# D6.3 – Energy brokerage module

*Support energy exchange in campus, neighbourhood or district.*

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*Publication date:*
2014

*Document Version*
Publisher's PDF, also known as Version of record

# ENCOURAGE

**Embedded iNtelligent COntrols for bUildings with Renewable generAtion and storaGE**

**Grant Agreement No.: 269354**

## D6.3 – Energy brokerage module

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| **Document Number** | D6.3 |
| **Document Title** | Energy brokerage module |
| **Version** | 1.0 |
| **Status** | Final |
| **Work Package** | WP6 |
| **Deliverable Type** | Report/Prototype |
| **Contractual Date of Delivery** | M28 |
| **Actual Date of Delivery** | M28 – 27 September 2013 |
| **Responsible Unit** | AAU (task leader) |
| **Contributors** | AAU, ATOS, GNERA, ISA, ENORD, ENEL |
| **Keyword List** | Support energy exchange in campus, neighbourhood or district. |
| **Dissemination level** | CO |

# Amendment History

| Version | Date | Author (Unit) | Description |
|---|---|---|---|
| 0.1 | 08/02/2012 | AAU | Initial Draft – Task roles |
| 0.2 | 25/05/2012 | AAU | Table of contents. |
| 0.3 | 13/06/2012 | AAU, GNERA, ISA, ENORD, ENEL | Description of the laws and regulations in the European countries. |
| 0.4 | 01/11/2012 | AAU, GNERA | Energy brokerage at utility level. |
| 0.5 | 15/08/2013 | AAU | The energy brokerage module. |
| 0.6 | 12/09/2013 | AAU | Internal revision. |
| 1.0 | 27/09/2013 | AAU | Final check and formatting |

# Executive Summary

The aim of this task is to develop an energy trading module that will enable building to sell or buy electrical energy from other buildings in given campus, neighbourhood, or district. The decision making process will be supported by considering own generation capacity (both current and future levels), forecasted future electricity consumption in the building, the degree of matching between generation and consumption, the current status of the local electricity market. The decision support module will be interfaced with the building energy management system.

Partners: AAU, ATOS, GNERA, ISA, ENORD, ENEL

# Table of Contents

# 1. Introduction

## 1.1 Requirements from D2.2 and D2.3

Based on the requirement from D2.2 the following functionalities for the energy trading module can be defined:

The system shall allow the system to make localized decision on energy brokerage. (EZM.1.1.46).

The system shall support trade of energy in the local area so that the surplus of energy is used in the local area. (ENO1.1.44). This trade of energy between local producers and local consumers shall be based on local energy prices and timing constrains. To enable this, the energy trading module, shall manage local tariff and by that mean energy brokerage between producers and consumers. (EZM.1.1.27, EZM.1.1.37).

The utility's tariffs schemes is an important part of the local energy trading system, in such a way that the price level from the utility's must reflect the local prices, in other words the Encourage system must provide energy management strategies which enable the customer to comply with utility's tariffs schemes.

## 1.2 The functionality of the module

The energy trading module shall facilitate the implementation of the required local energy marked. This means that this module shall provide the user in a macrocell with the necessary tools for making local energy trade. Here the macrocell is defined as a number of cell that trading energy with each other. The system shall be an automatic trading system. This means that the energy trade should be governed by some pre-defined constraints set by the user.

The local trade marked can be based on different market ideas:

- The liberal market. Here the surplus of energy is put to sale on the local market and sold to the one that will pay the most. If the energy can't be sold locally then the price will be defined by the utilities. This market could be based on auction.
- Constrained auction. Here the user (the seller or the buyer) set some constrains that should be meet before a deal can be make, otherwise the utilities will define the price.
- Equal benefit. Here the system estimates the profit for the seller and buyer and pick a price that equals these two profits. This of course can be a complicated task to solve because the production cost depends on a number of parameters.
- And maybe more.

The work is divided into these two parts:

1. Describing the existing power trading and distribution system in a number of European countries. Chapter 2, 3 and 4.
2. Based on that design methods for local energy trade. Chapter 5.

# 2. The electrical grid

The electrical power grid, or often pronounced ‘the grid’, is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centres, and distribution lines that connect individual customers. [23]

The grid is normally divided into three different layers:

- National grid
- Regional grid
- Local grid

The nationwide grid (“highways”), are the part of the grid that transports electricity from one area of the country to another. This part of the grid is the high voltage part and operates typically in voltage level 400-100 kV. The large power plants are connected to the national grid.

The regional grids (“county roads”) are the part of the grid that transports power from the national grid up to the local areas distributions grids. This part of the grid is the middle voltage part operates typically in voltage level 130-5 kV. Decentralized power plants, business plants and wind farms typically are connected to the regional grid. Big industrial consumers can have a connection to the regional grid.

The local grids (“local roads”), are the part of the grid that distribute power to the normal consumers. This part is the low voltage net, typically operating at 400 V. Small local PV systems and wind mills are connecter to the local grid.

Within the grid, the activities of transmission and dispatching are subject to very strict technical constraints, such as:

- The need for instantaneously and continuously balancing the volumes of electricity injected into the grid and those withdrawn from the grid, taking into account transmission and distribution losses.
- The need for keeping the frequency and voltage of electricity on the grid within a very narrow range, so as to protect the security of installations.
- The need for ensuring that the power flows on each line do not exceed the maximum admissible transmission capacity (transmission limits) of the same line.

Even minimum deviations from any of the above parameters for more than a few seconds may rapidly trigger critical conditions in the power system. Compliance with these constraints is complicated by the characteristics of the technologies and the procedures through which electricity is generated, transmitted and consumed. In particular, the difficulties originate from three factors:

1. Non-rationale, inelastic and variable demand: demand on the grid has high variability in the short term (on an hourly basis) and in the medium term (on a weekly and seasonal basis);

2. No storage of electricity and dynamic constraints on the real-time adjustment of supply: electricity can be stored in significant amounts only indirectly and, in the case of hydro power plants, through the amount of water contained in the pondages. Other constraints are: power plants have minimum and maximum power output limits, as well as a minimum switching-on and power output adjustment time;
3. Grid externalities: after being injected into the grid, electricity flows through all the available lines. If a local imbalance is not promptly redressed, it will propagate to the overall grid inducing voltage and frequency variations.

The high complexity of grid and the co-ordination needed to guarantee its operation make it imperative to identify a central coordinating entity in charge of monitoring and controlling all the power plants making part of the system. This entity, known as transmission system operators (TSOs), represents the core of the power system and has the task of guaranteeing the continuity and quality of the service under maximum security conditions. The TSO ensures that generation matches consumption at any time and that frequency and voltage do not deviate from optimum values, while satisfying transmission limits on grids and dynamic constraints on power plants.

The TSO normally facilitates the grid controlling through the balance responsible parties (BRP's). This means that the BRP's, hour by hour, have the responsibility for the supply of the same amount of power that is being used by the electricity consumers.

The BRP makes a plan, on an hourly basis, in such a way that the production and purchasing of power correspond to the anticipated consumption and sales of the consumers/suppliers that the BRP has the balance responsibility for, and subsequently to financially regulate balance discrepancies with the control centre.

# 3. The laws and regulations in European countries

## 3.1 Spain

### 3.1.1 Wholesale electricity markets

**Unbundling**
Unbundling was introduced through the Electric Power Law of 1997 (Law 54/1997), which opened Spanish power market to competition. The Spanish regulatory framework already meets the main unbundling requirements established by Directive 2009/72/EC as regards transmission and distribution. The companies that perform regulated activities (system operation, transmission and distribution) cannot participate in production, supply or recharge of electricity (nor can own any kind of share capital in companies performing such activities). However, they are permitted to form part of a group that undertakes other activities - including: power generation, energy recharge services and selling of electricity – provided that a separate company performs the regulated activities with real separation at decision-making level (legal and functional unbundling).[6]

**Interconnections integration**
Spanish and Portuguese day-ahead and intraday electricity markets are fully integrated in the MIBEL (*Mercado Ibérico de Electricidad*). When there is congestion in the Portugal-Spain interconnection, the MIBEL is split into two price areas (zone price with market splitting). Convergence in is quite high, for example in 2010 prices in the Spanish area have been equal to those of the Portuguese area for 80% of the hours.[6]

Spain, Portugal and France form the South-West Europe electrical region. The cross-border exchange capacity between Spain and France is still limited, which causes the main congestions in Spain. Integration of day-ahead market with France and therefore with Central West Europe region is being pursued but has still to be improved because of that limited exchange capacity

In general, in Spain (and MIBEL) the price tends to be within the lower range of prices recorded in Europe, although following a similar trend to other European Power Exchange markets.

**Market participants**
The main market participants in Spain are the following:

- **Independent Regulatory Body**: Comisión Nacional de la Energía (CNE)
- **Independent System Operator**: Red Eléctrica de España (REE). Is in charge of the technical management of the system and of the security of supply and owns the transportation lines.

- **Independent Market Operator**: Operador del Mercado Ibérico, Polo Español (OMIE). It is in charge for the operation and settlement of electric energy buying and selling.
- **Distribution System Operators**: Own the distribution lines and distribute the electricity. The three biggest operators cover around 60% of the energy share in the wholesale market [1]. Each one of the five historical operators represents one geographical area in the country.
- **Generators:** Between 2007 and 2009, the main production companies, ENDESA and IBERDROLA were obliged, by law, to release part of their capacity through auction mechanisms (Virtual Power Plants, VPPs).

Market operation of the MIBEL (which, as said before, integrates Spanish and Portuguese markets) is assumed by OMI (Operador del Mercado Ibérico): OMI is constituted by OMIP (Portuguese operator), which operates the forward market and OMIE (Spanish operator), which operates the spot market.

Almost 64% of the energy in the daily programme is traded in the spot market (2010), therefore being still the most representative market. Nevertheless, forward contracts have steadily been increasing since CESUR auctions (see § "Supply of last resort") imposed to distribution companies to acquire part of their energy through these mechanisms. Bilateral contracts represented about 36.1 % of the wholesale market in 2010. [6]

In addition to the bilateral and day-ahead market, all market participants can adjust their positions in the intraday-market, which has six trading sessions per day. In all cases, the market price is established through the rule of the marginal price matching. Market participants are able to adjust their offers in the intraday markets, limiting their deviation costs (see § "Forecasts and deviations management"). This mechanism allows a better management of the grid.

**Forecasts and deviations management**
Once the day ahead market closes, the System Operator (Red Eléctrica de España) studies the feasibility of the despatch and modifies it according to the bids submitted by market participants on the day ahead, the six intra-day markets and the ancillary markets. The price is fixed by a Marginal Price methodology.

The system Operator associates some costs to part of the deviations between offer and production/consumption, but only deviations that enhance the total system imbalances are charged to generators (dual imbalance pricing system).

Renewable electric energy producers are, as all other producers, balancing responsible and are charged for these deviations.

### 2.1.2 Retail electricity markets

In Spain there are about 28 million consumption points with a power <15kW, 95% of which are domestic users. This represents 35% of the total electricity consumption. [6]

The "Supplier Switching Office" (OCSUM) was set up with the aim of monitoring and facilitating supplier switching procedures. Switching periods' deadlines (few days) are regulated.

**Pricing**

CNE has launched a web price comparison tool for gas and electricity offers, publicly available: http://www.comparador.cne.es/comparador/index.cfm?js=1&e=N

Tariff structure in Spain is as follows:

- Social tariff: a regulated, special tariff for "vulnerable" customers or with load <3kW.
- Last resort tariff (regulated tariff): load ≤ 10kW, with or without hourly discrimination (day/night)
- Small customers: load ≤ 15 kW (in practice, includes most of domestic customers): with or without hourly discrimination (day/night)
- Intermediate customers: 15 kW ≤ load ≤ 450 kW, with hourly discrimination in 3 periods
- Large customers: load ≥ 450 kW, with hourly discrimination in 6 periods

**Supply of Last Resort**

Since 1 July 2009, all electricity consumers are formally in the liberalised market. However, there is a last resort tariff available only for consumers with contracted load capacity below or equal to 10 kW. All consumers *over* that capacity that have not changed to a market company are charged a penalization of 20% in 2012, and the change is compulsory before end of 2012 (this is the case for example for many Hall Towns, schools…).

In addition to the access tariff (which is a regulated cost), the price for energy in the last resort tariff is computed by the Government according to CESUR auctions (i.e. Supply of last Resort Energy Contract Auctions), performed regularly (each trimester in 2012).

83% of all electricity consumers (about 27 million consumers) in mainland Spain are supplied by last resort suppliers. In terms of energy, by mid-2010, 31% of all energy retailed in Spain was supplied by last resort suppliers. [6]

Five last resort supply companies (belonging to the big five electricity groups working in Spain) were appointed by the Government, which have the obligation to supply consumers (≤10 kW) that request it. Endesa and Iberdrola cover around 80% of the customers.

**Contracts**

The user signs two different contracts with the chosen electricity supplier and the distribution company.

### 3.1.3 Metering

The distribution system operators are in charge for metering.

For bigger consumers hourly reading is compulsory, whereas for medium or small customers the reading is generally conducted physically by a DSO operator every 2 months (aggregated reading).

The Measurement Equipment Substitution Plan (ITC Order number 3860/2007) establishes the following calendar for introducing smart metering in Spain (for contracted power of less than 15kW):

a) 2008-2010: substitution of 30% of meters of each distribution company
b) 2011-2012: 20%
c) 2013-2015: 20%
d) 2016-2018: 30%

This means that in 2018 all 27 million meters are expected to be changed. Each distribution company (owner of most of the meters) has developed its own substitution plan: for example, Endesa (13 million customers) and Iberdrola (10 million customers) have planned that 100% of their meters will be changed by 2015.

The main possibilities offered by the new smart meters will be:

- To set different types of hourly discrimination
- Active demand response from the user
- Remote reading and managing

All companies will use in their smart grids PLC technology, but two different protocols are being developed[16]:

- Endesa is using the evolution of Telegestore protocol developed by Enel, certified by Meters and More and already operating in Italy.
- Iberdrola and Gas Natural Fenosa use the Prime protocol standard.

The electric companies have to assume the Smart grid investment costs, including meters substitution, but it is expected that the new meters rental costs will increase.

### 3.1.4 Distributed generation

The high development of renewable energies in Spain has led to a huge increase in number of generation points: from some more than 5,000 generation points in 2004 to more than 60,000 in 2011. This has made the system management much more difficult for the System Operator, who has had to adapt the system for a high RES-E integration, including financial incentives for optimal operation of renewable facilities (which are mainly not manageable).

**Self-consumption and net metering**

Self-consumption for grid-connected facilities has been enabled in 2011 through the Royal Decree 1699/2011 (until that moment, self-consumption was only allowed for private isolated facilities). There are nevertheless some limitations:

- a power limitation of 100kW
- a limitation on the number of installed m2 according to the type of building
- self-consumption is considered in the user inner grid, and the generation and consumption incumbents have to be the same (no energy exchange is allowed in this context).

The country is currently (2013) awaiting a new regulation that would specify the application of self-consumption in detail. There has been debate on the introduction of a net metering scheme (expected by the sector). To date, two drafts have been released and in the last one (august 2013) we can stress the following:

- no net metering applies (the balance between energy bought from the grid and self-consumed would be done hourly)
- a new fee would apply to the self-consumer over the energy self-consumed to cover part of the fixed costs of the electricity network
- no selling of surplus electricity is allowed, it has to be sent for free to the grid
- no technology mix is allowed, i.e.: the self-consumer could not install at the same site both wind and FV, for example.
- A compulsory self-consumption installations registry is created. Those installations not complying with this obligation face a huge fine.

The regulation is still at a draft level; so far only technical rules apply (RD 1663/2000).

One important barrier for the development of distributed generation in Spain is the high amount of bureaucracy and administrative procedures for the installation of energy facilities, even at domestic level.

**Retribution for DG producers**

The support instrument for RES-E has been based on Feed-in Tariffs (FiT). Spain has bet on Feed-In tariffs since early 90's, following Germany and becoming a world pioneer and leader in this kind of policy. Nevertheless, after an unexpected boom of FV in 2008 leading to high costs of FiT for the whole retribution system, the retribution for RES-E facilities have been decreasing and in 2012 a new law has enacted the suspension of the premiums for new facilities and in 2013 another law has removed the premiums also for existing facilities. The operational details of this last law are still unknown

To try to "contain" the 2008 boom, a quota and registry for solar plants was introduced in 2008 and a capacity cap with degressive tariffs in 2010. Regulation uncertainty has been a strong barrier against optimal development of RES-E in the country over the last years. For distributed generation, as stated before, another strong barrier is the high amount of administrative procedures even at domestic level.

Until now, FiT applied to the so-called *Special Regime*, which includes all renewables and CHP plants with less than 50 MW. Some technologies could choose between a fixed tariff or a premium paid over hourly market price, including in some cases a cap and floor to prevent from excessive or too low prices (for FV only fixed tariff applies). The Special Regime technologies participate like all other energies to the day-ahead and intraday markets, and this will the only revenue perceived from these technologies from 2013.

Differentiated support levels applied depending on technology, size, age, and other economic incentives for technical improvement (voltage dips, reactive energy, peak/off peak hours…). For FV the highest tariff applied to all facilities smaller than 100kW; in 2010 some incentives were introduced to promote on-roof mounted solar panels.

## 3.2 Germany

### 3.2.1 Wholesale electricity markets

**Market description**

The German electricity market is fully liberalized since 1998, when the EnWG (Energiewirtschaftsgesetz) came into effect. The EnWG governs the grid operation and codifies the negotiated access to the grid.

Germany is the largest and most liquid power market in Europe[9]: the wholesale volume in 2010 amounted to approximately 17 times the actual electricity requirement in Germany. Without taking account of the transactions cleared on the exchange, the over-the counter (OTC) trade volume in 2010 was more than fourteen times greater than the volume traded on the markets (EEX and EPEX Spot). More than half of the wholesale volume was traded over broker platforms and more than a third of the trade volume was accounted for by bilateral transactions between parties.

After German EEX (European Power Exchange) and French Powernext joined their market activities in 2009, the spot market moved to EPEX Spot (which comprise both day-ahead and intraday markets) and Forward market to EEX. In the context of this coupling process, the so called ‘Trilateral Market Coupling’ area (TLC: France, Belgium, Netherlands) has been extended to Germany in 2010, forming the Central West European (CWE) area. The market model applied is zonal pricing with a market coupling mechanism, which means that an area price is calculated for each country, with price convergence when the transmission capacity is sufficient.

Germany is already included in the Nord Pool Spot intraday market[7]: market coupling between EEX and Nord Pool Spot was launched in 2008 as Germany and Denmark were coupled through the EMCC (European Market Coupling Company).

The target is to intensify cooperation between the Nordic countries and the CWE countries to full price coupling in 2012 using a single price coupling algorithm.

**Market participants**

The main actors of the German electricity system are:

- **BNetzA**: Federal Network Agency. It is the German grid regulator. In charge of regulating grid access as well as electricity and gas grid fees.
- **TSOs**: German Transmission System Operators. They provide balancing energy. There are currently four transmission areas, operated by the companies TenneT (formerly E.ON Netz), 50Hertz Transmission (formerly Vattenfall), Amprion (formerly RWE) and EnBW Transportnetze, which act autonomously and independently of each other.

