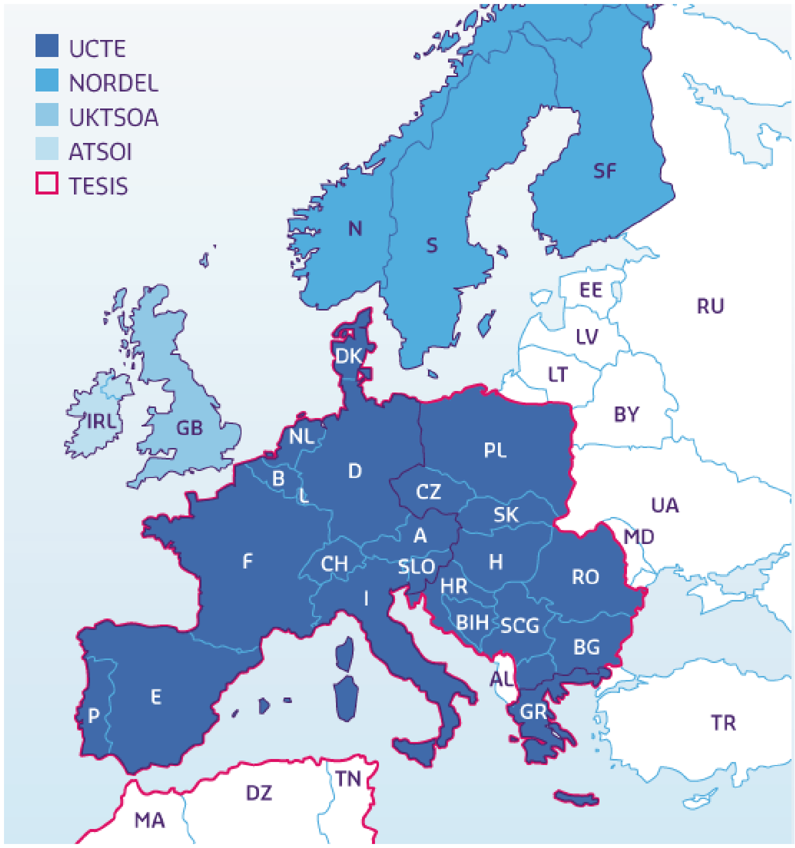


**Figure 13: European integrated network [Ampr]**

#### 4.2.2.2 Historic development

The liberalization of the German electricity market, starting in 1998, ended more than 100 years of local monopoly supply. Germany implemented the EU Electricity Market Directive of 1996 into a new energy law, the Energiewirtschaftsgesetz (EnWG), on 19 April 1998. This was its first fundamental change since 1935. The EnWG combined the negotiated third party access model with an optional single buyer approach for small municipalities in order to protect their local interests (e.g. using profits from sales of electricity to fund public transport). With these legal changes, Germany, in contrast to most of its neighbors, opened its market fully to competition at once, ending an era of regional monopolies protected by demarcation agreements. Suddenly every consumer was able to choose from a wide range of different suppliers.

The results were remarkable. Wholesale market and heavy industry prices fell sharply by as much as 60% and approached marginal production costs during 1999. Average industry tariffs were reduced by 27% from the beginning of the liberalization to the end of 1999. As a result of the fall in profitability, all eight of the major vertically integrated generating companies, and many smaller ones, were involved in merger negotiations by the beginning of 2000.

Germany rejected the idea of an independent system operator and left questions, for example the detailed regulation of grid access and transmission pricing, to be negotiated by different associations in the electricity industry itself and the German heavy industry. The results of these talks were the so-called association agreement or

Verbändevereinbarung (VV) in May 1998, and the grid code by the grid operators' organization. However, practical problems still remained, mainly because of insufficient regulation of transmission. High transmission prices, several cases of transmission access being refused and the vertically integrated structure of the German ESI with 8 large companies owning the grid and most of the generation capacity provoked criticism, leading to a revision of the first VV. The VV2 came into effect on 1 January 2000 and was designed to overcome major problems, abolishing distance-based tariffs apart from a transmission fee between two newly established zones (North-South) and facilitating access for small customers.

Just like the other member states of the European Union, Germany was obligated by the EU legislation to establish an independent electricity regulator, and also to introduce an ex-ante regulation of the electricity tariffs, where they are either set or approved by the regulator, before they are applied to the customers. The German choice to respond to this EU requirement, as well as to promote cost efficiency and thus lower total energy costs, was to introduce a new regulatory model for the electricity market called incentive based regulation. In 2005 the new federal regulator was established, the Bundesnetzagentur, which is involved in the responsibility of regulating multiple public services: electricity, gas, telecom, railways and postal services.

### 4.2.2.3 Market players

#### 4.2.2.3.1 Transmission system operator

Transmission system operators are natural or corporate persons or juridical dependent organizational units of a power supply company. They are responsible for the operation, the maintenance and if necessary for the extension of the transmission grid in a definite area and if need be also for the connecting line to other grid operators. In terms of the topic Smart Metering and with the coupled import of intelligent meters among the household customers the transmission system operators are mainly unconcerned.

##### 4.2.2.3.1.1 Network Access

EnBW Transportnetze AG (TNG) calculated the prices for the use of the transmission network of TNG in accordance with the requirements of the "Ordinance on Incentive Regulation of Electricity Networks (ARegV) which came into force on 29th October, 2007. The revenue cap for the year 2010 in accordance with ARegV is the basis for the calculation of the prices for the use of the transmission network and the prices for measuring and the allocation of the meter data.

##### 4.2.2.3.1.2 Price Components

The price components comprise network use, reserve network capacities, monthly demand charge and other services.

*Network use*. The price for the network use includes:

- The network infrastructure, i.e. provision and maintenance of lines, circuit breakers, transformers and further operational components of the transmission network.
- System services, i.e. services required for transmission and distribution of electricity and for determining the functional efficiency and safety of the electricity supply. This includes: primary control power and output, provision of secondary control power and minutes reserve power as well as operational management of the transmission network.

- Coverage of electric losses, i.e. provision of electrical energy for compensation of losses occurring during transport of electricity in the transmission network.

*Reserve network capacity.* Customers with in-plant generation can order reserve network capacity for the failure of their in-plant generation systems. Details are governed by the network utilization agreement.

*Monthly demand charge*. EnBW Transportnetze AG offers a monthly demand charge system for customers with temporarily high power consumption versus significantly lower or even no power consumption at all during the remaining time. The established price system consisting of demand charge and kilowatt-hour rate is applied irrespective of the network customer's hours of consumption.
To use the monthly demand charge system the customer has to chose this system before the beginning of the accounting period and give EnBW Transportnetze AG written notice on that.

*Other services*. In addition to the above-mentioned prices, the following services are charged separately:

- Operation of measuring point: The operation of measuring points includes the installation, the operation and the maintenance of measuring devices.
- Measurement: They depend on the technical design of the tapping point, the measurement and metering devices and the extent of data provided.
- The prices for billing include the services for commercial processing of the meter data as well as expenses for the provision of due charges for system usage and billing.
- Additional charges in accordance with KWK-G (Act on Retention, Modernization and Extension of Cogeneration): according to KWK-G dated 19th March, 2002 surcharges for ultimate consumers are raised with the network charges.

#### 4.2.2.3.1.3 Code of practice for calculation of network charges

The following data of a network customer are required to calculate the charges for network utilization:

- Tapping level (in kV),
- Annual output E in kWh of received energy,
- Maximum annual power P in kW (highest quarter hour power average per accounting year);
- For network customers with own generation, reported reserve network capacity PR in kW.

We calculate the charges for the reserve network capacity based on an annual demand charge (EUR/kW and year). This is dependent on the duration of the annual reserve utilization (hrs p.a.) and the tapping level.

#### 4.2.2.3.1.4 Metering

The liberalization of metering implemented with § 21b EnWG requires a consistent requirements profile for the metering performed by the operator of the measurement point. Here we provide information about the principles of metering and measurement in the networks of EnBW Transportnetze AG.

In the principles of metering and measurement, EnBW Transportnetze AG defines the EnBW standard for metering in the electricity networks. The principles are classified according to voltage level, output and annual volume of kilowatt-hours.

#### 4.2.2.3.1.5 Balancing Groups of EnBW Control Zone

EnBW Transportnetze AG manages energy volume accounts as balancing groups for acting traders in the EnBW control zone. The documentation of energy deliveries (load) and energy procurements (coverage) of the balancing group managers (Balance responsible person) is accomplished by means of the following accounting transactions: load time series, feed time series and schedules. These accounting transactions conform to the provisions of the balancing group agreement. As the responsible transmission system operator, EnBW Transportnetze AG always compensates the total balance (i.e. the difference between load and coverage for every quarter-hour of all balancing groups).

The principles of schedule processing and daily trading are in accordance with § 5 German Regulation on Access to Electricity Networks
Since January 1st, 2007, EnBW Transportnetze AG has given all market participants the opportunity to register intraday scheduled trading with 45 minutes lead-time for every quarter-hour within Germany.
For this purpose, the German transmission system operators have developed a concept intended to facilitate the coordination of a large number of simultaneous short-term schedule changes in a highly automated manner in accordance with the time specifications set forth in the Regulation on Access to Electricity Networks.

The procedure and the prices for the settlement of balance groups is as follows.
EnBW Transportnetze AG offers the balancing group managers in the EnBW control zone to perform the balancing group settlement up to and including 31st December, 2001, thus beyond August 2000, based on the procedure of a simplified balancing group settlement.
On explicit request, we offer the individual balancing group managers to apply the balancing group settlement procedure described in VVII, i.e. with output prices as well as only weekly balancing possibility.
Since 1st January, 2002, balancing group settlement has been performed in accordance with the procedures published in the prices and provisions for the utilization of the networks of EnBW Regional AG and EnBW Transportnetze AG.
EnBW Transportnetze AG procures (positive) secondary balancing power with a maximum output of +870 MW and/or provides (negative) secondary balancing power with a maximum output of -390 MW. This is accomplished in graduated output bandwidths and different tariff zones (HT/NT) in a range from €65 per MWh to €90 per MWh for positive balancing output and from €0 per MWh to €16 per MWh for negative balancing output.
EnBW Transportnetze AG assures that the energy from the contractually available minimum reserve to support secondary balancing will be procured and further calculated at prices of maximum €100 per MWh until 31st July, 2002.
Within the scope of the above-mentioned contractually available secondary balancing and minimum reserve, EnBW Transportnetze AG guarantees that the balancing energy prices of the balancing group managers, in monthly average broken according to supply and delivery direction in the EnBW control zone, are not more expensive for positive balancing power and not cheaper for negative balancing power than the respective most favorable price of the transmission system operators RWE Net and E.ON Netz.

The procurement of balancing power in extreme situations, e.g. in case of deliberate misuse by the balancing group managers in times of highly volatile exchange quotations, beyond the reserved volume secured by us will be calculated at the then prevailing current market prices.

#### 4.2.2.3.1.6 Network Operation

The transmission network serves as the platform for market partners in the liberalized power market

Within the scope of schedule management, balancing group managers will have to submit reliable cumulative schedules for generation and consumption in a balancing group as well as obligatory schedules for control zone exchanging and control zone internal trading schedules during the previous day. Schedules are to be communicated to the respective transmission system operators concerned on workdays not later than 14:00h for the subsequent day.

As an operator of a transmission network, EnBW Transportnetze AG assumes responsibility for the operation, maintenance and needs-based expansion of a safe, reliable, efficient and ecologically compatible energy supply network as far as this is commercially reasonable.

EnBW Transportnetze AG is also responsible for permanently securing the efficiency of its network in line with the demand for transmission of power, and thus contributes to security of supply by means of appropriate transmission capacity and reliability.

In order to meet these requirements, EnBW Transportnetze AG in particular complies with German and European standards as well as accepted rules of technology. In principle, the transmission system of EnBW Transportnetze AG is planned and operated in accordance with the (n-1)-principle. A network is (n-1)-secure if it is still able to perform its network function for a forecasted maximum transmission and supply assignment under acceptance of tolerable functional restrictions in case of non-availability of an operating resource.

#### 4.2.2.3.1.7 Renewable Energy Act: Basics and Description

The Renewable Energy Act (EEG) dated 21st July, 2004 became legally effective on 1st August, 2004. For power input from specific renewable energies, the EEG stipulates acceptance by the network operators and the payment of a legally determined minimum compensation for a legally defined term. In addition, it provides for comparative distribution of different regional EEG input respectively burden of electricity supply companies (EVU) servicing the end consumer.

The transmission system operators (TSO) who are responsible for the German control zones are entrusted by the EEG with the accomplishment of nationwide “compensation of load” for power quantities from such sources and their financial impact.

In the course of this compensation of burdens, the distribution network operators (VNB) pass on the power amounts received in their networks from plant operators to the transmission system operators and in return receive the legally determined minimum compensation paid to the plant operators minus avoided network use charges.

The transmission system operators again shift the EEG power amounts to the electricity supply companies servicing ultimate consumers within the scope of nationwide compensation of charges in respect of their output to ultimate consumers at a nationwide average EEG price calculated based on the EEG power volume and the compensation paid.

Monthly installment payments have to be effected for the power amounts and payments to be expected.

Within the scope of an annual settlement, differences between the installments rolled over and the annual deliveries are determined by means of meter readings and subsequently balanced. The procedures for the implementation of these laws are organized according to civil law and are conducted by the network operators under coordination by the Association of Network Operators (Verband der Netzbetreiber e.V.(VDN) in Berlin. VDN has published instructions for the implementation in a so-called “Description of EEG procedures”.

The legal conformity of execution is confirmed by certifications from accountants respectively auditors on the part of all partners cooperating in this process. As a responsible network operator, EnBW Transportnetze AG implements the provisions of the EEG in the respective network area.

#### 4.2.2.3.2 **Distribution system operator**

Distribution system operators are natural or corporate persons or juridical dependent organizational units of a power supply company who observe the task of the distribution of electricity and are responsible for the operation, the maintenance and if necessary for the extension of the distribution grid and if need be also for the connecting line to other grid operators. Following § 21b EnWG the grid operator is responsible for the metering point running and the measuring as far as no other convention is resolved. Following § 4 passage 4 MessZV the grid operator is under obligation to manage the meter points in his grid area, to submit the rehashed account relevant measured data to the grid operator and also to archiving the transmitted dates in the course of the grid access needed period. The grid operator conclude the responsible contracts with the metering point operators and measuring service providers which are active in his grid area. If a third metering point operator falls out, the grid operator is obligated to take the services metering operation and measurement at the affected measuring point immediately. In this case the measuring instruments which don’t belong to the standard portfolio of the grid operator might have to be taken over.

The grid operator has no incentives to secure his investments in intelligent meters on a long term basis because the connection user makes alone the decision who carries out the metering point service and the measurement with him. This might be one of the reasons that currently investments in smart metering systems, on the part of the grid operator, stay assessable. Beside the insecurity of the investments, the standards for data formats are being absent until now.

It is of the above-named facts to reckon that from the 1/1/2010 on the part of the grid operator only measuring devices were built which fulfils the legal frame work.

#### 4.2.2.3.3 **Metering point operator**

The metering point operator is responsible for the installation, the operation and servicing of measuring devices. If no other arrangements are met, the grid operator takes over this part. The measuring point operator is according to the law responsible to the opening of the metrology for the installation of intelligent counters under the changed conditions § 21b EnWG. Herein stated in paragraphs 3a and 3b:

(3a) As far as this is technically doable and economically reasonable the metering point operator have from the 1 January 2010 by the installation of measuring devices in buildings, which are newly connected to the energy supply grid or which undergo a major renovation in the meaning of the leading line 2002/91/EG of the European Parliament and the council of 16 December 2002 over the energy efficiency of buildings (ABV. EG 2003 No.L1 p.65), for the given situation built in measurement devices which reflect the respective connection user the in fact energy consumption and the in fact use time.

(3b) As far as this is technically doable and economically reasonable, have the metering point operator from the 1 January 2010 for existing metering devices offer each time metering devices, which reflect the respective connection user the in fact energy consumption and the in fact use time. The connection user is entitled to reject the offer, according theorem 1, and agree to replace the existing installation of a measuring device as a device in the sense of theorem 1.

There is no clarification what is under the in fact use time and the in fact energy consumption meant. According to the Physical-Technical- Federal Institute is already fulfilling a Ferraris dual tariff meter statuary requirements, so that the metering operator maybe mustn't take a modification to fulfill the standards of the EnWG.
Also open is when a new facility is a stock plant, id est. from when the connection user, whom maybe a smart metering device built in against his will, can engage another measuring point operator who remove that measuring device again.
Therefore it is reckon from 1/1/2010 that for the ultimate consumer a confusing ragbag of measuring devices is available which all interpret the faulty legal conditions differently.

##### 4.2.2.3.4 Metering service providers

The metering service company is responsible for the measurement, so for the reading of the metering devices as well as the passing on of the dates to the entitled people. However, substitute value formation, plausibility and validation of the metered values remain an assignment of the grid operator.
If no other arrangements are met, the grid operator is also the measuring service provider. If the measuring device selected electronically, the market roles measuring point operator and measuring service provider falling together.

##### 4.2.2.3.5 Supplier

The supplier is responsible for the supply of the end customer with energy. He supplies his customer by means of finished supply contracts (with or without grid use) and regulates the use of the grid with the distribution grid operator to whose grid his customer is connected. For this purpose he concludes with the grid operator a supplier framework contract in which inter alia the details for the measuring data provision are regulated. Following § 40 EnWG the suppliers are obliged to cash up the energy consumption after their choice monthly or in other periods, which may not significantly exceed twelve months. By request of the end customer the supplier is obliged to agree on a monthly, quarterly or semi-annual billing. However the data provision of the account relevant data takes place after the measure access regulation through the net operator.
The suppliers play a central role in the future scenarios with a volatile production from regenerative energies and an influenceable consumption of the consumer.
To be able to perceive their role, the suppliers need in future possibilities for the transmission of tariff information to the customer and his counting features and in reverse direction for the accounting data which results from these tariffs.
Today the tariffs for private and small commercial consumers are mainly formed according to standardized load profiles. The meter reading takes place yearly. In tariffs with several tariff steps, as many counter mechanisms are led accordingly. The change between the different tariff steps happens time-controlled or by use of ripple control. Prize changes occur only in longer distances, also mostly in a yearly turn.
Variable tariffs dependent on the current energy offer should be offered to the customer in the future by the application of smart meters. On this the supplier needs from the smart meter suitable load curves and all relevant counting data for the accounting and billing of

variable tariffs. To be able to offer the customer time-variable tariffs and to deduct them rightly, the supplier must be able to transfer his tariff information in due time to the customer. To secure a timely transference of these data, a bidirectional communication must be available accordingly.

It means even so a significant challenge to the energy trading to calculate time variable tariffs, as well as for the accounting such tariffs needful counter dates to conceive and to deduct. A comprehensive changeover of the today's procedures of the price formation and of the energy amount balance will become necessary to this. Only so the economic advantages of an energy consumption shifting can affect more favorable tariffs also equal to in the equilibration of the supplier and cause thus the price advantages for dealer and customer initially.
The ICT systems must be adapted to the significant more complicated accounting and the processing of a multiple of the today's date volume rising amount of processed dates.
Changed account modalities might also cause a need for adaption of the legal basic conditions of the accounting, e.g. in the Measures and Weights Act.

#### 4.2.2.3.6 Load consumer

Load consumers are customers who purchase energy for own consumption. The customer concludes a supply contract with the supplier. The end customer decides alone in his role as power customer which metering point operator and measuring service provider is active for him. Market surveys have shown that the end customer rather has a temporary interest in detailed consumption data and wishes a short runtime for the services of the metering point operation and the measurement.

#### 4.2.2.3.7 Energy service provider

Due to the possibilities offered by smart meters, it is expected that a new quality of energy consulting for the end customers might develop regarding energy efficiency and energy saving. Because the metering instrument will be able to monitor the load curve also in a high resolution, exact conclusions on single behaviors can be analyzed promptly.

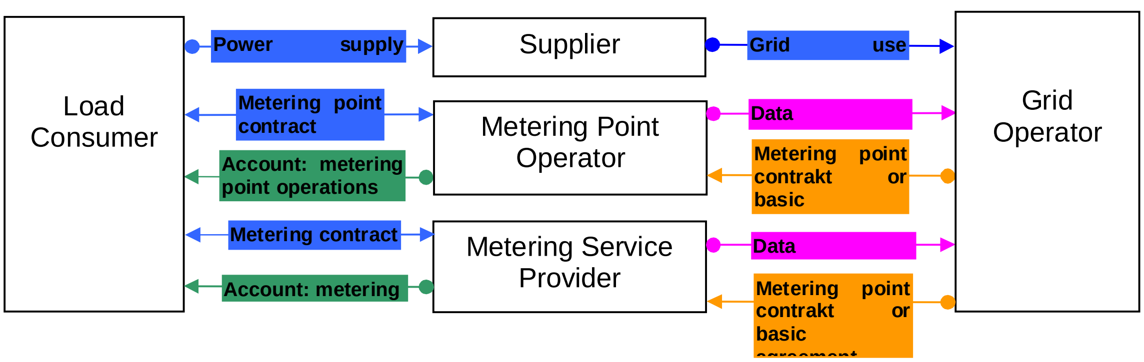


**Figure 14: Market roles in Germany**

#### 4.2.2.4 Market organization

##### 4.2.2.4.1 European Energy Exchange

The European Energy Exchange AG (EEX) [EEX] was founded in 2002 as a result of the merger of the two German power exchanges Leipzig and Frankfurt. Since then EEX has established itself as a leading trading market in European energy trading. Moreover, EEX has evolved into a corporate group which is open for European and international partnerships. EEX relies on an open business model which generates increased flexibility, market coverage and volumes through systematic spin-offs and partnerships. This model is reflected in the corporate structure of EEX.

In the field of power trading EEX cooperates with the French Powernext SA. EEX holds 50% of the shares in the joint venture EPEX Spot SE based in Paris which operates short-term trading in power – the so-called Spot Market – for Germany, France, Austria and Switzerland. German and French power derivatives trading is concentrated within EEX Power Derivatives GmbH, a majority-owned EEX subsidiary with headquarters in Leipzig. Clearing and settlement for all spot and derivatives transactions on power are provided by ECC, which has already been settling the natural gas transactions traded on Powernext since November 2008.

EEX is an exchange under the German Exchange Act and a regulated market within the meaning of MiFID. EEX has the following executive bodies: the Exchange Council, the Management Board of the Exchange and the Market Surveillance and the Sanctions Committee.

In Germany, an exchange is established as a public institution with a partial legal capacity upon granting of the corresponding exchange license by the exchange supervisory authority. The Exchange Supervisory Authority which is in charge of EEX is the Saxon Ministry for Economic Affairs and Labor (SMWA) in Dresden.

EEX is characterized by liquidity, transparency and fairness in pricing and this creates the confidence which the trading participants place in EEX. Safeguarding this is the central task of EEX and of its executive bodies.

For this reason, EEX has established a set of Exchange Rules, which is based on the German Exchange Act and binding both for itself and for all trading participants. This set of rules and regulations comprises the Exchange Rules, the Trading Conditions, the Contract Specifications, the Admission Rules as well as the Code of Conduct.

The Exchange Rules establish the essential provisions regarding the organization of the exchange, the tasks of its bodies and the preconditions for access to trading in the form of a statute. The Trading Conditions establish provisions regarding the trading process, while the Contract Specifications, which constitute a part of the Trading Conditions, establish precisely what is traded on the exchange. The preconditions for admission as a trader, especially the requirements with regard to the proof of personal responsibility and vocational qualification through a trader examination, are contained in the EEX Admission Rules. Now, EEX also has the Code of Conduct in addition; it contains the conduct to be observed by the trading participants and, in particular, serves the purpose of ensuring proper trading.

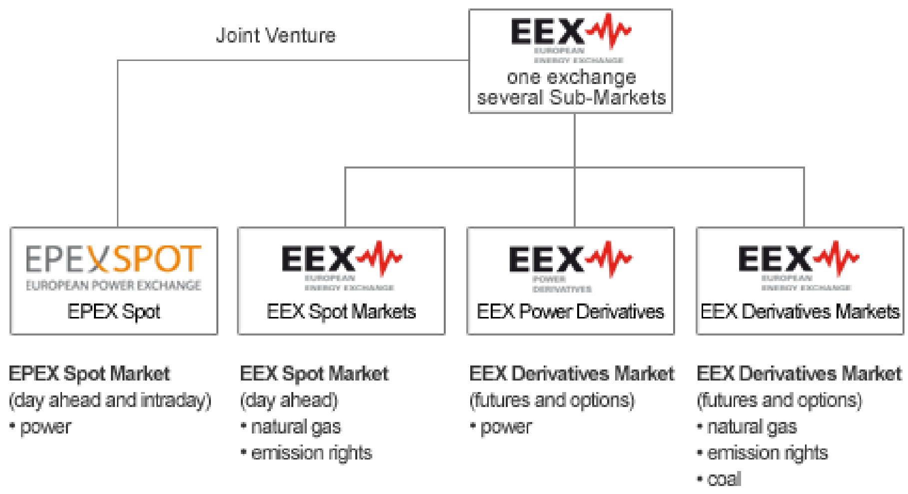


**Figure 15: Sub-Markets of the European Energy Exchange (Source: www.epexspot.com)**

#### 4.2.2.4.2 EPEX Spot Market

EPEX operates a Spot Market for electricity to optimize portfolios on short term. For that EPEX offers two options which are described in the following sections.

##### 4.2.2.4.2.1 Auction Trading

With this tool it is possible to trade electricity for optimizing for the following day for Germany and Austria. The trading participants use the day-ahead market in order to optimize short-term purchase and sale of electricity. The commandments of the hourly auction make it possible to simultaneously buy and sell different quantities at different prices in each auction. The exported quantity depends on the determined auction price.
The daily auction takes place at 12.00 am, 7 days a week, year-round, including statutory holidays. After the auction results, members have 30 minutes to raise objections against errors falling within EPEX Spot SE responsibility.
Deliveries are made within either of the following TSOs zones:

- Amprion GmbH
- Transpower Stromübertragungs GmbH
- 50Hertz Transmission GmbH
- EnBW Transportnetze
- Austrian Power Grid.

All these places of delivery form one market zone. In case of congestion between TSOs zones, prices can be determined by separate auctions for each market area. In case of changes in the composition of the market areas, EPEX Spot SE informs Exchange Members before auction price calculation in order to allow them to modify their bids accordingly.

##### 4.2.2.4.2.2 Intra-day trading of electricity

This means electricity contracts with delivery on the same or next day. Market participants usually buy because of increasing needs of additional electricity. In this way, it is possible to consider even short-term deviations from consumption forecasts and avoid schedule deviations.
The intra-day trading takes place every day of the year, around the clock.
Electricity traded for a delivery on the same or on the following day on single hours or on block of hours. Each hour or block of hours can be traded until 75 minutes before delivery begins. Starting at 3pm on the current day, all hours of the following day can be traded.
Deliveries are made within either of the following zones:

- Amprion GmbH
- Transpower Stromübertragungs GmbH
- 50Hertz Transmission GmbH
- EnBW Transportnetze

### 4.2.2.5 Balancing the production/consumption

#### 4.2.2.5.1 Market for control reserve in Germany

The German transmission system operators (TSOs) have the task of keeping equilibrium between electricity generation and consumption in their control areas at all times. For the performance of this task the TSO needs different types of control reserve as described in the UCTE (Union for the Coordination of Transmission of Electricity, now part of ENTSO-E) Operation Handbook Policy 1 (primary control reserve, secondary control reserve as well as minute reserve which is the equivalent of tertiary control reserve), which differ according to the principle of activation and their activation speed. Close co-operation between the TSOs contributes to keeping the total requirements for control reserve as low as possible.
Since 2001 the German TSOs have been procuring their required primary control reserve, secondary control reserve as well as minute reserve on an open, transparent and non-discriminatory market for control reserve according to the guidelines of the Bundeskartellamt.
The procurement is carried out as a tender auction on the German Control Reserve Market with participation of numerous bidders (both generation sets and (controllable) loads).
By pooling technical units (generation sets and (controllable) loads) in order to reach the minimum lot sizes (which differ across the three types of control reserve) it is also possible for small bidders to take part in the tender. Approximately 90% of all generation sets within the control block Germany are able to provide control reserve and have been prequalified by (at least) one of the TSOs. Starting in 2004, providers from the Austrian control areas of TIWAG and VKW have also been able to participate in the German market for minute reserve.
Until 30 November 2007, each TSO individually procured primary and secondary control reserve via half-yearly auctions. Prior to the start of joint procurement of minute reserve on 01 December 2006, each TSO individually procured minute reserve via daily tenders. In order to process these daily tenders, IT-based procurement platforms had been developed along with suitably defined, market-based control reserve products able to support the stable operation of the grid.
With the entry into force of the Energy Act (abbreviated as "EnWG" in German) on 13 July 2005 as well as the associated Electricity Grid Access Regulation ("StromNZV") and

Electricity Grid Tariff Regulation ("StromNEV") on 29 July 2005 the legal framework for procurement and use of control reserve changed significantly.
Since 01 December 2006 the TSOs' required minute reserve has been procured via a joint daily tender processed via the present internet platform. A common tender for the procurement of primary and secondary control reserve was introduced on 01 December 2007 and is also processed via www.regelleistung.net.
A certain amount of control reserve may need to be provided from within the TSO's control area (i.e., by technical units physically connected to the grid within the TSO's control area) as required by § 6 (2) Electricity Grid Access Regulation (StromNZV), the objective being to ensure continuous availability of the control reserve even in case of disturbances ("islanding" of the corresponding TSO's grid).