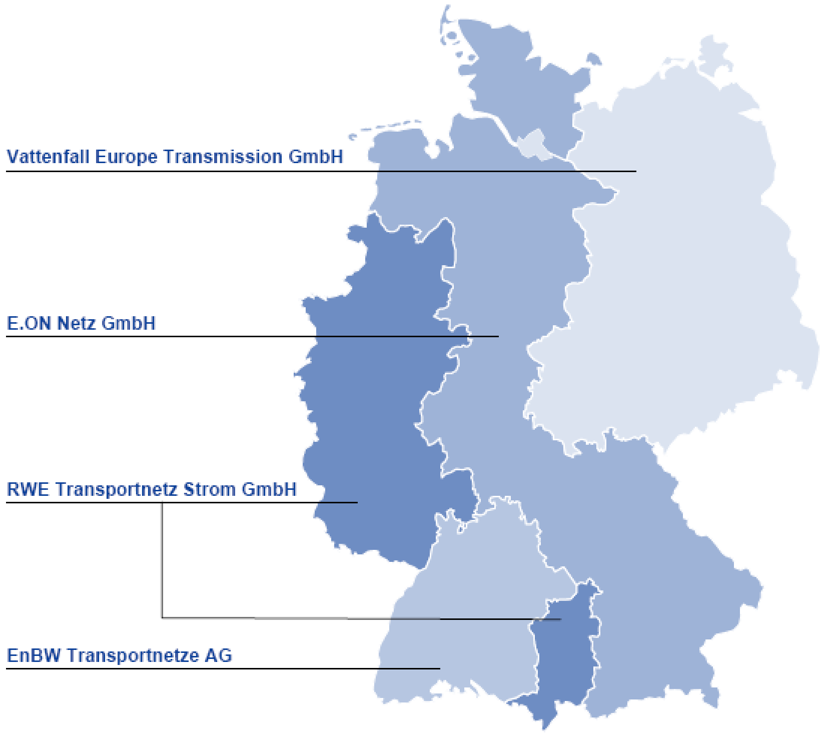



***Figure 1: The main four utilities in Germany.***[1]

[1] Source: http://rwecom.online-report.eu/factbook/en/marketdata/electricity/grid/controlareasingermany.html

- **Utilities**: main four utilities are: E.ON, RWE, Vattenfall, EnBN. In 2010 there were 866 DSOs in Germany, 790 of them having less than 100.000 customers. The 20 largest DSOs have a market share of 55%.

**Structure of generation and consumption sources** [11]
Total final energy consumption in Germany in 2011 was 8,685 PJ, from which 12.2% came from renewable energy sources, mainly biomass. Total electricity generation in 2011 was 121,939GWh, 20% of which was produced by renewable energy sources (46,500 GWh wind , 31,920 biomass, 19,000 PV, 19,500 Hydro). In 2011, installed capacity was 29.075 MW for wind and 24.820 MW for photovoltaic.

After the Fukushima disaster in March 2011, the German government U-turned its stance on nuclear energy and announced it would begin terminating all nuclear plants in the country. This saw the closure of eight facilities in 2011, removing therefore 8.3 GW of capacity. Compensation is being achieved through thermal (non-intermittent), with the construction of new coal-based power plants and renewables (intermittent energy sources).

Germany's National Renewable Energy Action Plan foresees a renewable energy share of 38.6% by 2020. Thus, the shares of electricity generated from renewable sources will more than double between 2010 and 2020. But this increase in renewables has already started, leading to major changes in the energy supply structure (the so called Energiewende). Due to the significant changes in the structure of generation, this increase in renewables also means that more generating capacity is now connected to the distribution systems (82.9 GW) than to the transmission systems (77.6 GW).

**Forecasts and deviations management**
RES-E producers receiving fixed tariffs do not have any balancing responsibility in Germany; instead TSOs is responsible for balancing their output. For RES-E production under the market premium, generators themselves market their production with all obligations that apply to standard market participants (including balancing responsibility). [13].

### 3.2.2 Retail electricity markets

Germany opened the retail markets to competition in 1998. Today around half of all German household customers are still supplied by universal supply, which tends to be the most expensive supply. In addition, universal suppliers are regionally very highly concentrated with little competition in this segment. Approximately 45% of all household customers who switch supplier are acquired by one of Germany's four largest suppliers either directly or via other marketing channels [9].

**Pricing**
Retail prices for electricity are not regulated.

### 3.2.3 Metering

Germany currently uses about 48 million traditional electric meters. Germany has no official policy on the adoption of smart meters.

It is unlikely that Germany will follow the smart meter rollout recommendations of the E.U. because installing the devices, which enable two-way communication between electric power utilities and the end user, would be too expensive.

Following the reform of Germany's Renewable Energy Act in 2011, large-scale consumers are obliged to install smart metering devices. This includes new buildings and those undergoing major renovations, as well as consumers with an annual consumption of more than 6000 kilowatt-hours, about 50 per cent above average annual household consumption. Part of the story behind Germany's delay in smart meter deployment is the special emphasis on data security and interoperability.

### 3.2.4 Distributed generation.

**Retribution for DG producers**
The support scheme for RES-E in Germany has been based until 2012 on a feed-in tariff and is regulated by the "Renewable Energy Sources Act" (EEG) from 2000, last revised in July 2011. A major change by this revision comes into force in 2012 with the introduction of an optional market premium as alternative support besides the feed-in tariff.

The tariffs vary according to energy source, technology and capacity of the installations and underlay fixed annual degression rates. For example, for solar the power categories are: Solar on-buildings places, Solar in-buildings <30 kW, 30 kW < P < 100 kW, 100 kW < P < 1 MW, > 1 MW.

Additional to the fixed tariffs, several bonuses may be paid for certain attributes of the technology used, the fulfilment of sustainability criteria for biomass or for certain energy produced in co-generation. The market premium is defined as the difference between the technology specific feed-in tariff and a benchmark market value plus an additional management bonus for direct marketing [13].

The change of the energy sale option between feed in tariff and direct selling (with a minimum period of one month), and proportional between the different options are allowed.

The costs of the support scheme (both feed-in tariff and optional market premium) in Germany are allocated to the end-consumers via the electricity suppliers, through the so-called EEG Surcharge.

Power generated from renewable sources has zero cost in the market and is given preferential access to the German grid, except in the new model of market Premiums.

**Self-consumption and net metering**

There is an indirect policy incentive for self-consumption of renewable energy (market integration model) through a limitation to fed-in electricity.

Until mid-2012, self-consumption is paid a lower feed-in premium than the standard feed-in tariff for the total renewable kWh production. This premium is higher if self-consumption is more than 30% of production and depends on installed power.

| Self-Consumption Premium and Electricity | | | |
|---|---|---|---|
| Self Consumption | <30 kW | 30 kWp - 100 kW | 100 kW - 500 kW |
| Support | | | |
| > 30 % of production | .1830 | 0.1690 | 0.1543 |
| ≤30 % of production | .1449 | 0.1308 | 0.1161 |
| Equivalent Economic Advantage | | | |
| > 30 % of production | (FiT+0.080) | (FiT+0.080) | (FiT+0.080) |
| ≤30 % of production | (FiT+0.036) | (FiT+0.036) | (FiT+0.036) |

Source: SunPower corporation, 2011

Profitability is therefore guaranteed by the energy savings derived from consumption of self-produced electricity and for the premium received. This remuneration scheme is however limited to systems attached to or on top of a building and up to a capacity of 500kW.

**Direct marketing**

Direct marketing implies that operators of PV installations may sell electricity directly to third parties and it is explicitly fostered by German regulation. Direct marketing has to be announced to the grid operator one month in advance. Self-consumption of PV power is remunerated provided that the third party consumes the electricity within the immediate vicinity of the installation.

**Energy efficiency**

Ambitious standards aim to raise efficiency in buildings. The Energy Saving Ordinance (EnEV) stipulates that from 2012 to 2020 standards for new buildings are to be gradually brought into line with the future European standard for nearly zero-energy buildings, as long as this is economically acceptable. From 2012 all new government buildings will already conform to these standards. [12]

The amendment to the Energy Industry Act (EnWG) strengthens the foundations for smart grids and storage facilities. The latter are essential for integrating fluctuating renewable energies. Therefore, new storage facilities are exempt from the usual grid charges. [12]

## 3.3 France

### 3.3.1 Wholesale electricity markets

The French energy sector has traditionally been dominated by high share of nuclear power, while renewable electricity sources had no significant growth during the last 20 years. Due to the large hydro resources, France started from a substantial share of renewable electricity, which was 14.8 % in 1990 and almost the same (14.9) in 2010 (including big hydro). Nuclear power represents 74.2% of the generation mix (2010), while fossil fuels only account for 10.8%.

**Photovoltaic development [15]**
The annual grid-connected PV power doubled between 2010 and 2011 (going from 817MW to 1,634MW) but the total number of systems decreased by 26 %. This 100 % photovoltaic installation growth in 2011 is mainly due to projects of medium and large power placed on the waiting list for grid-connection before the government's decision to suspend the feed-in tariff policy for three months by end 2010. In March 2011, the Government decided to control the development and financial impact on the CSPE tax (public electricity service contribution) by setting up a system of feed-in tariffs adjustable each quarter for projects of power up to 100 kW and a tendering system for installations of higher power. The development will be more modest in the future since the power capacity will be capped at 500 MW per year over the next few years with a strong emphasis on building integration.

**Market participants**
The French market is characterized by a high degree of concentration and with the incumbents exerting significant market power.

***Producers***
The main energy producers in France are EDF (which exploits 91% of the installed power), GDF-Suez (5%) and E.ON France (3%).[8]

Starting in 2001, after a decision of the European Commission, EDF launched a number of auctions to sell off virtual power plant capacity. Such capacity is currently held by 36 companies, but despite this EdF could maintain its dominant position.

***Transmission System Operator***

The French transmission system operator is RTE (*Réseau de Transport d'Électricité*), a subsidiary of EDF (EDF has historically controlled all generation and transmission activities). RTE was established in 2000 as a result of the unbundling European Directive.

***Distribution System Operators***

The dominating French distribution system operator is ERDF (*Électricité Réseau Distribution France*), being responsible for 95% of the French distribution grid. The remaining 5% are operated by 160 local electricity distribution enterprises. ERDF is 100% controlled by EDF.

***Regulator***

The French regulator is the Commission de Régulation de l'Énergie (CRE).

**Market description**

The French electricity market provides all the main trading options, including bilateral trading and exchange-based trading at the power exchange run by PowerNext. The exchange provides a day-ahead power auction that started in 2001 with hourly prices. In 2009, the French exchange merged with the German EEX and the joint EPEX Spot Auction was launched. There is a central balancing market ("Mécanisme d'ajustement") that is run by the system operator RTE. The French Intraday Market ("Marché infrajournalier") was launched in 2007, also operated by PowerNext.

Most of transactions in the French market are however still made on the counter (OTC), constituted by a direct OTC market (direct bilateral) and an intermediated OTC through the intermediation of brokers.

The high market concentration as well as the high share of bilateral trades has made it difficult to develop sufficient liquidity in the power market and can lead to high and unreasonable prices in the markets available, thus constituting an entrance barrier for renewable electricity sources. [13]

**Forecasts and deviations management**

Under the feed-in scheme, RES-E generators only feed their electricity into the grid whenever it is produced and have neither a scheduling nor a balancing responsibility and there are no incentives or penalties in place for wind generators to meet production forecasts. Plants above 12 MW that are supported under the tender scheme have to submit a production schedule to the TSO for the following day. [13]

### 3.3.2 Retail electricity markets

France opened the retail markets to competition in 2007. Since 01/07/2007, all consumers, including residential customers, can choose their electricity supplier in the free market. At the end of 2010, 35 million of sites were eligible, representing 441 TWh of annual electricity consumption.

The French retail electricity market is highly concentrated and in 2010, still 93.6% of the consumption sites were supplied by the 3 historical suppliers.

**Pricing**
In France, the Ministry of Energy and Economy determines the retail prices based on the regulator's recommendations.

Three types of contract are available for customers:

- Regulated tariffs contracts (only for the historical suppliers)
- Market price contracts
- TaRTAM contracts (tarif Reglemente et Transitoire d'Ajustement au Marché), which is a transitory tariff using 2008 tariffs increased by 10 to 23% (depending on the category price).

The regulated tariffs (TRV) are proposed to the Commission de Régulation de l'Énergie (CRE) by ministry of Energy. The TRV offer different categories, tariff options or versions. Category (Blue, Yellow or Green prices) depends on the subscribed power. Residential customers choose a contract power (from 3 to 36 kVA) and an option. The tariff option allows consumers to optimize their electricity bills based on its ability to shift some consumption away from peak hours. In consideration for this virtuous behaviour, the consumer benefits from lower bills adapted to this behaviour. Option 'base', option 'offpeak- peak hours' and options 'EJP' and 'Tempo'.[9] The price for a particular category and contract power can then depend on type of days (blue/white/red days) and the hour (offpeak/peak hours).

The electricity bill paid by the consumer is the sum of:

a. Cost of producing electricity (40 %).
b. Costs of delivering electricity through transmission and distribution (calculated by the regulator, 33 %,).
c. Local taxes (TLE, 7 %), and routing (CTA, 2 %).
d. Public electricity service contribution (CSPE, 4 % ).
e. VAT (14 %).

In small sites (domestic and non-domestic), the production cost is generally slightly lower than wholesale electricity market prices. For big and medium sites, the difference is higher.

**Contracts**
Suppliers have to offer the customers the possibility of signing a unique contract for electricity supply and distribution.

### 3.3.3 Metering

It is estimated that 95% of meters will be replaced by smart meters by 2016.

### 3.3.4 Distributed generation

**Self-consumption and net metering**
Self-consumption of electricity produced by independent producers is legally permitted if duly authorised by or declared to the relevant administrative authority; however, only “for their own use”. Resale to any other legal entity, such as tenants or neighbours is not authorised. The purchase scheme of the surplus of electricity fed into the grid is mandatory: EDF or the local distributor must sign an electricity purchase agreement with the facility owner, except for facilities up to 250 kW. In case of authorised self-consumption, only the surplus of electricity fed into the grid will be remunerated and not self-consumed quantities. [14]

Net metering is not explicitly regulated. PV electricity self-consumers sell and buy their electricity to and from the grid through distinct contracts and meters.

**Retribution for DG producers**
Renewable electricity (RES-E) is supported under a feed-in system and public tenders.
By a decree dated 4 March 2011, a new support system was proposed with a target of 500 MW per year of new projects over the next few years.

Priority is given to building-integrated photovoltaic applications. In 2010, building integrated residential systems of less than 3 kW represented 89 % of the total number of installations and 20 % of total cumulative power while systems of power greater than 36 kW represented 3 % of the number of installations and 69 % of total cumulative power capacity.

There are three kinds of market incentive:
- Enhanced feed-in tariffs (FiTs)
- Income tax credits: granted to owners of installations less than or equal to 3 kW. It covers 11 % of the cost of the materials shown on the estimate, with a threshold of 3,200€/kW. Private individuals benefit of a VAT reduction (7% instead of 19,6%).
- Direct financial subsidies from local authorities

The cost of promotion through the feed-in tariffs financed by customers of electricity companies through their CSPE contribution is estimated at 800 MEUR for 2011. The cost of tax credit is evaluated at 670 MEUR (2010). [15]

Regarding feed-in tariffs, the new support system introduces two separate mechanisms, based on the power of the installations.
- Under the first mechanism, for installations on buildings of less than 100 kW, feed-in tariffs are adjusted each quarter based on the total volume of projects submitted during the previous quarter.
- The second support mechanism involves a bidding system for large roof installations and photovoltaic ground-mounted power plants greater than 100 kW.

FiTs are also reviewed quarterly depending on the number of new applications, to control the PV development's achievement of targets.

| Title | Building usage | PV power (W) | Price (EUR/kWh) 31-12-2011 | Price (EUR/kWh) 31-03-2012 |
|---|---|---|---|---|
| IAB (Building-integrated photovoltaic system) | Residential use | P < 9 kW<br>9 kW < P < 36 kW | 0,4063<br>0,3555 | 0,3880<br>0,3395 |
| IAB | Building for education or health activities | P < 36 kW | 0,3325 | 0,3009 |
| IAB | Other type of building | P < 9 kW | 0,2882 | 0,2609 |
| ISB (Simplified building-integrated system) | Residential use, building for education or health activities, other type of building | P < 36 kW<br>36 kW < P < 100 kW | 0,2485<br>0,2361 | 0,2249<br>0,2137 |
| Other installations | Other installations | 0 MW < P < 12 MW | 0,1138 | 0,1108 |

IAB: Building-integrated photovoltaic system, ISB: Simplified building-integrated system

**Table1 : Applicable feed-in tariffs up to 31-12-2011 and 31-03-2012 in France [15]**

Remuneration regime of individual PV producers is capped: once a set limit of energy is reached, the electricity is purchased at only 5c€/kWh.

**Energy efficiency in buildings**
To meet its commitments "Factor 4" and as part of the Grenelle Environment, Parliament has set two objectives for this sector:

- 2012 new buildings meet the standards Effinergie low consumption, that is to say they should not consume more than 50 kWh/m² of primary energy per year.
- from 2020 new buildings, called BEPOS, must be "positive energy": they will produce more energy than they consume.

These two objectives can be achieved with the use of renewable energy especially solar building integrated, which will play a major role.[15]

# 3.4 Denmark

## 3.4.1 Wholesale electricity markets

**Market description**
The Danish electricity grid can be separated into three main areas:

- Generation
- Transmission
- Distribution

Figure 2 shows the structure of the Danish electricity system - from the large central power stations, wind farms and relations to other countries connected to the transmission grid (400 kV-132 kV), to businesses and households connected to the distribution network of (10 kV-0, 4 kV).

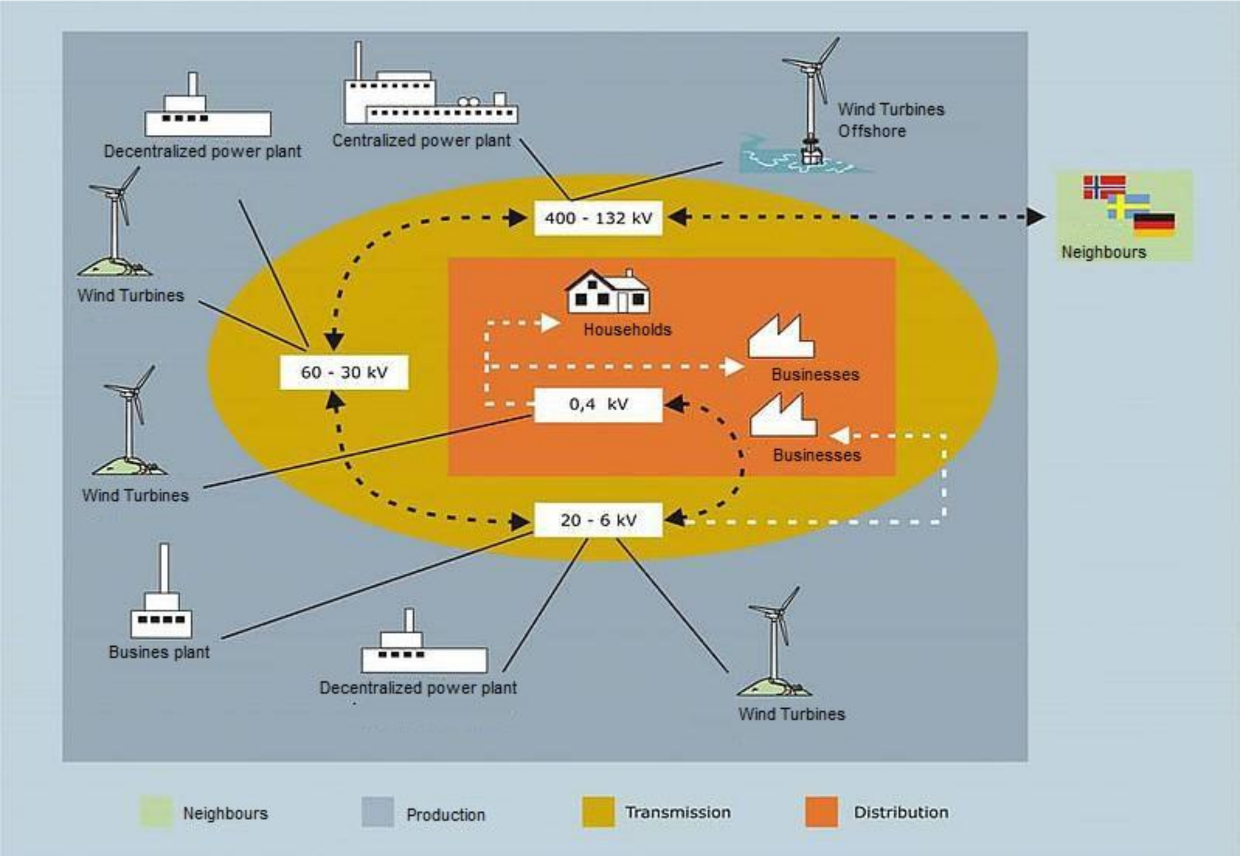



*Figure 2: The structure of the Danish electricity system.*[2]

**Generation**

In Denmark there are about 6,000 power generation units. They can be divided into 3 main types:

- Centralized power generation plants
- Decentralized power generation plants
- Wind Turbines

The centralized power generation plants are located in 15 special power seats. They use mainly coal but also biomass in a smaller scale. The decentralized power generation plant includes approx. 600 CHP plants, industrial plants and local plants. They typically use natural gas, waste, biogas and biomass. There are approx. 5,400 wind turbines in Denmark.