###### 4.2.2.5.2 General information on control reserve - imbalance pricing and settlement

The imbalance pricing system applied to balance responsible parties' imbalances has the following characteristics:

- Imbalance prices are computed for each balancing interval (equivalent to the scheduling interval of ¼ hour)
- The imbalance price for each balancing interval is determined by adding up the TSO's net energy expenditure (payable to or receivable from those providers of secondary control reserve and minute reserve that have been activated during the quarter-hour) and dividing this by the aggregate imbalance during the balancing interval
- The imbalance price is symmetric (a balance responsible party with a positive imbalance - i.e., which has fed more energy into the grid than scheduled - receives the same price as that paid by balance responsible parties with a negative imbalance and conversely). Note that because of negative energy prices a balance responsible party with a positive imbalance may have to pay
- Imbalance prices are published on TSOs' websites and are freely accessible to all market participants, thus ensuring transparency
- Capacity fees for secondary control reserve and minute reserve as well as the total cost of primary control reserve (for which no separate energy price is payable) are not passed on to balance responsible parties but are instead factored into grid use tariffs

###### 4.2.2.5.3 General information on control reserve - technical aspects

A permanent equilibrium between electricity generation and demand is an important precondition for the stable operation of the grid. Ensuring that their customers are supplied with power in a reliable fashion is at the heart of TSOs' responsibilities. For the purpose of maintaining the above-mentioned balance between supply and demand, TSOs procure control reserve (also known as balancing power).
A need for control reserve arises as soon as the current in-feed differs from current off-take. Such imbalances are caused, inter alia, by load fluctuations (on the demand side) and power plant failures (on the supply side). An excess of generation over load leads to an increase in the system frequency whereas an excess of load over generation causes the system frequency to fall.
The objective of activating control reserve is, on the one hand, to maintain the system frequency within a narrow range around its target frequency of 50 Hz and, on the other

hand, to eliminate deviations in exchanges between control areas from their scheduled values. To attain these objectives requires that three different types of control reserve be deployed in a coordinated fashion.
Based on the rules set out in the UCTE (Union for the Coordination of Transmission of Electricity, now part of ENTSO-E) Operation Handbook Policy 1 the German TSOs procure the following types of control reserve:

Primary control reserve

- Provided jointly and simultaneously by all TSOs in the UCTE synchronous area for the benefit of the entire system with each TSO's contribution a function of the corresponding control area's electricity generation
- Automatic and complete activation of primary control reserve within 30 seconds if required
- Primary control reserve has to be supplied for up to 15 minutes per incident

Secondary control reserve

- Deployed both to return frequency towards its target value as well as to bring exchanges with adjacent control areas back to their scheduled values
- Automatic activation by the TSO concerned (i.e., the TSO responsible for the control area in which the incident has occurred)
- Complete activation within five minutes (at most)

Minute reserver (tertiary control reserve)

- Activation by telephone by the TSO
- Complete activation within fifteen minutes of the telephone call
- Minimum activation time of fifteen minutes (and up to several hours if required)

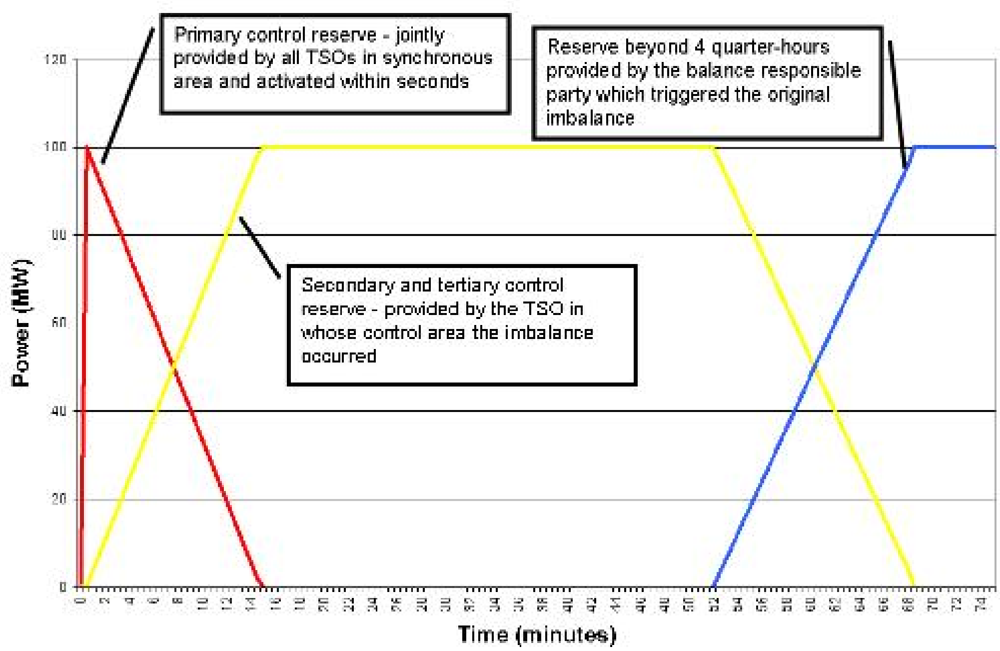


**Figure 16: Types of control reserves (Source: www.regelleistung.net)**

#### 4.2.2.5.4 Prequalification procedure for the provision and activation of control reserve

The transmission system operator (TSO) requires control reserve in order to be able to continuously balance generation and load.

Prospective providers of the different types of control reserve have to complete a prequalification procedure to demonstrate their ability to meet the TSOs' requirements in this respect. In addition to technical competence, prospective providers also have to demonstrate that they will be able to perform satisfactorily under operational conditions and that their financial situation does not give cause for concern.

The Reserve Connecting TSO (i.e., that German TSO in whose control area the technical units (generation sets and (controllable) loads) providing the control reserve are physically connected to the grid (independently of the voltage level)) is responsible for the prequalification procedure regardless of the type of control reserve. Upon successful completion of the prequalification procedure the Reserve Connecting TSO issues a certificate that is accepted as proof of successful prequalification by the other German TSOs.

In the case of secondary control reserve, prequalification also involves the connection of the technical units providing secondary control reserve to the Reserve Connecting TSO's load-frequency controller as well as verification of the correct functioning of this connection. If a bidder wishes to market technical units in several control areas, connections with all the relevant load-frequency controllers have to be established and the correct functioning has to be demonstrated via a separate test procedure. However, the prequalification procedure with the Reserve Connecting TSO has to be successfully completed first.

Following the successful completion of the prequalification procedure, TSO and prospective provider sign a framework agreement on the basis of which the prospective provider can participate in tenders. For each of the three types of control reserve, a separate agreement needs to be signed. In the case of primary control reserve and minute reserve, only the framework agreement with the Reserve Connecting TSO is required. In the case of secondary control reserve, the prospective bidder has to sign an additional framework agreement with each TSO whom it wishes to supply.

The prequalification procedure may be started at any time. Once all the required certificates and other documents have been submitted, a minimum of two months will normally be needed to complete the process. More time may be needed in the case of secondary control reserve if connecting the technical units to the TSO's load-frequency controller turns out to be particularly complicated.

Changes in the prospective provider's circumstances (equipment etc) that are relevant with respect to the prequalification requirements need to be signalled to the TSO immediately and may require renewal of the prequalification.

The prequalification requirements are contained (in German) in the TransmissionCode 2007 ("Netz- und Systemregeln der deutschen Übertragungsnetzbetreiber") issued by the TSOs. Chapter 5 ("Systemdienstleistungen" - ancillary services) contains general requirements whereas the detailed requirements for each of the three types of control reserve are described in Annex D.

### 4.2.2.6 End user business relations

As described in section 4.2.2.3 Market Players; the end customer today has a supply contract and a grid use contract. Since the liberalization of the metering he is also able to choose an metering point operator and a metering service provider. Normally all market roles are carried out by the supplier.

In the future a new market role might occur, the demand side manager. He bundles the requests of a number of customers to satisfy their needs and to trade control energy using the flexibility of a high number of participants.

#### 4.2.2.7 Future actions on the market development

**Smart grid**

Concerning renewable energy there is a lot of political framework conditions: first of all the resolution of the European Union. The European parliament demands a share of 20% of renewable energy until 2020 at the total energy consumption (electricity, mobility, heating, cooling). In addition to that there is a political cooperation contract in Germany. According to this cooperation contract there is consensus that the Renewable Energies Law and its goals (30% renewable energy until 2020) is to be continued. This increase of renewable energy leads to a higher flexibility on the generation side. This has to be equalized by also a higher flexibility on the consumption side.

**Use of renewable energies**

With the extension of wind energy, the main focus has lightly changed. The biggest extension followed in 2008 in Brandenburg. Since November 2009 there are 60MW offshore wind energy plants working in the test field “Alpha Ventus” in the North Sea. At the Federal Office for Sea Navigation and Hydrographic there are already more than 1.500 other plant locations in 22 wind parks sanctioned. In the next decade large grow rates of offshore wind turbines are expected. The Federal Government of Germany aims to grow up the installed capacity of offshore wind energy plants to 20 to 25 GW till 2030. Due to better wind conditions the use of wind energy is primarily concentrated in northern and eastern Germany. The expected expansion of offshore wind energy will increase the inequality of regional distribution.
With the expansion of renewable energies, especially the wind energy, the proportion of electricity from fluctuating production will increase. For the grid integration of this fluctuating energy there are new challenges coming up which have to be resolved:

- it occurs more and more generation situations with excess energy (strong wind/weak load situations)
- the large (and often short-term) fluctuations of renewable power generation must be compensated by balancing energy from conventional power plants for grid stabilization

The rising share of fluctuating renewable energy sources requires the flexibility of the German energy system. An important condition to improve the flexibility of the power generation system can be provided by the extension of the European UCTE (Union of the Co-ordination of Transmission of Electricity) grid. The power flow over country’s frontiers will increase significantly in the future. It is easily to point out that in strong wind situations in Germany also in the neighbored countries a high wind energy input is expected. This reduces the possibility to export excess wind energy. In addition to the grid expansion as well as optimization and flexibility measures the storage expansion is an important measure for reducing the current temporary excess energy.

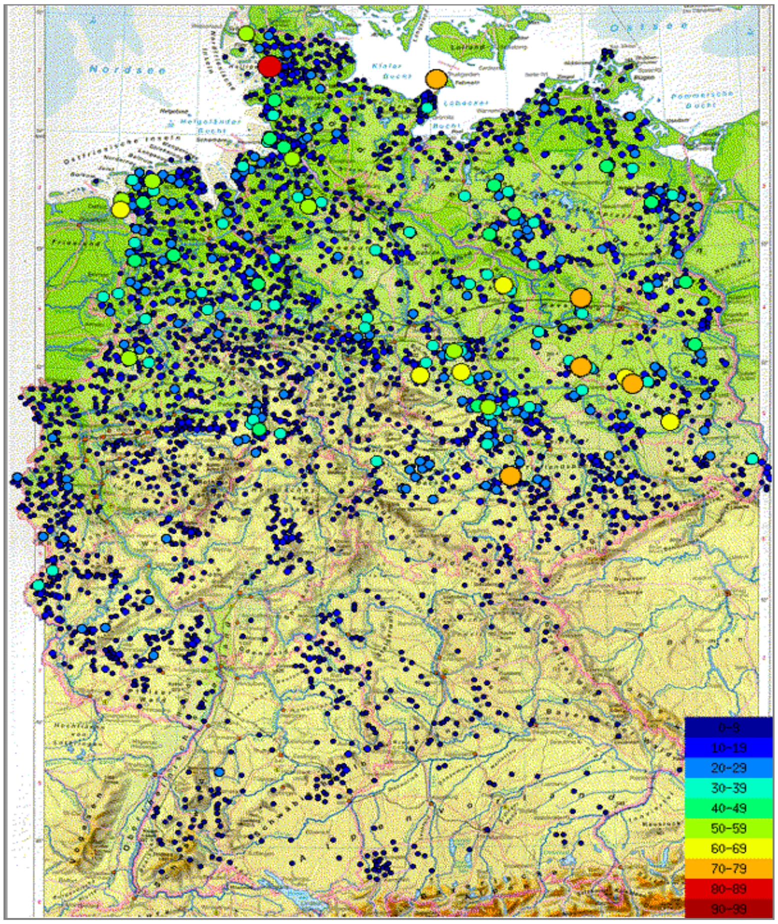


**Figure 17: Allocation of installed wind turbines (Source: ISET, IWES)**

The strong (an often short-term) fluctuations of renewable power generation can not alone be balanced by grid expansion or distribution within the European UCTE grid, or only by storing of the excess energy. For the compensation of these fluctuations it also requires flexible production plants to provide the higher demand of control- and balancing energy. Pumped hydro storage plants will be able to make these services available and thus they contribute to an efficient and safe power supply, also concerning the future needs by a higher share of fluctuating renewable energy.

### 4.2.3 Greece

#### 4.2.3.1 Description of physical grid

The Greek mainland has a well-developed electricity transmission system which is interconnected with the transmission systems of the neighboring countries in the north and through a DC 400 kV direct-current submarine cable, with the Italian transmission system; an interconnection at the border with Turkey is currently under construction. Greece operates under the UCTE system. However, the electrical stability of the Greek electricity system is vulnerable because of the high concentration of generation units in the northwest part of the country and the high distance from the south where most of the load is concentrated. In addition, the synchronous and the high capacity interconnections with other countries are also located at the northern borders. Transporting electricity to the main demand load which is situated in the South and principally in the Attica peninsula involves losses, high needs for reactive power and instability of voltage. Due to this high geographical imbalance between generation and demand, it is necessary to transfer large quantities of capacity along the North–South axis, through four long-distance High Voltage (HV) lines, which operate in parallel. The interconnected Transmission System consists of the High Voltage (HV) lines of 149–400 kV, including the interconnections with neighboring countries, and of the 66 kV submarine connections to some of the islands. It has currently a length of approximately 11,300 km. The (interconnected) Distribution Network consists of the Medium (MV) and Low Voltage (LV) lines of 15kV, 20kV and 400V of voltage has approximately 7 million metering points and a length of 207,300 km, covering the whole population. Part of the Distribution Network is also the autonomous networks of the approximately 2000 non-interconnected islands of the Aegean Sea. The exclusive owner of both the Transmission System and the Distribution Network is Public Power Corporation (P.P.C.). Within the framework of the unbundling requirements, however, the operation of the Transmission System was granted in 2000 to a separate company, namely the Hellenic Transmission System Operator S.A. (HTSO S.A.), which since July 1st, 2007 also became responsible for the operation of the Distribution Network. The HTSO does not own the grid assets.

#### 4.2.3.2 Historical development

For almost 50 years, the electricity sector in Greece has been organized according to the monopolistic model: a vertically integrated, 100% state owned company, namely the Public Power Corporation (P.P.C.), was granted exclusive rights for all electricity activities as regards the construction, functioning and exploitation of hydroelectric and thermal power plants, as well as of the transmission and distribution networks. At the same time, the Law prohibited any private business initiative or action in the electricity sector. The liberalization of the Greek electricity sector started in 1999, with the enactment of Law 2773/1999, which divided the electricity sector into two sub-sectors: the networks which have remained monopolistic and regulated, whereas free market rules have been applied for electricity generation and supply to eligible customers with the institution of a Regulatory Authority of Energy (RAE) to supervise the whole market. The law imposed, as a condition for any activity in the electricity sector, the issuance of a relative license, issued upon decision by the Minister of Development after a simple opinion of RAE. Also, during the first years of market restructuring, several electricity system codes such as the System Operation Code (2001), the Power Exchanges Code (2001), the Authorizations Regulation (2000) and the Supply Code (2001) were adopted. In 2003, a Mandatory Pool System was introduced where all suppliers acquired the obligation to purchase energy from the Pool and all generators can now operate only if selected by the market operator according to their economic bids to the Pool. Furthermore, in 2007 it granted the right to the consumers to choose their supplier, after all consumers, even household customers, became eligible with the exception of the customers situated on the non-interconnected islands. Finally, in April 2010 a new Law regarding RES licensing procedure is designed to be issued in order that the whole procedure becomes direct and simplified, releasing the licensing of small RES units from bureaucracy procedures regarding permissions from urban-planning authorities, archaeology authorities and forest – inspection authorities.

#### 4.2.3.3 Market Players in Greek Electricity Market – Resemblance to Role Model

The roles existed and distributed among the different parties and entities in Greek Electricity Market can be identified in the following:

#### 4.2.3.3.1 Consumers

Consumers of electricity can be specified in eligible customers and non–eligible customers. Eligible customers are considered gradually:

- From 2001 to 2005 all High Voltage and Medium Voltage consumers,
- From 2005 to 2007 all consumers except residential consumers and
- From 2007 all consumers even households.

Currently with the existing law framework eligible customers are those who are located on the mainland and all interconnected islands. The eligible customers in contradiction to non-eligible can choose their own electricity supplier in the electricity retail market and also can participate in the Market Pool System declaring their loads if having the licence to do so. In that case, the customers are self–supplied customers and can act as Balance Responsible Party representing their own production in the Market Operation. Eligible customers are the large hydro-electric plants which declare as load the Pumping Units used for pumping the water to the appropriate height. The non–eligible customers are the ones located on the non-interconnected islands where their electricity supply is assigned to P.P.C. automatically. In reality, all residential consumers, households, small industries which are connected to low and medium voltage are having their electricity supplied by P.P.C and act as non–eligible customers. Despite the law issuing towards the total liberalization of the market, the ownership of the DSO network by P.P.C, the strong market barrier posed by its monopolistic activity all those years and the strong regulated tariffs to low and medium voltage consumers render P.P.C. as the dominant party on supplying electricity in Greece obtaining almost 98% of market (95% on wholesale market and a virtual 100% on retail).

#### 4.2.3.3.2 Producers

The producer role in the Greek Electricity Market is performed by parties or entities licensed from the former Ministry of Development (now Ministry of Environment, Energy and Climate Change) after the recommendation of RAE to inject their producing capacity into the transition or distribution network. Producers can be distinguished into traditional producers producing electricity through thermal stations units or through big scale (bigger than 10MW) hydro plants (mostly owned by P.P.C.) and RES producers (P.P.C. and independent, RES energy companies or individuals). All thermal stations units and large scale hydro plants owned either by P.P.C. or private companies are obliged to be declared for their generation offer declarations into the day–ahead schedule (DAS) at the Wholesale Market along with Declaration of Units' Techno-Economical Data and Non–Availability Declaration. Independent individuals acting as RES producers and small CHP producers (smaller than 35 MWe) declare their nominal capacity to the Market Operator and Regulator (RAE) through the licensing procedure and after the issuing of it their whole electricity production is absorbed by the Market in priority to all other (traditional) producers. Furthermore, RES producers and small CHP producers do not need to submit any power injection declarations to the DAS System as this obligation is being carried out by the Market Operator itself.

#### 4.2.3.3.3 Suppliers (Traders), Balance Responsible Parties

The process of trading into the Greek Electricity Market is being implemented only by the licensed authorized Suppliers. The Licenses for Authorization for Supplying Energy are issued following similar procedure to the Producers' Licenses. Suppliers of Electricity can be parties or entities which are contracted to consumers (Eligible and Non–Eligible) and have the obligation to fulfill their electricity needs. They have the right to participate in the wholesale market declaring the loads offers derived from their customers' needs, declaring generation offers representing traditional producers into the wholesale market or declaring imports (or exports) satisfying loads in Greece (or abroad) acting as Traders in the broad European Electricity Market.

To be authorized to supply, a supplier must:

- Own adequate capacity in the EU
- Own, or contract on a firm basis, additional capacity to meet reserve requirements
- Arrange, on a long-term basis, the necessary interconnector capacity and transmission capacity within Greece

Suppliers also must provide Power Availability Certificates (PAC) of appropriate size that corresponds to a long term guarantee of system load demand supply. In the most usual case, suppliers in Greece have their own generation by having their own production units. The suppliers' activity in Greece makes them perform the role of Balance Responsible Parties responsible for their Balance Groups, comprised by consumers and traditional producers. In reality P.P.C. is the biggest supplier in Greek Electricity and the major Balance Responsible Party responsible for the generation absorption of the Generation Units (95% of total generation capacity, except RES) under its ownership and at the same time for the load coverage of the consumers contracted to it (98% of total market). P.P.C. - also operating as a Distribution Operator (DSO) at Medium and Low Voltage - is virtually the sole supplier to non–eligible customers and of the consumers of non–interconnected islands. Despite the provision of the Law 3426/2005, where since 1 July 2007 all customers, including households, became eligible, there is practical no customer that has changed supplier so far. This is mainly due to the regulated tariffs that P.P.C. is obliged to apply, these tariffs are often below cost, making new entry into the supply business almost impossible.

##### 4.2.3.3.4 **Market Operator, Transmission System Operator (TSO), Distribution System Operator (DSO)**

Before 1999, P.P.C. was the sole operator of the transmission and distribution network in Greece and the market opening of the electricity market was still unrealistic so no market operator role was existed. According to the initial provisions of Law 2773/1999, legal unbundling was introduced only for the operation of the transmission system. The related responsibilities were assigned to Hellenic Transmission System Operator S.A. (HTSO), or DESMIE, a majority state-owned company, with 49% of its shares belonging to P.P.C.. The full unbundling of P.P.C. activities is yet to be implemented. Currently the HTSO operates the transmission network where P.P.C. still holds the operation of distribution network covering all non–eligible customers and most of eligible customers under the medium/ low voltage. With the liberalization of the electricity market, after the enactment of Law 3175/2003, a new System Operation and Power Exchanges Code, providing for the organization of a competitive day-ahead wholesale market, was adopted in 2005. The HTSO is granted the duties of the market operator along with those of System Operator, Imbalance Settlement Responsible. Within that framework, the HTSO:

- Collects (a) the demand declarations that are submitted by the load representatives and exporters, and (b) the generation offers that are submitted by the generators and the importers.
- Computes the system marginal price (SMP) for each hour of the next day by sorting in ascending order the economic bids.
- Determines the operation schedule for the next day applying least cost unit commitment based on economic offers and system constraints.

- Controls the operation of power plants and the use of interconnections acting as Control Area Operator.
- Settles financial transactions, and manages imbalances acting as Imbalance Settlement Responsible.
- Plans for and carries out the provision of ancillary services, such as voltage control, reactive power and power reserves.

##### 4.2.3.3.5 Market regulator

The Regulatory Authority for Energy (RAE) was established under the provisions of Law 2773/1999 as an independent administrative authority, and started to operate in summer 2000. More specifically, RAE duties and responsibilities may be summarized to: (i) advisory duties, (ii) decision making powers, (iii) dispute settlement procedures, including arbitration in cases of disputes between consumers and market participants or between market participants and the companies having duties with regard to the networks, (iv) monitoring and reporting duties regarding the performance of energy enterprises, (v) monitoring duties regarding security of supply.

#### 4.2.3.4 Market organization

The Greek Electricity Market structure with the involvement of the above mentioned entities and parties performing the roles identified in the market are illustrated in Figure 18. Continuous lines show the electricity flow from the generation to the consumption of eligible and non-eligible customers through the HTSO transmission network and P.P.C.'s Distribution. It clearly illustrates the necessity of P.P.C. distribution network for the supply of electricity coming for independent suppliers owning their generation units or contracted with traditional generation units. It can also be shown that the non–eligible customers are available for electricity contracts for other suppliers than P.P.C..
After the enactment of Law 3175/2003, a new System Operation and Power Exchanges Code, providing for the organization of a competitive day-ahead wholesale market, was adopted in 2005. According to the Law, a Mandatory Pool System was introduced for power generation and wholesale supply, covering the entire market for the interconnected system. All suppliers acquired the obligation to purchase energy from the Pool and all generators can now operate only if selected by the market operator according to their economic bids to the pool. The pool was designed to operate on an hourly and daily basis. The applicable model is the one of the mandatory pool system which can be illustrated at Figure 19.
As it can be seen on the Figure 19 schematic illustration of the processes in Greek Electricity Market, all the basic occur on three Days referring to Dispatch Day, which are day ahead (D-1), dispatch day (D) and on the day after (D+1). On the day ahead (D-1) the processes of consumption and production forecasting through the load and generation declaration offers from the responsible parties to the market and the initial scheduling of units, resulting to the first calculation of SMP. On the dispatch day, the real load consumed and generation produced is being scheduled by adjusting the one of Day Ahead resulting to the final SMP. After the Day after (D+1), the imbalance settlement between measured and scheduled production and consumption is initiated. All imbalance settlement procedures including the funds and payments transfer are concluded several days after dispatch day (D).

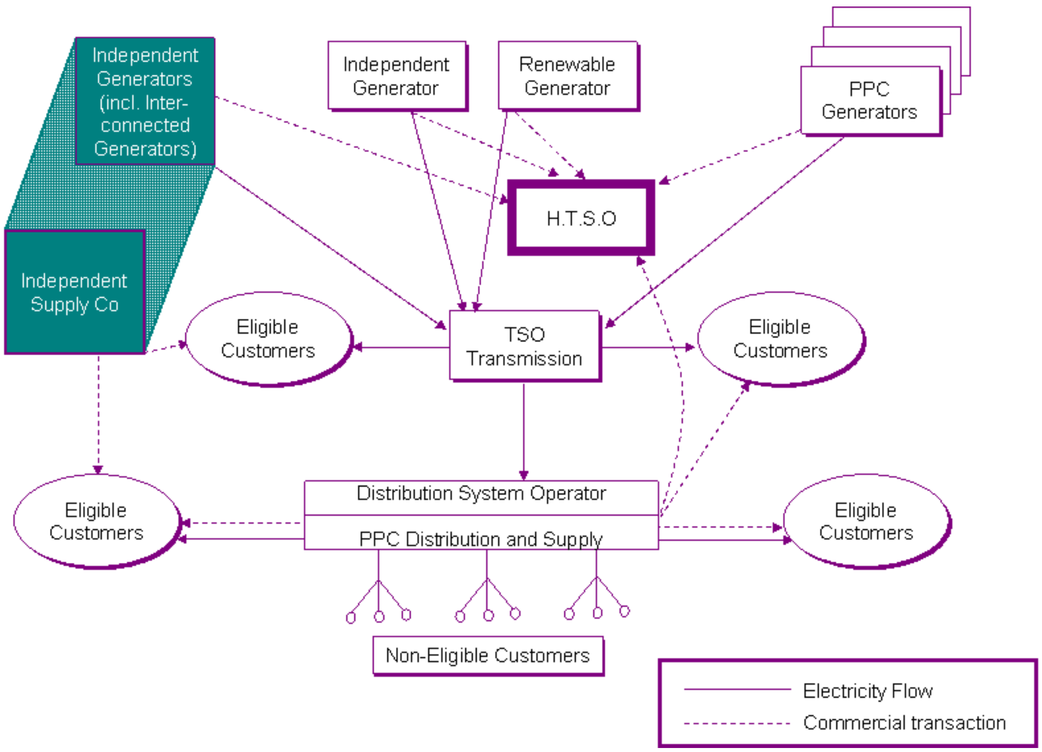


**Figure 18 : Greek Electricity Market Structure**

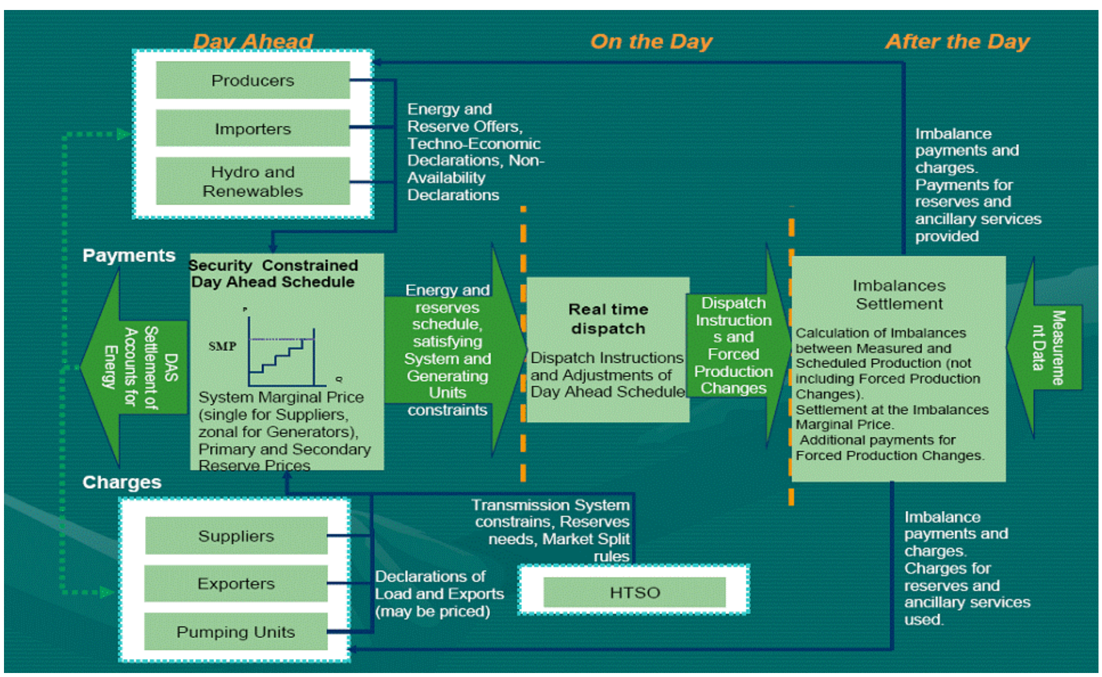


**Figure 19: Model of Day-Ahead Wholesale Market**

#### 4.2.3.4.1 Electricity Trading Processes on the Wholesale Market

The processes occurring among the identified roles in Greek Electricity Market can be categorized in six basic steps:

##### 4.2.3.4.1.1 Day-ahead forecasting

On the day- ahead forecasting participate the parties and entities which are authorized to declare load and generation offers on the day ahead scheduling. These entities are Balance Responsible parties of the Balance Group of clients they represent and for the Greek Market can be:

- *Producers*, holders of production licenses units, registered in the Record of Distributed Units
- *Suppliers*, holders of supply license
- *Self–supplied* customers, selecting customers which choose to be supplied energy from the electricity trading system for their own

Load declarations are submitted by the BRP of each group trading for load in the market. The content of Load Declarations can be:

- Non–priced declarations (offers) for every consumption in Greek territory which include the load quantity for every dispatch time period (one hour) of the dispatch day.
- Priced offers for exports and pumping which include pairs of load quantity and respective price for every dispatch time period of the dispatch day.