[2] Source: www.climateminds.dk

The total Danish electricity production in 2011 was 33,210 GWh, which is about 9% lower than in 2010. The specification of the production was:

| Specification of the production (in GWh) | 2010 | 2011 |
|---|---|---|
| Electricity from centralized power plants | 21,611 | 17,268 |
| Electricity from decentralized power plants | 7,179 | 6,159 |
| Electricity from wind turbines on shore | 5,122 | 6,360 |
| Electricity from offshore wind turbines | 2,686 | 3,405 |
| Electricity from hydropower and solar panels | 21 | 18 |

**Table 2: Specification of the Danish production.**[3]

The increasing amount of wind generation increases the challenge of handling the unbalance between production and consumption. For instance, during periods with or without wind - these imbalances are covered by changing the production from the central power plants and/or via export and import from international connections. With an increasing amount of production related to wind power the need for power control are increased.

**Transmission**

Denmark has two separated transmission systems, of which the eastern one is synchronous with Nordic (former NORDEL ) and the western one with the synchronous grid of Continental Europe. The *Great Belt Power Link* connecting the two systems was commissioned in July 2010 and started commercial operations in August 2010.

The Danish transmission system is owned and operated by *Energinet.dk*. *Energinet.dk* is an independent company owned by the Danish Climate and Energy Ministry.

The grid is hierarchical build and consists at the top of a transmission network, which is the "backbone" of the power system. The transmission system network's primary function is to connect generation nodes in Denmark and abroad with electricity consumer nodes. The transmission system consists of 400 kV and 150/132 kV installations.

*Energinet.dk* owns the 400 kV installations and the international connections, whereas the 150/132 kV installations are owned by the regional transmission companies, which make the 150/132 kV grids available to *Energinet.dk*. However, *Energinet.dk* owns the 132 kV grids in northern Zealand.

The Danish transmission system is interconnected to the transmission systems in Germany, Sweden and Norway.

[3] Source: www.energinet.dk

**Distribution**
The distribution system are owned and operated by the local grid companies which transmit the electricity to the individual consumers. The local grid companies ensure the connection of businesses and households to the distribution network of 10 kV-0.4 kV level. Besides operating the distribution system the grid companies also measure the customers' electricity consumption, either by automatically reading or when customers themselves read their meter.
Between the various voltage levels (transmission and distributions systems) are transformer stations which enables the electric voltage up or down.

**Market participants**
There are many participants in the Danish electricity market some of them are already mentioned above. The scope of activities for players in the electricity market is based partly on the provisions of the Danish Electricity Supply Act and partly on the framework provisions laid down by *Energinet.dk* (market regulations).

**The producer**
The producer produces electricity and sells the electricity either directly to an electricity supplier or to Nord Pool. The producer sells electricity to or buys electricity from *Energinet.dk* in the regulating power market. This enables *Energinet.dk* to maintain and create balance in the electricity system and ensure the security of supply.

**Transmission system operator**
As a transmission system operator (TSO) *Energinet.dk* is responsible for the Danish electricity system. It is *Energinet.dk's* responsibility to ensure that the physical balance in the electricity system is maintained. They are also responsible for the development of rules which provide the settings for a well-functioning electricity market, with regard to the wholesale as well as retail.

**Grid companies**
The grid companies are responsible for operating the distribution network and for metering data on production as well as consumption. The grid companies also have the obligation to keep track of which balance responsible parties (BRP) each end user has chosen, and to supply *Energinet.dk* with information on metered data for consumption and production per BRP; these data are used by *Energinet.dk* for settlement of imbalances. All grid companies operate as monopolies.

**Balance responsible parties**
Production, consumption and trade activities must be assigned to the balance responsible parties (BRP) who must enter an agreement with *Energinet.dk* to assume responsibility for the specific activities, i.e. production, consumption or trade. Upon entering the agreement on balance responsibility the BRP assumes the financial responsibility for the imbalances they may incur. In the Danish market we work with approximate 10 very active BRP's.

**Electricity suppliers (local electricity trading companies)**

The electricity supplier concludes contracts for the supply of electricity with the end users. The electricity supplier buys electricity either at a power exchange (e.g. Nord Pool) or directly from an electricity producer, or from another supplier. The end user has the right to change from one electricity supplier to another supplier; by changing supplier the end user helps promoting the market competition.

**Companies with a supply obligation**

Company with a supply obligation is supplying end users who have not exercised their right to choose an electricity supplier. The amount collected by the companies from the end users is regulated by the Danish Competition Authority in order to ensure fair prices.

**End users with grid access**

The end user consumes the electricity bought from the electricity supplier. As a result of the liberalization, all end users have access to the grid and are therefore free to choose their own electricity supplier. Just like production, consumption can also be used in the regulating power market in order to create balance in the electricity system.

**Nord Pool - the Nordic power exchange**

Nord Pool Spot is the Nordic power exchange owned by *Energinet.dk* and the other Nordic TSOs. The power exchange has two market places for electricity trading: Elspot and Elbas. Trade on Elspot is based on the auction principle. Once a day Nord Pool matches bids and offers in order to calculate the market price in consideration of limitation in the capacity in the transmission grid. At the Elbas players trade to obtain balance when Elspot is closed. Nord Pool Spot also operates an exchange for financial trading/hedging.

Figure 3 shows very simple the communication and the connection between the players in the market.

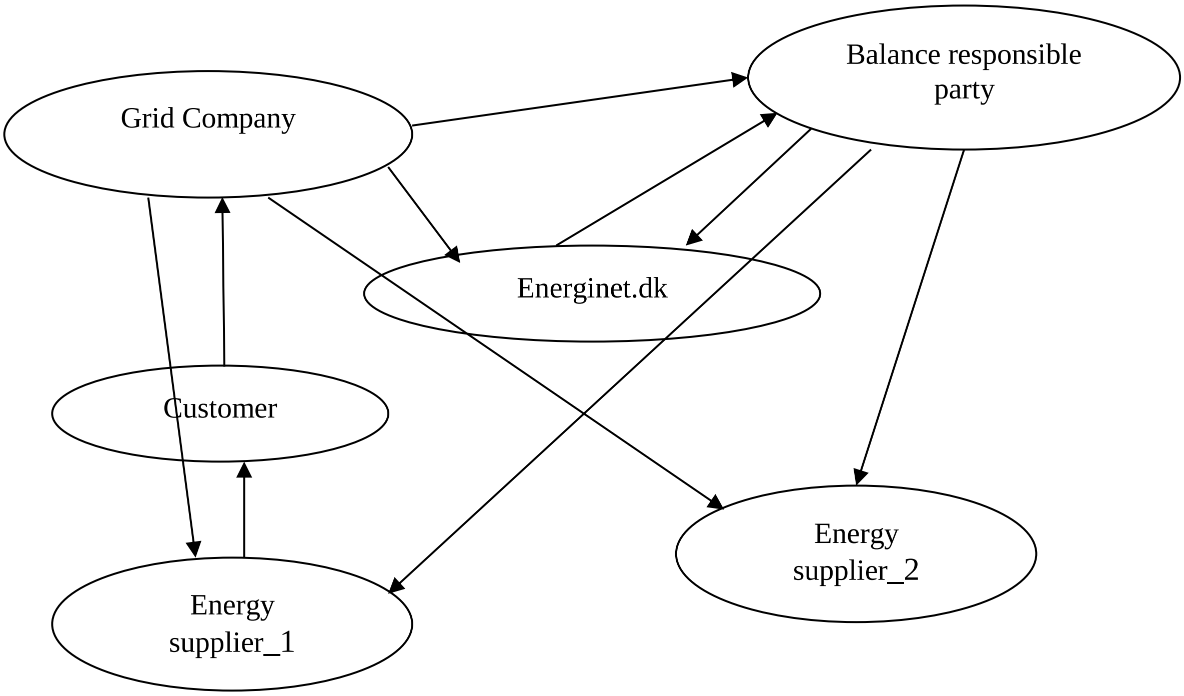



***Figure 3: The communication between the players in the market.***

### 3.4.2 Retail electricity markets

The electricity market in Denmark is regulated by the Danish Electricity Supply Act.

The law's goal is to ensure that the country's electricity supply is arranged and is completed in agreement with the consideration to security of supply, economics, and environment and consumer protection.

The law is to guarantee the consumers within this objective access to cheap electricity and still to give the consumers influence on the administration of the electricity sector's assets.

The law is to promote a sustainable energy use, including in connection with energy savings and use of combined power and heating, lasting and environmentally compatible energy sources, as well as to secure an effective use of financial resources and to create competition on markets for production and trade in electricity.

The precondition for the liberalization of the electricity market has largely been the establishment of the internal EU energy market. The intensions with the internal market are to improve the efficiency and the competitiveness whiles the considerations of the supply security and the environmental protection is taken into account.

**Pricing**

The Danish retail market or end users' market has been liberalized since January 2003. This means that the Danish electricity consumers have the right to choose from whom they want to buy their electricity.

Consumers who do not want to use the free choice are guaranteed power supplies. Companies with a supply obligation offers electricity to all consumers to publicly regulated prices.

*Energinet.dk* is responsible for ensuring a well-functioning electricity retail market. This means that *Energinet.dk* initiates or participates in work which has the purpose of ensuring that electricity consumers are offered better products, prices or conditions on the electricity market. Furthermore, *Energinet.dk* is responsible for establishing the rules applying to the retail market within the frames of the Executive Order on transmission system operation and the use of the electricity transmission grid, etc. *Energinet.dk* aims at collaborating with a wide range of players and stakeholders to ensure that small as well as large customers, electricity suppliers, grid companies and authorities are involved in the work. Recent initiatives include:

- Introduction of a DataHub, which among other things has the purpose of facilitating change of electricity supplier
- Participation in the re-launching of the Elpristavlen (webpage on which you can compare electricity prices: www.elpristavlen.dk)
- Participation in the establishment of a standard for promoting green energy
- Participating in the creation of a common Nordic electricity retail market

The Danish price structure has changed over the years but the price has always been composed of 4 elements with different content:

- Charges to the government
- Charges to *Energinet.dk*
- Charges to the local grid operator
- Payment for commercial electricity to the electricity supplier

Before the liberalization of the electricity market the end users was unable to deal with companies other than the electricity supplier, who was located in the area, where the end user lived. In the current electricity marked the end users can freely choose between several electricity suppliers in Denmark. The following describes the different elements in the electricity price:

The transport part cover costs of operating, maintaining and developing the local and overall electricity grid in Jutland/Funen. This part is divided between the TSO and the local grid operator.

The Public tax liabilities have changed its name to Public fee Grid. This fee covers the cost of the tasks which *Energinet.dk*, according to the Danish law of electricity is obliged to perform in areas such as research, security and development of environmentally friendly electricity.

The electricity tax is a tax paid to the government.

The distribution part is a tax that all electricity consumers must pay. The tax is paid the TSO.

The $CO_2$ tax has changed its name to Energy Saving Fee per. 01.01.2010. The Energy Saving tax is an environmental tax, on all kind of electricity production.

The public trading fee is a fee paid to the TSO, which is responsible for overall security of supply in Denmark.

The payment for the commercial electricity varies dependent of which supplier the end user has chosen. It is only this part of the electricity price which can be negotiated. This part is less than 25% of the total price. Figure 4 shows the composition of the Danish electricity price.

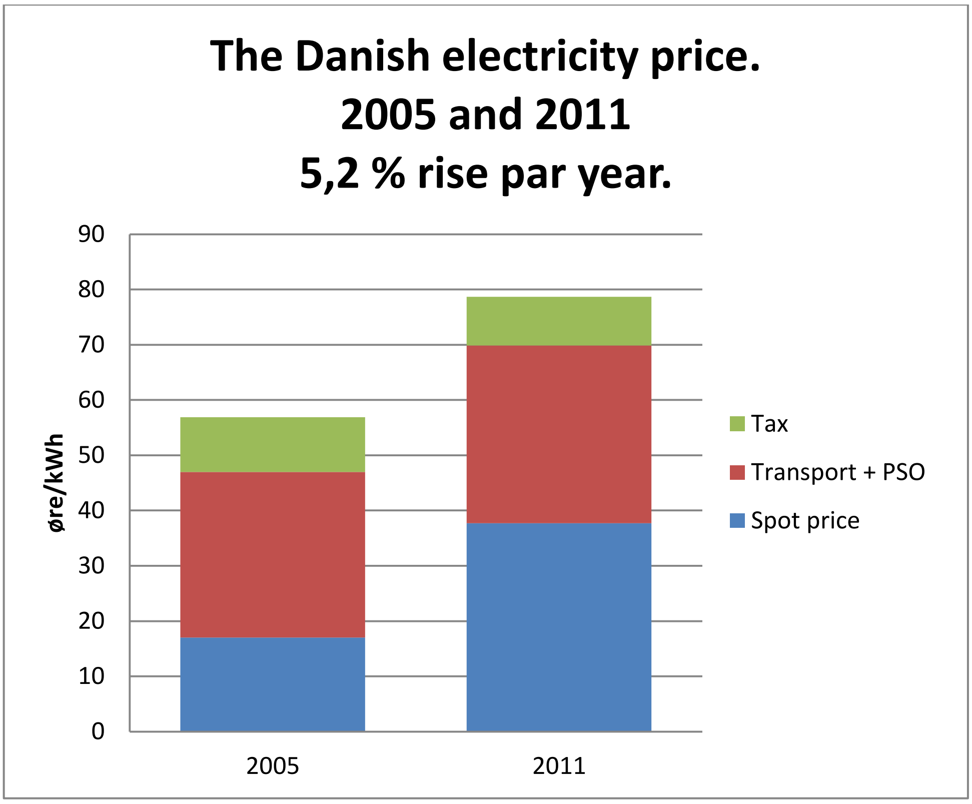



*Figure 4: Composition of the Danish electricity price.*

All end users regardless of size can freely choose their electricity supplier. There are many approved electricity suppliers in the Danish market. On an annual basis about 6% of the electricity customers are switching supplier. The number is expected to increase with the introduction of the Danish DataHub on March 2013, which would make it easier to switch supplier.

The Danish consumers are divided into two sections based on the size of the electricity consumption.

Consumers with consumption *under* 100.000 kWh are named “template customers”. The customers are mostly private houses and smaller business. These consumers are settled after the same profile depending of which distribution company they belong to. The consumption is typically read once a year. They are typically settled on a fixed price that can be individualized if they have used their opportunity to choose an electricity supplier. If the consumers have chosen the company with the supply obligation the electricity price is settled by the Danish Energy Regulatory Authority.

Consumers with consumption *over* 100.000 kWh are named “customers by hour reading”. These customers are measured on an hourly basis and settled once a month. They are settled in different ways; fixed prices, spot prices, half fixed and half spot prices and other variants between. It is also possible for the consumers to choose the company with the supply obligation as an electricity supplier.

### 3.4.3 Metering

In Denmark, the grid companies are responsible for unloading the customers in their respective distribution areas. The grid companies are in charge of the measuring and responsible for correct and safe installation of the meters and that the meters are read at least once a year.

The trend in Denmark is that more and more grid companies choose to replace the old meters with new smart meters. Status of replacement of meters is shown in Table 3:

| Customer type | Number |
|---|---|
| Template customers with smart meters by the end of 2009 | 550,000 |
| Template customers with smart meters by the end of 2010 | 420,000 |
| Template customers where smart meters will be installed after 2010 | 680,000 |
| Template customers where there are no plans for smart meters | 1540,000 |
| Customers by hour reading | 50,000 |

**Table 3: Status of replacement of smart meters (source: The Danish Energy Association)**

There are currently no requirements for grid companies that all meters should be remotely read.

The Danish Energy Association and *Energinet.dk* published in September 2011 a survey (“Fremme af prisfleksibelt elforbrug for små og mellemstore kunder”) for the introduction of a new settlement group, so template customers are divided into 2 subgroups:

- Consumption in the range of 0-50,000 kWh
- Consumption in the range of 50,000-100,000 kWh

The publication also deals with economic considerations about making the prices flexible depending on time for consumption and how much electricity is used. These billing forms require time registration for all customers.

The smart meters which are installed in Denmark are primarily from three providers:

- Kamstrup
- Landis / Gyr
- Echelon

Each grid operator makes their own choice about providers.

The communication lines to the smart meters are by PLC, RF or GPRS. The form of communication depends on what the individual grid operator prefers and the possibilities in each area.

The smart meters are provided with various functionalities. Most of the smart meters can provide the following measures:

- Active energy in two directions
- Reactive energy in two directions
- Peak power
- Accumulated peak power
- Date
- Hour
- Hour counter
- Number of debiting periods
- Power threshold counter
- Pulse input

### 3.4.4 Distributed generation

The development, in Denmark, of renewable sources having a nominal installed power at maximum 6 kW has exploded in the recent years. The latest numbers shows that at the end of 2011 2,700 solar plants were registered at Energinet.dk. The latest update per June 15$^{th}$ 2012 shows that 8,346 solar plants were registered and installed all over Denmark. The expectation is that at the end of the year more than 20,000 plants are installed.

The electricity produced at the solar plants is converted from DC to AC through an inverter and supplying the electricity to the low voltage grid.

The plants we are working with in the ENCOURAGE project are all based on renewable energy and a total output which not exceed more than 6 kW. These plants have a specific set of settlement rules and a set of guidance for measuring.

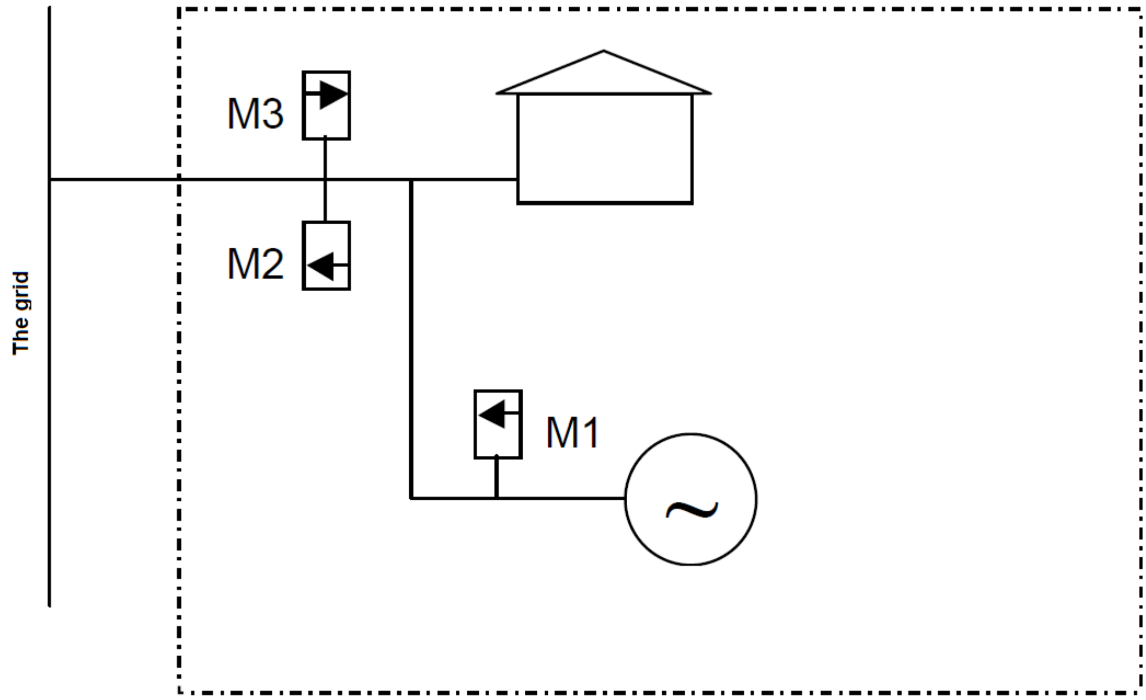



***Figure 5: The measurement setup.***

M2 and M3 is one smart meter with 2 or more counters. M2 measure the delivering of electricity to the grid after some of the production of electricity from M1 is used in the house. M3 measure the purchase from the grid.

The customers are settled once a year.

If M3-M2 is positive, the customers receive a bill for the yearly consumption corresponding to the difference between M3-M2 measured in kWh and the actual electricity price incl. various charges.

If M3-M2 is negative, the customers will not receive a bill for the yearly consumption. Instead the customer will receive payment for the surplus production corresponding to the difference between M3-M2. The payment for the surplus production is 60 øre/kWh for the first 10 years after installation of the plant.