Loads can be declared for 48 hours until the end of the Day Ahead 12:00pm and there is a possibility of re–declare for 5 times for each participant and is declaration is mandatory in relation to the mandatory representation of clients from the BRPs on the market.
Regarding generation offer declarations, those are submitted by each producer or importer. The content of generation offer declarations for the day ahead can be:

- Pairs of generation offer quantity and respective price for each block of generation offer which are categorized to: i) priced block of generation offer for every registered production unit, ii) priced block of generation offer for imports, with the number of maximum blocks of generation offers to be defined to 10 and prices for each block of generation offer are monotonous increasing.
- Non–priced quantities of generation offers for RES and mandatory Hydro Units.

Generation offers can be declared for 48 hours until the end of the day ahead 12:00pm with possibility of re-declare also for 5 times for each producer. Generation offer declarations are submitted mandatory and separately for each production unit. The producer is obliged to submit offer for the total of nominal power of each production unit which agrees to the data of the record of production and distributed units. Producers along with the generation offer declaration must also submit declaration of techno-economical data for each of the units and unit non–availability declaration as well.
After the declarations of load and generation offers the HTSO as market operator continues with the load forecasting on the day ahead level taking into consideration all load declaration data, and then the forecast schedules for the generations units production. These schedules are “unconstrained” or “constrained”. The unconstrained schedule does not take into consideration the transmission constraints of this system where the “constrained” does. Both schedules also ignore the long terms contracts of

generators. The result of market operation is the hourly system price, published by HTSO officially at its website. This initial calculation of SMP's is a forecast of the final SMP which will apply after the real dispatch of the Units, where the real quantities of generation will be injected to the system and real consumption load will be demanded. The day–ahead forecasting process concludes with the HTSO publishing the forecasted initial SMP's for each hour of the dispatch day and sends the schedules to the participants. The full timeline of the day ahead processes is illustrated in figure 20.

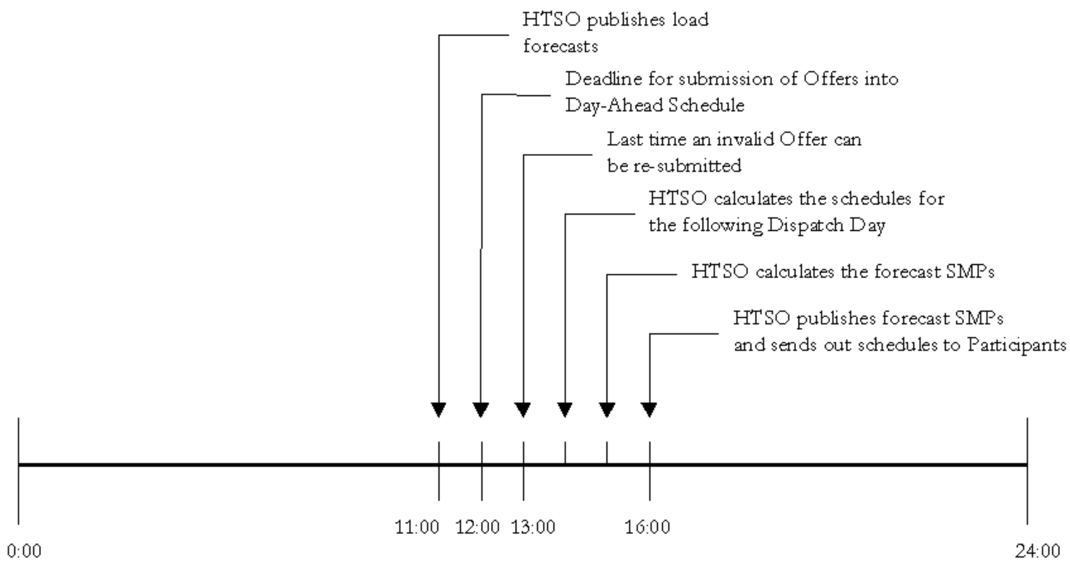


**Figure 20: Timeline of Day-Ahead Processes**

The HTSO may instruct available Units in Greece to start-up and synchronize at some point during or before the dispatch day to ensure adequate generation capacity is available for the real time dispatch of the system. Generators are obliged to follow these instructions. In real time, system load, generation availability and other constraints may change from those forecast on the day-ahead. Although these changes are normally not significant, they must be accounted for so that the transmission system is operated reliably. Accordingly, a separate dispatch in each dispatch hour determines the actual energy quantities dispatched from units in Greece to meet actual demand on the system. The dispatch is determined according to the merit order established day-ahead from the prices in the offers. The units have to obey their dispatch instructions in real time so as to keep the transmission system stable. Scheduled generators are not able to resubmit the quantity component of their offers between the time the offer was submitted and the dispatch hour unless they have a "legitimate" reason to do so. A legitimate reason is a prior approval by the HTSO, or an unexpected (forced) outage that renders some or all of the capacity of the unit unusable or hazardous to use for reasons of safety or protection of physical equipment. The HTSO may only issue prior approvals for reasons relating to unpredictable external factors such as wind strength in the case of wind-powered units. Offer revisions that are not demonstrably legitimate may result in penalties being assessed. Under no circumstances may the price parameters of an offer change between the time of submission into the day-ahead forecast and the actual dispatch hour.

#### 4.2.3.4.1.2 Metering and calculation of Systems Marginal Price (SMP)

In the day ahead an initial calculation of the SMP is occurred as a forecast to the final calculation of the SMP taking place after the dispatch day where the real quantities of energy have been consumed and produced. The System Marginal Price (SMP) in each dispatch hour reflects the marginal cost of meeting actual demand on the system given actual generation availability in that hour. The SMP is calculated ex-post, i.e., after the dispatch has been completed, and after Meter Quantity data has been determined. They are calculated on the Calculation Day (D+4), the day four days after the dispatch day. SMPs are calculated independently for each dispatch hour of the dispatch. SMPs are calculated based on the same principles as are used to determine the day-ahead forecast SMPs, except that the calculation includes updated information on actual unit availability and actual load so SMPs are used also in the settlement process and also called as Imbalance Marginal Price. In the event of suspension of the System's Trading Arrangements, SMPs are set to an Administered Price.

#### 4.2.3.4.1.3 Metering

All electricity delivered to or taken from the transmission system must be metered for HTSO settlement purposes. All energy produced by distribution-embedded units and all energy consumed by those eligible customers connected to the distribution system who are not supplied by P.P.C. distribution must also be metered for HTSO settlement purposes. Each BRP is required to account to the HTSO for all the energy used by customers for whom it has responsibility. The registered information for a BRP must identify the meters of eligible customers whose load must be evaluated in order to calculate the total load of the BRP. In the case of P.P.C. distribution, the registered information also specifies the meters at each connection point between the transmission system and the distribution system, and identifies the meters of distribution-embedded units and eligible customers not supplied by P.P.C. distribution connected to the distribution system below each transmission connection point.
BRPs are obliged to notify the HTSO whenever they acquire a new eligible customer or lose an existing one, or when their responsibility or allocation for the metered volume of an existing eligible customer otherwise changes, so that the HTSO can update the registered information for BRPs accordingly. The HTSO is responsible for maintaining the registered information and maintaining a central register of each eligible customer, identifying the corresponding meter, the corresponding BRP that have responsibility for its metered load, and the allocation rules, if any, to apply. The HTSO ensures that for settlement purposes, participants take responsibility for 100% of all data metered. In the calculation of the meter quantity attributable to each BRP responsible for supplying its clients and generator at each node, the HTSO uses the registered information to determine:

- which meter-readings to aggregate for each purchaser at each node; and
- which unit meter-readings to aggregate for each generator at each node.

The HTSO is also responsible for verifying and correcting metered data, collected from participants' meters, in order to establish meter quantity information. Such verification and correction shall be carried out in accordance with the validation, editing and estimation procedures published on the HTSO web-site. At the request of HTSO, participants shall assist HTSO in correcting or replacing defective meter data and in detecting and correcting the underlying causes of for such defects.

#### 4.2.3.4.1.4 Calculation of Settlements

Imbalance is the Energy Deviation which shall be defined separately per Energy Offer and Load Declaration and separately per dispatch period, and it shall be the difference in MWh between the energy quantity scheduled for injection to the system or absorption by it in accordance with the DAS schedule and the energy quantity injected to or absorbed by the system in real time operation as is measured for the same dispatch period and corresponded to the participant and the Energy Offer and Load Declaration in question.
There are two types of Energy Deviations:

- Uninstructed Generation Deviation in MWh of a unit for a dispatch period shall be the difference between the quantity energy established by dispatch instructions to be injected to the system for the same dispatch period and the energy quantity measured for the same dispatch period at the Unit Meter;
- Instructed Generation Deviation in MWh of a unit for a dispatch period shall be the difference between the quantity energy declared in the energy offer for the unit to the extent that this is included in the DAS schedule for the same dispatch period and the energy quantity established by the dispatch instructions for injection to the system for the same dispatch period.
- Imbalances Settlement apart from those related to Generation Deviations can also be identified in the settlement of transactions for Ancillary Services and the Uplift Accounts.

The procedure followed for the calculation of Settlements is that at the end of each dispatch day, the HTSO activates the Imbalances Settlement Procedure which shall be completed within four (4) calendar days (Imbalances Clearing Period). Clearing Day (or Calculation Day) shall be the last day of the Imbalances Clearing Period. Generation Deviations will be settled at a single price (€/MWh), (Imbalance Marginal Price).
The HTSO's timeline at the Clearing Day can be described as:

- Determination of final SMPs (imbalance marginal price) and meter quantity information
- Calculation of each participant's daily purchases and sales of energy through the market and records them in the participant's account;
- Accumulation of any Ancillary Services costs, HTSO administrative costs, the net cost of energy exchanges with adjacent control areas, the net cost of payments in respect of energy generated, Constrained-On Payments and Constrained-Off Payments, net revenues from transmission losses, and participant non-compliance net revenues, as they are incurred, in the Uplift account; and
- Accumulation of the cost of payments made to the P.P.C.'s Transmission Business Unit as they are incurred and in accordance with the terms of the Transmission Control Agreement, in the transmission account.

The HTSO is not involved in the settlement of any existing or future contracts between Participants, nor the settlement of retail tariffs. Nor does the HTSO collect charges from Participants in respect of penalties. On the Billing Day in respect of a month, HTSO informs the RAE of the amount of any penalties assessed on a Generator for each day in the month.

#### 4.2.3.4.1.5 Billing & funds transfer

On the Billing Day in respect of each calendar month (the day fifteen days after the last Dispatch Day of each calendar month) the HTSO clears, on an accrual basis, the Uplift costs accumulated for the month. It does this by making transfers to the participants' accounts so that the Uplift account has a zero balance on the HTSO's books as of the beginning of each new settlement month. Uplift costs are allocated to BRPs on the basis of their pro-rated energy consumption for the month. Funds due must be transferred on or before the day fifteen days after the billing day (or on such day as the HTSO specifies when it publishes its calendar of payments prior to the beginning of each year).

##### 4.2.3.4.2 Bilateral Contracts

Apart from the day–ahead pool market mandatory to participants in the system, an important feature of the Greek Electricity Market is that it also has gross settlement in respect of contracts and net settlement in respect of ownership. This means: i) all electricity generated or consumed is sold by generators, bought by purchasers, and settled by the HTSO, ii) the HTSO does not take into account independent contractual arrangements between Participants with regard to its settlement of transactions in the Market, iii) the HTSO does, however, consolidate invoices and remittances of participants owned by the same parent entity. Suppliers, which are both purchasers and generators are therefore invoiced or paid for their net financial imbalance. (Each supplier is treated as a separate generator and purchaser in the market – in this way it is possible for the HTSO to conduct a least cost dispatch of the full available capacity of suppliers and not just the capacity net of their final customer load.) The purpose of this is to illustrate how a supplier, being both purchaser and generator, can use the market serve its load and match imbalances between its generation and consumption. It also illustrates how participants can enter into bilateral energy contracts with one another within the framework of the Market to buy and sell imbalance energy at predetermined prices, rather than at SMPs, if they so wish. SMPs fluctuate according to market conditions. Participants, if they desire, can make bilateral contracts between one another to "lock-in" the price at which imbalance energy is bought and sold, so as to remove the financial uncertainty of paying or being paid the SMP. The form of contract that participants can enter into for this purpose is a Contract for Differences (CFD). A CFD is a financial contract between the parties to the bilateral transaction and is independent from the HTSO. A CFD has a strike price and a MW quantity. In its most simple form it specifies that:

- when the SMP is higher than the strike price, the generator pays the purchaser the SMP minus the strike price, multiplied by the CFD MW quantity, for that hour; and
- when the SMP is lower than the strike price, the purchaser pays the generator the strike price minus the SMP, multiplied by the CFD MW quantity, for that hour.

The financial effect of a CFD, therefore, is that both the generator and the purchaser receive a guaranteed net price – the strike price – at which they respectively sell and buy the CFD MW quantity of imbalance energy. The existence of a CFD does not change the way the Generator offers its capacity to the HTSO, or the way in which the HTSO operates the system. Furthermore, the settlement of CFD payments is made independently of the HTSO, between the participants concerned. Consequently, since executing bilateral transactions in the form of CFDs does not require any special action from the HTSO in addition to its regular responsibilities as system operator and market operator, there are no special rules regarding these contracts in the market. The HTSO does not need to be aware of their existence.

#### 4.2.3.5 Balancing the production/consumption

The balancing of production/consumption in the Greek electrical system due to the mandatory pool market for all the participants occurs on the system operator level as this is the level that P.P.C. and all other potential suppliers of electricity acting as BRPs submit their load declarations to the pool and thus HTSO having the responsibility to balance the whole Greek Area. Balancing the production/consumption apart for covering the electricity deviations derived at the dispatch day, ensures the system's reliable system operation. For that reason HTSO sets requirements for the so-called "ancillary services" including:

- Frequency control: fast response to fluctuations in frequency achieved either through governor action and/or by use of Automatic Generation Control.
- Reserves: several types of reserve are usually required to maintain system security. The definition of these services varies according to the required time frame for response and duration of response. The types of reserves used will in part depend on the generation mix and security standards.
- Voltage control: can be provided by either dynamic sources or static sources.
- Black start: arrangements to restore the transmission system following an outage.

Reserves are separate commodities that can be traded in the day-ahead market, thus establishing reserve markets. The primary reserve requirement is set at 80 MW, while the secondary reserve requirement varies between 150-300 MW for secondary reserve up, and between 50-150 MW for secondary reserve down. Tertiary reserve requirement is set for the moment at about 5% of the system load. Currently, there are separate primary and secondary reserve markets; tertiary reserve is not remunerated, but the relative requirement enters the DAS program as a constraint.

#### 4.2.3.6 Tariff system

The structure of P.P.C. tariffs has remained unaltered since the beginning of the monopoly period, i.e. for almost 40 years. Only the numerical values of total tariff levels per sector are changed every year as a result of government's regulations. These tariffs are applied in a uniform manner for all customers independently of their geographic location in Greece. The tariffs vary per connection voltage level and sector to which the consumer belongs (for example industry, residential, etc.). Recently RAE launched a procedure for the revision and rationalization of P.P.C. tariffs. This procedure is ongoing. Furthermore, P.P.C. recently elaborated and presented an unbundled tariff structure, separating the regulated from the competitive charges. Low tariffs are exceptionally applied for agriculture, P.P.C. employees and families with more than three children. The High Voltage (HV) and the Medium Voltage (MV) tariffs are based on separate charges for power and for energy. The tariffs apply a generally higher price on the power component (MW) than on the energy component (MWh). The related supply contracts apply 'take-or-pay' obligation clauses regarding the power component, based on mentioning in the contracts per customer the volume of power on which take-or-pay obligations apply. The Low Voltage (LV) tariffs are based only on an energy component and include a fixed payment term. The residential tariffs vary stepwise and follow an upwards increasing slope; the first step is almost half the fourth and the subsequent steps. Commercial and small industry electricity prices are significantly higher than average electricity cost, whereas the high voltage prices as well as the residential and agriculture tariffs are below average cost. Therefore, cross-subsidizations between different consumer categories exist in Greece. Also cross-subsidizations apply to the benefit of consumers located in non-interconnected islands.

### 4.2.4 Netherlands

#### 4.2.4.1 Description of physical grid

##### 4.2.4.1.1 Transmission network

The Dutch high voltage grid is being operated by a single system operator; TenneT. The layout of the high voltage network is shown in Figure 14.


**Figure 21: High voltage network in the Netherlands**

The network consists of multiple high voltage levels; 110 kV (black lines), 150 kV (blue lines), 220kV (green lines) and 380 kV (red lines). The layout of the transmission networks shows two rings; a 220 kV ring in the north east and a 380 kV ring for the rest of the country. The ring structures are essential for the high availability of the network as they allow the reversal of the direction of the electricity flows in case of outages.
The Dutch network is interconnected with the networks of Germany, Belgium, Norway (sea cable) and the United Kingdom (sea cable).

#### 4.2.4.1.2 Distribution networks

On the distribution level there are multiple grid operators. Figure 15 provides a geographical overview of the Dutch distribution grid operators.


**Figure 22: Dutch distribution grid operators**

The regions correspond with the following operators: 1. RENDO netwerken 2. Cogas infra en beheer 3. Liander 6. Stedin 7. Westland infra 8. Stedin 9. DELTA netwerkbedrijf 12. NRE Netwerk 13. Enexis 14. Enexis. The majority of the organizations that are mentioned here also operate distribution grids for gas. However in a given area one organization may be the electricity grid operator while another operates the gas distribution grid. There

is a tendency to align these areas so that electricity and gas are operated by the same organization.
Since the liberalization of the Dutch energy market in 2004 grid operators are separated from energy suppliers.

#### 4.2.4.2 Historical development

The current Dutch suppliers and grid operators are the result of merging a lot of smaller energy companies into a few large ones. This process started in the 1980's.
The energy market was liberalized in 2004. This means that consumers are free to choose their energy supplier irrespective of their geographical location. In order to make this possible the energy suppliers and the distribution grid operators that used to be combined into one organization were strictly separated. The tariffs that are associated with the distribution grid operators such as transport costs and connection fees are regulated whereas the tariffs for the supply of energy are left to the market. The basic assumption is that this liberalization leads to more competition with better services and lower tariffs.

#### 4.2.4.3 Market Players

The main players on the Dutch market are:

- **Electricity producers.** The largest producers in the Netherlands are NUON, Essent, Electrabel, Intergen, Delta en E.O.N. The total production in the Netherlands amounted to 104 TWh in 2008.
- **System Operator.** TenneT is the single System Operator of the Netherlands and is responsible for the high voltage network on which production and consumption is balanced.
- **Distribution grid operators.** The distribution grid operators operate the medium (between 10 and 110 kV) and low (< 10 kV) voltage networks. There is a strict separation of grid operators and trading and/or retailing organisations.
- **Programma verantwoordelijken (Balance Responsible Parties).** The BRP's are responsible for the purchase of energy (either on a market or OTC).
- **Supplier.** Suppliers supply energy to consumers and buy their energy from "Programma Verantwoordelijken". In most cases the supplier and "Programma Verantwoordelijke" are combined into one organisation.

#### 4.2.4.4 Market Organisation

Several options exist for the trading of energy:

- **Bilateral Market.** On this market producers and buyers of energy can enter into bilateral agreements on volume, duration and period of the supply of electricity.
- **OTC.** Unlike the bilateral market the over the counter market works with standardized contracts. The two main products are base load and peak load. Producers and buyers of energy are brought together by brokers.
- **APX/Endex.** This is the Dutch energy exchange. All parties can trade on this exchange without the mediation of a broker. The exchange facilitates two markets:
  - Day Ahead Market. Here parties can trade hourly instruments (single hours or blocks of consecutive hours) for the day ahead.
  - Intraday Market. Parties can trade power products in 15 minutes intervals, 1 and 2 hour blocks up to two hours prior to delivery.

- **Imbalance market.** The imbalance market is a single buyer market with the System Operator TenneT as the only buyer. On this market reserve power is offered to the System Operator. The reserve power is being used to balance the grid.

#### 4.2.4.5 Balancing production and consumption

Balancing is only performed on the transmission grid and is the responsibility of the System Operator. Every Balance Responsible Party has to provide an energy and a transport program to the System Operator prior to the delivery of energy. The system operator checks whether the provided programs are all in line with each other, only then approval for the execution of the programs is granted.
During the operational phase deviations from the programs will occur that render the grid imbalanced. In order to counteract these unbalances the system operator has the disposal of reserve power that it buys at the imbalance market.
After the operational phase the system operator compares actual measurements with the programs that were provided prior to delivery. When significant deviations are found penalties will have to be paid. The costs for the reserve power that had to be used are passed on to all balance responsible parties as system costs.

#### 4.2.4.6 End user business relations

At the moment an end user has a relation with the following business parties:

- **Supplier.** Most end users have an open contract with a supplier.
- **Metering Responsible.** The metering responsible is responsible for gathering the metering input for the billing process. In most cases, this is the same organization as the supplier.
- **Grid Operator.** The grid operator is responsible for the physical connection to the grid.

The tariff for electricity is made up of the following components:

- **Supply costs.** These are split in fixed costs and variable costs that are being paid for each kWh that is being delivered. The supply costs are being billed by the supplier.
- **Grid management costs.** These are also split in fixed costs that are related to the connection and variable transport costs that are associated with each kWh that is transported. In some cases these costs are being presented on a consolidated bill by the supplier in other cases the distribution grid operator sends a separate bill for the grid management costs.
- **Energy tax.** This tax is being paid per kWh and is being used by the government to stimulate the use of renewable energy sources by taxing other energy source more.
- **Value Added Tax.** The VAT tariff for energy is 19%.

#### 4.2.4.7 Summary of the role model

No reference has been found to any formal role model for the Dutch electricity market issued by an official party such as the system operator. However the Dutch market situation is in line with the ENTSO-E Harmonized Electricity Role Model although the latter contains more detailed roles (e.g. subdivision of Balance Responsible Party in a Production, Consumption and Trade Responsible Party).

### 4.2.5 Slovenia

#### 4.2.5.1 Description of physical grid

Slovenian power system consists of the transmission and distribution.

Production units connected to the transmission network, have total installed power of 2486 MW, of which

- 866 MW belongs to hydroelectric power plant
- 1,272 MW thermal power plant and
- 348 MW Nuclear Power Plant. (this is the half which belongs to Slovenia, the other half belongs to Croatia)

Power plants are arranged in the following locations:

- nuclear power plants: Plant Krško;
- thermal power plant: power plant, Trbovlje, TE-TO Ljubljana and substations;
- hydro: Soča (Doblar, blue, Bridges), Sava (bridge, Mavčiče, Malinska and
- Impoundment), sound (Dravograd Vuzenica, Vuhred, Ožbalt, Fala, Maribor Island, Zlatoličje and Formin).

| Year | 2010 | 2011 | 2012 |
|---|---|---|---|
| Total [MW] | 3,302 | 3,282 | 3,282 |

**Table 9: Installed generation capacities from 2010 to 2012**

Installed generation capacities are published on the basis of the data provided by generation companies connected to the transmission and distribution network.

| UNIT | 2010 | 2011 | 2012 |
|---|---|---|---|
| Nuclear | 700 | 700 | 700 |
| PB4 Thermal | 114 | 114 | 114 |
| PB5 Thermal | 114 | 114 | 114 |
| TEŠ4 Thermal | 275 | 275 | 275 |
| TEŠ5 Thermal | 345 | 345 | 345 |
| TET 4 Thermal | 125 | 125 | 125 |

**Table 10: Installed generation capacities [MW] for units >100 MW from 2010 to 2012**

The dynamics and structure of the production of electrical energy in the years 2005 to 2010 is presented in Table 11. The production of the electricity energy in the year 2009 was 16,397 GWh. The major part of the electricity was produced by nuclear power plant (5,739 GWh) and hydro power plants (4,713 GWh).

| | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| | GWh | | | | |
| Gross production-total | 15,117 | 15,115 | 15,043 | 16,398 | 16,397 |
| Import | 7,234 | 7,071 | 6,140 | 6,218 | 6,156 |
| Export | 7,558 | 7,020 | 5,911 | 7,820 | 9,222 |

**Table 11: Production, import and export of electricity, Slovenia, 2005-2009**

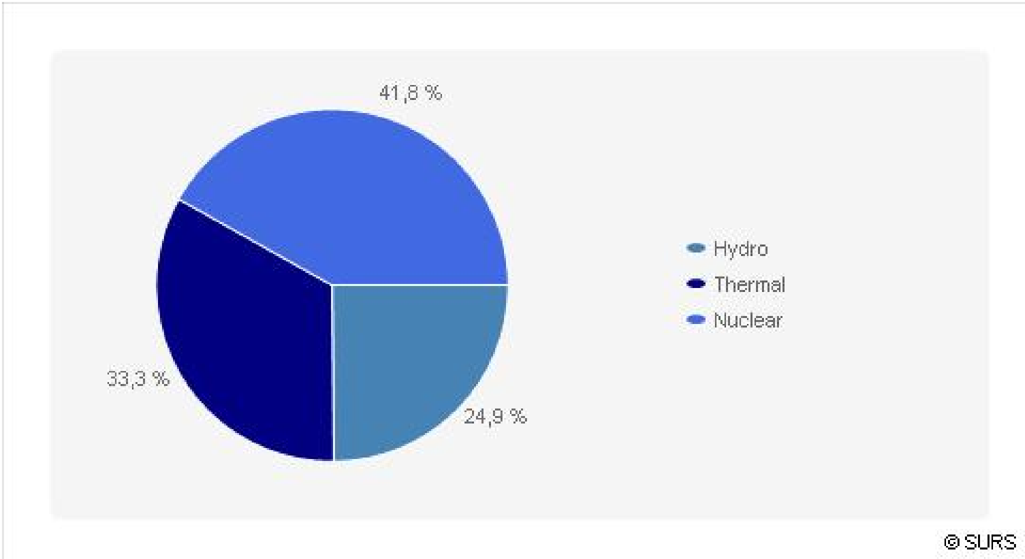


**Figure 23: Net electricity production, Slovenia, April 2010 (Total 1195 GWh)**

The structure of electricity generation has not significantly changed in the past ten years. The nuclear power plant in Krško still represents the largest electricity producer with around 42% of generation (half of that generation belongs to the Croatian system operator, in accordance with the agreement between countries), on the second place is the production of thermal power plants with 34% and on the third place the generation of hydro power plants, which produced 24% of electricity in 2008.
In April 2010, the total gross electricity generation was 1,195 GWh, 653 GWh of electricity was imported and 846 GWh was exported; shares are presented graphically on Figure 23.

#### 4.2.5.1.1 **Transmission network**

Slovenia's transmission network contains:

- 1,736 km of 110 kV transmission lines and 8 pertaining transformers,
- 328 km of 220 kV transmission lines and 10 pertaining transformers and
- 508 km of 400 kV transmission lines and 9 pertaining transformers.

The combined system length of all transmission lines is 2,572 km and the aggregate power of all transformers is 4,768 MVA.
Slovenia's transmission network is connected across border with three neighboring countries.

- One 220 kV transmission line and two 400 kV lines link Slovenia with Austria;
- one 400 kV and one 220 kV lines link with Italy, whereas three 400 kV,
- two 220 kV and three 110 kV transmission lines traverse the Croatian border.

As yet, however, there are no transmission line connections between Slovenia and its neighbor Hungary. However, a 400 kV connection on the relation Cirkovce-Pince has been planned.

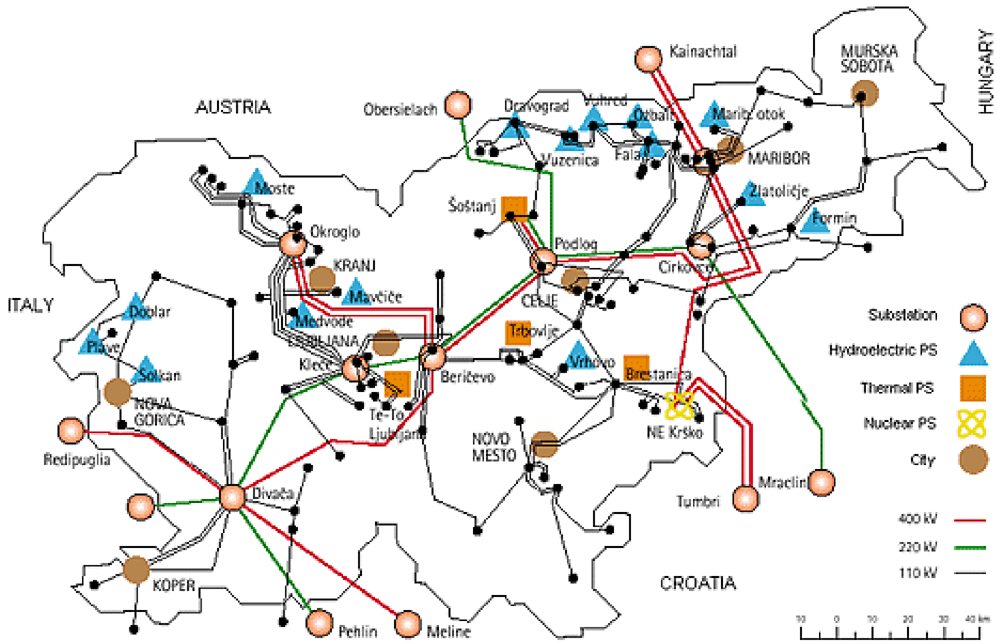


**Figure 24: Map of Transmission Network**

#### 4.2.5.1.2 **Distribution network**

DSO electricity distribution system operator, d.o.o. (Ltd.) (abbreviated name: SODO, d.o.o.) is an electricity distribution system operator in the Republic of Slovenia. It provides supply of electricity to more than 900,000 users of distribution network in the Republic of Slovenia.

The electricity distribution system is entirely owned by the five public companies, and includes:

- 90 distribution transformer stations (110/x kV);
- 55,300 km of high-, medium- and low-tension wires;
- 12,650 transformer stations.

### 4.2.5.2 Historical development

Slovenia published the Energy Law and Regulation in 1999, which prescribed how to implement utilities for transmission and distribution of electricity, which has led to the Slovenian electricity market reaching changes. The internal market has been opened for Slovenian producers in April 2001, when it is already eligible customers can choose their supplier. In January 2003, Slovenia was opened from the outside and become a member of the Single European cross-border trading mechanism. July the 1st 2004, the electricity supplier of their choice, all customers except households. This, following the entry of Slovenia into the EU more open market for electricity. The market is the first time opened in July 2007 for all electricity customers.

### 4.2.5.3 Market players

#### 4.2.5.3.1 **Producer**

Only legal entities are classified as producers.

#### 4.2.5.3.2 **Consumer**

Consumer is any entity which consumes electricity.

##### 4.2.5.3.3 **Balance Group**

For the purpose of balancing the supply and consumption of electricity there are two balancing groups: balance groups and balance subgroups. Balance group is a group of actors within a control area, where consumption is measured and deviation from schedule is accounted for. Balance group is headed by Balance responsible party.
Any demand for energy or the energy transfer request must belong to one group. The right of access to the network is held by the balance responsible party.
Each entity connected to the grid has the right to select which balance group or which balance sub-group it will belong to.
Any operator of a distribution network may represent a special balance group or subgroup, in which power is exercised purchase to cover losses on the distribution network. The balance group also includes qualifying producers who are not liable for the payment discrepancies.

##### 4.2.5.3.4 **Balance sub group**

Balance groups may be further structured into balance sub groups. Balance sub group responsible is responsible to Balance responsible party for imbalances and to market organizer for market actions, i.e. trading, schedule exchange, etc.
Balance sub-groups can be further structured into sub-sub groups.

##### 4.2.5.3.5 **Market Organizer**

The basic task of the market organizer BORZEN is the organization of the open electricity market according to legislation of the regulatory authority Energy Agency. Organized electricity market is a central place where the supply and demand for electricity are faced.
Basic tasks of market organizer are:

- Meeting of supply and demand of electrical energy (power exchange),
- Clearing and settlement of transactions
- Registration of bilateral contracts
- Production schedules,
- Public publishing market trends.

Members of organized market are producers, eligible customers, dealers, commercial agents and commercial brokers.

##### 4.2.5.3.6 **TSO (SOPO)**

The tasks of the Slovenian Transmission System Operator (ELES) are

- Responsible for safety/stability of the electrical transport system ( > =100 kV)
- Measurements on transmission network
- Balancing the transport network endpoints (online measurements)
- Control the energy reservation (primary, secondary, terciary)
- Controls/executes auctions on the capacities of international transport
- Independent balance group (buying technical losses)
- Participate in imbalance process

On a basis of data received from distribution companies and direct consumers connected to the transmission network ELES prepares and publishes year-ahead, month-ahead and week-ahead load forecasts. Day ahead forecasts ELES prepares by itself. Load forecast and realized loan encompasses electricity consumed by distribution companies and direct consumers connected to the transmission network whereby electricity losses on the transmission network and consumption of pump storages is not included.

##### 4.2.5.3.7 DSO (SODO)

The tasks of the system operator of the distribution system are

- Supports the distribution grid (<100 kV)
- Buys the (technical) losses
- Provides services (measurements)

The distribution system operator is a separate balance group for providing the financial transactions for the self operation.
The distribution system operator unifies five geographical dislocated distribution companies and provides common functionalities.
Each distribution company forms its own balance subgroup to buy technical losses.

#### 4.2.5.4 Market organization

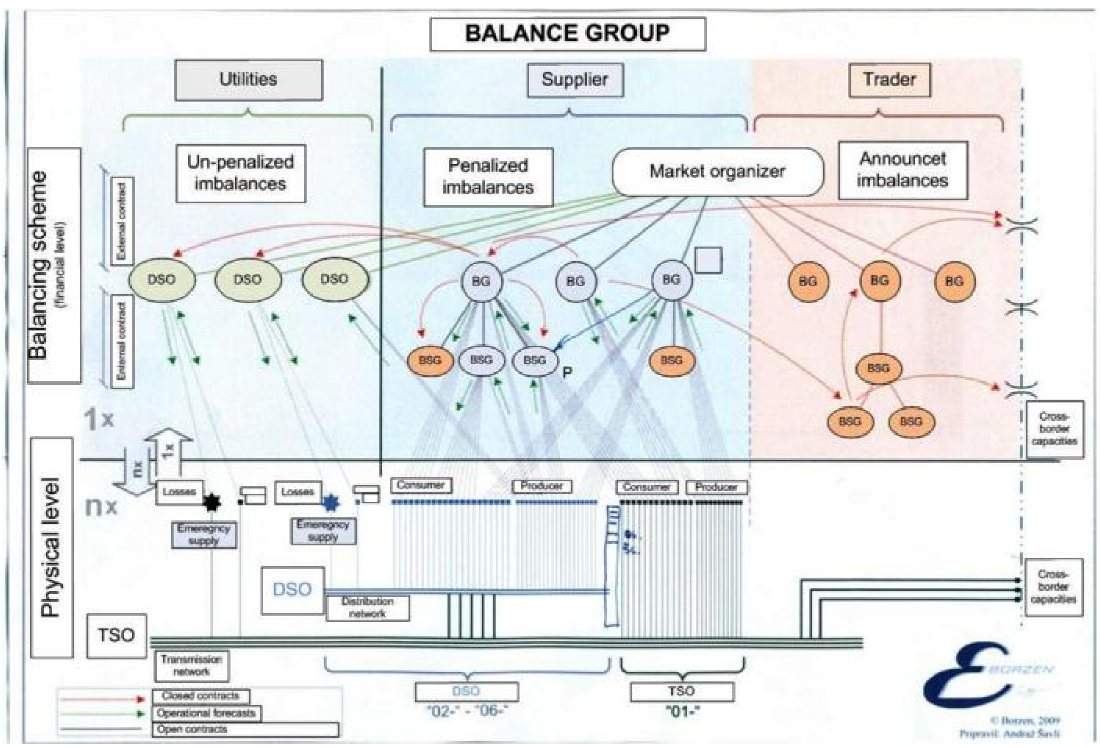


**Figure 25: The scheme of Balance Group**

A part of the electricity exchange is trading in the territory of Slovenia, which means that the products with the supply in Slovenia are traded. Only the companies, which have obtained the right of participating by way of the accepted application, are allowed to participate in this market segment.
The electricity exchange is a point in which the offer of and the demand for standardized electricity products for the following day or for the period of time until and including the next working day meet.
Trading participants are trading with following standardized products:

- Base (00:00 – 24:00),
- Peak (06:00 – 22:00),
- Off-peak1 (00:00 – 06:00),
- Off-peak2 (22:00 – 24:00),
- Euro-peak (08:00 – 20:00),
- Euro-off-peak1 (00:00 – 08:00), and
- Euro-off-peak2 (20:00 – 24:00)

Trading is organized as continuous (spot) and auction trading. At continuous trading, the trading phase runs from 9:00 a.m. to 12:00 p.m. During continuous trading, the participants can enter, change and delete their orders, see current prices and most favorable orders, and have the insight into the order book. Deals are concluded on the basis of the price/time priority criterion. Auction trading is divided into the following phases:

- call phase runs to 8:45 a.m., however, it is possible to enter the bids 14 days prior to the trading day. In this phase, orders can be entered, changed or deleted, and the participants can see only their own orders;
- freeze phase runs from 8:45 to 9:00 a.m. at the latest. During the freeze phase, the market supervisor can examine the orders and react in case of any irregularity. At the end of this phase, a marginal price is calculated for each hour at which all deals for an individual product are to be realized;
- price determination is made between 8:45 and 9:00 a.m., marginal prices calculated at auction are shown to the trading members;
- after the price determination phase, the trading members have an overview of marginal prices and their own deals.
- The auction trading method is used for trading with hourly electricity products (24 hours of a single day are traded).

#### 4.2.5.5 Balancing the production/consumption

Electricity intended for covering deviations is a sum of electricity produced by production units which co-operate in secondary and tertiary regulation, the electricity for ensuring minute reserve power and electricity from the purchase and sales for balancing the system. In order to balance the electric power system (balancing of longer deviations of electric power system from the agreed exchange schedules) the system operator (ELES) purchases or sells electricity for balancing deviations in real time according to the tertiary reservation contract.

#### 4.2.5.6 Tariff system

The electricity supply differentiates three tariff periods: lower daily tariff (MT), higher daily tariff (VT), and uniform tariff (ET). The smaller and bigger daily tariff are read by the in-built two-tariff counter, while the uniform tariff is read by the one-tariff counter. Household consumers in the basic package 1 cannot choose between two-tariff and one-tariff measuring, since this basic package includes only one-tariff measuring of electric power. Household consumers in the basic packages 2 and 3 have a stationed counter which enables one-tariff and two-tariff measuring of electric power.
The arrangement of daily tariff times is the following

- VT – higher daily tariff, read by the two-tariff counter each working day from 6 am to 10 pm.

- MT – lower tariff is a tariff read by the two-tariff counter each working day from 10 pm to 6 am of the following day, each Saturday, Sunday, and on each public holiday from 0 am to 12 pm.
- ET – is a uniform tariff read by the one-tariff counter each day 0 am to 12 pm.

### 4.2.6 Austria

The energy market in Austria is well documented. The Energie-Control GmbH which is the Austrian regulatory authority for electricity and gas economy has published material which is the base for this section.

#### 4.2.6.1 Description of physical grid

The electricity market in Austria is shown in Figure 19. The grid is divided into three balance areas and 35 balance groups. The balance area marked in blue is managed by Verbund AG (http://www.verbund.at/). The turquoise balance area is managed by TIWAG-Netz AG (http://www.tiwag-netz.at/). The violet balance area is managed by VKW-Netz AG (http://www.vkw-netz.at/) which belongs to the Vorarlberger Kraftwerke AG (http://www.vkw.at/). In Austria, there are two clearing centers, approx. 150 suppliers, 155 distribution system operators, approx. 4 million end consumers (i.e. measuring points). The yearly demand is about 63 TWh. The installed power is 16.800 MW; the peak demand is 9.200 MW [Kape2005].

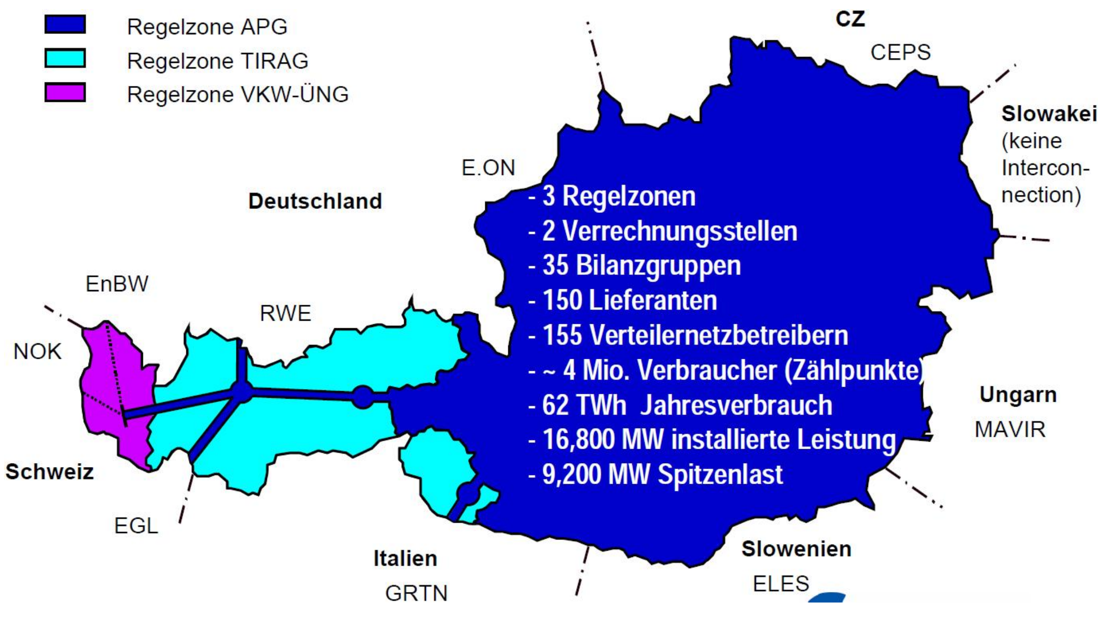


**Figure 26: Electricity market in Austria**

The physical grid is visualized in Figure 20. The 380 kV grid is shown in red. There is a 380 kV ring. The dotted lines are cables that are planned or under construction. The green lines are 220-kV cables and the blue ones 110-kV cables. The triangles visualize transformation substations, the rectangles are grid control stations.
The Austrian grid has 380 kV connections to Germany, Switzerland, Slowenia, Ungary and Czech Republic. It has 220-KV connections to Italy, Slowenia, Hungary, Czech Republic, and Germany. There is a 110-kV connection to Germany.

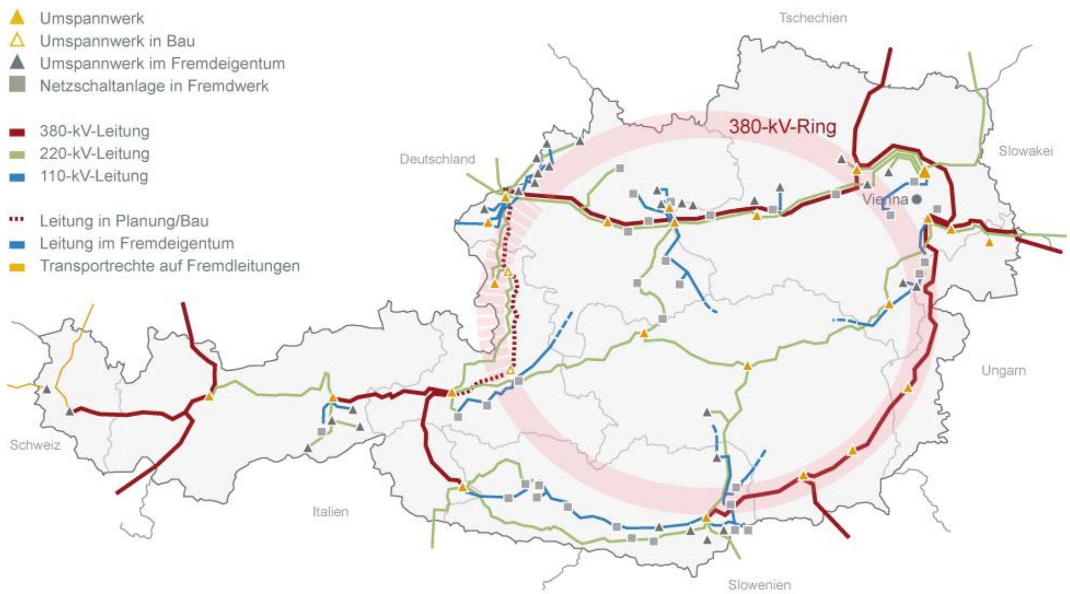


**Figure 27: Physical grid [WP]**

#### 4.2.6.2 Historical development

The deregulation of the Austrian electricity market is specified in the law called "Das Österreichische Elektrizitätswirtschaft- und -organisationsgesetz (ElWOG)". The law has been enacted in 1999. The law has been changed in 2000. The changed law has opened the electricity market for all customers in 2001.

#### 4.2.6.3 Market players

The market players in Austria are the following [Econ1]:

- An **Imbalance Settlement Party** (Bilanzgruppenkoordinator, BKO) is a legal entity which operates a clearing center (Verrechnungsstelle) for the organization and the billing of the balance energy provisioning within a balance area based on a governmental license.
- A **Balance group responsible** (Bilanzgruppenverantwortlicher, BGV) represents a balance group to other market participants and the *Imbalance settlement party*.
- **Balance group participants** are *suppliers* and *customers* which belong to a balance group. Within a balance group production and delivery of electricity are balanced.
- A **Supplier** (Lieferant) is a legal entity which provides electricity to other entities.
- A **Customer** (Kunde) is an *end consumer*, *electricity broker* or *electricity company* which buys electricity.
- An **End consumer** (Endverbraucher) is a consumer of electricity which buys electricity for its own usage.
- An **Electricity broker** (Stromhändler) is an entity which sells electricity in order to make profit.

- A **Wholesaler** (Großhändler) is an *electricity broker* which has no transmission or distribution function within or beyond the grid in which he acts.
- A **Distribution system operator** (Verteilnetzbetreiber) operates a part of the middle- and low-voltage distribution grid.
- A **Transmission system operator** (Übertragungsnetzbetreiber) operates a part of the high-voltage transmission grid.
- An **Electricity company** (Elektrizitätsunternehmen) is a natural person or a legal entity that performs one of the functions production, transmission distribution, delivery or purchase of electrical energy in order to make profit.
- A **Net operator** (Netzbetreiber) operates a transmission or distribution grid with a rated frequency of 50 Hz.
- A **Producer** (Erzeuger) is a natural person or a legal entity which produces electricity.
- A **System operator** (Regelzonenführer, RZF) is responsible for the power-frequency control in a control area.
- A **Grid user** (Netzbenutzer) is a natural person or legal entity that feeds in or takes electricity from the grid.
- **Energy exchange** (Strombörse)

The relations among some of them are described in [Econ2,Kape2005] and visualized in Figure 21.

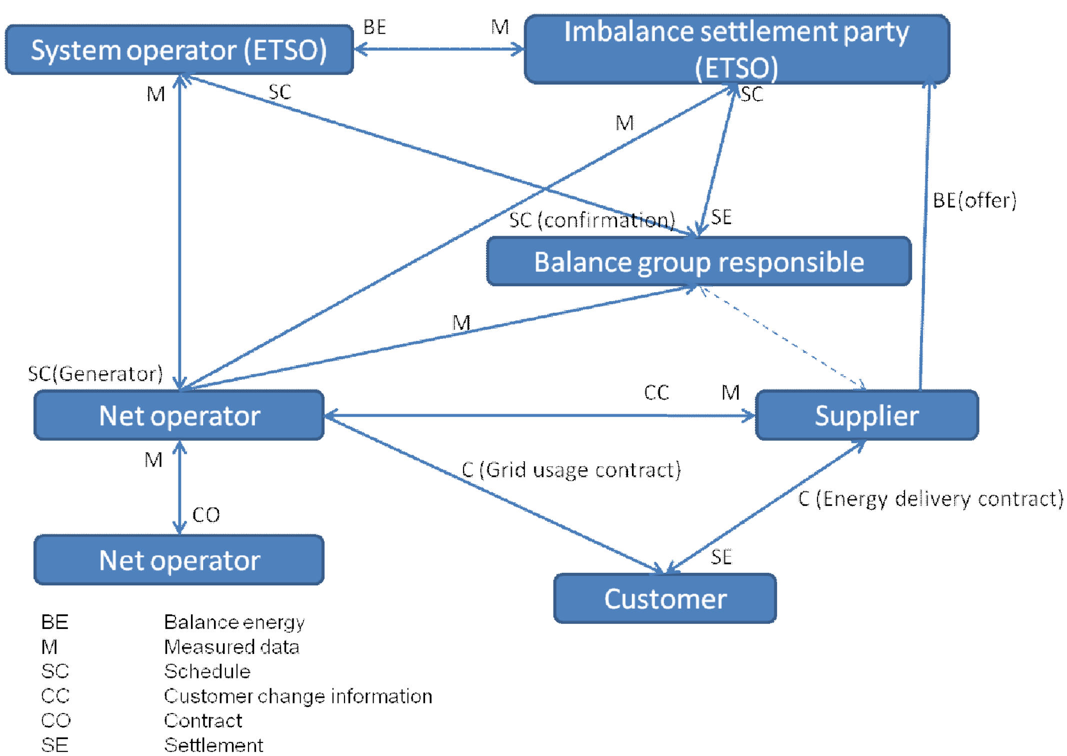


**Figure 28: Relations of market participants in Austria**

A customer has an energy delivery contract with a supplier and a grid usage contract with a net operator. When a customer changes the supplier, the supplier informs the net operator about this change. The customer settlement is done by the supplier.
A supplier offers balance energy to the Imbalance settlement party. The system operator uses the balance energy.
The net operator sends measurements to the system operator, the imbalance settlement party and the balance group responsible.
The balance group responsible sends the schedule for demand and supply to the system operator. The system operator confirms the schedule. The balance group responsible sends the schedule also to the imbalance settlement party which then settles imbalances based on the measurements received from the system operator.

#### 4.2.6.4 Market organization

EXAA Energy Exchange Austria is the energy exchange of Austria. The EXAA Spotmarkt Strom executes an auction for the day-ahead market to determine the market clearing price [EXAA]. The 24 hours of a day are defined as single products. Also block products that combine consecutive hours are traded. The minimum energy amount for the trading is 0.1 MWh. Larger amounts can be traded in steps of 0.1 MWh. EXAA does not operate an intra-day market.

#### 4.2.6.5 Balancing the production/consumption

The balance group responsible forecasts the demand of the participants in the balance group and plans together with the suppliers the production. It organizes and clears the balance energy of the balance group.
The system operator measures the electricity exchange between balance groups and accesses reserves.

#### 4.2.6.6 End user business relations

End users have an energy delivery contract with a supplier. The electricity demand is charged once a year. Since there are only a few smart meters installed in test projects, there are no advanced tariff systems in the mass market. The projects are run by Energie AG, Stadtwerke Feldkirch, Linz AG, Salzburg AG and Bewag [Bolt09]. 40.000 customers take part in these projects.
A customer can chose on average among 10 suppliers depending on its location. The tariff calculator offered by E-Control (http://www.e-control.at/de/konsumenten/service-und-beratung/tarifkalkulator) determines the best supplier based on the location of the customer and the yearly demand.

#### 4.2.6.7 Summary of the role model

The mapping between the roles in the Austrian market and the ETSO roles [Econ3] is shown in Table 12. The ETSO roles Consumption Responsible Party and Balance Responsible Party are currently not used in Austria. However, the role Bilanzgruppenverantwortlicher is similar to the role of a Balance Responsible Party.

| Austrian market model | ETSO Model |
|---|---|
| Regelzone (RZ) | Balance area (BA) |
| Regelzonenführer (RZF) | System operator (SO) |
| Bilanzgruppe (BG) | (Balance Responsible Party (BRP)) |
| | - Trade Responsible Party (TRP) |
| | - Production Responsible Party |
| | - (Consumption Responsible Party (CRP)) |

| | |
|---|---|
| | Bilanzgruppenverantwortlicher (BGV) |
| Imbalance Settlement Responsible Party (ISPR) | Bilanzgruppenkoordinator (BKO) |

**Table 12: Mapping of roles in the Austrian market model to roles in the ETSO model**

### 4.2.7 Summary discussion of the current role & processes models in individual EU countries

Originally, one of the aims of Section 3.2 had been to provide the basis for synthesis, i.e. to define the Miracle roles & processes model in the "best cross-section" of the national models.

With the advent of the Harmonized model (cf. Section 3.3. below), this aim has been rendered superfluous. However, there are still sufficient reasons to inspect these models from the point of view of Miracle:

- To establish the link between the abstract categories of the Harmonized model and the real entities in the electricity markets, even though transitory. Also, through inspection of various countries, a feeling for more or less mainstream solutions can be obtained, which can influence the solutions in Miracle (e.g. one sided and two sided pools markets, cf. Section 3.1).
- To provide the real world link and the basis for Miracle trial cases; this is true for both Germany (TSO and LDE trial case) and Greece (Households trial case).

Furthermore, it may be remarked that the Harmonized model will continue to evolve. The current national models may give us some indication as to what directions the evolution might take.

## 4.3 Harmonized European model ETSO, ebIX, EFET

The three major stakeholders on European market,

- ETSO - European Transmission System Operators (presently named ENTSO-E),
- ebIX - European forum for energy Business Information eXchange,
- EFET - European Federation of Energy Traders,

started cooperation on preparing a coherent model of the electricity market in Europe, as a prerequisite to a feasible concept which could be gradually put into practice. Work on the ETSO side started already in 2001 with other two partners joining subsequently; the algorithm for defining the accepted solutions was voting (40:40:20, respectively). The model has been termed the "Harmonized role model", but it comprehensively addresses on the one hand organization and structuring of players and on the other hand the processes which (should) constitute the electricity market and the processes which are necessary to assure the operational capability of the electricity grids in the new circumstances.

Prompted by European directives, the evolution of the Harmonized role model has been accompanied by gradual diffusion into national role models and national regulations covering the organization of national electricity markets.

In 2009, the year of the current issue of the model, the model has been harmonized on lower levels but not yet on top level(s). The work is being continued and further evolution of the model is envisaged. Since other stakeholders from the major industry players and other configurations of stakeholders are also active, e.g. European Electricity Grid Initiative [EEGI09], we may foresee additional incentives towards further modifications of the model.

The basic documents describing the model are:

- The Harmonized Electricity Market Role Model version 2009-01, by ENTSO-E [ENTS09]
- UMM 2 Business Requirements View for structuring of the European energy market, by ebIX [EBIX09]

which are further detailed in collection of documents collectively called "Implementation guide" [ENTS09a] (for the Harmonized Electricity market Role model). The Implementation guide documents address major segments and processes of the Harmonized model, mainly through a series of use cases for major processes, e.g Scheduling process, settlement process etc.
Present list of documents in the Implementation guide is the following:

- ETSO Acknowledgement Document 3 (EAD) 4 Implementation Guide
- ETSO Balancing Process 4 Results Document 5 6 Implementation Guide
- ETSO Capacity Allocation and Nomination System (ECAN) Implementation Guide
- ETSO Problem Statement Document 3 Implementation Guide ETSO Reserve 2 Resource Process (ERRP) 4 CROSS-BORDER REDISPATCH 5 Implementation Guide
- ETSO Reserve 2 Resource Process 3 (ERRP) 4 Implementation Guide
- ETSO Status Request Implementation Guide
- ETSO 2 Scheduling System 3 (ESS) Implementation Guide
- ENTSO-E Capacity Auction Specification Document Implementation Guide
- ETSO 4 Outage Document 5 6 Implementation Guide
- ETSO Publication 2 Document 3 Implementation Guide
- ETSO 2 Scheduling System 3 (ESS) 4 Implementation Guide
- ETSO 2 Scheduling System 3 (ESS) 4 Implementation Guide
- ETSO Capacity Allocation and 2 Nomination System
- 3 (ECAN – Total Allocation Results) 4 Implementation Guide
- Implementation Guide for the 3 ESS (ETSO Scheduling System) 4 in the UCTE processes

The model is represented by roles and domains and their inter-relations and interactions, as can be seen in Figure 29.

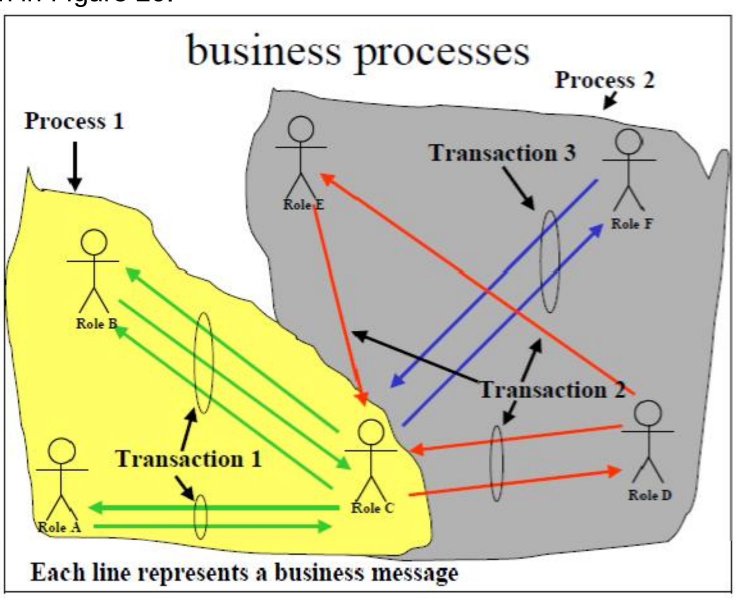


**Figure 29: Business processes, transactions and messages [ENTS09]**

The diagram in Figure 30 provides an example of different relationships that can appear in the role model.