For plants based on renewable energy which are bigger than 6 kW have there one set of rules. These rules are depending on the size of plant, and how the customers are connected to the electric market.

In the ENCOURAGE project we are working on demonstration for energy trade between buildings. There are no rules in Denmark today for this scenario.

## 3.5 Sweden

### 3.5.1 Wholesale electricity Market

**Market description**

The Swedish electricity grid is largely constructed like the Danish electricity grid, but using somewhat different terms when the construction should be explained. The Swedish power grid is structured as follows:

- Generation
- National grid
- Regional grid
- Local grid

Figure 6 shows the structure of the Swedish electricity grid from generation to electricity trading.

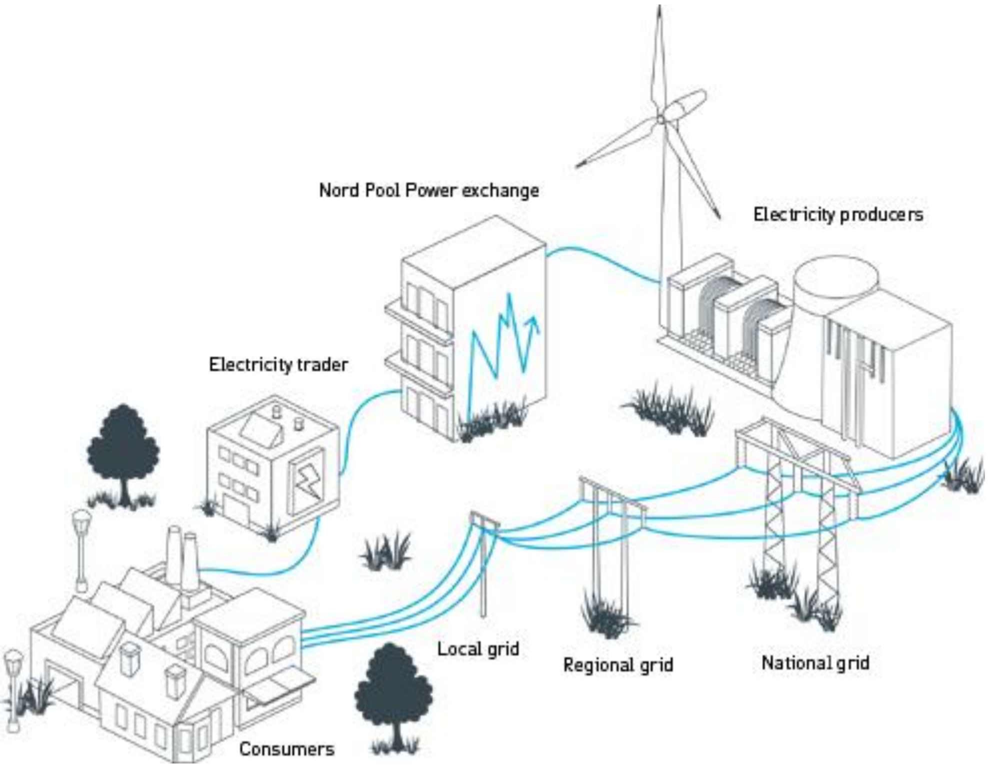



**Figure 6: The structure of the Swedish electricity grid.[4]**

**Generation**

90% of the Swedish electricity is produced by hydropower, nuclear power and CHP. It is only the largest production facilities and the regional grids that are connected to the national grid.

**National grid**

Svenska Kraftnät administers and runs Sweden's national grid and is the transmission system operator in Sweden. Svenska Kraftnät is a stat-owned public utility. The national grid has been built up in order to transmit large volumes of energy over great distances. The national grid or the main grid operates in voltage level 400-220 kV lines. The customers at the main grid are the grid operators of the regional grid.

**Regional grid**

Before the electricity is transported to the regional grid the electricity is transformed from voltage level 220 kV or 400 kV to the voltage level of the regional grid at 40-130 kV. Energy-intensive companies such as smelters and paper mills are often connected to the regional grid.

[4] Source: www.statnett.se

There are three main owners of the regional grid in Sweden:

- E.ON Elnät Sverige
- Vattenfall Eldistribution
- Fortum Distribution

**Local grid**

The local grid operators take over from the regional grid operators and sends electricity to the small industries, households and other users. The local grids or distribution grids are owned by the regional grid companies or other companies with local relations. Before electricity reaches our wall socket, it has been gradually transformed to 230 volts, which is the voltage level in private households.

There are 170 grid operators in Sweden. Each grid operator has within its geographic area exclusive right to provide electricity to the customers.

**Market participants**

The actors in the Swedish electricity market are mainly electricity producers, electricity suppliers (traders), balance responsible parties, grid companies and end customers.

The electricity passes through the various grid levels as it is transported from the power stations to the consumer.

On the commercial side, producers sell electricity – either directly or via the power exchange – to electricity traders, which turn to sell it to the consumers. The market players carry out their commercial activities in competition.

Consumers pay for two separate services – the production and handling of electricity on the commercial side, and the physical transport over the grid.

The many players and functions in the electricity market need to cooperate closely, ensuring that the consumers not only receive a reliable supply, but can also can buy their electricity in a market where there is free and fair competition.

**Transmission system operator**

The transmission system operator, Svenska Kraftnät manages Sweden’s national grid, which includes about 15,000 km transmission lines, sub-stations and international 400 and 220 kV interconnectors.

Svenska Kraftnät is also responsible for maintaining the balance between the production and consumption of electricity in Sweden. This is called system responsibility. The task is to monitor the electricity balance in the short-term and keep the frequency of the grids at 50 Hz. Deviations in the frequency occur when the planned production of electricity does not correspond with the actual consumption.

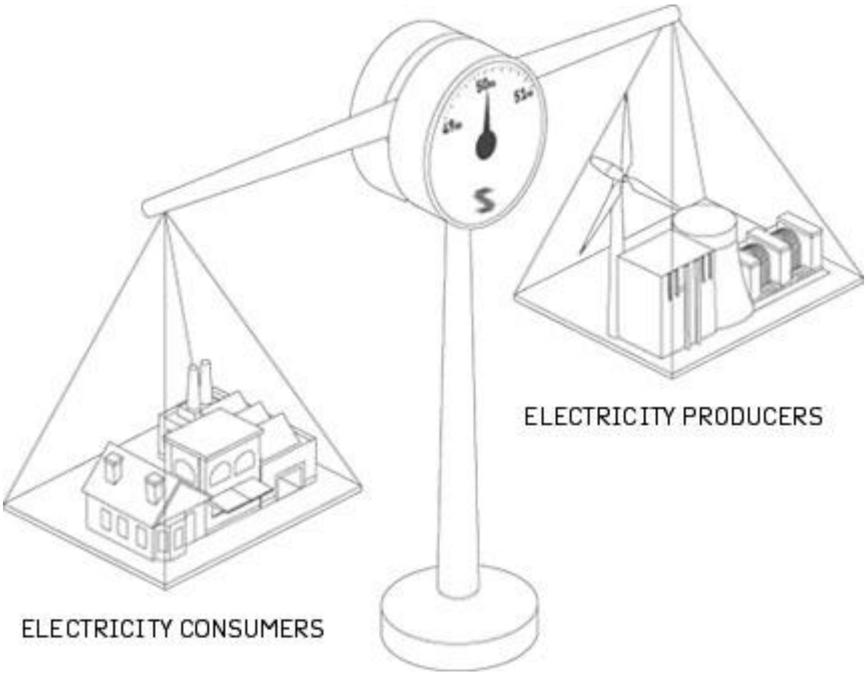



***Figure 7: Balance between production and consumption.***[5]

**Balance responsible parties (or balance providers)**
Sweden has about thirty balance providers. The balance responsible parties have the financial responsibility for Sweden's electricity system. This means that they, hour by hour, have the responsibility for the supply of the same amount of power that is being used by the electricity consumers for each balance providers.

The BRP makes a plan, on an hourly basis, in such a way that the production and purchasing of power correspond to the anticipated consumption and sales of the consumers/suppliers that the BRP has the balance responsibility for, and subsequently to financially regulate balance discrepancies with Svenska Kraftnät. The BRP creates a balance between supply and consumption by planning of production or through trade with other balance providers and/or on the power exchange Nord Pool Spot.

**Electricity supplier**
As a consumer, you buy your electricity from one supplier. Electricity suppliers buy electricity on the Nordic power exchange Nord Pool Spot, or directly from an electricity generator. About 70% of the electricity produced in Sweden is traded on Nord Pool. The remaining part is traded directly from electricity producers. If an electricity supplier does not want to manage their own balance responsibility, they can choose a balance responsibility for their electricity.

[5] Source: www.statnett.se

**Generation (producer)**
Companies that produce electricity are called producers. In Sweden, most of the electricity comes from hydropower and nuclear power. There are also wind and other power plants such as gas turbines.

## 3.5.2 Retail electricity markets.

Sweden has, since November 2011, been divided into four electricity areas. Figure 8 shows the four areas in Sweden.

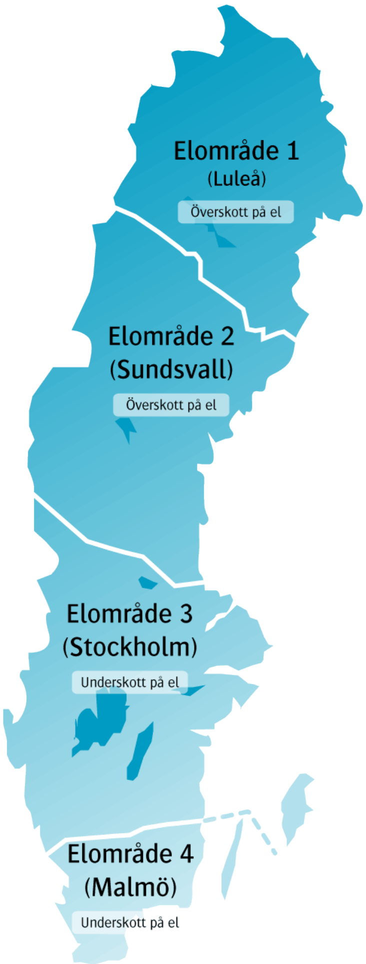



*Figure 8: The four electricity areas in Sweden.*[6]

[6] Source: www.energimarknadsinspektionen.se

**Pricing**

On January 1996 the Swedish electricity market and all network operations were separated from generation and trading. By doing so, the consumer can choose their electricity supplier.

The division of Sweden in four electricity areas has no influence on the free choice of electricity supplier. It is only the electricity price that is affected. This means that customers in the southern Sweden will pay a higher price than customers in northern Sweden. The reason is that the production in northern Sweden is higher than the consumption, while the consumption in southern Sweden is higher than the production.

In the absence of competition, the Swedish Energy Markets Inspectorate (EI) has the task to review the fairness of the grid charges. EI can tell the electricity grid companies to reduce charges and return money to customers. EI also monitors that the companies with network license complies with the applicable laws and regulations.

All customers pay a fee for the connected to the grid – a grid charge.

The grid charges are based on the cost that the local grid company has for electricity transmission. The fee may vary between different companies. The difference is due, among other things, line length, geography and soil conditions that are important for what it costs to operate the grid.

In addition to the costs including operation and maintenance, the fee also includes the cost of the connected to regional and national grid. The connection to the national grid is based on a tariff structure where the users of the grid are charged for injection or outtake of electricity at a connection point in the transmission grid. The tariff level is not dependent on the distance between generation, or source of energy, and load. Generation from renewable energy sources pay the same fees as conventional power plants. The transmission tariff consists of two parts, a power charge and an energy charge.

The grid company is also entitled to a reasonable return. Grid fee also includes some authority charges that grid owners must pay. Regulatory fees help to fund the government activities for electrical safety and preparedness and EI's supervision of the Swedish electricity monopoly.

Most grid companies charge fees that contains both a fixed component (subscription fee) and a variable component (transmission cost). The fixed component varies with the fuse or the subscribed power. The variable component varies with consumption (øre / kWh). The division between the fixed and variable component varies between DSOs. A few companies have chosen to have a completely solid part. There is also the opposite.

The tariff level is reviewed by Svenska Kraftnät on an annual basis. The grid users are informed about all important amendments of the tariff in advance and all changes are discussed in the Electricity market council, which is Svenska Kraftnät´s information and consultation forum for the market actors.

If the customer has chosen to change electricity supplier then the variable part of the electricity price is settled after different types of contract. The primary types of contracts are:

- Fixed price, where the electricity price is agreed for a specified period.
- Variable pricing, where the price is the last month's price at Nord Pool Spot and the electricity suppliers additional cost.

The price of electricity on the Nord Pool Spot is determined by an auction procedure. The cheapest production facilities are used first and then the more expensive facilities in order to meet the demand.

When there is limited electricity in the system, or when electricity use is high, the price rises. Such is the case during dry years when it is very cold and consumption is high.

In Sweden it is possible to choose a contract with or without an environmental agreement.

There are several ways a supplier may choose to show that the electricity is environmentally friendly. Environmental labelling is voluntary, and the criteria may vary. These are the products of wind power, hydro- and wind power and “Bra Miljöval” (Good Environmental Choice).“Bra Miljövall” is launched by the Swedish Society for Nature Conservation. The aim is to promote development towards a more sustainable electricity generation.

### 3.5.3 Metering

Sweden was the first country to install smart meters for its customers in 2009. The grid operator reads the meter at least once a month. The reading is done so that the grid operator and the electricity supplier know how much the consumption is. The grid operator owns and installs the meter and is obliged to read the meter at the following times:

- Once every month
- When switching suppliers
- When the customer move
- When the electric meter are replaced

### 3.5.4 Distributed generation

From May 1 2003, the payment for renewable electricity production is replaced by a system of energy certificates.

The idea behind energy certificates is that they will bring two financial benefits to producers of renewable electricity. Besides the physical value of electricity - i.e. the price per kWh that the producer can charge - there is another benefit in the form of a certificate confirming that the power has been produced using renewable sources of energy.

One produced MWh of renewable electricity corresponds to one certificate. The intention is that certificates will be traded and form a marketplace of their own, detached from physical trading in power.

These certificates will prove that the production of electricity originates from a plant meeting certain requirements. This will enable Sweden to support production originating from renewable sources of energy.

## 3.6 Norway

### 3.6.1 Wholesale electricity Market

**Market description**
The Norwegian electricity grid has basically the same structure as the Danish and Swedish grids however there is used other terminologies to describe the correlation.

The distribution system in Norway is divided into three levels:

- The nationwide main grid (power supply "highways"), which transports electricity from one area of the country to another
- The regional grids (power supply "county roads") which transport power from the main grid up to the local areas distributions grids.
- The local grids ("local roads"), which distribute the power over the last stretch to the consumers.

It is mainly local municipalities who own the regional and local grids, while the government through Statnett owns the main grid.

**Main grid**
The power lines in the main grid or the transmission grid has the highest voltages for the longest transport distances typically 300 and 420 kilovolts.

More than 80% of the power lines, transformers and switchgears in the main grid are owned by Statnett (www.statnett.no). The rest is owned by 27 other companies.

**Regional grid**
The regional grid power lines are usually between 66 and 135 kilovolts. Regional transport grids make the connection, from the national grid to the local distribution network.

**Local grid**
The local distribution grid ensures supply of power to ordinary electricity consumers.

In many places it is the same grid owner who owns both the regional and local distribution grids. In order to distribute power between the different grids the electricity is transformed down to an acceptable voltage level.

**Generation**
All generating companies supply electricity to the transmission or distribution grids.

Norway is the sixth largest hydropower producer in the world. In a year with normal precipitation, the hydropower generation corresponds to approximately 99 per cent of Norway's total power production. In addition to hydropower, Norway has wind power stations, thermal power plants, and gas-fired power plants.

Hydropower generation can vary substantially from one year to another, depending on precipitation and inflow. Precipitation levels vary between regions, between seasons and between years. Inflow is high during the spring thaw, but normally decreases during summer and towards autumn. Autumn floods generally result in an increase before the onset of winter, when inflow is normally very low. The spring flood comes later in inland regions and in the mountains than near the coast and in lowland areas. Precipitation varies substantially from year to year and is more than twice as high in the wettest years as in the driest ones.

Many power plants can store water in reservoirs and are referred to as reservoir power plants. The reservoirs allow water to be retained in flood periods and released in drought periods, typically in the winter. Water is collected in the reservoirs when inflow is high and consumption low. Normally, water will be drawn off during autumn and winter, when electricity demand is highest. In spring and summer electricity demand reaches its lowest level, and the reservoirs refill.

The Ministry of Petroleum and Energy administers the energy resources of the mainland and of the watercourses. As other industrialized nations, Norway has a high consumption of energy. But the use of energy is unlike most other countries, mostly based on electricity.

**Market participants**

***Transmission system operator***
In addition to providing a balance between production and consumption Stanett must sure that the transmission system stay within the physical limitations of the wiring, and that electricity reaches consumers with a proper security of supply.

Statnett is also responsible for the Norwegian main grid - with a duty to ensure that this network is open to all players in the electricity market. Statnett is the owner of approx. 90 per cent of the national grid.

A company who provides or consumes power from the main grid pays a transport price in accordance with the commercial agreement.

It is the Norwegian Water Resources and Energy Directorate (NVE) which regulates the state's revenue through an annual income ceiling for the overall operations as transmission system operator.

While you are free to choose supplier of electricity, the transport of power are based monopoly. It is not possible to choose a different grid owner than the owner of the grid where the consumers live.

**Generation (producer)**
To maximize income, generators dispose the water in the reservoirs on the basis of the spot price at any given time and future price expectations. To ensure that output corresponds to sales commitments, generators can buy and sell power in the market at Nord Pool.

**Balance responsible parties (or balance providers)**
The balance responsible parties have the same function in Norway as in Sweden and Denmark.

**Electricity supplier**
As in Sweden and Denmark it is also possible for the consumer to choose an electricity supplier. Electricity suppliers buy electricity from the Nordic Power Exchange. The electricity supplier can choose a balance responsible party to manage trade at Nord Pool.

**ENOVA**
Enova was established to promote an environmentally friendly restructuring of energy consumption and production in Norway. Enova's goal is to make it easier to choose simple, energy efficient and environmentally sound solutions for everybody. Both private and public actors are important target groups, in both private and professional arena. Enova's activities are financed through the levy on the electricity distribution tariff and the national budget. Enova SF is a state enterprise owned by the Ministry of Petroleum and Energy (OED).

### 3.6.2 Retail electricity Market

Construction of grids is costly, especially in Norway and therefore grid management and operation have been defined as a natural monopoly, where the users are tied to their local distribution company. The sector has not been opened to competition, and the authorities regulate the activities. The regulation, described as monopoly regulation, is intended to safeguard consumer rights, a well-functioning power market and ensure efficient management and development of the grid.

All grid companies are required to use point tariffs when charging for transmission and distribution. Transmission and distribution tariffs are payment for use of the electricity transmission and distribution grid. Point tariffs mean that grid customers pay the same transmission tariff regardless of whom they buy electricity from or sell to. An individual customer only pays a transmission tariff to the local grid company. Consumers pay one tariff to tap electricity from one point in the grid, consumption tariff, whereas generating companies pay another tariff to feed power into a connection point, input tariff. Point tariffs provide easy market access for customers and thus promote the establishment of a nationwide power market.

The distribution tariff to households normally consists of a fixed component and an energy component. The fixed component covers customer-specific costs and a share of the fixed costs in the grid. These are costs that for the grid company basically remain the same, regardless of whether the customer is a large or a small consumer. The energy component varies with the consumption of electricity, and shall at minimum cover the variable loss in the grid. This means that the expenses related to the energy component is lower for a consumer with low consumption than for one with large consumption.

**Pricing**
The electricity price is primarily determined by supply and demand in the Nordic power market.

The power market is often divided into wholesale and end-user markets (retail market). The wholesale market embraces generators, suppliers, big industrial enterprises and other large undertakings. Electricity is traded bilaterally between different market players and in the markets organized by the Nordic power exchange, Nord Pool.

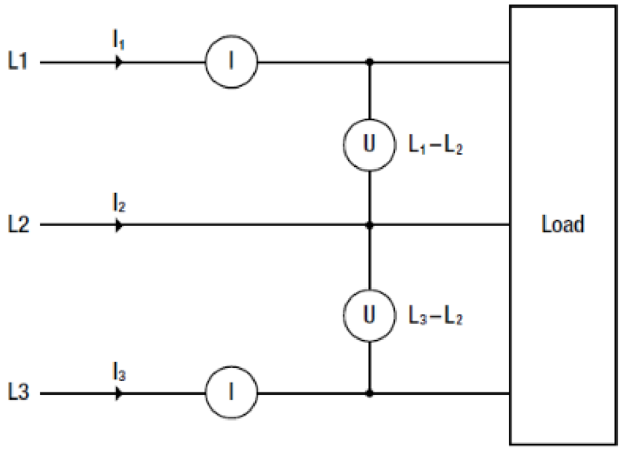
Small end-users normally buy power from an electricity supply company. Larger end-users, such as industrial enterprises, often buy directly in the wholesale market.

The total electricity invoice has several components: electricity price, transmission tariff, consumption tax (electricity tax), VAT and a levy on the transmission tariff earmarked for the Energy Fund. All end-users must pay a transmission tariff to the local grid company to which they are connected. The consumption tax is imposed on electricity that is consumed in Norway.

All end-users are free to choose electricity supplier and contract type. The most common contracts for households have prices that vary according to market conditions. In the first quarter of 2006, 57.8 per cent of households had contracts with variable price, which means that the power suppliers can change the price according to the market conditions, given that they announce this two weeks in advance. 25.4 per cent of the households had Elspot-based contracts, for example a contract that charges the Elspot price plus a fixed mark-up. The remaining household customers had various types of fixed-price contracts. A fixed price, for example for one year, means that the power supplier cannot alter the price during the contract period, even if market prices change. As at the first quarter of 2006, 16.8 per cent of household customers had this type of contract.

### 3.6.3 Metering

Basically there are 2 kinds of meters: a standard 3- phase meter and a special meter which measures via the Aron principle. The Aron principle is used in places where it is not possible to make a proper ground connection.




Like in Denmark it is the grid manager which is responsible for the metering.

Consumption under 100.000 kWh a year is reported to the grid manager once a year, manually by the consumer.

Consumption over 100.000 kWh a year is automatically collected once a day with hourly values.
In the end of 2018 all the meters should be changed to smart meters.

### 3.6.4 Distributed generation

Like in Sweden, Norway uses Energy Certificate. A certificate is a documentation of how much power is produced and when. It makes it possible to "act" with the environmental value of electricity produced from renewable energy sources.

In Norway RECS certificates and guarantees of origin are the only energy certificates that it is possible to trade with. Today there are only issued combined RECS certificates and guarantees of origin for the same amount of energy produced. These certificates / guarantees status may only be used together.

The Energy Certificate as a correlation between the ways of energy production for the power they buy and the environmental impact it creates

## 3.7 Italy

### 3.7.1 Wholesale electricity markets

The electrical system in Italy is composed of several subsystems that interact with each other and can be summarized as follows:

- The generation system, the set of the plants that producing electricity, combined with the imports.
- The transmission system, the set of very high and high voltage lines which acts as a link between the generation system and distribution system to the end user. The management of the transmission network also includes dispatching activities: it is the supervising and coordinating the current flow on the lines, which ensures the proper functioning of the network and adequate supply to end users.
- The distribution system, the set of medium and low voltage lines, which bring the electricity to end users (households, small and medium industries, tertiary, etc..)
- The sales systems, the set of technical and commercial structures that are in contact with the end user, organizing contracts, manage bills and payments.

The structure of the electrical system before the market liberalization was "vertically integrated": the entire national system of production, import, transmission, distribution and sale of energy was owned of only one company (ENEL).

In 1999, Decree No. 79/99 (Bersani Decree) has forced the unbundling of the various subsystems that make up the national electricity system, which has undergone a remarkable transformation:

- The generation and import activities have entered in the free market: anyone can produce and import Energy. In order to facilitate the creation of the market with more operators, the Enel monopoly position has been reorganized through selling of some production plants.
  Enel, currently, contributes around 40% of Italy energy production, while Edison, Sorgenia, A2A, Iride Group is now major manufacturers that compete for the remaining Italian market.
- The transmission and dispatching activities, being of national interest, are regulated: the manager of the national transmission grid is unique and must ensure, without discrimination, access to the network to all businesses that request it, on payment of a rate of energy transport (the amount of which is defined by the Authority). The operator has also the obligation of grid maintenance and extension. Currently, the transmission grid is privatized but government controller, and Terna Rete Elettrica Nazionale SpA is its owner.
- The distribution activities, which are also of national interest, are not carried on under the free market but are given in grants from the state to different operators through public tender, for a period not exceeding twelve years.

**Market description**

The Electricity Market, better known as Italian Power Exchange (Ipex), arose from the approval of Legislative Decree no. 79/99. This Decree, which marked the beginning of the structural reform of the Italian electricity sector, responded to the need for:

- promoting competition in the activities of electricity generation and wholesale through the creation of a “marketplace”;

- Maximising transparency and efficiency in the naturally monopolistic activity of dispatching.

The Electricity Market is an electronic venue for the trading of wholesale electricity, where the electricity price corresponds to the clearing price resulting from the intersection between the volumes of electricity demanded and offered by its Participants.
It is a real physical market, where the schedules of injection1 and withdrawal2 of electricity into and from the grid are defined under the economic merit-order criterion3. The power exchange is a voluntary market: operators may also conclude purchase and sale contracts off the exchange, the so-called bilateral contracts.

Under article 5 of Legislative Decree no. 79 of 16 March 1999, “Gestore dei mercati energetici S.p.A.” (GME) is the company vested with the organization and economic management of the Electricity Market, i.e. the regulated wholesale electricity market, commonly known as “Italian Power Exchange” (Ipex).

GME is fully owned by the company “Gestore dei Servizi Energetici - GSE S.p.A.” (GSE), which is in turn fully owned by the Italian Ministry of Economy and Finance. GSE also has full control of the company “Acquirente Unico S.p.A.” (AU). The creation of GME is part of the wider process of liberalization of the electricity sector, which was started in 1999. The mission of GME is to favour the development of a competitive national power system.

GME manages the “Mercati dell’Energia” (Energy Markets), which consist of: i) the “Mercato a Pronti dell’Energia” (Day-Ahead Market – MGP), “Mercato Infragiornaliero” (Intra-Day Market - MI) and “Mercato per il Servizio di Dispacciamento” (Ancillary Services Market - MSD); and ii) the “Mercato a Termine dell’Energia con obbligo di consegna fisica dell’energia” (Forward Electricity Market with obligation of physical delivery of electricity - MTE) and the “Piattaforma per la consegna fisica dei contratti finanziari conclusi sull’IDEX” (Platform for physical delivery of financial contracts concluded on IDEX – CDE).

Since 2007, GME has also been operating the “Piattaforma dei Conti Energia a Termine” (Forward Electricity Account Trading Platform - PCE). On this platform, operators who trade electricity bilaterally off the energy markets register their commercial obligations and nominate the related injection and withdrawal schedules.

GME is not only active in the electricity sector, but also participates in the implementation of Italian environmental policies, by managing the “**Mercati per l’ambiente”** (Environmental Markets): “Mercato dei Certificati Verdi” (Green Certificates Market - MCV), “Mercato dei Titoli di Efficienza Energetica” (Energy Efficiency Certificates Market – MTEE) and “Mercato delle Unità di Emissione” (Emissions Trading Market – MUE). Through these markets, GME promotes the development of renewables, the increase of energy savings and the reduction of greenhouse gas emissions. Indeed, the market is an instrument through which companies may make environmentally sustainable choices, while minimising their overall costs.

The national power system is an organized grid system. In a context of open energy market, the typical activities of this system are well distinguished and carried out by different entities. These activities are: generation, transmission and distribution of electricity.

Electricity generation is a liberalized activity: primary energy sources are converted into electricity by power plants (generation centres) and then transmitted to consumption zones through a grid system, which consists of lines, substations and transforming stations. In this system, all the electricity withdrawn by end users is generated and injected into the grid by power plants and installations that are distributed throughout the country. This electricity adds to the one that is imported from neighbouring countries. Therefore, the grid operates as a system of communicating vessels, where all the electricity is injected and from which all the electricity is withdrawn, without the possibility of determining the plant or installation from which the electricity that is consumed derives. The last stage of the cycle of the national power system is distribution, i.e. the delivery of electricity at medium and low voltage to users.

In addition to the Italian Parliament and Government, the main entities which contribute to the operation of the power system - each with a specific role explicitly defined by the applicable legislation - are: i) the Italian Ministry of Economic Development (MSE), which defines, among others, the strategic and operational guidelines for the security and cost-effectiveness of the national power system; ii) the "Autorità per l'energia elettrica ed il gas" (the Italian electricity & gas regulator – AEEG), which guarantees the promotion of competition and efficiency in the sector and has regulation and monitoring tasks; iii) Terna S.p.A., which manages the national transmission grid under security conditions, as well as the power flows thereon through the dispatching activity, i.e. by balancing supply and demand of electricity for 365 days a year and 24 hours a day; iv) "Gestore dei Servizi Energetici" (GSE), which buys the electricity generated by CIP-6 power plants and sells it in the market4; v) "Acquirente unico" (AU), which guarantees electricity supply within the framework of the "servizio di maggior tutela e di salvaguardia" (universal service and default service), as per Law-Decree no. 73 of 18 June 2007, converted into Law no. 125 of 3 August 2007; and vi) "Gestore dei Mercati Energetici" (GME), which organises and manages the Electricity Market under principles of neutrality, transparency, objectivity and competition between producers.

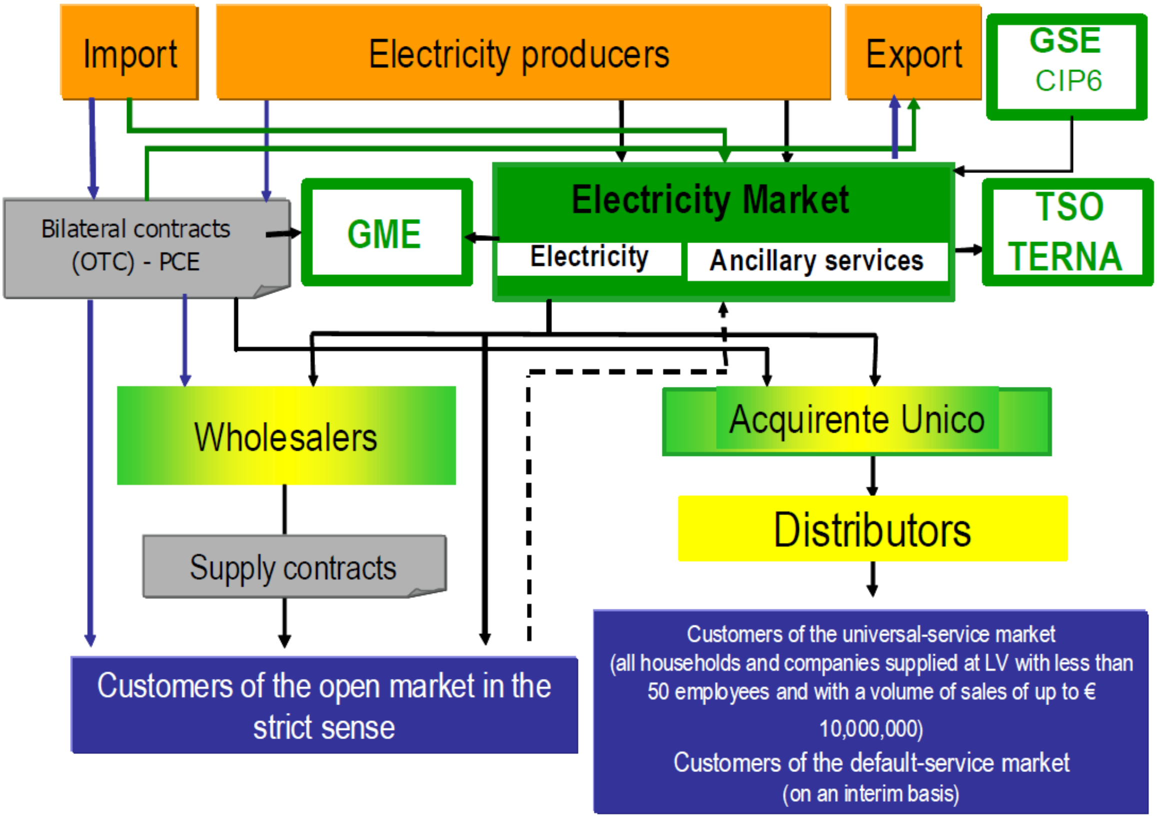



***Figure 9: Organization of the Electricity Market in Italy.***

## 3.7.2 Retail electricity markets

Before of the market liberalization, the end users could purchase the energy exclusively from only distributor (ENEL), which took care of all energy supply aspects, both technical (maintenance of the network connection, services in any case of failure, etc.) and commercial (price, managing bills, collecting payments, etc..). End users had not the opportunity to make any choice with respect to their energy supply.

At the same time of the sale liberalization, the purchase has also been liberalized and, since the 1st of July in 2007, anyone is free to choose own energy supplier.

Therefore each end user can freely choose to remain a captive customer or become a free market customer.

Residential captive customers (households in low voltage) are applied to the average reference prices as a function of the different fees for transmission, distribution and metering services. In particular there are three different fees:

- D1 fee: it expresses the cost recognized to the distribution companies for the household customers supply. This fee is not currently applied to the final customers.
- D2 fee: it is applied to home contracts with commitment power not exceeding 3 KW. The energy cost increases with consumption.
- D3 fee: it is applied to home contracts with commitment power not exceeding 3 KW, both with and without residence. The energy cost increases with consumption.

In this case the energy price is independent from the hours, it has the same value in each time period of consumption.

From the 1st of July in 2010, this energy price has been changed, two different energy fees have been created and they have been applied to the residential captive customers. There two different energy prices are a function of the consumption hours:

- F1 fee: it is the most expensive time slot and goes from 8.00 a.m. to 7.00 p.m. on weekdays;
- F23 fee: it is the cheapest time slot and goes from 7.00 p.m. to 8.00 a.m. on weekdays, the weekend and all holidays.

In the captive regime, the bulk purchase is in charge to the Single Buyer (Acquirente Unico AU), while the retail sale is in charge to the local Distributor. The prices, fixed by the AEEG, every three months, are based on the burdens sustained by AU due to energy supply, other than secure the coverage costs of commercialization sustained by DSO.

In the free market, the supply price is the result of the bilateral contract between the request (end users) and the offer (energy producer). Each energy supplier presents on the market its contract proposals and the end users are free to choose which is better for them, as a function of their energy consumption. For example, one of the possible contract established with Enel Energia Society, allows four different size of contract (S, M, L, XL) where the energy price is fixed, for a total period of two years, up to specific energy consumption. In order to give a better understanding of this type of contract, a table with the different size and price is shown below.

| SIZE | SMALL | MEDIUM | LARGE | EXTRALARGE |
|---|---|---|---|---|
| Max energy Consumption | Up to 150kWh/month | Up to 225kWh/month | Up to 300kWh/month | Up to 375kWh/month |
| Energy Price | 29,00 €/month | 40,00 €/month | 59,00 €/month | 80,00 €/month |

**Table 4 – Example of Enel Energia contracts on the free market.**

For each kWh/month consumed above the threshold, different all-inclusive price is applied (0.28€/kWh for small size, 0.29€/kWh for medium size, 0.30€/kWh for large size, 0,30 €/kWh for extra-large size). Prices, excluding VAT and taxes, are valid for 12 months and they are valid for domestic residents with power not exceeding 3 kW. For non-resident or supply contract with commitment power exceeding 3 kW will be subject to a fee of 9,00€/month being added to the cost of the basic package.

### 3.7.3 Metering

In Italy, while the transmission service is provided by a single operator (Terna), the distribution of electricity to end users has been liberalized to several operators (Decree No. 79 of 1999), raising free competition in the electricity market.

Delivery to 230/400 V occurs through an energy meter.

The meter is essentially an electromechanical or, in the recent devices, electronic wattmeter able to totalize the consumed active energy. In the relevant three-phase delivery, the reactive energy, on which a surcharge is applied, is also accounted, since it is harmful for the service provider.

Since 2001, ENEL has been replacing the old meters with the new smart ones. Until now ENEL Distribution has installed 32 millions of meters, in Italy.

### 3.7.4 Distributed generation

In order to promote the use of the renewable sources, in 2005, some incentives have been created for the building of photovoltaic plants,: the total energy produced is directly sold to GSE at an incentivized tariff.

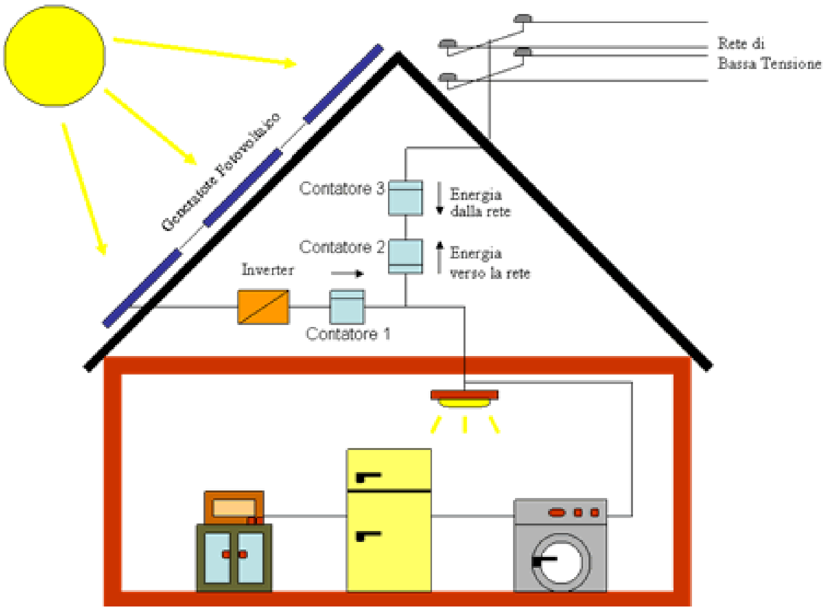



***Figure 10: Scheme of a user with a photovoltaic plant connected to the grid.***

The Energy produced by the photovoltaic plant is converted through the inverter and it is put into the low voltage grid.

The smart meter 1, positioned by the GSE, records total energy produced from the plant and, consequently, the total amount of the incentive: the incentive tariff is paid to the producer for a total period of 20 years and it is a function of the total power and the type of plant as listed below:

- Non-integrated plant.
- Partial integrated plant.
- Integrated plant.

In the following table are listed the incentive tariffs as a function of the total power and the type of the plant:

| **Power P (kW)** | **First half of 2012** | | **Second half of 2012** | |
|---|---|---|---|---|
| | *Integrated and Partial-integrated plant [€/kWh]* | *Non-integrated plant [€/kWh]* | *Integrated and Partial-integrated plant [€/kWh]* | *Non-integrated plant [€/kWh]* |
| 1 ≤ P ≤ 3 | 0,274 | 0,240 | 0,252 | 0,221 |
| 3 < P ≤ 20 | 0,247 | 0,219 | 0,227 | 0,202 |
| 20 < P ≤ 200 | 0,233 | 0,206 | 0,214 | 0,189 |
| 200 < P ≤ 1000 | 0,224 | 0,172 | 0,202 | 0,155 |
| 1000 < P ≤ 5000 | 0,182 | 0,156 | 0,164 | 0,140 |

| | | | | |
|---|---|---|---|---|
| P > 5000 | 0,171 | 0,148 | 0,154 | 0,133 |

**Table 6 - The incentive tariffs as a function of the total power and the type of the plant.**

The smart meter 2 records the Energy put into the grid; the smart meter 3 records the energy absorbed by the residential loads. In the last months these two meters have been replaced from only one bidirectional smart meter.

It is possible to increase the incentive tariff with an additional amount, if energy efficiency actions are coupled with the installation of the PV.

It is possible to sign two different kinds of contract: the selling or the local exchange. Both of them provided an additional profit to the incentive tariff.

In the sell regime the plant owner sell the total produced energy to the GSE and pays for the consumptions.

In the local exchange regime, allowed for plant with a power less than 200kW , the owner receives a fee for the energy put into the grid net of his own consumptions.

For plant with power more than 200kW, it is possible only the sell regime and the owner can decide to sell the produced energy indirectly through the GSE or directly to the electric market.