It can be seen that role C participates in both Process 1 and Process 2.The intent of the role model is not to define the business process of both process 1 and 2 in all transactions. The role model will only provide the principle business messages that are exchanged between two roles. The business messages provide the main justification for the roles presence in the role model.

In [ENTS09], a business transaction is defined as "a predefined set of activities that are initiated by a role to accomplish an explicitly shared business goal and terminated upon recognition of one of the agreed conclusions by all the involved roles". It is therefore composed of one or more information flows, which are termed business messages, exchanged between roles.

The summarized view of the role model is presented graphically on the following scheme:

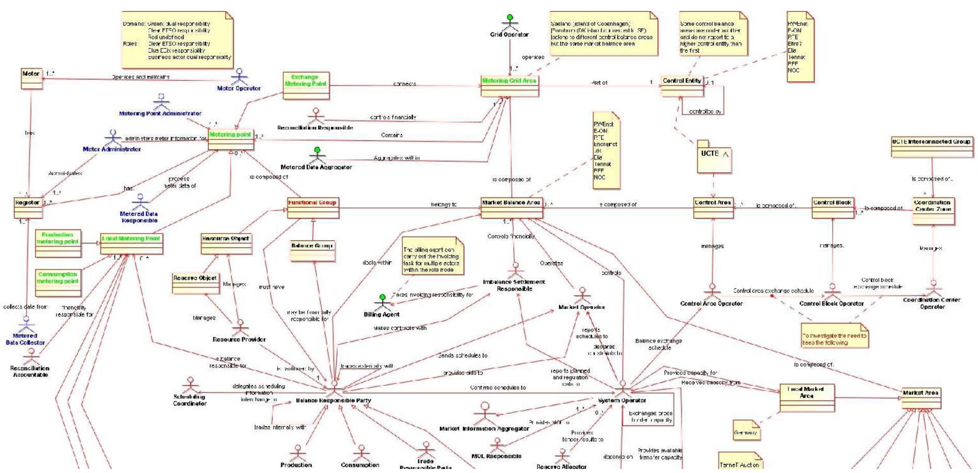

**Figure 30: The ETSO-ebIX-EFET Harmonized role model [ENTS09]**

The roles and domains are defined in tabular form in the same document.

Due to the length of the table, only two sample parts of the table are presented in Table 13 and Table 14, for roles and for domains definition; complete table is available in the original document.

The model is conceptually inclusive, i.e. a union of all accepted national/regional models. For this reason there are two consequences:

- on the lower levels the structuring of roles exceeds the actual structuring of roles in individual countries. Effectively this means that the roles in individual national/regional models may integrate several roles of the Harmonized model
- on the upper level(s), specifics of the markets in major countries (Germany, etc) and regions (e.g. Nordic) are recognized and not harmonized; also the market or trading aspect of the market is not fully defined on this level as yet.

While the basic representation of the Harmonized role model focuses on organizational aspects of the market (roles and domains), it is important to note that the ebIX document focuses on structuring the processes of the Electricity market. The basic view from this viewpoint is depicted in Figure 31.

| ROLES | | |
|---|---|---|
| TYPE | ROLE/DOMAIN NAME | DESCRIPTION |
| Role | Balance Responsible Party | A party that has a contract proving financial security and identifying balance responsibility with the imbalance settlement responsible of the market balance area entitling the party to operate in the market. This is the only role allowing a party to buy or sell energy on a wholesale level.<br><br>*Additional information:*<br>The meaning of the word "balance" in this context signifies that that the quantity contracted to provide or to consume must be equal to the quantity really provided or consumed. Such a party is often owned by a number of market players.<br>Equivalent to "Program responsible party" in the Netherlands. Equivalent to "Balance responsible group" in Germany. Equivalent to "market agent" in Spain. |
| Role | Balance Supplier | A party that markets the difference between actual metered energy consumption and the energy bought with firm energy contracts by the party connected to the grid. In addition the balance supplier markets any difference with the firm energy contract (of the party connected to the grid) and the metered production.<br><br>*Additional information:*<br>There is only one balance supplier for each metering point. |

**Table 13: First sample segment of the roles model definition table [ENTS09]**

As already mentioned, the ebIX European energy market domain model is defined using the method of the UseCases (phases). As can be seen in the Figure 31: The phases of the European energy market in ebIX model above, they are: structuring, trade, planning, operation (production, consumption and transport), Measure (meter reading), settlement (physical and financial, including reconciliation) and billing.

The repartition of tasks between the three partners is as follows:

- Modeling of the Structure, Measure, Settle (partly) and Bill UseCases are mainly ebIX responsibility, while
- Modeling of the Plan and Settle (partly) UseCases are mainly an ENTSO-E responsibility,
- (Modeling of the Operate UseCases is manly an IEC responsibility) and
- Modeling of the Trade UseCases is mainly an EFET responsibility.

| DOMAINS | | |
|---|---|---|
| Domain | Allocated Capacity Area | A market area where the transmission capacity between the balance areas is given to the balance responsible parties according to rules carried out by a transmission capacity allocator. Trade between balance areas is carried out on a bilateral or unilateral basis.<br><br>***Additional information:***<br>This is a type of Market Area |
| Domain | Balance Group | A collection of metering points for imbalance settlement<br><br>*Note:*<br>Equivalent to "balance group" (Bilanzgruppe) in the Austrian market or (Bilanzkreis) in the German market<br>German definition: It is composed of a various number of metering points within a Market balance area.<br><br>***Additional information:***<br>This is a type of Functional group. |
| Domain | Capacity Market Area | A market area where the transmission capacity between the balance areas is given to the balance responsible parties in a price based process separated from trading carried out by a transmission capacity allocator. Trade between balance areas is carried out on a bilateral unilateral basis.<br><br>*For example,*<br>The auctioning system between TenneT and RWE Net.<br><br>***Additional information:***<br>This is a type of Market Area |

**Table 14: Second sample segment of the roles model definition table [ENTS09]**

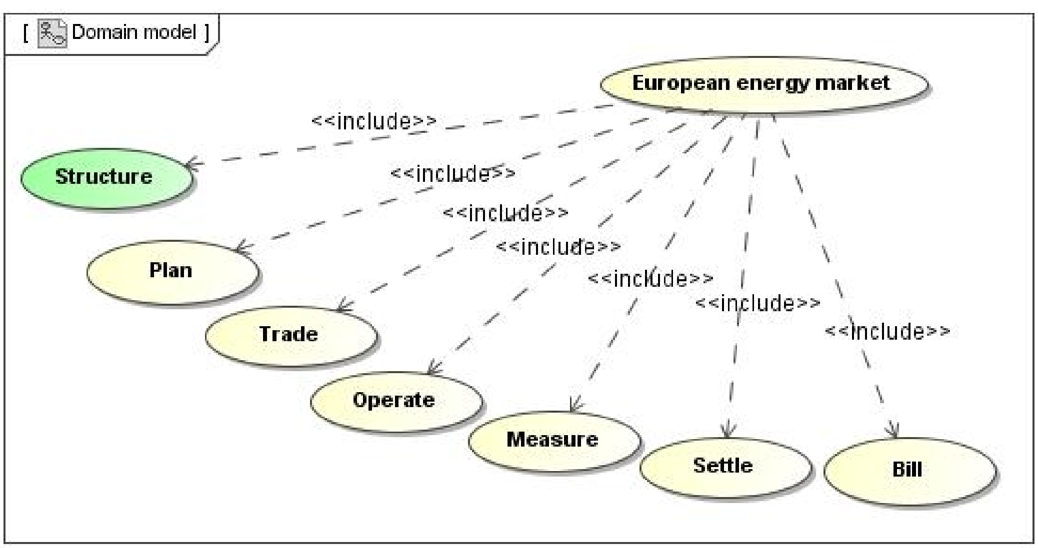


**Figure 31: The phases of the European energy market in ebIX model [EBIX09]**

**Summary description of the phases, taken from [EBIX09]**

**Structure.** In the structuring phase, the actors exchange information (master data) necessary for the later business processes. The different parties request creation of, changes to or deletion of energy market business objects, such as metering points, meters, contracts etc, or to its attributes. Thereafter the information related to the created, changed or deleted business object or its attributes is exchanged between relevant parties (roles). The alignment of master data between the actors in the energy market should result in all participants having the needed information to fulfil their obligations to the market.

**Plan.** The messages defined in these business processes enable *Balance responsible parties* (i.e. Trade responsible, Production responsible and Consumption responsible parties) to send their schedules (planned consumption, production, capacity, transport, exchange etc.) to the *System operators* and/or the *Transmission capacity allocator* (congestion management) the day ahead. The messages may also be used for the transmission of intraday schedules associated with day-ahead schedules.

**Trade.** In the trading phase, the *Balance responsible parties* are buying and selling energy for fulfilling their contractual obligations. The trading phase includes trade through the *Market operators* (e.g. Power exchanges).

**Operate.** The business process operate includes the message exchanges to handle the Balance regulation market and Ancillary services markets, e.g. the *System operator* orders up and down regulation to keep the balance in the system.

**Measure.** The measure phase (Exchange of metered data) covers all stages from the collecting of the metered data until the settlement and reconciliation phase, with a focus on the exchange of information between *Metered data collectors, Metered data aggregators, Imbalance settlement responsible* and *Balance responsible parties*. E.g. the *Metered data collectors* read *Registers* (within *Meters*) and distribute metered data (transport, production, consumption). Thereafter the metered data are validated, aggregated and distributed to relevant roles.

**Settle.** The messages defined in this phase enable *Imbalance settlement responsible parties* to receive aggregated executed schedules, regulation- and metered information, and to send imbalance reports and bills (invoices) to the *Balance responsible parties* (consumption, production, capacity, etc.). The *Reconciliation responsible party* make the final reconciliation and distribute data to relevant roles.

**Bill.** The billing phase is the final process in the chain and includes all message exchange needed for billing the Consumers and the internal billing in the upstream energy market. I.e. invoicing and related basis documents needed for controlling purposes.

It may be relevant to note that neither **Trade (**nor **Operate)** has been so far elaborated by any common European projects.

In line with this view, in the Implementation guide documents, individual processes are presented and analyzed. Such viewpoint differs from the static viewpoint of the role model schematic, as can be seen from the example in the following Figure 32:

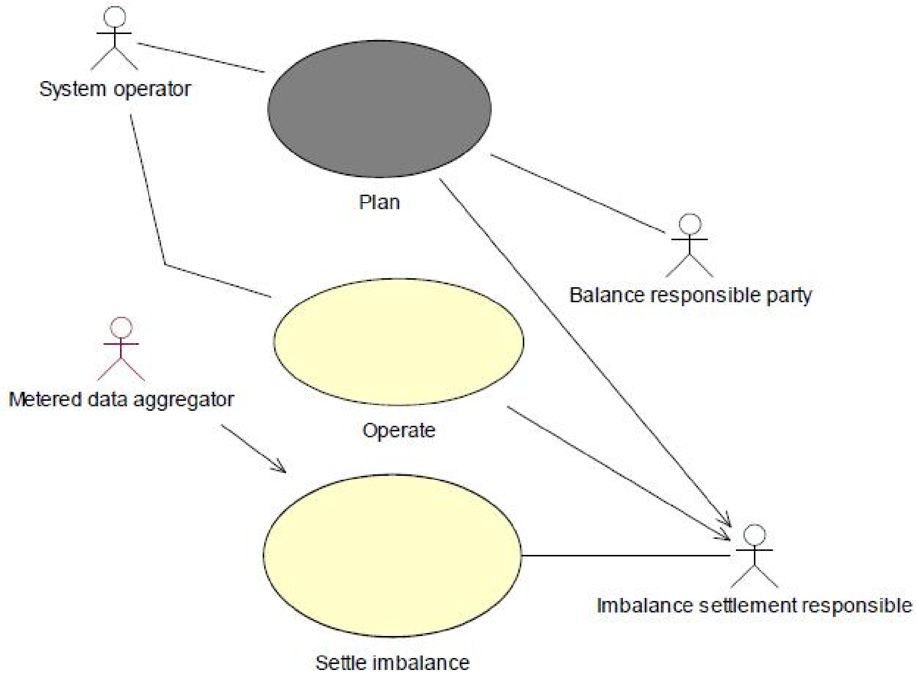


**Figure 32: Example of process time-flow scheme from ETSO Scheduling system guide [ENTS09]**

It is clear that the viewpoint of ebIX model and this viewpoint is closer to the viewpoint of the Miracle project, which is management of the processes, and contains vital complementary information for setting up appropriate roles and processes model for developing the Miracle technology.
In summary, the Harmonized role model is the common denominator for all evolving national role models and provides guidance for future evolution of national role models towards a coherent European electricity market. Consequently, it represents the basis for Miracle role model.

# 5 Draft of a role and process model for MIRACLE

The introduction and development of the special role and process model in the Miracle project is necessary due to several reasons:

- There is no common or general role model in force in EU. Each country has some own specifics and it would be unreasonable to favor one of them by choosing it for the basis
- The Miracle approach, by introducing the new concept of the ”micro-request” into the business process, provides new relationships between roles and consequently changes the existing and introduces new processes into the system.

As The ETSO harmonized model [ENTS09], the result of joint undertaking of major stakeholders on the electricity market in Europe aimed at unification of various national electricity markets in European countries, (cf. Section 4.3), thus represents the ideal base for the Miracle role and process model.

The roles in the role model are described by the processes they perform and transactions through which they are connected. It was decided that processes which are closely related or are even the result of the Miracle micro-request concept, are determined through the analyses of the use cases.

The setting up the Miracle role model has gone through the following process:

- first the structure of the electricity market system is described, and the concept of primary processes introduced, which is a necessary background for the use case definition,
- the use cases are formed in a way to present the essential Miracle characteristics,
- the unit processes extracted from the use cases are listed and described, and finally
- the Miracle role model with role description and responsibilities is set up.

## 5.1 System description

### 5.1.1 Systemic approach, requirements and conventions

In describing the framework for Miracle project, we shall use the point of view relevant to the task of managing and controlling the electrical energy market system – the viewpoint of system engineer. There are three main constituents to this approach:

- the structure of system itself and its environment,
- the roles of the entities that constitute the system, and
- the processes that occur in these roles

We shall consider that the requirements which are relevant to Miracle system design are:

- those which stem from the requirements of the electrical energy grid market and electrical energy grid system on the one hand, and
- those which we have set as project objective for the Miracle system. Of these, scalability of the Miracle system is an important systemic requirement.

In describing the constituents, we shall use:

- conventions, terms and categories, used in the Harmonized Electricity Market Role model
- terms and categories, required by the Miracle technology; this only if they are not in contradiction with the previous requirement.

To provide a consistent system, we shall build a glossary of definitions of the conventions, terms and categories used in the Miracle project, consisting of entries from both Harmonized Electricity Market Role model and internal Miracle descriptions and nominations.

### 5.1.2 Structuring of Electricity Market System

Based on observation of the Harmonized Electricity Market Role model and related documents, we make the following basic assumptions:

1. The electrical energy market system can be vertically and horizontally decomposed – structured.
2. The main line of vertical decomposition follows the concept of nested fractal subsystems, with each nested subsystem having essentially the same functions as “parental subsystem” on the next higher level but as consistent with its level of decomposition. For reasons of convenience, we shall refer to these type of subsystems as “primary subsystems” and the processes that occur in them the “primary processes”.
3. Horizontal decomposition refers principally to a number of fractal-like subsystems, i.e. systems with exactly the same functions, which exist in parallel on the same level;
4. Additionally to this structure of vertically and horizontally decomposed primary subsystems there exists a specific subsystem, which does not have the same functionality as fractal-like primary subsystems but specific functions of joint and supportive processes, necessary for operation of the electricity market, mainly processes for maintaining the electricity grid, in technical and business sense.
   This subsystem is not vertically structured in levels or rather its structure does not follow completely the structure of the primary subsystems. However, for the purpose of management of processes in the primary subsystems, it can be considered as the “environment” of the primary subsystems on each vertical level, defining the boundary operating conditions of these systems. For convenience, we designate this type of subsystem as “structural subsystem”; and the processes within the structural subsystem as “joint & supportive processes”.

Schematically and conceptually, this vertical and horizontal decomposition of the electricity market is illustrated on Figure 33. On each vertical level, a number of similar primary subsystems exist, with one modeled structural subsystem, depicted as hexagonal, containing the part of joint & supportive processes interacting the processes in all the primary subsystems on this vertical level. On the graphic, four levels of vertical decomposition are sketched.

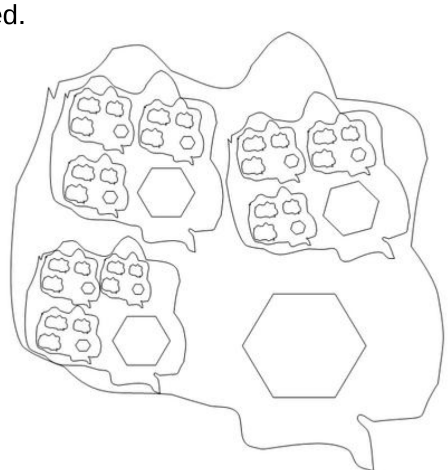

**Figure 33: Schematic representation of vertical and horizontal decomposition of electrical grid system into nested subsystems.**

This concept of the electricity market system structure has the following major advantages:

- Scalability: each fractal subsystem has essentially the same set of functions, and Miracle solutions in principle apply to all of them; this does not apply to "structural subsystem" on each level; if it exists, it is defined separately and does not make part of the Miracle technology
- Scalability implies usage both on the level of a single subsystem as on the level of several subsystems and system levels. The concept imposes transparent and consistent requirements on system architecture and system communication
- The electricity market system with the electricity grid system on each it is imposed are a complex system, which is through the act of European regulators in actual practice being decomposed vertically and laterally; we are trying to do the same with our management and control system of the electricity market system, in a consistent way. Decomposition greatly facilitates the task of management or governance of the system. Each lower level consists of a number of subsystems which reduces the size of the entire system, and, what is more important, makes the concept of market on the lower levels a viable concept: competition between various subsystems for increasing the number of members of the subsystem, competition between members of the same subsystem.
- It accommodates existence and growth of complex business entities, i.e. subsystems
- Through inter-level consistency, it supports further systemic evolution and integration of the electricity market and grid system in Europe.

### 5.1.3 System, process and roles

Generically, a process consists of transformation of energy, material and information occurring in a system.
The process in the electricity market and grid system consists of energy production, (transmission – flow of energy), consumption and trading. The primary process in the electricity market system is trading of energy.
The control and management process is a sub-process of complete process occurring in the system.
The Electricity market system is vertically and horizontally structured into subsystems. The control and management system is a subsystem of the complete system.
In Harmonized Electricity market role model, subsystems are represented by *domains.* This term, while explainable in the context of complete electricity market and grid system, is somewhat misleading from the point of view of functionality of a management and control system such as Miracle. For this reason, the term *subsystem* will be used unless referring to the correspondence with the Harmonized model.
Electricity market and grid system is distributed and occurs concentrated in points (except for transmission) – active components, each with a specific function or a set of functions. This refers to both »process« part and to the control and management part of the system. Usually, the control and management subsystem is clearly delineated from the process part of the system. In the case of the electrical market and grid systems, many system components have been institutionalized through the operation of the system and their function may not be clear due to the system complexity. However, in the course of restructuring the complete system and concurrently designing a new management and control system, the functions of the existing system components have to be identified. What is more, since the restructuring of the system involves decomposition of the existing system, the existing components have to be decomposed into primary (atomic) units to

enable new types of integration. To make this procedure transparent and consistent, we shall use the following nominations:

- *Unit component* of the system: part of the system which performs unit process or several unit processes and which can be institutionalized i.e. assume the form of a separate business entity. In line with the convention of the Harmonized model, we shall call such unit component role component or role player - shortened *role*, thus somewhat misleadingly equating the system and the process
- *Unit process* is the process which performs a unique function in the context of Miracle process and role model. We shall call such process a *unit process* and characterize it as “atomic”.

Some additional clarifications and conventions referring to the atomic character of a *unit process:*

- Unit processes cannot consist of or include other processes, which are defined otherwise as unit processes in the model
- unit processes must be mutually exclusive. In a role and process model, each unit process should be defined only once; there must not be any overlap between different unit processes
- Exhaustive. A role and process model should include all unit processes that are needed to describe the complete process covered by Miracle. If a unit process is missing, the Miracle management and control system as a whole will not work, rendering the other unit processes useless.

Some additional clarifications and conventions referring to the character of a *role*:

- Roles cannot consist of or include other roles, which appear otherwise as roles in the model
- Roles must be mutually exclusive. In a role and process model, each role should be defined only once; there must not be any overlap between the functions that different roles fulfil
- Exhaustive. A role model should include all roles that are needed to describe the complete system. If a role is missing the model as a whole will not work, rendering the other roles useless
- Black box. Roles should only be described in terms of their responsibilities and in and output with respect to other roles. In other words only the service portfolio that a role offers to other roles matters. The internal implementation of a role is not relevant for the description of a role model.

The control and management system must have certain functions to fulfill the requirements stemming from the process and necessary for its (optimized) operation.

### 5.1.4 Processes in primary subsystems

In each primary subsystem, processes (unit processes) are carried out by the roles (in the roles!) which make part of the subsystem.

The processes in the subsystem interact (“roles communicate”) with the processes in the subsystem environment:

- Processes in other primary subsystems
- Processes in structural subsystems

Processes in primary subsystems will be defined and analyzed with the aid of Use Cases. For this reason, use cases will be selected to cover complete EEM system addressed by Miracle, and also to cover the 3 trial cases of Miracle:

- Household community
- LDE (Local Distributor of Energy)
- TSO

## 5.2 Unit processes

### 5.2.1 Unit processes on the level of each primary subsystem

In each primary subsystem, the primary processes are carried out. In Electricity market system these are processes of trading the energy. They have to be broken down into unit processes according to the need of the Miracle technology but also consistently with the boundary conditions of the Harmonized model.
The following types of unit processes occur in each primary subsystem:

- Production (supply) of energy
- Consumption (accepting) of energy
- Requesting for the energy (supply for consumption)
- Requesting for production of the energy (for supply)
- Aggregation of requests for energy
- Aggregation of requests for production
- Trading the energy
- Negotiating
- Auctioning
- Contracting
- Scheduling of request for energy
- (Assigning the scheduled requests for energy)
- Scheduling the requests for production
- (Assigning the scheduled requests for production)
- Measuring the consumption data
- Measuring the production data
- Forecasting the aggregated production
- Forecasting the aggregated consumption
- (Forecasting the transmission losses)

Proper structuring of the overall primary process into unit processes and showing that these unit processes occur at different levels of the vertically decomposed system makes it possible use the technology to be developed on different levels of the system – i.e. scale it simply to the system where it is used: there is no (appreciable) difference for the unit process if different roles are involved – at least there should not be if the unit processes are properly defined (e.g. negotiation process is negotiation process whether performed between consumer and BRP or between BRP and BRP, etc.).
For this reason, the above list of unit processes is tentative in scope and generic in formulation. The final scope of the list and the specific nominations of unit processes will be made in analysis of the market system processes through Use cases, in Section 4.4 of this document.
A specific question unresolved at the time of the draft model is whether the transmission line is active or passive component of the system: the reason for this dilemma is that with changing ambient conditions the transmission lines behave as »changing energy consumer«; the losses influence the energy balance and have to be taken into account and settled. The distance between two production and consumption points influence the energy loss:

1. If it is an active component; this is equivalent to introduction of role of »line consumer« (or transmission loss, etc). Such role would enable/accommodate future change of the method of settling the transmission losses – assigning them to the concrete transaction. It would also enable forecasting of these losses due to weather conditions
2. If passive component: the transmission loss is not part of the Miracle roles and process model, the loss is a fixed external datum, occurring in calculating the costs of DSO/TSO or of whoever covers these costs.
3. It may be important to note that transmission is physically not structured into fractal-like subsystems, but exists at precisely defined level of the system, although its function is carried out at each subsystem level. The exception to this rule is micro-grid subsystem, which is fractal-like subsystem of the complete system as a whole.

### 5.2.2 Unit processes on the level of joint and supportive subsystems

The following unit processes occur in structural subsystems:

- Measuring the consumption data
- Measuring the production data
- Forecasting the aggregated production
- Forecasting the aggregated consumption
- (Forecasting the transmission losses)
- (transmitting the energy)
- Operating the (high voltage) transmission system
- Operating the (medium voltage) distribution system
- Operating the (low voltage) distribution system
- Regulating – system rules setting
- (transmitting the energy)
- Operating the (high voltage) transmission system
- Operating the (medium voltage) distribution system
- Operating the (low voltage) distribution system
- others

The above list of joint and supportive unit processes is very sketchy and is presented only as indication of type of processes that belong into these subsystems..

However, the joint & supportive processes as such are not of interest to Miracle project and will not be modeled. They are interesting only to the extent to which the primary processes interact with them. For this reason, we shall only define points of interaction of these processes with the primary processes inside the primary subsystems. This means that:

- we limit ourselves to indentifying the interacting roles, without looking into processes carried out by the role, and
- only the immediately adjacent roles are relevant.

The mode of interaction is message, document and similar type of “non-process” transaction.

## 5.3 Primary subsystems of Electricity Market system

Subsystems are represented in the Harmonized model by *domains*.Based on the above model, we identified the following vertical structure of primary *subsystems* in the present state of the Harmonized Electricity Market role model:

- 1$^{st}$ level: Balance group

- 2nd level: Market balance area
- 3rd level: Market area (Local market area) (tentatively!)

There may be further subdivision of the 1st level into Balance Subgroups (in some countries this already happened), but it is reasonable to assume that the level of common European regulation will not set this sublevel as a separate level from BG's and will leave it to intra-BG arrangements, providing that they "stay within" the regulatory constraints imposed on BG level.
Also, a 4th – unified European level is logical extrapolation for the future. However, close inspection of the model shows that already the 3rd level is unharmonized and incomplete – it does not include complete range of primary processes and it is reasonable to assume that further evolution of the system is dependent on implementation of the existing scope of the model.
For this reason, Miracle is in practical terms concerned with the first two levels (bottom up), 3rd level is introduced mainly for the sake of completeness and model consistency. When referring to an electricity market system or to an energy grid system, we shall therefore mainly talk about the electricity market system within one Market Balance Area or the energy grid system on the territory of one TSO; with the environment of the system extending into Market Area (Local Market Area).
However, for Miracle this is important as a message to define the role & process model in a way to accommodate consistent vertical decomposition: when the Harmonized model is extended consistently as fractally structured system to the pan-European level and put into practice, the 3rd level, and at least conceptually also the 4th level, could be supported Miracle:

1. The basic Miracle structure could accommodate it without undue problems
2. The level of support of Miracle technology would be reduced to decision support in trading but could play some on-line role in on-line/short term trading inter-MA (Local Market Area).
3. For the time being, this possible extension of the Miracle technology can be kept feasible by maintaining formal fractal consistency of the system and architecture, thereby making it easier to apply the solution to this level.

In this concept, supported by the Harmonized model, the Balance Group is a *new* subsystem, which within the constraints imposed by the Harmonized model may form its own rules for participation in costs or revenues from trading on the inter-BG level.
In principle, the rules for intra-BG trading could be the same as the rules used in inter-BG trading (on MBA level) or different.
It is reasonable to assume that based on the needs of its majority users a BG system will have simplified rules for its members, especially if it includes households. They will continue to evolve on the tariff system concept with various benefits, but with elements of the market which can be introduced by dynamic pricing concept
On the other hand, to simplify the transformation between the two levels, the traders (BRP's) will tend to make the energy trading products in the BG similar to the energy trading products on the inter-BG trading level. This assumption leads us to assume that the energy trading products in the intra-BG trading will tend to become similar at least in structure to those on the grid level, but their variety will tend to remain limited – emulating some of the characteristic of a multi-tariff system.
The BG subsystem is therefore the natural user of automatic trading technology, due to the fact that major part of it are households with little capacity for continuous active trading. The BRP's trading partners are unlicensed actors – predominantly households

and small to medium companies; their number is very large, they will trade in a limited number of energy products and time horizons which emulate tariff systems (e.g. a daily arrangement for fixed hours, agreed on for a longer period).
By way of prediction, they will use complete functionality of the Miracle system, including automatic trading.

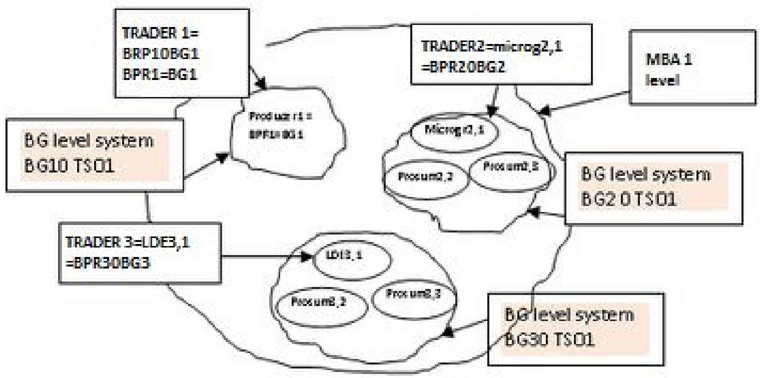


**Figure 34: The concept of the MBA level system with three sample types of BG level systems**

Conversely, in inter-BG trading, the energy products are traded between licensed traders (BRP's); the number of traders is comparatively small, they trade in all kinds of energy products and time horizons (long term, medium term, short term). By way of prediction, they will use the Miracle technology as information exchange system and a decision support system.

## 5.4 Use cases

The use cases described and analyzed in this document were chosen and formed in the way to follow the Miracle project goals. The use case scenarios, its boundary conditions and roles involved were determined in the way to expose the main characteristic of Miracle project – energy scheduling and delivery on the bases of the prosumers micro-requests.
The following use cases have been defined to analyze and define the primary processes of the two complete primary subsystems of the electricity market:

- Balance Group Use Case, structured into 3 scenarios (sub cases)
- Market Area Use case, structured into 3 scenarios (sub cases)

In selecting these use cases, two main criteria were adhered to:

- The use cases should together describe complete area of the electricity market where the Miracle solution can be used
- the use cases within each subsystem (Balance Group, Market Balance Area) are selected in a way to establish clear understanding of interdependencies and causality, i.e. as a yardstick for establishing the requirements for development. The complete use case for BG is use case 3, the complete use case for MBA will be use case 3.

It is important to note also that by respecting the first criterion the two groups of use cases cover the trial cases planned for Miracle (see DoW [Mira]):

- BG Use case covers: household community, and sufficiently LDE trial
- MBA use case covers sufficiently TSO trial

The described use cases were chosen according to the physical and economical specifics of the electrical energy trading:

- The BG Use case 1 describes the process of selling the electric energy as goods with no real environment restriction (like physical network). This use case should enable isolation of the micro request concept for detailed analyses.
- The BG Use case 2 introduces the physical property of the electricity transporting – imbalances. The electricity cannot be stored therefore the consumption must be equal to the production at every moment. These facts have significant influence on the roles of the market players and trading processes.
- The BG use case 3 introduces the economic component - the competition which was introduced during the evolution of the electricity market from the hierarchic organization to open market.

Additional use cases, which are planned for the final version of the model address the other subsystem of interest, MBA, and introduce additional properties like geographical limitation on the transmission systems and their interconnection.

### 5.4.1 Definitions

**Types of intra-BG energy trading contracts**
There are two types of contracts

- Closed (firm) contracts
- Open contracts

*Closed contracts* define quantity, profile and time (essentially we can consider them as type of energy products); price; and contractual penalty.
Closed contracts in energy trading are contracts for the period ahead in time: day ahead or intra-day. The closed contracts are between the balance responsible parties or between balance responsible party and market organizer when trading the energy.
In the Miracle project the closed contract is also introduced between prosumer and balance responsible party on the bases of the successful match between consumption and production micro-request.
For these contracts, imbalances are established. These internal imbalances constitute one part of total imbalances of BRP contracts on the extra-BG, i.e. inter-BG level.

*Open contracts* define price and optionally time, quantity is not defined.
Open contracts regulate the trade of the energy that is not covered by the closed contracts. The energy covered by the open contract is the difference between the total metered energy consumed (or supplied) and the energy actually consumed (or supplied) covered by closed contracts.
In open contracts there is no concept of process control involved; this is completely assigned to closed contracts. The open contracts are between consumer and balance supplier.
As opposed to the closed contracts, open contracts could be considered as an approximation of continuous trading in real time; for proper continuous trading, the pricing method would have to be based on actual situation which occurs in the system at the time of delivery of energy.

If the pricing method is not based on actual situation but is rather predefined based on fixed model , these contracts can hardly be classified as trading contracts because delivery and acceptance of the energy is unconditional within and the closing of the contract is not the result of market action (negotiation, auctioning) or its emulation. Majority of present contracts are of this class.

**Imbalances**

Imbalance is the difference between contracted and really consumed (or produced) energy. The really consumed or produced energy is the metered and aggregated energy to the level defined by the closed (firm) contract. These data have to be supplied by the metering part of the system, which is not a part of the BG.

The imbalances in intra-BG trading constitute one part of reason for total imbalances of BRP contracts; the other part of the reason occurs in BRP's inter-BG trading. These two types may add or subtract (through optimized management). The business goal of BRP is that the total sum of imbalances as measured on the grid is zero – the BRP operation is balanced.

**Imbalance settlement**

Imbalance settlement refers to financial settlement penalty for not fulfilling the contractual obligation and not to supplying or accepting the energy.

The imbalances are established in periodic time intervals for past time intervals and billed in normal business intervals (e.g. monthly).

The imbalance settlement in BG for consumers and producers (and Balance suppliers) is carried out by BRP – Settlement responsible. The imbalances are/may be charged by BRP to prosumers.

In inter-BG trading, the penalties due to imbalances are settled between Balance responsible party and Imbalance settlement responsible (ISR), for all BPR’s contracts in Market balance area. These imbalances are charged by ISR (or its Billing agent) to BRP.

Responsible role for closed contract trading is the Balance responsible Party. BRP is also responsible for external energy trading, i.e. wholesale trading for the BG. The wholesale contracts, i.e. inter-BG trading, are closed contracts.

For closed contracts in intra-BG trading the contract is between

- Producer and BRP
- Consumer and BRP

The missing energy is supplied by the role balance supplier. Additionally, there is a contract between balance supplier and BRP. This contract is necessary because the conditions in open contracts and the conditions in closed contracts have to be interdependent to stimulate responsive behavior of the prosumers in closed contracts.

This contract does not have to be closely analyzed, because it is not based on micro requests, but transformation of information on trading conditions on interface would have to be realized, to use it as a boundary or reference condition, e.g. how expensive has to be energy in open contracts as to preference the closed contracts.

**Request collection deadline**

A moment till when the micro-requests are collected for the period ahead interval, i.e. at a “day ahead market” the offers are collected till noon of the present day (request collection deadline) for the period from 0:00 till 24:00 of the next day (period ahead interval)

**No request interval**
The time interval from the request collection deadline till the start of the interval ahead period, i. e. at the “day ahead market” the “no request interval” lasts from the noon of the present day till the 24:00. This time is reserved for the contracting and balancing and it is not allowed to accept any offer for the interval ahead period (but it is allowed to accept the offer for the period after the interval ahead period).

**Interval ahead period**
Is a time interval which starts at the end of the “no request interval” and lasts one interval unit (i.e. 24 hours) or it is unlimited.

### 5.4.2 Balance group use case 1: Internal energy sale process

This use case about the internal energy sale process is strictly limited to the transactions and processes, which are a consequence of micro-requests. Its intention is to describe the mechanism of handling the prosumers micro-requests and resulting closed contracts.

#### 5.4.2.1 System description

In the system there is only one isolated balance group with:

- “n” producers (classical and/or RES and DER)
- “m” consumers
- 1 Balance responsible party
- The network and network operator are responsibility of the balance responsible party ( BRP), but actually they are not important in this case

It is assumed that there are no imbalances. The prosumers strictly provide production and consumption according to the contracts (schedules). Since all the energy is sold on closed contracts no metering is needed. Therefore there is no need to involve the network relevant party as a role (for example grid operator, ...)
No external trading is provided - all the necessary energy which is produced internally is consumed by the consumers in BG.

#### 5.4.2.2 Energy sale Process

The producer and consumer offer their production capacities and consumption needs in the form of micro–request. The micro-request contains the following parameters

- Energy time schedule of the production / consumption with the temporal variation
- Variation of the time of production /consumption
- Variation of the price
- Constraints at changing the parameters

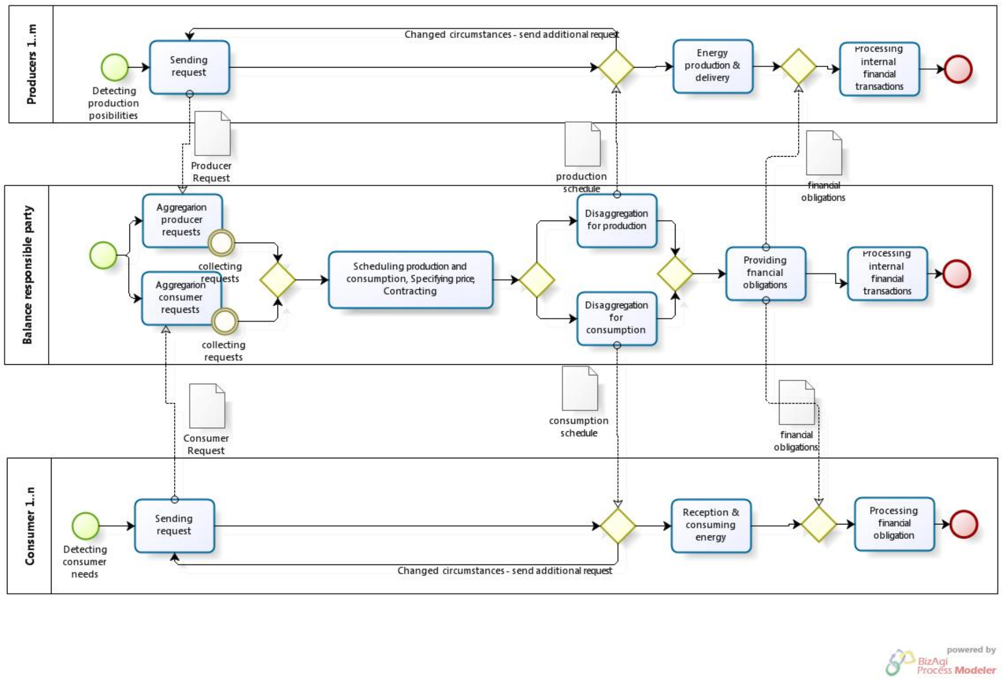


**Figure 35: BPMN presentation of the use case balance group 1 process**

The BPMN presentation in the Figure 35 shows the time line (from the left to the right) of the processes and messages exchanged between the roles involved in the use case, The Balance responsible party is collecting the prosumers micro-request till the “request collection deadline” (see definitions) which contain the power time line for the “interval ahead period” (see definitions). After the “request collection deadline” it is allowed to collect the micro-requests for the next period after the “interval ahead period. For example the BRP is collecting the micro-requests for the day ahead till noon of the present day. After the noon it is accepting only the micro-requests for the day after the “day ahead”. Therefore there is always a time gap between the finishing the micro-request collection and actual consumption of the electricity.
After finishing the collection of the micro-requests the BRP provides the micro-request aggregation separately for the production and the consumption. This is necessary to provide optimal matching between production and consumption. Finding the optimal matching is closely connected with the scheduling process. The matched production/consumption is contracted. On the bases of the contracts the de-aggregation is provided separately for the producers and the consumers and final schedules are sent.
The scheduling information contains the energy time schedule for the production/consumption. The schedule is within constraints defined within the micro-request.
After delivering the energy the financial obligations are processed.

### 5.4.2.3 Messages

| Domain model Phase | Message/ document | From/by whom | To/by whom |
|---|---|---|---|
| Plan | Producer request | Producer | BRP (Balance responsible party) |

| | | | |
|---|---|---|---|
| Plan | Consumer request | Consumer | BRP (Balance responsible party) |
| Plan | Production schedule | BRP | Producer |
| Plan | Consumption schedule | BRP | Consumer |
| Operate | Energy Delivery | Producer | Consumer |
| Billing | Producer financial obligation | BRP | Producer |
| Billing | Consumer financial obligation | BRP | Consumer |

**Table 15: List of messages at internal energy sale process**

**Producer/consumer request**

Due to the differences in the behavior between the producer and consumer also the content of their request shall differ.

The producers request shall contain:

- The time schedule of the maximum power production
- Constraints about the power variation
- Price

The constraint about the variation of the power holds the information, what is the producer minimal production power and how fast can he adopts the production according to the needs of the consumption.

On the other hand the consumer request shall contain:

- The time schedule of the energy consumption
- The constraints about the shifting the consumption in time
- The price (limit)

The constraint about shifting the consumption holds the information about the time interval when the energy is actually consumed. In contradiction with the micro-request of the producer, where the power can be changed, the consumer shall insist on the fixed quantitative of energy and time schedule.

**Production/Consumption schedule**

The schedule is formed after the “micro-request collection deadline” for the “interval ahead period”. For example at “hour ahead market” the micro-request collection deadline is at 12.00 for the time interval from 13.00 and further in the future. In the time 12.00 – 13.00 the schedule is formed for the period 13.00 – 14.00. Meanwhile the micro-requests for the period from 14.00 and further in the future are being accepted.

The production schedule must be within the micro-request’s constraint. While the producer must know the exact schedule for the production, the consumer needs only the consumption start up trigger.

#### 5.4.2.4 Unit processes

The sample described bellow is used to illustrate the necessary processes from collecting the micro-request to contracting and scheduling. It is not necessary that exactly the same will be provided in the Miracle project. It is rather used only for presentation purpose for listing the processes which are necessarily involved in the energy trading with micro-request and interactions among them.

**Generating micro-requests**

*The consumer micro-request*

The consumer sends micro-request when the end user decides to use the load. The sending algorithm shall start by a trigger from the consumer and result into consumer micro-request according to the input parameters. The consumer micro-request shall contain the information about the energy, the interval of time for usage the load and the price. These information shall be supplied by the load manufacturer and by the consumer settings.

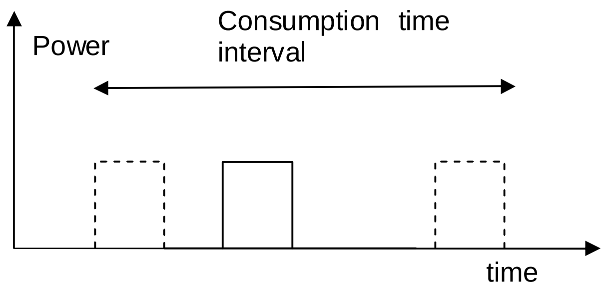


**Figure 36: The consumer micro-request with the usage time interval**

It would be possible for the consumer to put constraints about the price in the micro-request. He may set the preferable moment when the load should be started by setting the maximum price for that moment, while for the rest of the interval its request price is lower.

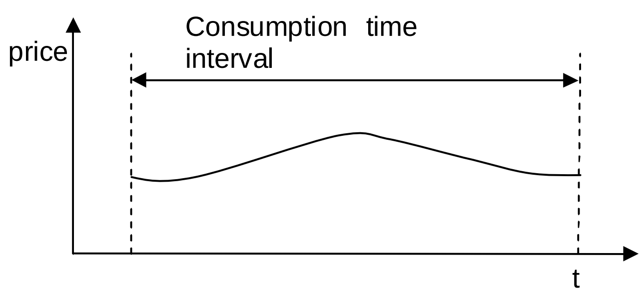


**Figure 37: The consumer request constraint between time of usage and price**

For the consumer it might be difficult to set up the optimal price, which should not be too high to overpay the BRP and too low to stay without electricity. Therefore, the consumer might send the micro-request without the price parameter, but rather instructing the BRP to catch the minimum price in that interval.

*The producer micro-request*

Compared to the consumer the producer micro-request shall probably not contain the time variation parameter because it is offering its capacities rather than its needs. Its price shall be set according to the production cost. The RES send their micro-requests according to the weather forecast while the classical producers has very predictable production and their request shall vary only in the price parameter according to the price of their input material (coal, oil, gas ,…).

**Aggregation**

Before the aggregation the energy time history in the production and the consumption requests must be transformed into some generalized form like trading products what is a subject of WP 3-5 and it is not specified in this document.

The aggregation is provided separately for the production and the consumption. The aggregation is closely connected with the matching the production-consumption and contracting.

*Aggregation of the production micro-requests*

The aggregated production request shows the maximal capability of the electricity production for the certain period. Originally the aggregation is provided on the trading products but in the illustration in the Figure 38 it is presented as a cumulating of the power production sorted by price over the certain time period. The white area shows the time line of the power of the cheapest production facility, and the darkest shows the most expensive production unit capacity.

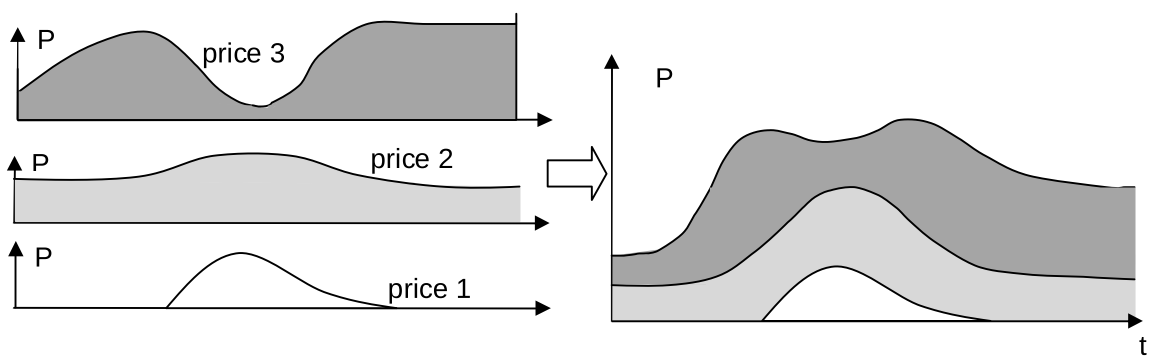


**Figure 38: A sample of aggregated production requests**

*Aggregation of the consumption micro-requests*

The consumption micro-request aggregation is not so straightforward as the production, because the consumption micro-requests contain the variation parameter of the consumption start.

Similarly as in production, also the consumption requests must be transformed into the generalized form before the aggregation. The Figure 39 shows one possibility of the consumer micro-request aggregation when the aggregator has taken the most preferable moment of the consumption indicated by the highest price (it might happen that everyone prefer to wash the clothes at the same time). This aggregation resulted in a very irregular consumption. The figure shows the aggregated micro-requests as a cumulative power consumption sorted by price over the certain time period. The white area shows the time line of the power of the cheapest consumption offer, and the darkest shows the consumption offer with the highest price.

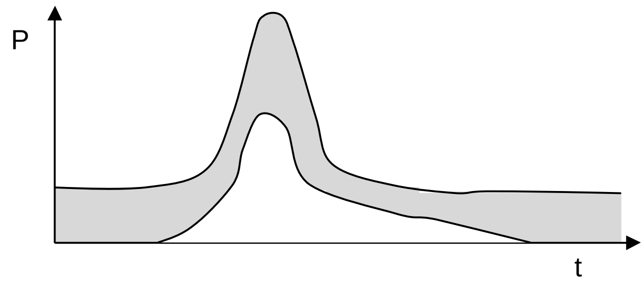


**Figure 39: A sample of irregular aggregation of consumption requests**

Figure 40 shows another possibility of the consumer micro-request aggregation, where the aggregator tended to provide the regular consumption.

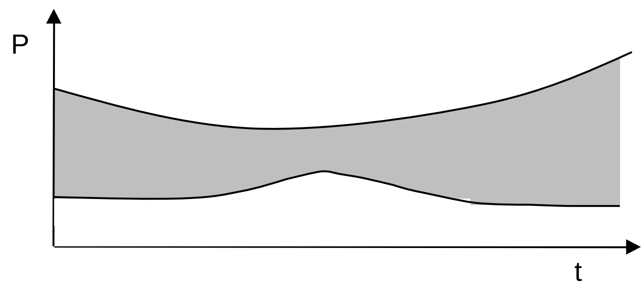


**Figure 40: A sample of regular aggregation of consumption requests**

While the sample in the Figure 39 might be quite problematic for the producers to fulfill it, the sample in the Figure 40 might be very suitable for the classical production units, but it is still not suitable for the RES with its irregular production.

There might be infinite possibilities to aggregate the consumer micro-requests and one should get some criteria to choose the most proper one, which shall be used for matching the production with the consumption and the scheduling.

To establish the aggregation criteria one should follow the interests of the parties involved in the process:

- The producer wants to sell the largest amount for the highest price
- The consumer wants to buy the needed amount (as small as possible) for the lowest price
- The BRP wants to make the largest profit, i.e. get the producer's electricity as cheap as possible and sell it to the consumer for the highest price

**Matching and Scheduling production-consumption**

The aggregation in Figure 39 does not follow the interests of the parties involved, which is seen when matching to the production capacities with the consumption needs (Figure 41):

- Some consumers did not receive the electricity despite they were willing to pay for it and there are enough production capabilities.
- Producer could sell more if the consumption would be more regular.
- The BRP could make more money by shifting part of the consumption to the time when the production is not exhausted to maximum capacity.

The BRP would make the largest profit when it finds the cheapest electricity for the consumers. That situation also follows the interests of the consumers. It partly also follows the interest of the producers – they will sell as much electricity as there is demand for. Only producers with the expensive production shall not be capable to sell as much electricity as they would in some irregular situations.

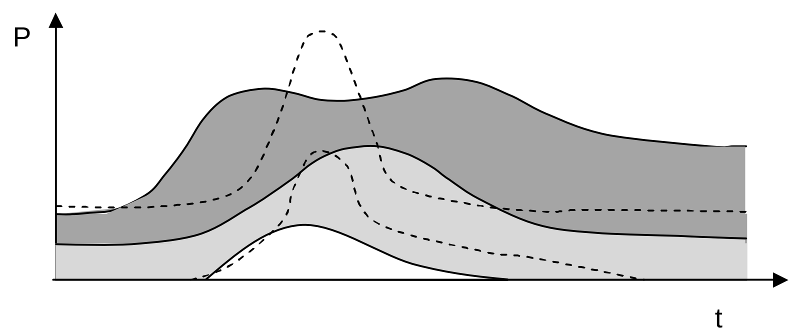


**Figure 41: Matching the production with the consumption**

The optimal matching between production and consumption is a complex mathematic and iterative process. The main criteria to find the optimum might be the profit of the BRP. If the production side also provides the micro-request with time variation parameter, they are included in the aggregation/scheduling process in the same way as the consumption.

**Contracting**

The contracting is provided after matching the production and consumption for the time period, which cannot be affected by the micro-requests any more.
The contracting is provided on the trading products. In this sample the trading products may be “one hour” energy packet and the contracting shall be provided by the auction.
The auction sample in Figure 42 shows the surplus of the offers on the production side for a certain sailing product (one hour energy), while the consumption is all covered, what means that the production shall not be seized to maximal capacity. The beginning of the consumption line does not touch the vertical axes because the consumer’s micro-requests with no price limit parameter were aggregated for this product.
At the intersection of the curves the reference price is set up and put into contracts for the energy delivery.
It might happen that the part of the consumption line finishes bellow the production line or even that there is no intersection between lines. In that case some consumers stays without electricity.

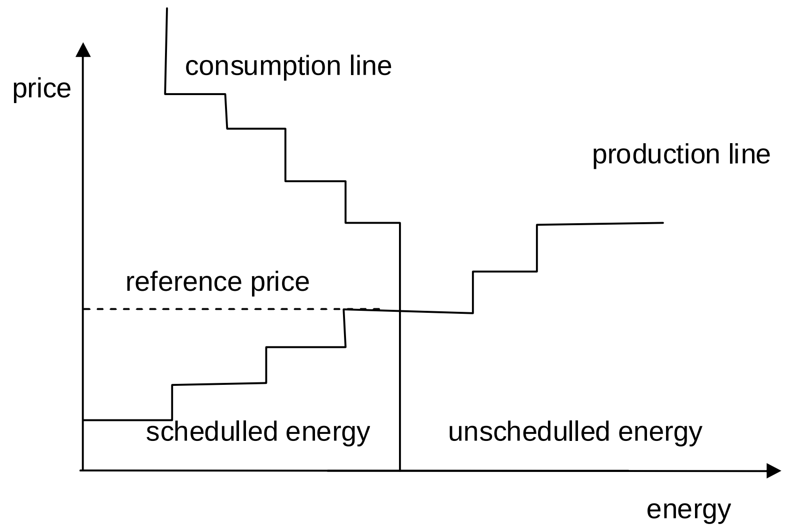


**Figure 42: An auction with production and consumption offer**

**Disaggregation**
After the contracting the contracted energy is disaggregated according to the involved micro-request so each producer receives the schedule for the production and consumer receives a signal to start the consumption.

#### 5.4.2.5 Role model

As a result of the use case balance group 1 the role model involves the following roles

- Producer,
- Consumer,
- Balance responsible party

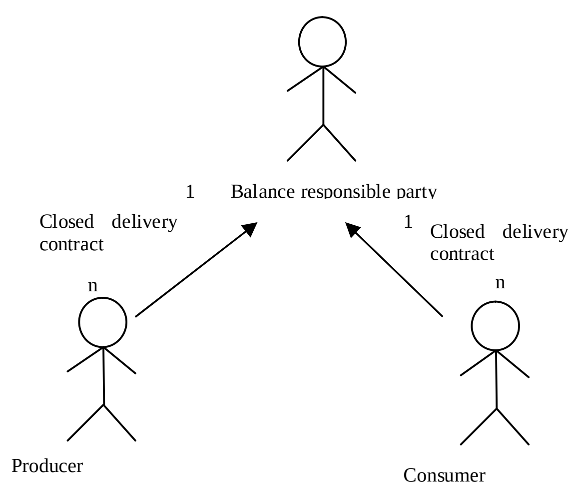


**Figure 43: Miracle role model base on the balance group use case 1**

### 5.4.3 Balance group use case 2: Imbalance process

The balance group use case 2 describes the situation, which is closer to the reality than balance group use case 1. In the real electro energy system the electricity production must be balanced with the consumption all the time. The network has no internal capacity to store the energy. In the balance group use case 1 this fact was artificially prescribed, while in reality there are dedicated roles and complex mechanisms to sustain the stability of the network. The balance group use case 2 therefore tries to represent how the Miracle approach with micro-requests faces the imbalance situation.

#### 5.4.3.1 System description

Additionally to the system of balance group use case 1

- "n" producers (classical and/or RES and DER),
- "m" consumers,
- 1 Balance responsible party,

the following two main items were added

- The prosumers are allowed to produce/consume the energy on open contract
- There might be a difference between the contracted and actually consumed energy, which is called imbalance

The consumer in present electro energy system consumes their energy on open contract, what means they are allowed to consume as much they need at the contracted price (which is usually fixed). This needs to be introduced in the Miracle application in the system because the consumers shall probably not want to put all their consumption on closed contract micro-request system but shall rather leave part (more likely majority) of it on open contract.
The balance supplier is capable to market the imbalances i.e. it is responsible for the open contracts which are treated as imbalances.
The imbalances involves additional roles and domains into the system

- System operator, which is responsible for the safety of the network and online balancing the production and consumption.
- Network, which is a subject of balancing
- Meter data responsible, which provides the measured data to calculate the imbalances
- Imbalance settlement responsible, which calculates the penalties

This use case is dedicated to imbalances and corresponding activities, therefore no external trading is included, which is a subject of the balance group use case 3.

#### 5.4.3.2 Imbalance Process

Additionally to the balance group use case 1 here is a balance supplier, which collects the data from the meter responsible party. Beside the micro-request and firm contracts for the energy delivery there is also the production and consumption on open contracts, which are the responsibility of the balance supplier.
The sources of imbalances are

- the differences between energy with the prosumer on the closed contract and actually metered energy on the meter for the consumption on the closed contract,
- the difference between the energy consumed on the meter for the open contract and forecasted energy.

The balance supplier introduces the forecasting in the system, which is used to forecast separately the production and consumption on the open contract. The balance responsible party includes the forecasted result into the aggregation/scheduling process.
After the aggregation/scheduling process and before the contracting, the balance responsible party sends the schedules to the system operator for checking the eventual congestions. After the conformation the process is continued similarly as balance group use case 1.