## 3.8 Portugal

### 3.8.1 Wholesale electricity markets

**The Portuguese Electricity System [1]**
The national law followed the Electricity Directive and established the new legal framework for the Portuguese electricity sector. Decree-Law no. 172/2006, as amended, further developed this legal framework and established rules for activities in the electricity sector.

Following implementation of the Electricity Framework, the binding and non-binding sectors of the SEN (Sistema Elétrico Nacional) were replaced by a single market system, and the generation and supply of electricity and management of the organised electricity markets are now fully open to competition, subject to obtaining the requisite licenses and approvals. However, the transmission and distribution components of the electricity industry continue to be provided through the award of public concessions.

Under the Electricity Framework, the SEN is divided into six major functions: generation, transmission, distribution, supply, operation of the electricity market and the logistical operations that facilitate switching electricity suppliers for consumers. Subject to certain exceptions, each of these functions must be operated independently of other functions, from a legal, organizational and decision-making standpoint.

The electricity sector activities are required to be developed in accordance with the principles of rationality and efficiency in the use of resources throughout the entire value chain (i.e., from generation to final consumption of electricity) and in accordance with the principles of competition and environmental sustainability, with the purpose of increasing competition and efficiency in the SEN, without prejudicing public service obligations.

**Electricity generation**

Electricity generation is subject to licensing and is carried out in a competitive environment. Electricity generation is divided into two regimes: ordinary regime and special regime. Special regime relates to the generation of electricity from endogenous and other renewable sources (except large hydropower plants). Special regime generation is subject to different licensing requirements and benefits from special tariffs. A last recourse supplier, currently EDP Serviço Universal, is obliged to purchase electricity generated under the Portuguese special regime. The ordinary regime covers all other sources, including large hydropower plants.

**Ordinary Regime**

The principle of centralised planning of generation plants has been abandoned in the New Electricity Framework. Initiatives to construct and operate new plants lie with market participants, and the Portuguese government will only intervene to supplement private initiatives, cover market failures or ensure electricity supply.

On June 30, 2007, all of the PPAs executed by EDP under the Old Electricity Framework have been terminated early pursuant to Decree Law 240/2004, and accordingly the power facilities that generated electricity for those agreements are now operated under market conditions.

In addition, EDP has regularised the status of the water concessions for its hydropower plants in accordance with Decree-Law no. 226-A/2007, of May 31. As a result, EDP has retained the rights to operate 26 hydropower plants under market conditions (with 4,094 MW of installed capacity) beginning on the expiration dates previously provided in their respective PPAs until on average, 2047.

**Special Regime**

Special regime generation is primarily governed by Decree-Law 189/88 of May 27, and the amendments thereto (including Decree-Law no. 312/2001, of 10 December and, in respect of tariffs, Decree-Law no. 168/99, of May 18, Decree-Law no. 339-C/2001, of December 29, Decree-Law no. 33A/2005, of February 16, and Decree-Law no. 225/2007 of May 31) (“Decree-Law 189/88”). However, special regime generation is also affected by Decree-Law 29/2006 and Decree-Law 172/2006, insofar as these relate to the SEN.

The statutory and regulatory regime applicable to the generation of renewable electricity differs from that applicable to the generation of electricity from other non-renewable sources in relation to licenses, tariffs and electricity sale rights.

The Portuguese special regime provides that qualified special regime operators may sell electricity to last recourse suppliers that are required to purchase electricity under the special regime pursuant to article 55 of Decree-Law 172/2006, of February 15. The right of the special regime operator, and the correspondent obligation of the last recourse supplier, do not, however, limit the ability of special regime operators to sell electricity to other suppliers of electricity operating in the market. When the special regime operator sells the electricity to the last recourse supplier, it will receive an amount corresponding to the tariff applicable to special regime generation for the electricity sold.

**Electricity Transmission**

Electricity transmission activities are carried out through the national transmission grid, under an exclusive concession granted by the Portuguese government. Presently, the exclusive concession for electricity transmission has been awarded to REN Rede Eléctrica by article 69 of Decree-Law 29/2006, following the concession already awarded to REN Rede Eléctrica by article 64 of Decree-Law no. 182/95, of July 27.

Under the concession, REN Rede Eléctrica is responsible for the planning, implementation, and operation of the national transmission grid, the related infrastructure, as well as all of the relevant interconnections and other facilities necessary to operate the national transmission grid. The concession also provides that REN Rede Eléctrica must coordinate the SEN infrastructures to ensure the integrated and efficient operation of the system, as well as the continuity and security of electricity supply.

**Electricity Distribution**

Electricity distribution under the New Electricity framework occurs through the national distribution grid, consisting of a medium and high voltage network, and through the low voltage distribution grids.

The national distribution grid is operated through an exclusive concession granted by the Portuguese state. This exclusive concession for the activity of electricity distribution is held by EDP's subsidiary EDP Distribuição pursuant to article 70 of Decree-Law 29/2006, as a result of converting the license held by EDP Distribuição under the Old Electricity Framework into a concession agreement. The terms of the concession are set forth in Decree-Law 172/2006.

The low voltage distribution grids continue to be operated under concession agreements to be entered into after a public tender administered by the relevant municipalities. The existing concession agreements will be maintained but amended to comply with the new regime as provided for in Decree-Law 172/2006.

**Electricity Supply**

Electricity supply is open to competition, subject only to a licensing regime. Suppliers may openly buy and sell electricity. For this purpose, they have the right of access to the national transmission and distribution grids upon payment of the access charges set by the Portuguese Energy Services Regulatory Authority (Entidade Reguladora dos Serviços Energeticos, ‘‘ERSE’’), an autonomous public entity.

Under market conditions, consumers are free to choose their supplier, without any additional fees for switching suppliers. A new entity, whose activity will be regulated by ERSE, will be created to oversee the logistical operations that facilitate switching suppliers for consumers.

The New Electricity Framework enumerates certain public service obligations for suppliers to ensure the quality and continuity of supply, as well as consumer protection with respect to prices, access charges and access to information in simple and understandable terms.

EDP's licensed supplier of electricity for the liberalised market is its subsidiary EDP Comercial.

As required by the Electricity Directive, since January 1, 2007, the role of last recourse supplier has been undertaken by an independent entity, EDP - Serviço Universal, S.A., created for this purpose by EDP's subsidiary EDP Distribuição, and by the local low voltage distribution concessionaires until the free market is fully efficient and until the respective concession contracts have expired.

Pursuant to amendments introduced by Decree-Law 264/2007 of July 24, the last recourse supplier is further required to buy forward energy in the markets managed by OMIP and the Sociedade de Compensação de Mercados de Energia, S.A. ("OMIClear") in the quantities and at auctions defined by DGEG. Purchases of energy in the market managed by OMIP include listed annual, quarterly and monthly electricity futures contracts, at base-load and with physical delivery. The purchases are recognised for the purpose of regulated costs whenever they reach maturity.

The last recourse supplier must manage the different forms of contracts in order to acquire energy at the lowest cost. All unneeded surplus electricity acquired by the last recourse supplier is resold on the organised market.

**Operation of the Electricity Markets**

The operation of organised markets for electricity is subject to joint authorisation from the Minister of Finance and the Minister responsible for the energy sector. The entity managing the organised markets is also subject to authorisation from the Minister responsible for the energy sector and, when required by law, from the Minister of Finance. Organised electricity markets should be integrated into any organised electricity markets established between Portugal and other EU Member States.

Generators operating under the ordinary regime and suppliers, among others, can become market members.

The organised market corresponds to a system with different methods of contracting that allow supply and demand of electricity to meet, encompassing the forward, daily (comprised of bulk energy transactions to be delivered on the day after the contract date that must be physically settled) and intra-daily markets (comprised of transactions that must be physically settled).

Since July 1, 2007, MIBEL has been fully operational, with daily transactions from both Portugal and Spain, including a forward market that has operated since July 2006. MIBEL currently has at present two market operators:

- OMEL, which is the current market operator of the Spanish market, manages MIBEL's spot transactions market; and
- OMIP, which is presently managed from Portugal, manages MIBEL's forward transactions market. It is planned that OMEL and OMIP will be merged into a single market operator, OMI, pursuant to an agreement between the Spanish and Portuguese governments dated October 1, 2004, as amended.

The non-organised markets consist of bilateral contracts between the entities of MIBEL, settled either by physical delivery or by differences and are subject to approval by ERSE in Portugal.

**Logistics for Switching Suppliers**

Under market conditions, consumers are free to choose their electricity supplier and are exempt from any payment when switching suppliers. In order to manage the process of switching suppliers, which will also be required to manage the electricity reading and measurement equipment, a

Logistics Operator for Switching Suppliers (“OLMC”) will be created. This entity will have to be independent in a legal, organisational and decision-making sense, from the other entities in the SEN.

Transmission, distribution and last recourse supply, as well as the logistics and terms applicable to the operations for switching suppliers and for managing organised markets are subject to ERSE regulation.

Legislation applicable to this activity has yet to be developed. Nevertheless, until the incorporation of the OLMC, ERSE has determined that management of the logistics for switching suppliers should be conducted by the operator of the medium and high voltage distribution grid, which currently is EDP Distribuição.

### 3.8.2 Retail electricity markets

The process of liberalization of the electricity sectors of most European countries was carried out in a phased manner, and started by including clients with higher consumptions and higher voltage levels.

In Portugal, an identical methodology was followed, and the market was progressively opened between 1995 and 2006. Since the 4th of September 2006, all consumers in mainland Portugal have been able to choose their electricity supplier.

This date anticipates the compliance with Directive no. 2003/54/EC, which established the 1st of July 2007 for all electricity purchasers to be able to freely choose their supplier.

Associated with the liberalization and the construction of the internal market in electricity is an expected increase in competition, reflected in the level of prices and the improvement in the quality of the service, which should lead to greater satisfaction on the part of electricity consumers.

**Tariffs and Prices [2]**
For electricity to be used, it must be produced and later transported and distributed to the consumer's premises. This route comprises various stages which define the value chain for the Electricity Sector: production, transmission, distribution and sales.

For each of the activities mentioned, ERSE determines the profit allowed in accordance with the methodologies of regulation defined in the Tariff Code.

The profit allowed gives rise to the electricity tariffs which are defined and published annually by ERSE, in accordance with what is established in the Tariff Code.

The various stakeholders in the Electricity Sector (consumers and electricity industry) are involved in the process for the approval of the tariffs and the Tariff Code.

- The tariff for the Global Use of System must provide profits for the Global System Management activity which includes costs for the operation of the system, costs arising from energy or environmental policy measures, or measures with a general economic interest, and costs from the maintenance of the contractual balance (CMEC).
- The tariff for the Use of Transmission Network must provide profits from the Electricity Transmission activity which includes the establishment, operation and maintenance of Very High Voltage (VHV) transmission networks and interconnections.
- The tariff for the Use of High Voltage (HV) and Medium Voltage (MV) Distribution Networks must provide profits from the regulated activities of distribution of HV and MV electricity which correspond to the planning, establishment, operation and maintenance of the distribution networks in a way which connects electricity from its points of reception to the end customers. Similarly, the tariff for the Use of LV Distribution Network allows for the recovery of profits from the regulated activity of Distribution of LV Electricity.
- The Energy tariff must cover permitted costs arising from the last resort supplier's activity of Buying and Selling Electricity, which includes the costs of acquiring the electricity, supplying it to the clients, and related operating costs.
- The Retail Commercial tariff must provide profits for the regulated supply activity which includes the last resort supplier's structure for selling electricity to its clients, namely contracting, invoicing and collecting payment for the electricity sold.

In this context, the planned tariff system is said to be additive because for each regulated activity there is an associated regulated tariff and the final sales tariff applicable to each client is composed of a sum of the various activity tariffs which are attributable to this client's supply.

The Networks Access tariffs (Portuguese version), which includes the tariffs for the Global Use of System, the Use of Transmission Network and the Use of Distribution Network are paid by each electricity consumer in the Regulated and Free Market, and are included in the sales tariffs of the various suppliers, its value being listed in the electricity bill that the client receives from their supplier. These tariffs are approved and published annually by ERSE.

The End User Tariffs (Portuguese version) from the last resort supplier are obtained by adding the prices of the Networks Access tariffs to the prices for the Energy tariffs and the Retail Commercial tariff, and are only applied to Regulated Market consumers. These tariffs are approved and published annually by ERSE.

The End User Tariffs for Very High Voltage, High Voltage, Medium Voltage and Low Voltage Special (> 41,4 kW) were extinct in September 29th 2010, by the Decree-Law no. 104/2010.

The prices practised in the Free Market are determined by each supplier and negotiated individually with each client.

Method of Recruitment and Selection of Supplier [3]

Under the electricity market, the RRC (Rule of Trade Relations) provides the following methods of procurement of electricity:

a) Contract of electricity supplying with vendors in a market regime.
b) Contract of electricity supplying with the last resort traders.
c) Through the trading platforms of organized markets;
d) Through bilateral contracts with entities legally authorized to supply electricity.

Considering the eligibility of all the facilities of electricity, and on ensuring that the process of changing supplier is not in itself a barrier to switching, the RRC establishes the procedures, terms and obligation to disclose information relating to procedure for changing supplier. It is guaranteed to all customers the right to change supplier, no charge may be required by the change.

### 3.8.3 Metering

**Measuring and readings [3]**

The electrical meters (meters and power indicators), and their accessories are supplied and installed by the grid operator at points of entry to the clients home's that are physically connected to distribution networks. The supply and installation of measuring equipment shall be borne by the grid operator, as the owner thereof, which may not charge any amount as compensation for the rental or use of these devices. The measuring equipment of facilities for customers in BTE, MT, AT and MAT must have technical features that allow its integration into centralized telemetry.

The verification of measuring equipment is mandatory for the operator of the distribution network, and in accordance with the schedule established in the regulations.

**Reading of consumption**

- The operator of the distribution grid should promote the monthly reading for customers in BTE (contracted power exceeding 41.4 kW). For customers BTN (contracted power up to 41.4kVA), which include domestic, should be ensured that the interval between readings is not more than three months. If this reading was not successful, the operator must notify the customer that he was tempted to read or take action to inform the client of the date of the next reading. The information collected by direct reading of meters precedence over any other, but methods can be used to estimate consumption.

In 2001 the Portuguese Government published a resolution with several energy efficiency measures, and described the objective to "support the progressive implementation of telemetering for electricity, water and gas as a strategy for distribution network and quality service improvement". [4] Also during 2001 the Portuguese and the Spanish Governments took the first steps towards the Electricity Iberian Liberalized Market (MIBEL) where both Portuguese and Spanish consumers could buy electricity freely from any agent in the market. Technical agreements specified by

MIBEL include: the compulsory installation of digital meters for new facilities since July 2007 and also the replacement of all traditional meters (6 million in Portugal) by telemeters. This represents an enormous cost and political negotiations are still in course to clarify who will pay for the equipment's substitution. In 2002 the National Energy Regulator Entity (ERSE) was created for electricity and natural gas market regulation. Telemetering was not, however, a much discussed topic in the following years.

Portugal started in March 2011with large-scale implementation of Smart Electricity Grid - Smart Grid - in charge of a consortium led by EDP Distribuição. [5]

The first phase of the project consists of installing approximately 30,000 new electrical energy meters - the Energy Box - on Low Voltage customers, covering most of the city of Évora, thus initiating the concept of InovCity. It is intended to cover six million of all customers in seven years, namely in 2017.

### 3.8.4 Distributed generation

Most of the interconnection requirements for Distributed generation in Portugal are defined in certain decree-laws and in one base document, the so called "Guia Técnico das Instalações de Produção Independentede Energia Eléctrica".

An update on interconnection requirements was included in a revision. The present grid code is a step in the direction of international tendencies, since it already defines fault-ride-through requirements as well as reactive power support during faults. However, this is only defined for wind farms over 6 MVA.

This type of requirement confirms two things:

1. Wind power dominates the DG technology mix in Portugal.
2. Most wind power is connected at higher voltages (for the distribution network this means the 60 kV voltage level) and the plants have significant installed power (over 5 MW).

If a growing number of small units (< 1 MW) start to connect to the MV and LV network, the grid code may need to be adapted.

# 4. Energy brokerage methods

## 4.1 Wholesale pricing models

Because storing of electricity in large volumes is not yet possible, electricity offer and demand has to be balanced at every instant to ensure the system stability. The transmission system operators (TSOs) are the body responsible for keeping this balance. Setting the electricity market prices is key for trading operation and therefore to ensure this balance.

Market price of electricity is typically formed in the day-ahead market to balance the generation and consumption during the delivery hours of the following day. The prices obtained constitute an essential tool to determine the optimal merit order of generation (efficient use of generation capacity) [7].

The main pricing models implemented for electric energy pricing are marginal cost (MC) and pay-as bid (PAB):

***Marginal cost pricing***
Marginal cost pricing strategies are made through so-called uniform-price auctions (or single clearing price auctions). Here, all suppliers receive the same market-clearing price, which is set at the offer price of the most expensive resource chosen to provide supply. The system will accept first the cheaper options before turning to more expensive technologies. This way, each supplier would tend to bid at its actual marginal cost.

This pricing strategy is characterized by a market-facing approach that tries to estimate and influence demand for a product. The business sets production targets and bases pricing on what it costs to produce additional units at that point.[18]

Figure 11 describes the price fixation mechanism, while crossing demand (red) and supply (green) curves. The demand curve indicates the consumers' willingness to pay and the supply curve indicates marginal cost of generation. Only offers below the crossing price (light green) are accepted and they are paid this so-called marginal price, i.e. the price of the most expensive accepted offer.

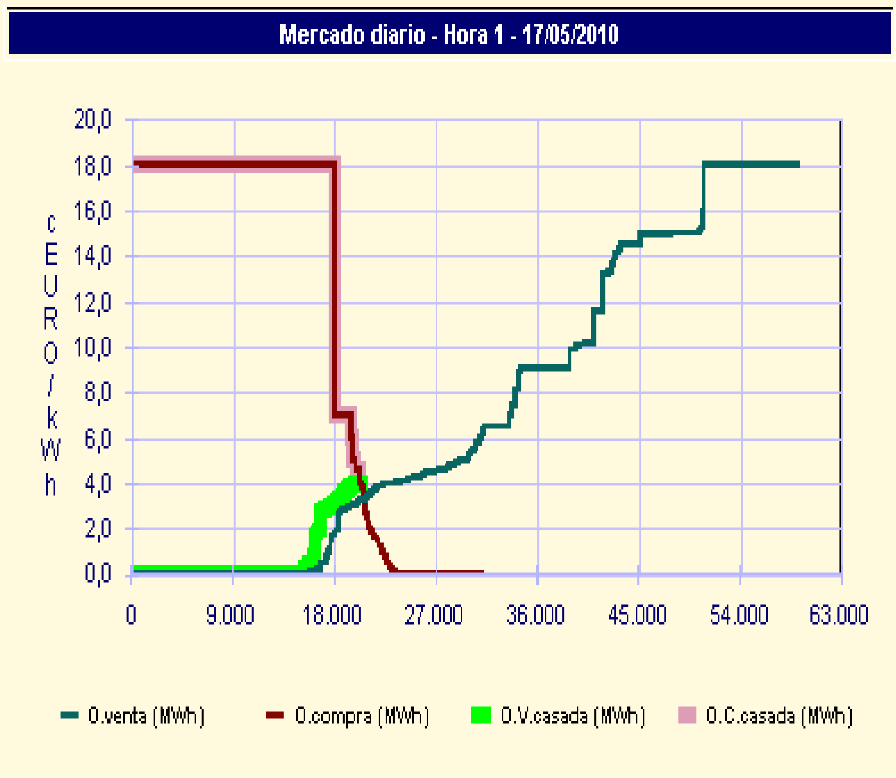



***Figure 11: Demand and supply curve for price fixation.*** [7]

With the margin obtained, the suppliers can cover fixed costs incurred by plant owners. Critics point out the fact that the already redeemed technologies would obtain a high income that represent entirely a profit (the so-called "windfall profits").

It is interesting to note that the demand curve is inelastic; therefore minor changes in the supply can result in major price changes. As renewable power, like wind or solar, has a low marginal cost due to zero fuel costs, their bids enter the supply curve at the lowest level. This shifts the supply curve to the right, resulting in a lower power price. This is called the 'merit order effect'.

***Pay-as-bid pricing***

Under pay-as-bid auctions, prices paid to winning suppliers are based on their actual bids. Incumbents are supposed to set prices by using the full cost of making the products at the set production volume. Therefore, we can consider that this pricing strategy is "inward-looking", focusing on the product and how on much it costs to make it. [18]

[7] Source: www.omel.es

Nevertheless, critics of this system argue that suppliers in a pay-as-bid auction would tend to bid their best-guess of the final market price in order to maximise their revenues, instead of bidding their actual marginal price. Bids would therefore be higher than actual product costs and price paid to each supplier would not stick to reality.

## 4.2 Wholesale market models

To avoid congestion problems, different systems can be applied to determine the price within a market (country level).

***Zonal pricing [7]***
In zonal pricing (area price) systems the target is to determine a single price for the whole market area. When the congestion of the transmission network prevents the formation of uniform market price, the market contains separate market areas that have separate prices. The basic principle is that the congested lines are known and market can be divided into the areas in which the intra-zonal congestion is rare.

In the zonal pricing model, the electricity transmission system operators responsible for the main transmission grid inform about the transmission capacity available, and the power exchange calculates the price for electricity based on the bids of market parties.

In Central Europe and the Nordic countries, the zonal pricing model is applied. However, there are some differences between the implementation of the models.

- Market splitting: applied, for example, in the Nordic countries. One power exchange (Nord Pool Spot) calculates the system price for entire Nordic region and if there is grid congestion, the market are divided into two or more price areas.
- Market coupling: applied, for example, in the CWE (Central West European Region). Two or more power exchanges carry out the price calculation. The wholesale are prices first calculated for each region and then if the available transmission capacity between regions is sufficient the common electricity price is obtained.

***Nodal pricing***
Nodal pricing (also called Locational Marginal Pricing, LMP) model systems are typical for a congested transmission system and they comprise several small submarkets (nodal points). If there are numerous bottlenecks in the system, the required power has to be generated locally and consequently, the price is determined locally. [7]

This is the system used in some areas in the US, in Australia, New Zealand or Russia. In the nodal pricing model, the transmission system operator is responsible both for the operation of the transmission grid and the electricity price calculation.

With Locational Marginal Pricing, prices are determined by the bids/offers submitted by market participants. In addition to the energy component, the electricity price includes a transmission congestion fee and losses.

The prices differ by location when transmission congestion occurs. The idea behind is that during congestion low-cost generation cannot access the market, resulting in higher prices. With nodal prices, the constrained area would form a single node, which would be served by high-cost generation (raising the market price in the constrained area), whereas in the unconstrained area will concentrate more low-cost generation (lowering the market price in the unconstrained area).

In the nodal pricing, a major risk lays in the price differences between nodes caused by transmission congestions; this uncertainty can be hedged against by purchasing certain transmission hedge products, such as Financial Transmission Rights (FTRs). Another risk is that usually one node is a small elementary market with few generators and so there is a chance a market power abuse, therefore market surveillance is usually tight.

Although in Europe congestion management is traditionally addressed by zonal pricing (with market coupling or splitting), some projects and research[20] advocate for nodal pricing as the method which addresses the best the needs for an integrated smart grid market and a low carbon economy in Europe. The explanation for this is that with zonal pricing, price zones do not match country borders and are variable, whereas actual prices are defined taking into account those national borders. As a result, the actual price zones are artificially created and prevent an optimal grid operation. On the contrary, with nodal pricing the price zones defined are very small and would better deal with these variations.

## 4.3 Retail dynamic pricing schemes

***Time-of-use (TOU)***
Different unit prices are defined for usage during different time periods within a day (o-peak/off-peak hours). It rates the average cost of generating and delivering power during those time periods.

***Critical Peak Pricing (CPP)***
The on-peak times are limited to just a few critical days per year when demand is expected to be the highest (instead of daily on-peak hours as in TOU structures). The consumers can be charged a much higher electricity price during those times or benefit from an electricity bill rebate to encourage consumption reduction.

***Real-time pricing (RTP)***
Pricing based on real-time movements in electricity prices based on trade in spot markets, balancing markets or other exchanges. It links hourly or half-hourly prices to corresponding changes in real-time or day-ahead power costs. Customers are typically notified of expected RTP prices on a day-

ahead or hour-ahead basis to elicit load response. With RTP tariffs, consumers can see (and react to) changes in marginal costs throughout the day. The standard approaches typically involve a one-part pricing arrangement where prices fully reflect movements in hourly or half-hourly wholesale spot prices. More sophisticated variants may involve two-part pricing where real-time prices are charged for marginal usage above or below a historic baseline for consumption. Two-part methodologies have been adopted to provide a means of protecting customers from undue exposure to price volatility. [17]

***Combinations***

Some utilities have implemented pilots that combine the elements of both CPP and TOU or RTP and CPP [18].

***Peak load reduction credits***

Credits for consumers (generally with large loads) as result of agreement with the utility. Instead of charging a high rate during critical events as in CPP, consumers (willing to participate) are paid for load reductions during those critical times.

# 5. The module for local energy brokerage

The energy brokerage module will take care of energy trade between a numbers of cells in a microgrid.  A microgrid is here defined as a number of cells that trade energy with each other. The main objective is to secure that as much as possible of the local produced energy are used locally. This has a number of advantages. E.g. the losses in the main grid will be minimized. The load requirement to the main grid will get lower. If it is profitable for the local consumer they will properly act more responsible i.e. use the energy when it is available.

Implementing of such a local energy exchanges market isn't possible in many countries in Europa due to regulations in these countries. E.g. for two of the major countries in EU the regulations are as followed:

**Microgrid regulation in Spain**
Self-consumption for grid-connected facilities has been enabled in 2011 through the Royal Decree 1699/2011. The regulation explicitly forbids the energy exchange from a self-producer to another consumer, i.e. forbids the selling of any energy produced by a self-consumption installation. Actually, the regulation states that the generation and consumption incumbents have to be the same.

This would clearly prevent any microgrid creation with energy exchange.

**Microgrid regulation in Germany**
Germany recognises the Direct Marketing option, which would allow the creation of a microgrid with energy exchange. Direct marketing implies that operators of PV installations may sell electricity directly to third parties and it is explicitly fostered by German regulation. Direct marketing has to be announced to the grid operator one month in advance. Self-consumption of PV power is remunerated provided that the third party consumes the electricity within the immediate vicinity of the installation.

The idea of making local energy trade in a microgrid is a relatively new research field. Not much can be found about the subject.[21],[22] describe who two microgrid in Islanding Mode can trade energy. They use a centralized and a distributed approach to the problem and fund that the centralized solution are the optimal one. However this centralized method can have some problem with respect to privacy, because it has to have access to all necessary information. In the ENCOURAGE case it is assumed that there won't be any problems with privacy, because all information a kept inside the local community. This means that all parties shall be willing to expose their production, consumption and flexibility to the energy trading system.

The local energy trade has to be fully automatic. This is because it has to run as an autonomic system without interaction form the users. Furthermore it has to be profitable for all the involved parties. These parties are the producers, the consumers the prosumers and the one responsible for implementing and maintaining the microgrid.

Main requirement:

- The energy trade shall be an autonomic system. I.e. the system shall be independent of user inputs. It can use user inputs for optimization but should not be depending on these inputs.
- The local selling and buying price shall be calculated by the system. These prices shall secure that all the involved parties will have a benefit of the system. I.e. The buying price from the microgrid shall be lower than the buying price from the utilities. Like vice the selling price to the microgrid shall be higher than the selling price to the utilities. This leads to the main assumption: **The buying price from the utilities shall be higher than the selling price to the utilities.** This is not the case in all countries in EU. E.g. in DK are these two price the same, for some kind of small producers. For them there is no idea in implementing a local microgrid.
- The system shall secure that, as much as possible of the local produced energy, are consumed locally.

The ENCOURAGE three layer control hierarchy as shown in Figure 12.

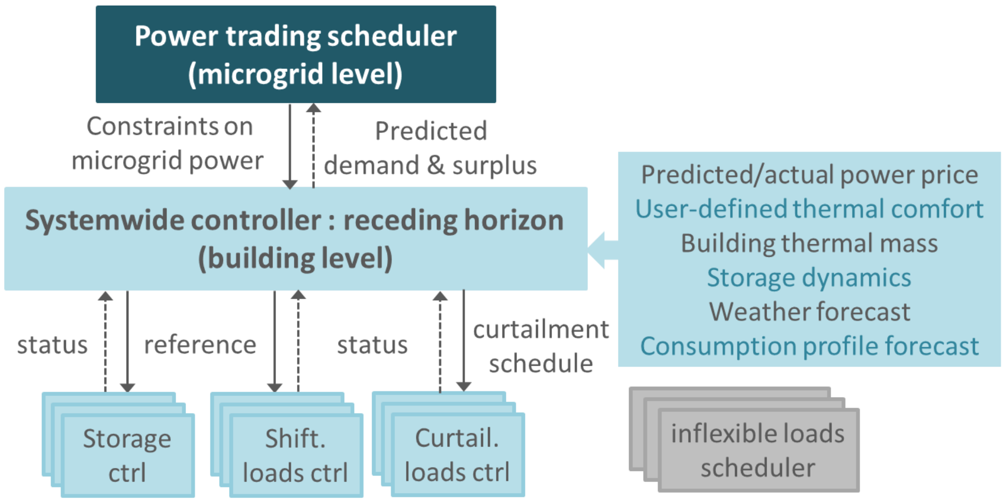



***Figure 12. Structure of the hierarchical controller composed three layers.***

- Device layer at the bottom of hierarchy comprises single loop controllers for controllable (shiftable and curtailable) loads, controllable generation units (not available) and storage devices (not available). It is responsible for maintaining set points and light adjustment.
- Cell (building) level at middle of hierarchy includes a system-wide controller that keeps the economy and comfort in balance. It minimizes the cost of electricity consumption while maintaining the comfort levels determined by the user. A priori knowledge about building dynamics, comfort preferences, weather changes, power generation and price of electricity

are needed. The forecast inputs are supplied by a prediction module which is part of *Encourage*. This layer receives status signal from device controllers i.e. heating/cooling thermostats and provide them with reference signals.

- Microgrid level at the top is responsible for distribution of locally generated energy among households with energy demands. It receives predictions of power surplus profile (for sale) and power needs profile (to be purchased) from the system-wide controllers in the middle. Based on these inputs, it assigns surplus of power and energy in the microgrid among the demanding houses. The system-wide controller is designed such that power produced by PVs is consumed by the producing house at the first place. The surplus of energy is distributed by the energy trading system among the other houses with power need/demand.

The building level controller is described in full details in Deliverable D5.3. The focus of this report is on energy trading system at the microgrid level.
The energy trading system can either be implemented as a marked based strategy or as a mathematical solution to a formal described problem with some constraints. The mathematical solution will be described in deliverable D5.4 Energy management system. Here the focus will be on the marked based strategy.

## 5.1. The marked based strategy

The marked based strategy is built on ideas from ordinary energy trade. Normal energy trade is centred on a marketplace i.e. NordPool, beside that there is a regulating market for adjusting the production and consumption. In the microgrid cast, it is also necessary, to have a load distributer. The task for this sub-module is to handle the problem with unbalanced production and consumption. I.e. everyone can’t have their needs fulfilled, by the microgrid, and must therefore use the main grid.

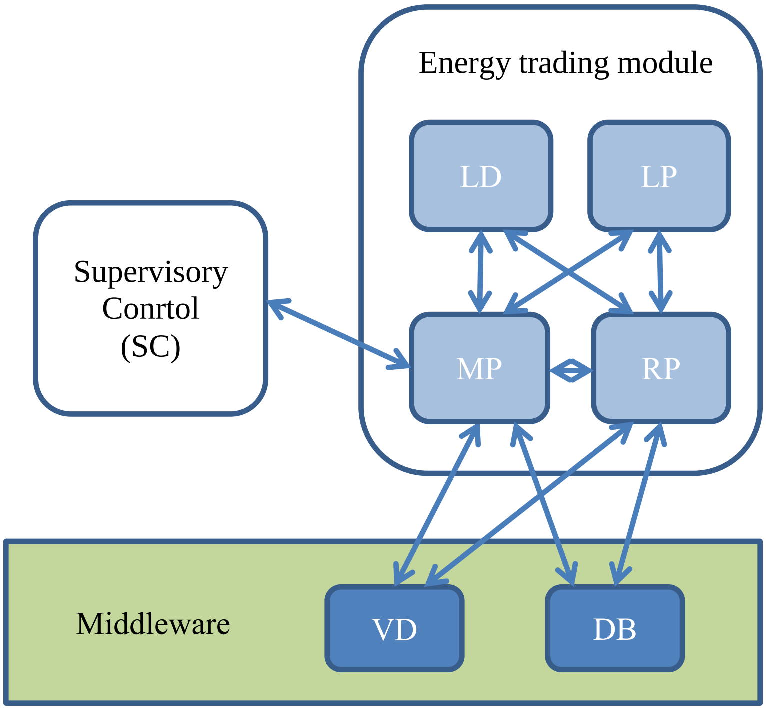



***Figure 13: The structure of the energy brokerage module and the communication with the rest of the system.***

The energy brokerage module are divided into four sub module, the Marketplace sub module(MP), the Regulating Power sub module(RP), the Load Distributer sub module(LD) and the Local Price calculator sub module(LP).

Figure 13 shows the structure of the energy brokerage module and the communication with the rest of the system.

- MP: The task, for this sub module, is to coordinate the trade of energy inside the macorcell. The selling parties are cells with a surplus of energy and the buying parties are cells with a need/demand for energy.
- RP: This sub module will come into play if there is a mismatch between the production and the consumption inside the microgrid. This, of course, will be the normal case, which means that this sub module will be used almost all the time. The task for RP is to utilize the flexibility of the individual cells, and by that means, try to use as much as possible of the local produced energy and buy as little as possible from the utility.
- LD: This sub module will, depending on the strategy chosen for the MP sub module, secure that every cell are treated according to the chosen strategy. This means, in the real case, that each cell shall be treated as fair as possible.

- LP: This sub module will, on an hourly base, calculate the local energy prices. This will be done based on the prices from the utilities and if necessary input from the MP and RP module.

Figure 14 illustrate the trading scenario to two different time samples. The tradable energy is distributed to the cells with a consumption need/demand. This is done by the MP sub module. The regulatable energy is minimized by using the flexibility of each cell. This is done by the RP sub module.

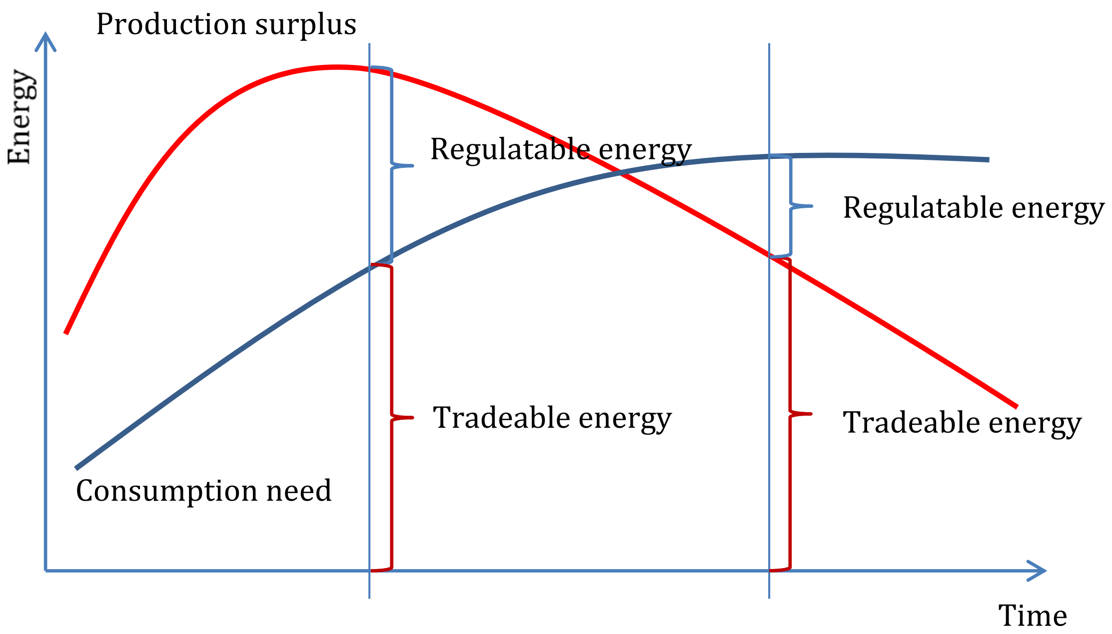



***Figure 14: The tradable energy done by the MP sub module and the regulateable energy done by the RP sub module.***

The input to the Energy brokerages module will come, either from the middleware module through the virtual devices, or from the middleware database, or directly from the Supervisory control module.

The Inputs from the middleware are:

| Signal name | Periodicity | | | | | |
|---|---|---|---|---|---|---|
| **Production measurement** | **15 min** | **Cell ID (Integer)** | **Device ID (Integer)** | **Active power (float) (kWh)** | **Reactive power (float) [kWh]** | **Time (long)** |
| **Consumption measurement** | **15 min** | **Cell ID (Integer)** | **Device ID (Integer)** | **Active power (float) (kWh)** | **Reactive power (float) [kWh]** | **Time (long)** |
| **Energy surplus/demand** | **15 min** | **Cell ID (Integer)** | **Power ([kW] Float)** | **Energy ([kWh] Float)** | **Time (long)** | |
| **Consumption forecast** | **1 hour** | **Cell ID (Integer)** | **Energy ([kWh] Float)** | **Time (long)** | | |
| **Production forecast** | **1 hour** | **Cell ID (Integer)** | **Energy ([kWh] Float)** | **Time (long)** | | |
| **Utilities offers and prices** | **1 hour** | **Utility ID (integer)** | **Timeframe (long)** | **Power Price (float) [€/kW]** | **Energy Price (float) [€/kWh]** | |

**Production measurement and Consumption measurement:** These signals is production/consumption from a single device or a total cell (Device ID = 0).

- **Cell ID**: The Cell ID for the actual cell.
- **Device ID**: The device ID if needed.
- **Active power**: The production/consumption in kW. The real part of the total power which is the part we are trading.
- **Reactive power**: This part of the production/consumption will not be concerned, because the trading system will not try to balance the mismatch between the current and the voltage phase.
- **Time**: The actual time for generating the signal.

**Power surplus/demand**: The surplus/demand signal from a cell.

- **Cell ID**: The Cell ID for the actual cell.

- **Power**: The power surplus/demand signal from a cell. If the value is positive then the cell has a power surplus to offer to the microgrid. Otherwise if the value is negative then the cell wanted to buy this amount of power from the microgrid.
- **Energy**: The Energy surplus/demand signal from a cell. This value is the accumulated energy surplus/demand since last sample.
- **Time**: The actual time for generating the signal.

Notes: If the cell have utilized some flexibility then this part are subtracted from the signal so the values reflect the normal surplus/demand without the use of flexibility.

**Consumption/Production forecast**: The forecast signals from the forecast module. See deliverable 6.2.

- **Cell ID**: The Cell ID for the actual cell.
- **Energy**: The 24 hour ahead forecast.
- **Time**: The actual time for generating the signal.

**Utilities offers and prices**: The price signal from the utilities.

- **Utility ID**: The ID that identifies the utility.
- **Timeframe**: The price are for the next 24 hours starting from the time defined by this signal
- **Power price**: A 24 hour power price.
- **Energy price**: A 24 hour energy price.

The Inputs from the supervisory control module are:

| Signal name | Periodicity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Flexibility | 15 min | Cell ID (Integer) | Duration 'From' (long) | Duration 'to' (long) | Storage capacity up ([kWh] Float) | Storage capacity down([kWh] Float) | Up power ([kW] Float) | down power ([kW] Float) | Time (long) |
| Stored energy | 15 min | Cell ID (Integer) | Stored energy ([kWh] Float) | State (Integer) | Time (long) | | | | |

**Flexibility:** This signal is generated by each cell and describes the cells possibility to turn up or turn down the consumption of electricity.

- **Cell ID**: The ID for the actual cell.
- **Duration From/to**: The time window for applying the flexibility
- **Storage capacity up**: The amount of energy that the cell is able to store.
- **Storage capacity down**: The amount of energy that the cell is able to release.
- **Up/down power**: The amount of power that the cell is able to increase/decrease the consumption.

- **Time**: The actual time for generating the flexibility signal.