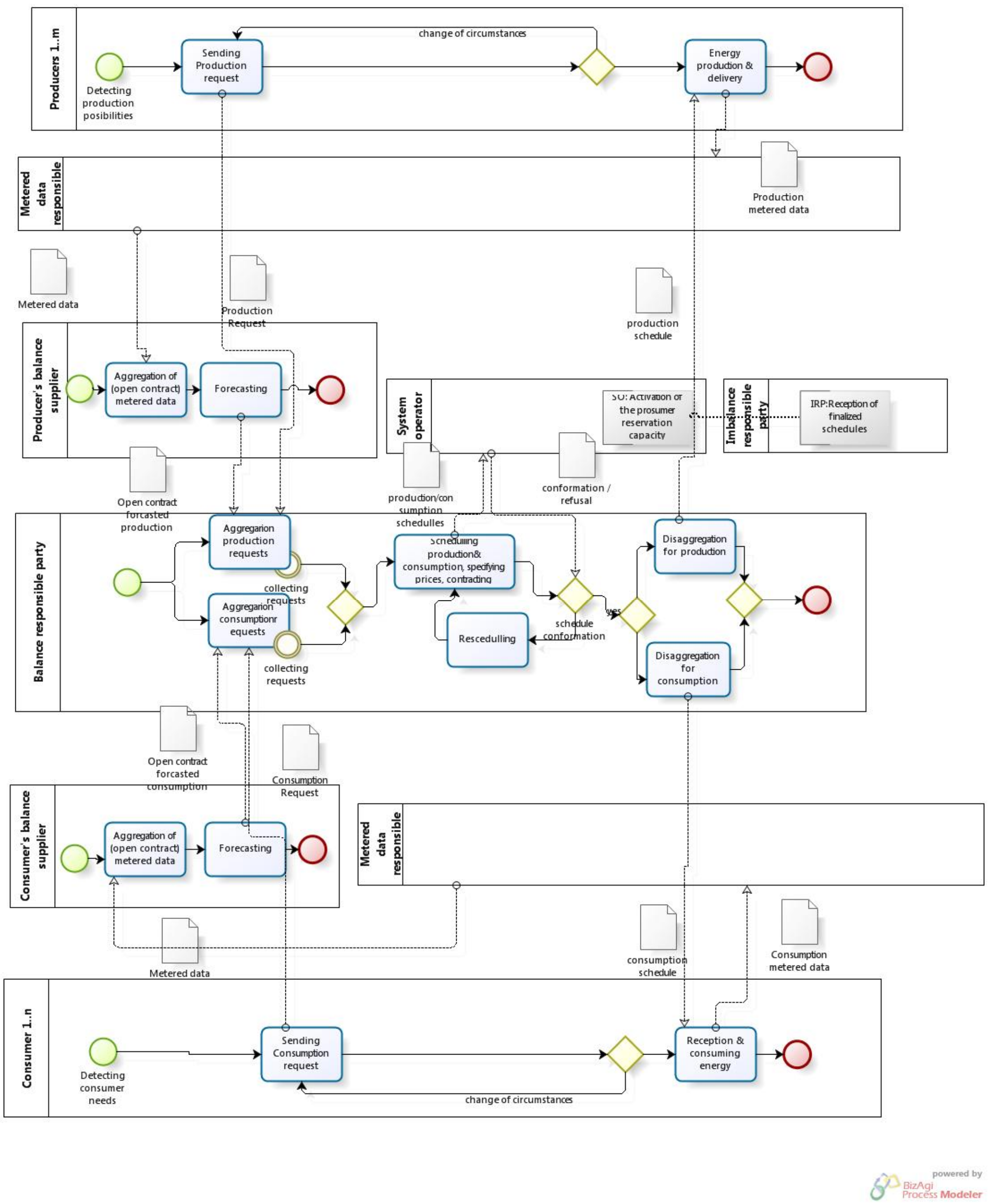


**Figure 44: BPMN diagram for BG use case 2 with system operator**

When the energy is delivered the imbalances in the network are balanced:

- internally within the balance group when the imbalances of the prosumers have opposite sign. These imbalances are the matter of the balance responsible party and are not exposed outside the balance group,
- externally by the system operator, when the imbalances of the prosumer have the same sign and the system operator needs to start the intervention system.

The imbalances are measured and penalized:

- the internal imbalances are calculated as a difference between metered consumption/production on a meter for the closed contracts and amount of energy on he closed contract
- the external imbalance is calculated as a difference between scheduled consumption/production and metered one

**Intraday imbalance process**

Some existing electro energy markets do not provide the intraday market but only the day ahead one. The period of one day might be much too long to handle the RES efficiently.

For example, if the balance responsible party in the present day concludes with the contracting and scheduling for the next day and it is not capable to make any adaptation during the “day ahead” (for example intraday), then it cannot efficiently include the effects of the weather changes on RES, which very often changes during intraday.

The Miracle project is planned to have the “request deadline period”  at most a few hours before the “interval ahead period” ahead, but the electro energy system might not be prepared to respond so quickly (system operator shall not be capable to confirm the schedules).

Therefore the imbalance process needs two scenarios

- the scenario where interaction with the system operator confirms the schedule and reports the energy flow to the Imbalance Settlement responsible in the Figure 44
- the scenario, where there is no interaction with the system operator. The process is presented in the Figure 45.

In the process with the system operator interaction it detects the imbalances and congestions in the network and may reject the schedule by returning it to the BRP for the reformation.

In the intraday process the BRP holds additional responsibility of the balancing production and consumption. Any imbalance causes the intervention of the safety system installed at the system operator during delivery what results into penalization by the imbalance settlement responsible.

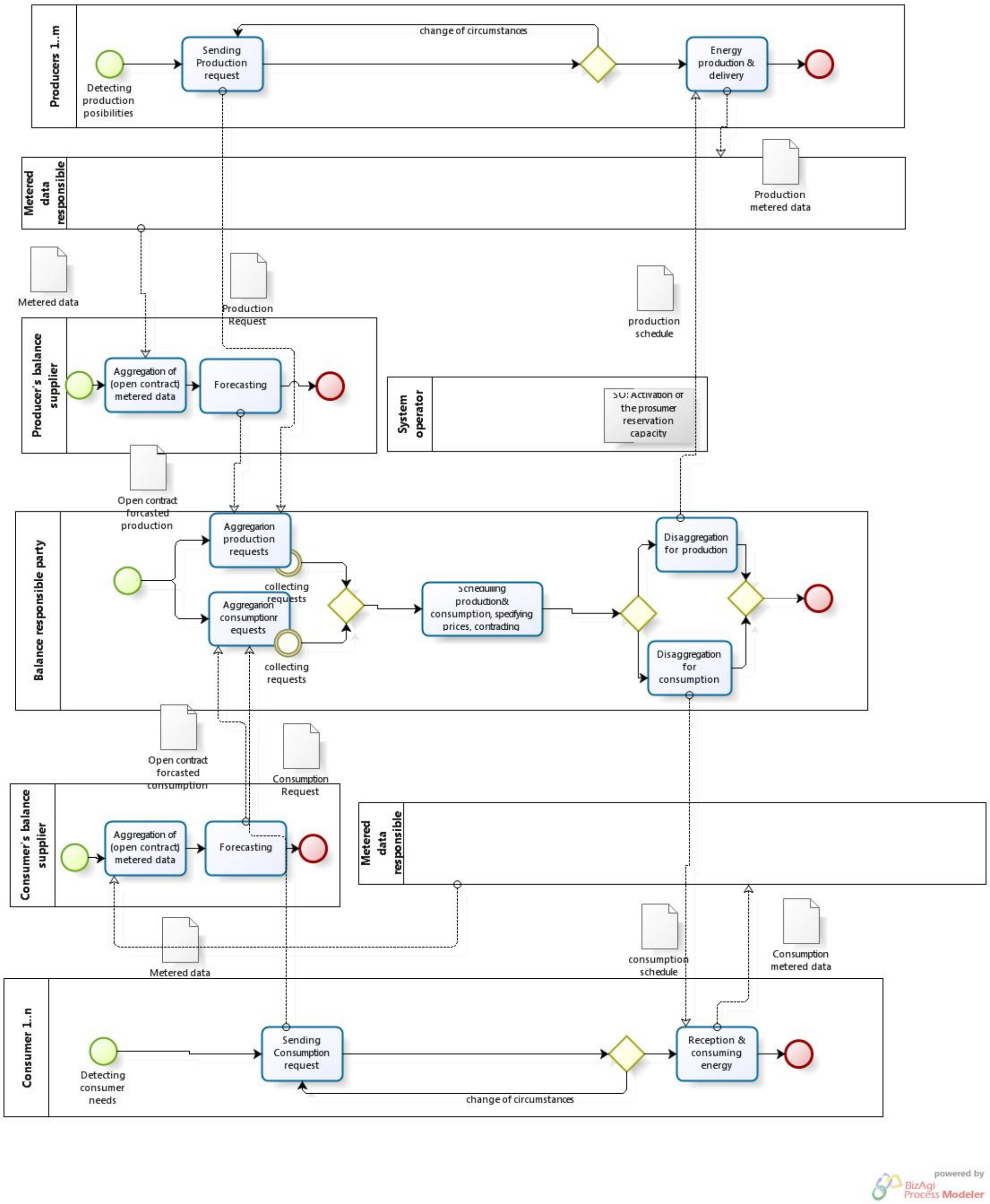


**Figure 45: BPMN diagram for BG use case 2 for intraday**

### 5.4.3.3 Messages

In this subsection only messages which are different or new compared to the balance group use case 1 are described. All the messages are listed in Table 16 for consistency with the BPMN diagrams in the Figure 44 and Figure 45.

**Production/consumption measured data**

For the exact calculation of the imbalances the consumer should have two separated measurement lines

- Measurement of the consumption on the open contract – the consumer is not limited to specific quantity and the consumption usually reflects the consumer characteristic behavior (Figure 46 left)
- Measurement of the consumption on the closed contract – the consumption may be compared to the contracted energy quantity and the difference (imbalances) may be penalized (Figure 46 right)

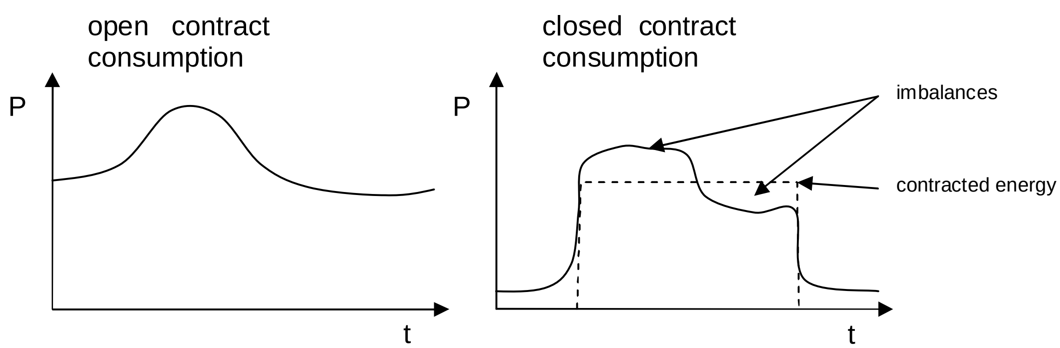


**Figure 46: A sample of separate measurements of the open and closed contract consumption**

Such installation enables to measure and penalize the consumer's consumption on closed contract.

The same is valid for the producer. Therefore the actor which acts in both roles – producer and consumer – needs the equipment which is capable to measure four separated data.

It might be very difficult to install the smart meter which would separate the consumption on open and closed contract. The simplified configuration would contain only one meter for both types of consumption (see Figure 46).

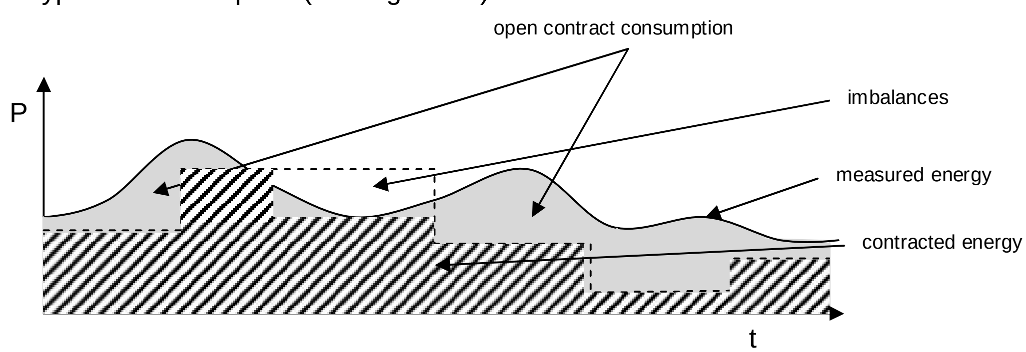


**Figure 47: Measurement of the open and closed contract consumption on one line**

In this case the contracted energy is taken as a base for measuring the open contract consumption. The open contract consumption is the difference between the measured consumption and the contracted energy on the closed contract. If the consumer exceeds

the closed contract energy he will pay the difference by the open contract price which should be higher than the closed one. Therefore there is no need for the additional penalization.
On the other hand if the measured energy is lower than the contracted one then the imbalance can be detected by the meter and the consumer may be penalized.
In the option with the common measurement of the open and closed contract consumption the consumer may manipulate the process by sending the false micro-request which results in contracted energy and then it covers the contract by the open contract consumption achieving the lower price for it. This manipulation cannot be detected from the measurements but alternative mechanism should be implemented (for example smart meter is capable to detect the turning on/off the devices on the closed contract). On the other hand such manipulation is not necessary bad, because the consumer managed to proved larger part of the consumption under the closed contract what makes the system more reliable in its prediction (smaller part of the open contract consumption results in more accurate forecasting).

| Domain model Phase | Message/ document | From/by whom | To/by whom |
|---|---|---|---|
| Measure | Production measured data | Metered data responsible | Balance supplier |
| Measure | Consumption measured data | Metered data responsible | Balance supplier |
| Measure | Producer request | Producer | BRP (Balance responsible party) |
| Measure | Consumer request | Consumer | BRP (Balance responsible party) |
| Measure | Production forecast | Balance supplier | BRP (Balance responsible party) |
| Measure | Consumption forecast | Balance supplier | BRP (Balance responsible party) |
| Settle | Production/consumption schedules | BRP | System operator |
| Settle | schedule conformation/refusal | System operator | BRP |
| Settle | Finalized Production/consumption schedules | System operator | Imbalance settlement responsible |
| Plan | Production schedule | BRP | Producer |
| Plan | Consumption schedule | BRP | Consumer |
| Operate | Energy Delivery | Producer | Consumer |
| Settle | Production metered data | Producer | Measured data responsible |
| Settle | Consumption metered data | Producer | Measured data responsible |
| Billing | Producer closed contract financial obligation | BRP | Producer |
| Billing | Consumer closed contract financial | BRP | Consumer |

| | | | |
|---|---|---|---|
| | obligation | | |
| Settle | Producer open contract metered data | Measured data responsible | Balance supplier |
| Billing | Producer open contract financial obligation | Balance supplier | Producer |
| Settle | Consumer open contract metered data | Measured data responsible | Balance supplier |
| Billing | Consumer open contract financial obligation | Balance supplier | Consumer |
| Settle | Summarized measured data | Measured data responsible | Imbalance settlement responsible |
| Billing | Imbalance penalties | Imbalance settlement responsible | Settlement responsible |
| Billing | Producer closed contract penalties | Settlement responsible | Producer |
| Billing | Consumer closed contract penalties | Settlement responsible | Consumer |

**Table 16: List of messages for the balance group use case 2**

**Forecasting the production/consumption on the open contract**

The responsibility of the balance supplier is to collect the measured data of the prosumers, combine it with some other parameters (weather report) and provide the prognoses of the consumption and production.

#### 5.4.3.4 Unit processes

In this chapter only processes which are different or new compared to the balance group use case 1 are presented.

The processes in roles "Metered data responsible", "system operator", "imbalance settlement responsible" shall not be analyzed for this use case because their activity in this (Miracle) use case is the same as in "classical" circumstances (without Miracle micro request). Therefore the role "metered data responsible” is not modeled. The other two are modeled as a boundary condition as an endpoint for the interactions with active roles.

**Forecasting**

Based on measurements and other relevant data (weather) the forecasting predicts the consumption of the open contracts. The predicted open contract schedule is sent to the balance responsible party, where it is included into the aggregation process. In the case, when the smart meters measure the open and closed contract energy flow on one line one must subtract the contracted energy from the measurement before making the forecast.

**Aggregation**

The forecasted production (for example wind mills) might be included into the aggregation as a separate (virtual) production unit (in the same way as it is presented in balance group use case 1). Its predicted energy time history is included as a maximal power capacity with the constraint that it cannot be controlled (i.e. reduced).

In the comparison to the aggregated micro-request consumption data, the forecasted consumption has no variation of the start time parameter and is included into the aggregation as a "background" consumption before the matching process of finding the optimal consumption scheduling.
The open contract price has to be higher than the closed contract price, otherwise the consumer shall not be motivated to transfer their consumption to the closed contract.

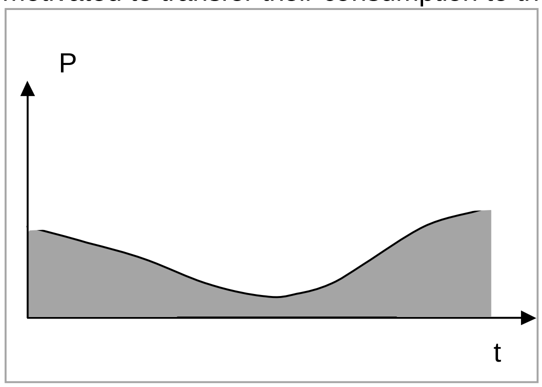


**Figure 48: The example of open contract forecast for a group of consumers**

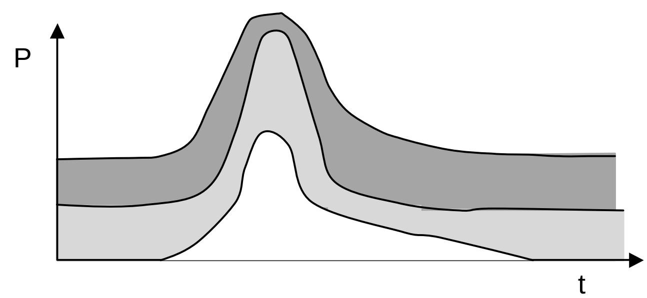


**Figure 49: Aggregation of the open contract forecast and consumption of the sample in the Figure 39**

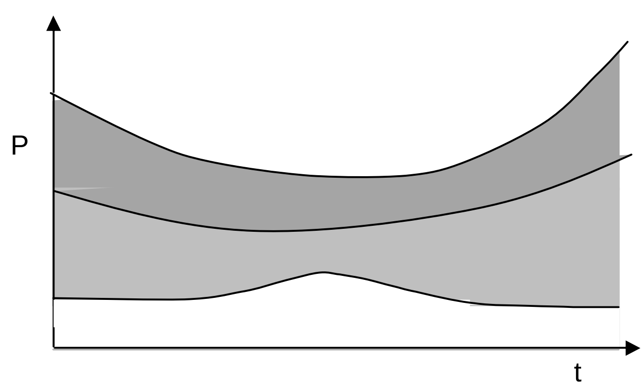


**Figure 50: Aggregation of the open contract forecast and consumption of the sample in the Figure 40**

**Disaggregation**
The disaggregation for the producer is the same as at balance group use case 1.
At the de aggregation for the consumer the open contract part is not relevant and must be subtracted before sending to the schedule to the consumer.

#### 5.4.3.5 Role model

As a result of the use case balance group 2 the role model involves the following roles

- Producer,
- Consumer,
- Balance responsible party
- Balance supplier

In addition the following roles are involved as a boundary

- Metered data responsible
- Imbalance settlement responsible
- System operator

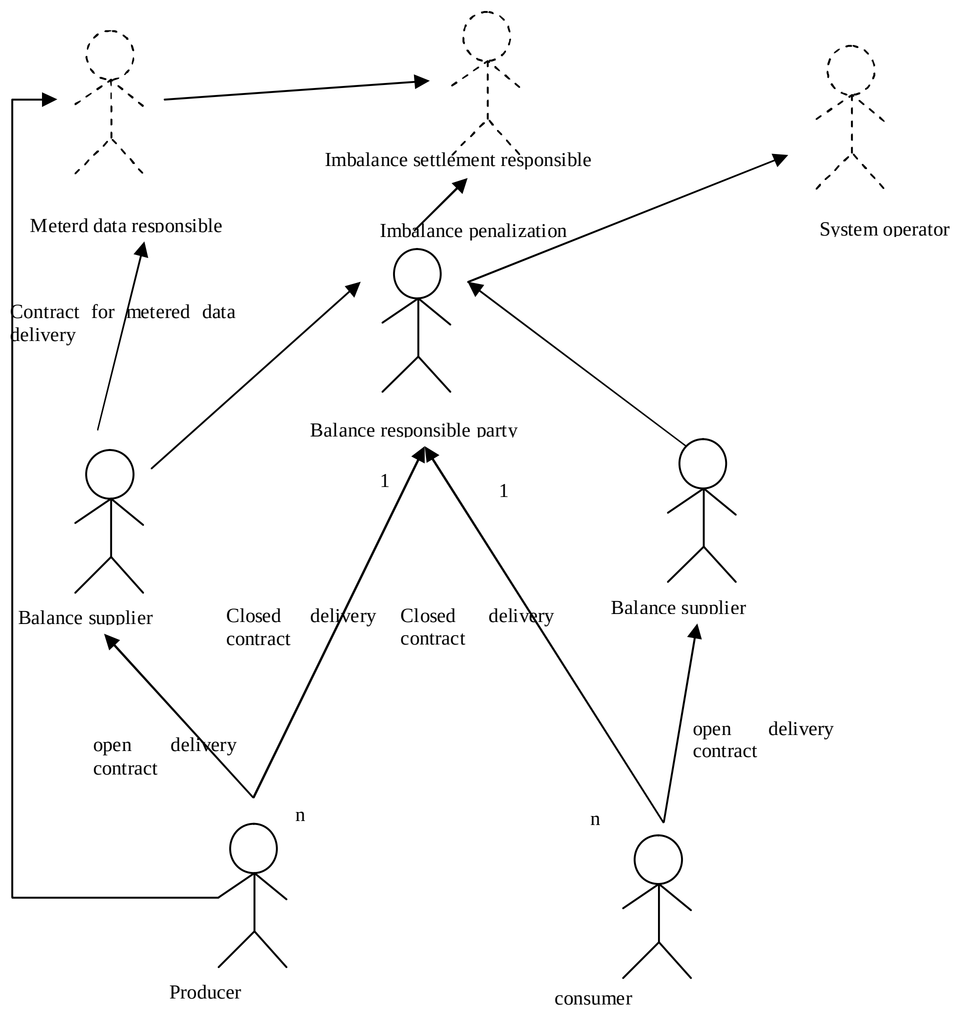


**Figure 51: Miracle role model base on the balance group use case 2**

### 5.4.4 Balance group use case 3: External energy sale process

Additionally to the balance group use case 2 at BG use case 3 the balance group is not isolated but is capable to provide trading and exchange energy with other balance groups. It communicates with the market organizer, which is a central point for the trading among balance groups.
Trading with BRPs in other balance groups enables the BRP to transfer the surplus of production capacities and/or consumption demands on the external market. That enlarges the possibility to make scheduling for the exceeded capacities of the energy which was scheduled in the BG use case 2. This scenario 3 concerns the view of Energy market on the level above BG, but we are interested in it only from the point of view of processes in the roles within BG.
The balance group use case 3 tries to represent how the Miracle approach with micro-requests faces the trading with other parties.

#### 5.4.4.1 System description

The BG use case 3 in addition to the use case 2 introduces:

- Market operator is a role which organizes the trading among the BRPs
- Market balance area is a domain controlled by the market operator.

The market operator defines the trading products, trading time and other rules connected with trading. In this document the exchange market with one hour energy packet as a product shall be used as a background system.

#### 5.4.4.2 External energy sale process

Additionally to the balance group use case 2 the use case 3 contains a market operator which collects the production and consumption offers from all the BRPs in the market balance area. In this use case it is assumed that the market type is the exchange market with the one hour electric energy product.

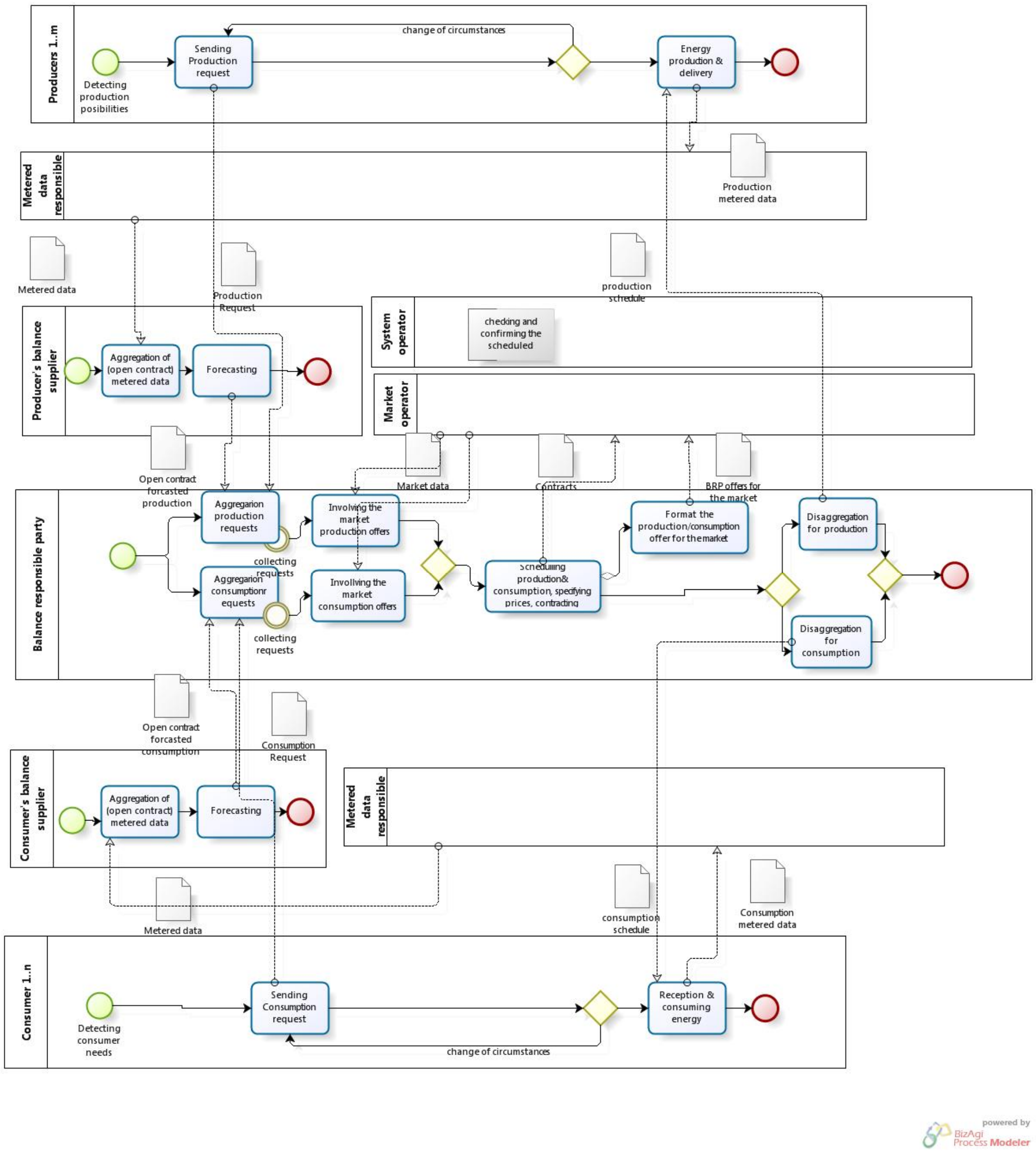


**Figure 52: BPMN diagram for BG use case 3 – external trading**

The market information about the production/consumption prices should improve the exploitation of the energy sources (RES). Describing the process one may take an example of the two balance groups, where one has the RES only and the other consumers on closed contracts. The first BG needs to sell the energy on the external market. It will form the production offer according to the weather forecast. The second group needs to buy the energy on the external market. It will reschedule the consumption to follow the external market lowest price what should be close to the production schedule (production prognoses).
The problem occurs when the weather forecast changes and there is no production foreseen, while the energy is already sold:

- The BRP of the first BG should buy the electricity on the external market to fulfill the contract obligation. This price should be lower than the imbalance penalties
- The BRP of the second BG should recognize the market opportunity by selling the energy bought from the first BRP on the market for a high price, reschedule its consumption on the time period, when the electricity is foreseen to be cheaper and buy corresponding energy.

The problem occurs also in the reversal situation when no RES energy was foreseen initially and the BRP of the second BG has bought the energy from the classical sources. Then suddenly the forecast changes and the cheap RES electricity is foreseen:

- The BRP of the second BG should recognize the market opportunity to sell the contracted energy from classical sources, reschedule the consumption and buy the unexpected energy from RES. It must take care to make a profit even it is not capable to sell the energy and pay penalties.
- The BRP should of the first BG should stop the RES production if it is not capable to sell the energy

It is clear that the market rules may not guarantee that the RES electricity shall be exploited in the optimal way. Penalization of the market imbalance (the BRP buys the energy, but it does not resale it or consume it) is the key factor. If it is too high, the market is not flexible and sudden energy violation in production are not absorbed.

#### 5.4.4.3 Messages

In this subsection only messages which are different or new compared to the balance group use case 2 are presented.

**Market data**
The BRP takes the market data into account during the matching the production-consumption process. The market data contains the price and the offered amount of the energy on both – production and consumption – sides.

**Contracts**
If the market offers are included into the matching process, the resulting contracts are sent to the market operator. The contracts must contain the identification of the offers, which are not relevant for the market

**BRP Offers**
BRP shall decide which part of its capacities and demand offers shall be offered to the exchange market. The offer must be put in the form of the market selling products (i.e. one hour packet of energy).

#### 5.4.4.4 Unit Processes

In this chapter only processes which are different or new compared to the balance group use case 2 are presented.

**Aggregation**
The market data are included onto the iteration process to find the optimal consumption scheduling. The market data are included as:

- a (virtual) production unit maximal capacity on the production side
- an aggregated open contract consumption on the consumption side

The aggregation and later matching is provided in the same way as in balance group use case 2.

**Contracting**
In contrast to internal trading, the external market offers must be contracted for a longer period than only for the “no request period”. The contracted energy must be omitted from the market offers, otherwise the production/consumption capacity of the market balance area is not clear.

**Exporting offers to the external market**
The BRP shall send the following offers to the external market:

- surplus of the production/consumption capacities
- a part of the unscheduled production capacities –depends on the market price and BRP policy
- a part of the unscheduled consumption capacities –depends on the market price and BRP policy

#### 5.4.4.5 Role model

As a result of the use case balance group 3 the role model involves the following roles:

- Producer,
- Consumer,
- Balance responsible party
- Balance supplier

In addition the following roles are involved as a boundary:

- Metered data responsible
- Imbalance settlement responsible
- System operator
- Market operator

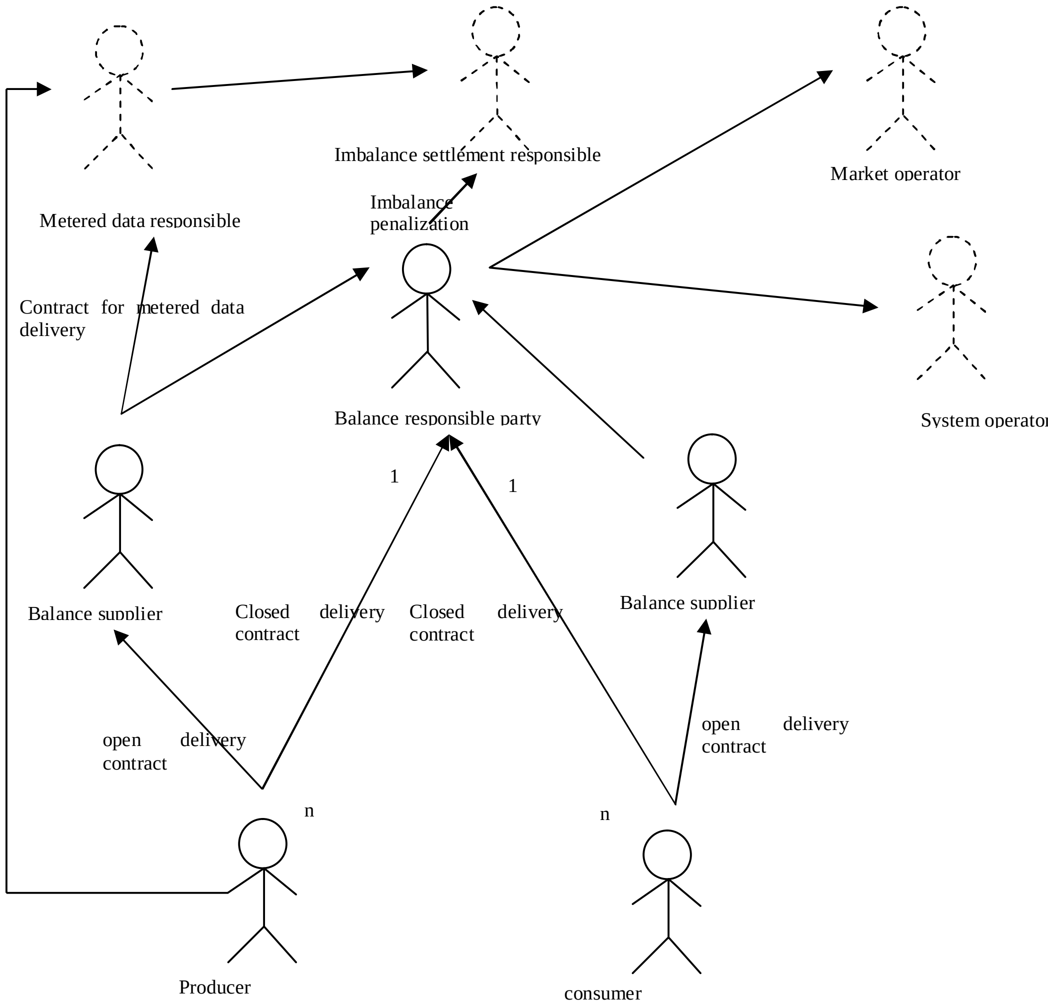


**Figure 53: Miracle role model base on the balance group use case 3**

### 5.4.5 Market Area Use case, structured into 3 scenarios (sub cases)

This use case shall not be analyzed in the draft version of the document but rather in the final version.

## 5.5 Miracle Role model

The primary goal of Miracle role model is to make it suitable for largest possible market. With the advent of the Harmonized model of the Electricity market in Europe, the task of defining the Miracle role model is facilitated, since the harmonization process under way is striving towards coherent union of national markets on pan-European level.
The Miracle role model is therefore limited to identifying those parts of the complete Harmonized role model which participate in carrying out or interacting with the primary processes as defined and used by Miracle. Thus, the Miracle role model is defined by the following main conventions and boundary conditions:

i) The relation of Miracle System components and systems to categories of Harmonized market model

Inspection of the Harmonized role model documents [ETSO09] shows that the following relations hold between these categories

- system components in Miracle = roles in Harmonized model
- subsystems in Miracle = domains in Harmonized model

ii) Identification of roles used in Use cases
As already discussed, these roles fall into two categories:
1. Roles carrying out primary processes: Intra BG, intra MBA
2. Roles carrying out primary process in MA, if they directly interact/communicate with roles in the paragraph 1 above
3. Roles carrying out joint and supportive processes if they directly interact/communicate with roles in the paragraph 1 above

iii) In some cases the Harmonized model allows for further structuring of roles functions by defining a set of new roles which are "a kind of" the original "envelope" or generic role. In these cases, the Miracle model will use the generic role unless the finely structured functionality is deemed necessary for modeling the processes in Miracle. An example of such generic role is Trade responsible Party with further possible structuring into Trade responsible party, Consumption responsible party, Production responsible party and Interconnection responsible party.
This "integration" is principle suitable for roles in joint & supportive processes, which we do not model, but in some case also for primary processes.

iv) Conversely, in some cases the roles in the Harmonized model might be too generic for the purpose of developing the Miracle technology. In such cases a part of the functions of the role can be modeled separately as an additional role within Miracle. Such a role will functionally always be a sub-role of the original role in the Harmonized model.

In the following subsections, the Miracle roles will be defined for each primary subsystem:

- Balance Group, as use case
- Market Balance Area, as use case
- Market Area; for this subsystem only in the extent that these roles participate in the other two primary subsystems.

### 5.5.1 Roles involved in the Balance Group use case:

The roles inside BG carry out the primary process, structured into unit processes and interact with the processes in the environment of the BG carried out by the neighbouring roles.
For the Balance group use cases, the roles which participate in the processes, and the subsystem of the Electricity market system which they are part of, are presented in Table 17.

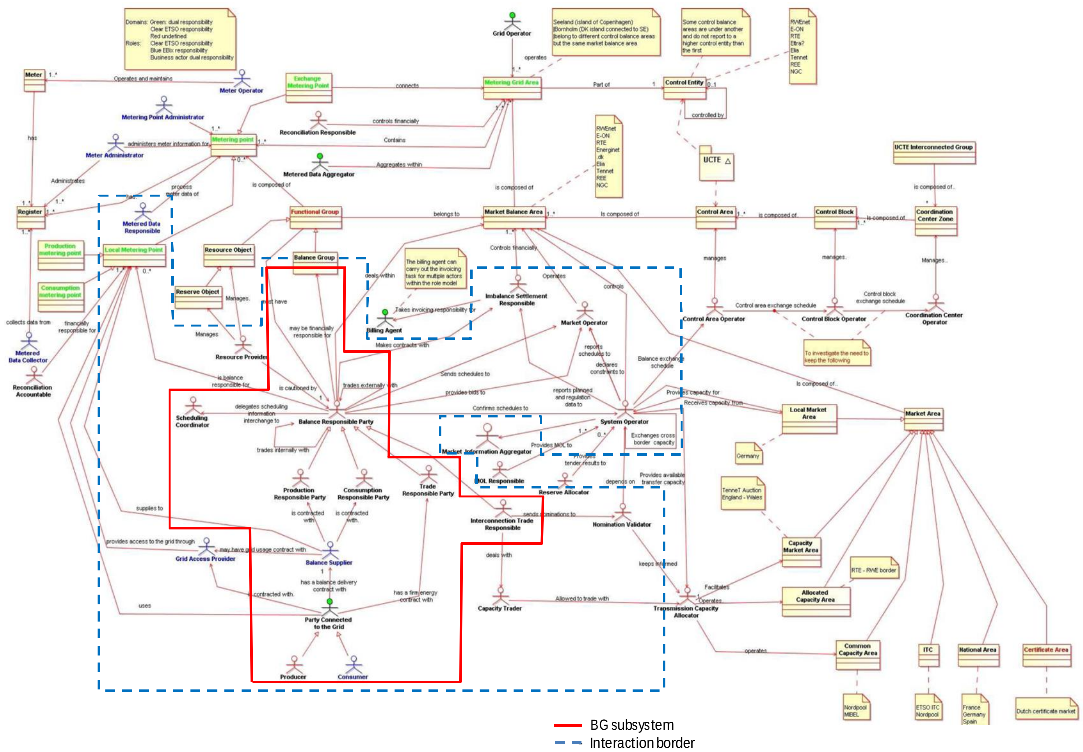


**Figure 54: Delineation of the Balance Group subsystem and its interaction border with the surrounding part of the Electricity Market of the Harmonized market model**

| Subsystem (domain) | Type of subsystem | Role | Note |
|---|---|---|---|
| Balance Group | Primary | Consumer | |
| Balance Group | Primary | Producer | |
| Balance Group | Primary | Balance supplier | |
| Balance Group | Primary | Balance responsible party (BRP) | |
| Balance Group | Primary | Settlement responsible | Miracle role, sub role of BRP |
| Market Balance Area | Primary | Market operator | |
| Market Balance Area | Primary | Imbalance Settlement responsible | |
| Control Area, Market Balance Area | Joint & supportive | System operator | |
| Local Metering Point | Joint & supportive | Metered data responsible | |

**Table 17: Roles participating in the Balance group use cases and their domains**

### 5.5.2 Roles involved in the Market Balance Area use case

The roles inside Market Balance Area (MBA) carry out the primary process, structured into unit processes and interact with the processes in the environment of the MBA carried out by the neighboring roles.

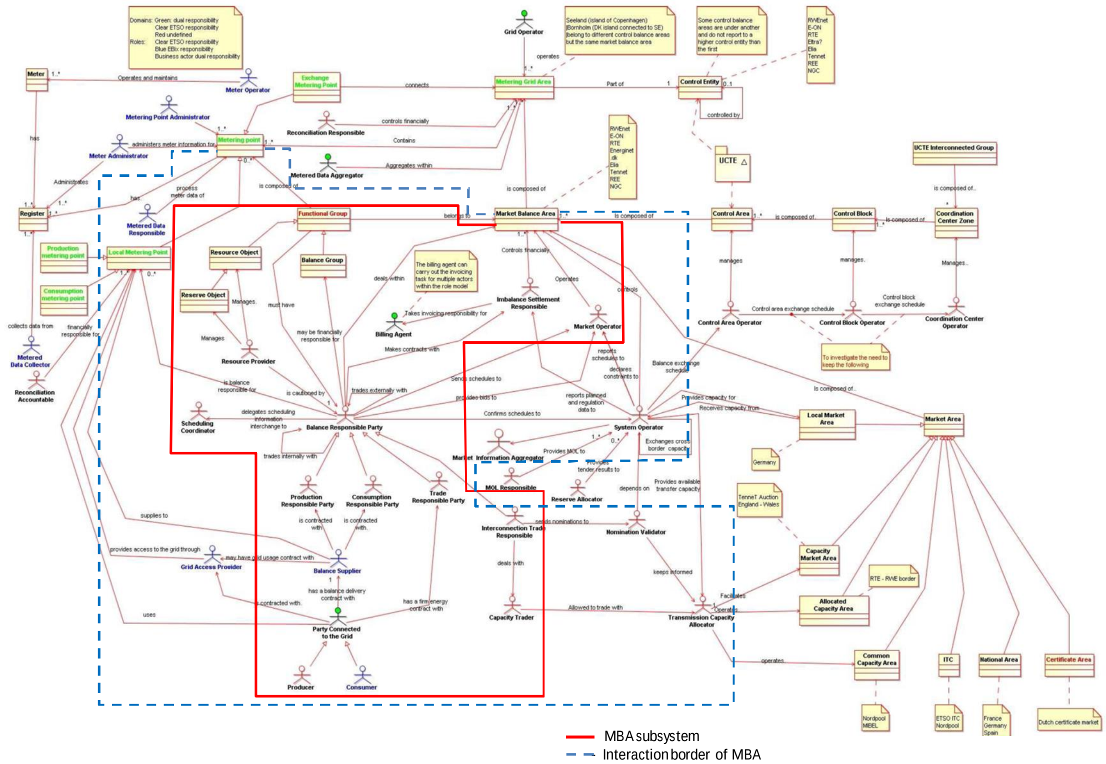


**Figure 55: Delineation of the Market Balance Area subsystem and its interaction border with the surrounding part of the Electricity Market of the Harmonized market model**

In the Figure 55 above, it can be noticed that the roles and domains of the Reserve Resource Process System are delineated from the MBA use cases. This system is part of the Market Balance Area and in it there is an electricity market process carried out, but it is a separate process organized by TSO for the purpose of maintaining the grid reserves and apart from the mainstream market processes taking place between BPR's. Presently, it is felt that the Miracle model will not be applicable for this market (secondary market); it would have to be modeled as a separate use case, which does not seem to be justifiable. For the Market Balance Area use cases, the roles which participate in the processes, and the subsystem of the Electricity market system which they are part of, are presented in Table 18.

| Subsystem (domain) | Type of subsystem | Role | Note |
|---|---|---|---|
| Balance Group | Primary | Balance responsible party (BRP) | |
| Market Balance Area | Primary | Market operator | |

| | | | |
|---|---|---|---|
| Market Balance Area | Primary | Imbalance Settlement responsible | |
| Market Balance Area | Primary | Capacity Trader | |
| Control Area, Market Balance Area | Joint & supportive | System operator | |
| Control Area | Joint & supportive | Control Area Operator | |
| Metering Point | Joint & supportive | Metered data responsible | |
| Market Area (Common Capacity Area, Allocated Capacity Area, Capacity Market Area) | Primary | Nomination validator | |
| Market Area (with variants) | Primary | Capacity trader | |

**Table 18: Roles participating in the Market Balance Area use cases and their domains**

### 5.5.3 Roles involved in Market Area

This level of the Electrical Energy Market is not yet harmonized in the Harmonized model: specific types of MA's are recognized and the trading process is not completely developed. For this reason, this level is not fully addressed by the Miracle roles & processes model and we do not analyze it in a separate use case; only roles interacting in MBA use case are considered.

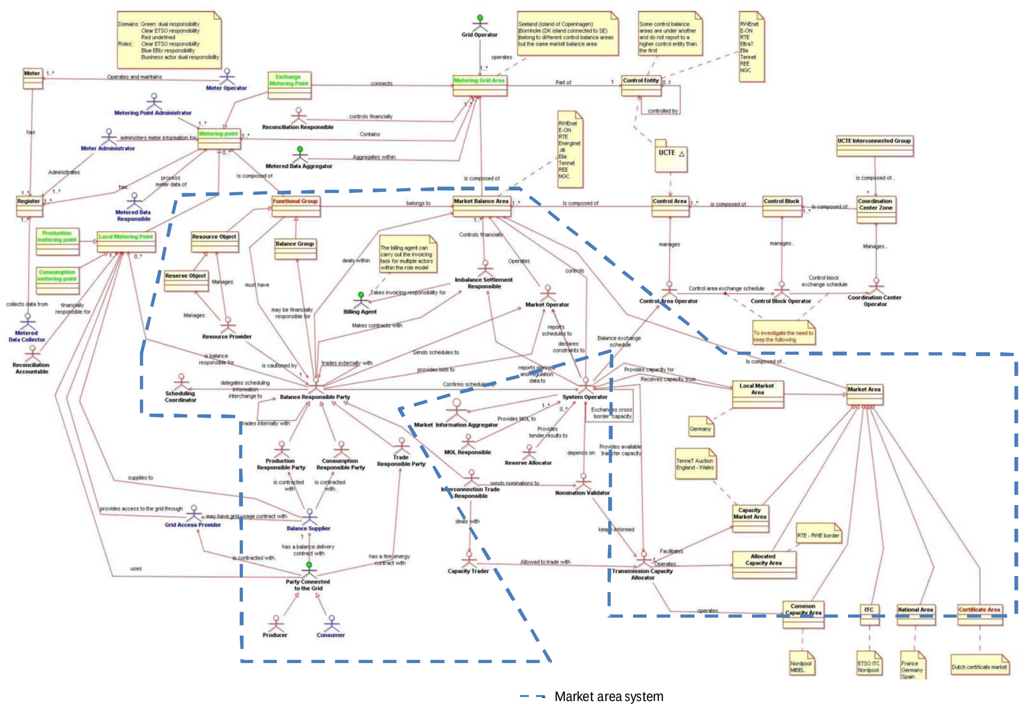


**Figure 56: Delineation of the Market Area subsystem in the Electricity Market of the Harmonized market model**

| Subsystem (domain) | Type of subsystem | Role | Note |
|---|---|---|---|
| Market Balance Area | Primary | Market operator | |
| Market Balance Area | Primary | Imbalance Settlement responsible | |
| Market Balance Area | Primary | Capacity Trader | |
| Control Area, Market Balance Area | Joint & supportive | System operator | |
| Control Area | Joint & supportive | Control Area Operator | |
| Metering Grid Area Point | Joint & supportive | Reconciliation responsible | |
| Metering Grid Area Point | Joint & supportive | Metered Data Aggregator | |
| Market Area (Common Capacity Area, Allocated Capacity Area, Capacity Market Area) | Primary | Nomination validator | |
| (Local) Market Area (with variants) | Primary | Capacity trader | |

**Table 19: For the Market Balance Area processes, typically the following roles participate**

As already mentioned, this subsystem is not yet sufficiently harmonized to model it with the same process model as the previous two subsystems; what is more, it is functionally incomplete as a primary subsystem in terms of intended Miracle technology. For these reasons, it is not included in the use case scenarios; the roles of this system are important only insofar as they represent the interacting environment of the Market Balance Area subsystem.

### 5.5.4 List of roles and domains in Miracle model

The complete list of the roles and domains involved in the three primary subsystems, as described in the previous subsections, constitutes the roles and domains of the Miracle model. As already described in Section 5.1.3, the domains in the Harmonized model represent subsystems of the Electricity market system. The complete list of these roles is presented in Table 20, and the list of domains in the Table 21. For comparison, both the description of their functions in the Harmonized model [ETSO09] and additional description of their functionality in terms of processes carried out within the scope of Miracle are included.

| Roles | | |
|---|---|---|
| **Role name** | **Description** | |
| | **The Harmonized Electricity Market Role Model** | **Additional Miracle** |
| Balance Responsible Party | A party that has a contract proving financial security and identifying balance responsibility with the imbalance settlement responsible of the market balance | Responsible role for closed contract trading (intra-BG) is the Balance responsible Party. BRP is also responsible for external (inter-BG) energy trading, i.e. |

| | | |
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| | area entitling the party to operate in the market. This is the only role allowing a party to buy or sell energy on a wholesale level.<br>***Additional information:***<br>The meaning of the word "balance" in this context signifies that that the quantity contracted to provide or to consume must be equal to the quantity really provided or consumed. Such a party is often owned by a number of market players.<br>Equivalent to "Program responsible party" in the Netherlands. Equivalent to "Balance responsible group" in Germany.<br>Equivalent to "market agent" in Spain. | wholesale trading for the BG. |
| Balance Supplier | A party that markets the difference between actual metered energy consumption and the energy bought with firm energy contracts by the party connected to the grid. In addition the balance supplier markets any difference with the firm energy contract (of the party connected to the grid) and the metered production.<br>***Additional information:***<br>There is only one balance supplier for each metering point. | Balance Supplier buys/sells the necessary energy of the prosumers on open contracts. The necessary energy is sold to/bought from balance responsible party. |
| Billing Agent | The party responsible for invoicing a concerned party.<br>***Note:***<br>This role has been introduced into the role model in order to underline the fact that the Imbalance settlement responsible has not the responsibility to invoice. However this role is not specific to the settlement process and may be used in other processes as required. | |
| Consumer | A party that consumes electricity.<br>***Additional information:***<br>This is a Type of Party Connected to the Grid | |
| Consumption Responsible Party | A party who can be brought to rights, legally and financially, for any imbalance between energy bought and consumed for all associated metering points.<br>***Additional information:***<br>This is a type of Balance Responsible Party | This role is not modeled separately from BRP in Miracle, but it is useful for proper structuring of unit processes performed by BRP |
| Control Block Operator | Responsible for :<br>1. The coordination of exchanges between its associated control blocks and the organisation of the coordination of exchange programs between its related control areas.<br>2. The load frequency control within its | |

| | | |
|---|---|---|
| | own block and ensuring that its control areas respect their obligations in respect to load frequency control and time deviation.<br>3. The organisation of the settlement and/or compensation between its control areas. | |
| Coordination Center Operator | Responsible for :<br>1. The coordination of exchange programs between its related control blocks and for the exchanges between its associated coordination center zones.<br>2. Ensuring that its control blocks respect their obligations in respect to load frequency control.<br>3. Calculating the time deviation in cooperation with the associated coordination centers.<br>4. Carrying out the settlement and/or compensation between its control blocks and against the other coordination center zones. | |
| Grid Access Provider | A party responsible for providing access to the grid through a local metering point and its use for energy consumption or production to the party connected to the grid. | |
| Grid Operator | A party that operates one or more grids. | |
| Imbalance Settlement Responsible | A party that is responsible for settlement of the difference between the contracted quantities and the realised quantities of energy products for the balance responsible parties in a market balance area. | |
| Interconnection Trade Responsible | Is a Balance Responsible Party or depends on one. He is recognised by the Nomination Validator for the nomination of already allocated capacity.<br>***Additional information:*** A party that is responsible for settlement of the difference between the contracted quantities and the realised quantities of energy products for the balance responsible parties in a market balance area.<br>This is a type of Balance Responsible Party | This role is not modeled separately from BRP in Miracle, but it is useful for proper structuring of unit processes performed by BRP |
| Market Operator | The unique power exchange of trades for the actual delivery of energy that receives the bids from the Balance Responsible Parties that have a contract to bid. The market operator determines the market energy price for the market balance area after applying technical | |

| | | |
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| | constraints from the system operator. It may also establish the price for the reconciliation within a metering grid area. | |
| Meter Administrator | A party responsible for keeping a database of meters. | |
| Meter Operator | A party responsible for installing, maintaining, testing, certifying and decommissioning physical meters. | |
| Metered Data Collector | A party responsible for meter reading and quality control of the reading | |
| Metered Data Aggregator | A party responsible for the establishment and qualification of metered data from the Metered data responsible. This data is aggregated according to a defined set of market rules | |
| Metering Point Administrator | A party responsible for registering the parties linked to the metering points in a grid area and its technical specification. He is responsible for creating and terminating metering points. | |
| Nomination Validator | Has the responsibility of ensuring that all capacity nominated is within the allowed limits and confirming all valid nominations to all involved parties. He informs the Interconnection Trade Responsible of the maximum nominated capacity allowed. Depending on market rules for a given interconnection the corresponding System Operators may appoint one Nomination Validator. | |
| Party Connected to the Grid | A party that contracts for the right to consume or produce electricity at a metering point. | |
| Producer | A party that produces electricity | |
| Production Responsible Party | A party who can be brought to rights, legally and financially, for any imbalance between energy sold and produced for all associated metering points. | This role is not modeled separately from BRP in Miracle, but it is useful for proper structuring of unit processes performed by BRP |
| Reconciliation Accountable | A party that is financially accountable for t | . |
| Reconciliation Responsible | A party that is responsible for reconciling, within a Metering grid area, the volumes used in the imbalance settlement process for profiled metering points and the actual metered quantities. | |
| Resource Provider | A role that manages a resource object and provides the schedules for it | |
| Scheduling Coordinator | A party that is responsible for the schedule information and its exchange on behalf of a balance responsible party. For example in the Polish market a Scheduling Coordinator is responsible for information interchange for scheduling | |

| | | |
|---|---|---|
| | and settlement. | |
| Settlement Responsible | N/A | The imbalance settlement in BG for consumers and producers (and Balance suppliers) is carried out by BRP – Settlement responsible. In Miracle, we model it as a separate role (sub-role of BRP) |
| System Operator | organisation of physical balance) through a transmission grid in a geographical area. The SO will also determine and be responsible for cross border capacity and exchanges. If necessary he may reduce allocated capacity to ensure operational stability.<br>Transmission as mentioned above means "the transport of electricity on the extra high or high voltage network with a view to its delivery to final customers or to distributors. Operation of transmission includes as well the tasks of system operation concerning its management of energy flows, reliability of the system and availability of all necessary system services." (definition taken from the UCTE Operation handbook Glossary). | |
| Trade Responsible Party | A party who can be brought to rights, legally and financially, for any imbalance between energy bought and consumed for all associated metering points.<br>***Note:***<br>A power exchange without any privileged responsibilities acts as a Trade Responsible Party. | This role is not modeled separately from BRP in Miracle, but it is useful for proper structuring of unit processes performed by BRP |

**Table 20: Roles in Miracle model**

| **Domains (subsystems)** | | |
|---|---|---|
| **Domain (subsystem) name** | **Description** | |
| | **The Harmonized Electricity Market Role Model** | **Additional Miracle** |
| Allocated Capacity Area | A market area where the transmission capacity between the balance areas is given to the balance responsible parties according to rules carried out by a transmission capacity allocator. Trade between balance areas is carried out on a bilateral or unilateral basis.<br>***Additional information:***<br>This is a type of Market Area | |
| Balance Group | A collection of metering points for imbalance settlement | 1st level primary subsystem of electricity market system |

| | | |
|---|---|---|
| | ***Note:***<br>Equivalent to "balance group" (Bilanzgruppe) in the Austrian market or<br>(Bilanzkreis) in the German market<br>German definition: It is composed of a various number of metering points within a Market balance area.<br>***Additional information:***<br>This is a type of Functional group | |
| Capacity Market Area | A market area where the transmission capacity between the balance areas is given to the balance responsible parties in a price based process separated<br>from trading carried out by a transmission capacity allocator. Trade between<br>balance areas is carried out on a bilateral unilateral basis.<br>***For example,***<br>The auctioning system between TenneT and RWE Net.<br>***Additional information:***<br>This is a type of Market Area | |
| Common Capacity Area | A market area where the available transmission capacity between the balance<br>areas is given to the balance responsible parties based on their bidding to the<br>market operator.<br>Trade between balance areas is carried out through the market operator.<br>***Additional information:***<br>This is a type of Market Area | |
| Control Area | The composition of one or more market balance areas under the same technical load frequency control responsibility<br>***Note:***<br>In some cases there may be some metering points that belong to a market<br>balance area that is not a part of the control area. However these do not impact<br>the general definition, for example, a village in one country connected to the grid of another. | Joint subsystem, not modeled by Miracle, but interacting |
| Local Metering Point | The smallest entity for which there is a balance responsibility and where a Balance supplier change can take place. It may be a physical or a logical point. | Supportive subsystem, not modeled by Miracle but interacting |

| | | |
|---|---|---|
| | ***Additional information:***<br>This is a type of Metering Point. | |
| Local Market Area | A market area where there is no transmission capacity restrictions between the<br>balance areas.<br>***Additional information:***<br>This is a type of Market Area | |
| Market Area | An area made up of several balance areas interconnected through AC or DC<br>links. Trade is allowed between different balance areas with common market<br>rules for trading across the interconnection. | 3rd level primary subsystem of the electricity market system (incomplete) |
| Market Balance Area | A geographic area consisting of one or more metering grid areas with common<br>market rules for which the settlement responsible party carries out a balance<br>settlement and which has the same price for imbalance. A market balance area<br>may also be defined due to bottlenecks | 2nd level primary subsystem of electricity market system |
| Metering Grid Area | A metering grid area is a physical area where consumption, production and exchange can be metered. It is delimited by the placement of meters for period<br>measurement for input to, and withdrawal from the area. It can be used to<br>establish the sum of consumption and production with no period measurement<br>and network losses. | Joint subsystem not modeled by Miracle but interacting |
| Metering Point | Metering Poin | Supportive subsystem not modeled by Miracle but interacting |

**Table 21: Domains in Miracle model**

The list of roles and their functions in the context of Miracle roles and processes model is tentative, at the phase of model draft. The additional description of their functions within the context of Miracle role and process model and the final list of roles will be arrived at through completion of the use case analysis and refinement of process modeling concepts.

## 5.6 Miracle Role model and Correspondence with current role models in selected countries

From the point of view of application value of the Miracle technology to be developed, a relation of the Miracle roles and processes model to the real situation in individual markets is not relevant.

However, the present organizational structure of actual national electricity markets is temporary: it is in transformation with the objective to harmonize to the extent possible with the Harmonized role model. By the time the Miracle technology is developed, it will further change. For this reason, its present state cannot be taken as relevant for applicability of Miracle solutions in 3 years. For this purpose, the only relevant reference is the Harmonized role model, with the limitation that it is also evolving and will also have changed during the time of development of Miracle. The assumption here is, that the major changes will occur on the upper level of the electricity market and that the lower levels will not change appreciably; and that the Miracle roles and processes model based on decomposition of the electricity market will be robust enough to handle the expected changes.

The one purpose, for which the comparison between the actual national role model and the Miracle role model is beneficial, is carrying out the trial cases of the developed technology. This will be done in Germany (TSO and LDE trial cases) and in Greece (household); of these, the TSO and LDE are especially nested in the environment market structure. For this reason, this comparison will be performed for Germany and the evolution of the actual market organization monitored through the course of the project. For the same reason, it will be performed at a later stage, and included in the final roles and processes model.

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