**Stored energy**: This signal contain the amount of releasable energy stored e.g. in batteries.

- **Cell ID**: The Cell ID for the actual cell.
- **Stored energy**: The amount of releasable energy stored e.g. in batteries.
- **State**: The state of the batteries. Are they chargeable, dischargeable or both.
- **Time**: The actual time for generating the signal.

**The Output**

There are two types of output from the energy brokerages system:

1. Control output to the SC module, telling each cell to increase or decrease the consumption.
2. Output to the database system, telling how much each cell buy and sell to/from the microgrid and what the local energy price are.

Control output to the SC module:

| Signal name | | | | | | |
|---|---|---|---|---|---|---|
| **Increase/decrease consumption** | **Cell ID (Integer)** | **Duration 'From' (long)** | **Duration 'to' (long)** | **Energy ([kWh] Float)** | **Power([kW] Float)** | **Time (long)** |

**Increase/decrease consumption**: This signal tells the specified cell to either increase or decrease its consumption:

- **Cell ID**: The ID for the actual cell.
- **Duration From/to**: The time window for applying the control signal
- **Energy**: The amount of energy that the cell shall store or release.
- **Power**: The amount of power that the cell shall increase/decrease the consumption.
- **Time**: The actual time for the control signal.

Output to the middleware database:

| Signal name | | | | |
|---|---|---|---|---|
| Price on the local market | Price ([€/kWh] Float) | Time (long Integer) | ID_LocalMarket (integer) | |
| Imported local energy | Cell ID To (Integer) | Cell ID From (Integer) | Consumed energy ([kWh] Float) | Time (long) |
| Exported local energy | Cell ID To (Integer) | Cell ID From (Integer) | Generated energy ([kWh] Float) | Time (long) |

**Price on the local market**: This signal contains the information about the local microgrid energy price:

- **Price**: The actual price.

- **Time**: The actual time for the control signal.
- **ID_LocalMarket**: The ID for the local marked (Microgrid ID).

**Imported local energy**: This signal tells the specified cell to either increase or decrease its consumption:

- **Cell ID To**: The ID for the buying cell.
- **Cell ID From**: The ID for the selling cell.
- **Consumed energy**: The amount of energy bought from the microgrid.
- **Time**: The actual time for the control signal.

**Exported local energy**: This signal tells the specified cell to either increase or decrease its consumption:

- **Cell ID To**: The ID for the buying cell.
- **Cell ID From**: The ID for the selling cell.
- **Generated energy**: The amount of energy sold to the microgrid.
- **Time**: The actual time for the control signal.

### 5.1.1. Marketplace: The MP sub module

The main job for the marketplace will be to facilitate the following:

The cells with a surplus, puts there extra energy in into a pool of available energy. The cells with a demand can, if there is available energy in the pool, buy from the pool. How much each selling cell get sold depend of how many and how much the buying cells are willing to buy. The marketplace use the actual surplus/demand of energy from each cell, given by: $E_{surplus,i}(k)$. This means that MP is based on what has been produced and consumed since last sample. The marketplace is, so to say, a local distribution of what has happened since last sample.

This will be done like this:

Find the total microgrid surplus $E_{surplus}$ by adding all positive energy surplus/demand from each cell.

Find the total microgrid demand $E_{demand}$ by adding all negative energy surplus/demand from each cell.

The smallest of the total microgrid surplus and the total microgrid demand,

$$E_{trade} = \min(E_{surplus}, E_{demand}),$$

is the amount of energy that is tradable within the microgrid.

Next step is to sell the tradable energy $E_{trade}$ to the cells with a demand. Below the algorithm for this energy trade is explained in pseudo programming language with some comments:

When there are a new set of energy surplus/needs available:

Set: $E_{left} = E_{trade}$

For all cells in the microgrid -

1. Ask the LD sub module which cell (cell # $i$) is the next, to buy. I.e. The MP queue.
2. If cell # $i$ have a negative energy surplus/demand sell some energy, given by $E_{buy,i}$ to that cell.

   If $E_{left} > E_{buy,i}$ then

   $$E_{left} = E_{left} - E_{buy,i}$$

   Else $E_{buy,i} = E_{left}$ and $E_{left} = 0$.

3. If not all cells with a demand are served and more energy to sell go to 1 otherwise stop.

Where: $E_{buy,i}$ are the amounts of energy that cell # $i$ is allowed to buy.

For all selling cells in the microgrid –

The amounts of energy that are sold to the microgrid by the cell # $j$ are given by:

$$E_{sell,j} = E_{trade} \frac{E_{surplus,j}}{E_{surplus}}$$

Where: $E_{surplus,j}$ Is the available surplus from cell # $j$.

The reminding problems are how to determine $E_{buy,i}$ and how to set the price for the local trade energy. Or in other word to decide how much each cell can buy and what they shall pay for it. This decision can be done in many ways:

1. **The liberal market**. Here the surplus of energy is put to sale on the local market and sold to the one that will pay the most. If the energy can’t be sold locally then the price will be defined by the utilities. This market could be based on auction.
2. **Traditional queue based shopping**. As long as there is energy left then the costumers are served in queue order. The queue shall be organized as a clock algorithm. Here the energy

price has to be a fixed price, independent of the buyer. This price can be calculated in many different ways. The two most relevant methods are:

1. **Equal benefit**. Here the system estimates the profit for the seller and buyer and pick a price that equals these two profits. This of course can be a complicated task to solve, because the production cost depends on a number of parameters and can be different from cell to cell.
2. **The mean price**. The selling and buying price are set to the mean of the selling and buying price to and from the utilities. It is of course possible to set the price higher than the mean price to encourage investment in production equipment.

If needed, the buying price can be slightly higher than the selling price, to gain some profit inside the system.

3. **A socialistic approach**. All with a need get a share according to the size of their need. The price can be calculated like described about. I.e:
    1. **Equal benefit**. Like 2.1.
    2. **The mean price**. Like 2.2.

| Method | Implementation effort | Fairness | Requires user input | Cheatable |
|---|---|---|---|---|
| 1 | Difficult | Very fair | Yes | Yes |
| 2.1 | Very difficult | Very fair | Yes | Yes |
| 2.2 | Relative easy | More or less fair | No | No |
| 3.1 | Very difficult | Very fair | Yes | Yes |
| 3.2 | Relative easy | Fair | No | No |

Method 1, 2.1 and 3.1 can't be used because they require user interaction. They will not be analysed further. Method 2.2 and 3.2 are good candidates for implementation. They will be described in more details.

Method 2.2: **Traditional queue based shopping with mean prices**

This method requires a queue based way of handling the buyers. Implementing this queue is done by the load distributer sub module. See the LD sub module for a description for this function.

Method 3.2: **A socialistic approach**

This method doesn't require a LD sub module because the distribution among the cells with a demand can be calculated based on the amount of traded energy and the individual demands.

For all buying cells in the microgrid –
The amounts of energy that are sold to the microgrid by the cell # $i$ are given by:

$$E_{buy,i} = E_{trade} \frac{E_{demand,i}}{E_{demand}}$$

Where: $E_{demand,i}$ is the demand from cell # $i$.
$E_{demand}$ is the total microgrid demand.
$E_{buy,i}$ is the amount of energy that cell # $i$ can buy.

### 5.1.2. Regulating Power: The RP sub module

After running the MP sub module, often there will still be a mismatch between the local production and the local consumption. The task for the RP sub module is to use the flexibility of the individual cell to find the best match between production and consumption in the next time period. This means that the RP sub module are based on a one step prediction of the energy surplus/demand from each cell, given by: $\hat{E}_{surplus,i}(k+1)$ and on a one step prediction of the power surplus/demand from each cell, given by: $\hat{w}_{surplus,i}(k+1)$. These predictions are the estimated production and consumption without any contribution from the RP module.

First steps are:

To find the prediction of the total microgrid surplus $\hat{E}_{surplus}(k+1)$ by adding all positive energy surplus/demand from each cell.
To find the prediction of the total microgrid demand $\hat{E}_{demand}(k+1)$ by adding all negative energy surplus/demand from each cell.

The smallest of the total microgrid surplus and the total microgrid demand, $\hat{E}_{trade} = \min(\hat{E}_{surplus}(k+1), \hat{E}_{demand}(k+1))$, is the amount of energy that is expected to be tradable by the MP sub module. The reminding part from $\hat{E}_{trade}$to either $\hat{E}_{surplus}$ or $\hat{E}_{demand}$ called $\hat{E}_{mismatch}$ are the amount of energy that is regulated by the RP sub module.

In the rest of the description all values will be to time k+1, unless specified other vice.

There are three possible scenarios:

- If $\hat{E}_{trade} < \hat{E}_{surplus}$
- If $\hat{E}_{trade} < \hat{E}_{demand}$
- If $\hat{E}_{surplus} = \hat{E}_{demand}$

Below these three cases are explained in pseudo programming language with some comments:

If $\hat{E}_{trade} < \hat{E}_{surplus}$ then:

If the microgrid has a larger energy surplus then it is possible to handle by the MP sub module then RP will try to sell this extra energy to a local cell with increase capabilities. Otherwise it will sell to the utility. The local price will be the utility sell price.

$\hat{E}_{mismatch} = \hat{E}_{surplus} - \hat{E}_{trade}$
$\hat{w}_{mismatch} = \hat{E}_{mismatch}/\tau$

Where:

- $\hat{w}_{mismatch}$: are the power mismatch between production and consumption.
- $\hat{E}_{mismatch}$: are the energy mismatch between production and consumption.
- $\tau$ : are the time between two samples. (15 minutes).

For all cells in the microgrid

1. Ask the LD sub module which cell (cell # $k$) is the next in the up regulating power queue.
2. If cell # $k$ have the possibility to increase the power consumption, then ask cell # $k$ to increase its consumption with the power $w_{reg,k}$ in a time interval given by $\tau_{frame}$ where $w_{reg,k}$ and $\tau_{frame}$ can be calculated like this:

If $\hat{w}_{mismatch} > w_{up,k}$ $and$ $\hat{E}_{mismatch} > E_{up,k}$ then

If $w_{up,k}\tau \leq E_{up,k}$ then $\tau_{frame} = \tau$ else $\tau_{frame} = \frac{E_{up,k}}{w_{up,k}}$

$w_{reg,k} = w_{up,k}$

If $\hat{w}_{mismatch} > w_{up,k}$ $and$ $\hat{E}_{mismatch} \leq E_{up,k}$ then

$\tau_{frame} = \hat{E}_{mismatch}/w_{up,k}$

If $(\tau_{frame} > \tau)$ then $\tau_{frame} = \tau$

$w_{reg,k} = w_{up,k}$

If $\hat{w}_{mismatch} \leq w_{up,k}$ $and$ $\hat{E}_{mismatch} > E_{up,k}$ then

If $\hat{w}_{mismatch}\tau \leq E_{up,k}$ then $\tau_{frame} = \tau$ else $\tau_{frame} = \frac{E_{up,k}}{\hat{w}_{mismatch}}$

$w_{reg,k} = \hat{w}_{mismatch}$

If $\hat{w}_{mismatch} \leq w_{up,k}$ $and$ $\hat{E}_{mismatch} \leq E_{up,k}$ then

$\tau_{frame} = \frac{\hat{E}_{mismatch}}{\hat{w}_{mismatch}}$

If $(\tau_{frame} > \tau)$ then $\tau_{frame} = \tau$

$$w_{reg,k} = \widehat{w}_{mismatch}$$

$$\widehat{E}_{mismatch} = \widehat{E}_{mismatch} - w_{reg,k}\tau_{frame}$$

$$\widehat{w}_{mismatch} = \widehat{w}_{mismatch} - w_{reg,k}$$

$\tau_{from} = \tau_{now}$ and $\tau_{to} = \tau_{now} + \tau_{frame}$

3. If not all cells with the possibility to increase the power consumption has been processed and $\widehat{E}_{mismatch} > 0$ goes to 1 otherwise stop.

If $\widehat{E}_{trade} < \widehat{E}_{demand}$ then:

If the microgrid has a larger energy need then it is possible to handle by the MP sub module then RP will try to buy this extra energy from a local cell with decrease capabilities. Otherwise it will buy from the utility. The local price will be the utility buy price.

$\widehat{E}_{mismatch} = \widehat{E}_{demand} - \widehat{E}_{trade}$
$\widehat{w}_{mismatch} = \widehat{E}_{mismatch}/\tau$

For all cells in the microgrid -

4. Ask the LD sub module which cell (cell # $k$) is the next in the down regulating power queue.
5. If cell # $k$ have the possibility to decrease the power consumption, then ask cell # $k$ to decrease its consumption with the power $w_{reg,k}$ in a time interval given by $\tau_{frame}$ where $w_{reg,k}$ and $\tau_{frame}$ can be calculated like this:

If $\widehat{w}_{mismatch} > w_{down,k}$ *and* $\widehat{E}_{mismatch} > E_{down,k}$ then

If $w_{down,k}\tau \leq E_{down,k}$ then $\tau_{frame} = \tau$ else $\tau_{frame} = \frac{E_{down,k}}{w_{down,k}}$

$$w_{reg,k} = w_{down,k}$$

If $\widehat{w}_{mismatch} > w_{down,k}$ *and* $\widehat{E}_{mismatch} \leq E_{down,k}$ then

$$\tau_{frame} = \widehat{E}_{mismatch}/w_{down,k}$$

If $(\tau_{frame} > \tau)$ then $\tau_{frame} = \tau$

$w_{reg,k} = w_{down,k}$

If $\widehat{w}_{mismatch} \le w_{down,k}$ $and\ \hat{E}_{mismatch} > E_{down,k}$ then

If $\widehat{w}_{mismatch}\tau \le E_{down,k}$ then $\tau_{frame} = \tau$ else $\tau_{frame} = \frac{E_{down,k}}{\widehat{w}_{mismatch}}$

$w_{reg,k} = \widehat{w}_{mismatch}$

If $\widehat{w}_{mismatch} \le w_{down,k}$ $and\ \hat{E}_{mismatch} \le E_{down,k}$ then

$\tau_{frame} = \frac{\hat{E}_{mismatch}}{\widehat{w}_{mismatch}}$

If $(\tau_{frame} > \tau)$ then $\tau_{frame} = \tau$

$w_{reg,k} = \widehat{w}_{mismatch}$

$\hat{E}_{mismatch} = \hat{E}_{mismatch} - w_{reg,k}\tau_{frame}$

$\widehat{w}_{mismatch} = \widehat{w}_{mismatch} - w_{reg,k}$

$\tau_{from} = \tau_{now}$ and $\tau_{to} = \tau_{now} + \tau_{frame}$

6. If not all cells with the possibility to decrease the power consumption has been processed and $\hat{E}_{mismatch} > 0$ goes to 4 otherwise stop.

If $\hat{E}_{surplus} = \hat{E}_{demand}$ then: Do nothing.

Where:
- $E_{up,k}$ : are the amounts of energy that cell # $k$ can increase its energy consumption.
- $w_{up,k}$ : are the amounts of power that cell # $k$ can increase its power consumption.
- $E_{down,k}$: are the amounts of energy that cell # $k$ can decrease its energy consumption.
- $w_{down,k}$: are the amounts of power that cell # $k$ can decrease its power consumption.
- $w_{reg,k}$ : are the regulation signal sent to cell # k.
- $\tau_{from}$ : are the start time for applying of the regulation signal.
- $\tau_{to}$ : are the stop time for applying of the regulation signal.

It shall be mentioned here that in the case $\hat{E}_{trade} < \hat{E}_{demand}$ then the entire production surplus in the microgrid will be handled by the MP module. In this case there is no need for a central down regulation handling based on the individual cell flexibility. The down regulation can, and in many cases will, be done by the building level control system. This means that there will be two controllers that try to control the same thing. This situation won't be a problem because the total setup are designed in such a way that if a local controller uses the local flexibility to lower the energy bill, then it doesn't have any flexibility to send to the energy trading system. By that mean, will the RP sub module; automatically be decoupled from the system with respect to that specific cell. If the local controller choose to use some of its flexibility locally and send the rest to the energy trading system then the two controllers will run in parallel. That won't give any problems because the control action from these two controllers will be added together and furthermore they will have the same control target namely to minimize to energy cost for the individual cell.

### 5.1.3. Load Distributer: The LD sub module

LD's task is to secure a fair distribution of cheap local produced energy. This can be done by a simple clock algorithm where each cell is connected in a specific order. The algorithm will, when asked, come up with the next, in the row, that fulfils some specific conditions. Other algorithms can be used e.g. when looking for a cell with a power need then take the one with the largest need. It is decided to use the clock based algorithm, because also cells with a small demand shall have the possibility to get some energy. This is like a normal shop, where everyone that wanted to buy, get served in queue order, independent of how much they wanted to buy.

The clock algorithm is given by this:

All cells are organized in a specific order in a cyclic list e.g. set by the local trade system maintainer. A microgrid with N cell is illustrated on figure 15.

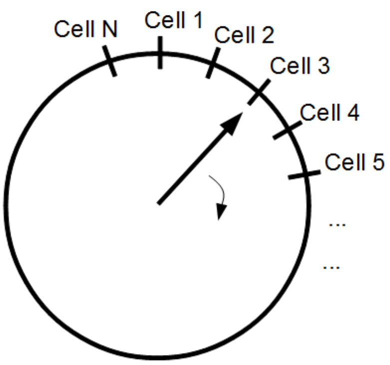



*Figure 15: The clock based cell queue.*

The hand is pointing to the cell that has been served latest. The next buying cell can be found by a simple clock algorithm:

1. Turn the hand one cell clockwise.

2. If this cell is a demanding cell then stop otherwise if not all cells are asked then go to 1.

Now the hand will point on the next cell that is allowed to buy energy from the microgrid. This cell will, if there is enough energy in the pool, get its need fulfilled. After that if there is more energy in the pool then run the clock algorithm again, and thereby find the next cell, in the row. The hand will stop when all the available energy is sold or all cells with a demand have got what they wanted. Next time there are energy available, the first cell to ask, is the one right after the last one served. This secure that all cells are asked the same number of times.

There will be three clock based queues in the LD sub module. One for deciding the next cell to buy power and one to decide the next cell to utilize the Up regulation flexibility, and one to decide the next cell to utilize the down regulation flexibility.

### 5.1.4. Local Price calculator: The LP sub module

The LP's task is to calculate the four local energy trading prices. These are:

1. The selling price on the local marked.
2. The buying price on the local marked.
3. The Up regulation price.
4. The down regulation price.

The first two prices are the selling and buying price of the local produced surplus of energy. Of course if the MP sub module is based on some kind of liberal market strategy then the price will be a result of the selling and buying at the market place.

The local price will always be something between the selling and buying price from the utility. A simple solution could be the mean of these two prices. Other more complicated method could be to take the investment in production facilities in to account. The idea here is to encourage the investment in production equipment by giving the people, who invest, more benefit then the consumer.

Another important issue is to gain some profit in the local system to secure the maintenance of the system. This can be done by having a slightly higher buy price then the selling price. It is assumed that this profit can be very low, because the system doesn't require any operation interaction. In this case, the only cost is replacement of computer hardware. Another way to handle this maintenance cost, is to let the users paid directly. This should be based on a collective agreement among the users of the microgrid.

In this case, it is chosen to let the selling and buying price (1 and 2) be the same and the price are set to the mean of the selling and buying price to and from the utility.

The up regulation price (3) will be the same as the selling price to the utility. This meant that, if there is a surplus in the microgrid, after the MP sub module has done its job, then the cell which are willing to consume more energy, will have to pay a price, for the extra energy, that are equal to the main grid selling price, which is the cheapest price in the system.

The down regulation price (4) will be the same as the buying price from the utility. This meant that, if there is a need in the microgrid, after the MP sub module has done its job, then the cell that are willing to reduce their energy consumption, will get a reduction in their energy bill that are equal to the main grid buying price, which is the highest price in the system.

This payment is, of course, indirect because it reflects the reduction in used energy. So this payment is handled locally in the individual cell and doesn't have any influence on other cells.

The up regulation price and the down regulation price prices are chosen so that the amount of up and down regulation won't have any effect on a user that doesn't let the system use there flexibility. They will pay the normal price for the energy. The total cost saving, by applying the flexibility will be given to those that participate in the local regulation power market. It shall be mention that the flexibility signals are generated by each cell. This means that the decision, to participate or not and when to participate, are up to each cell to decide. To make this decision, each cell will typically look at the selling and buying price from the utility, the time of day, the state of the house and so on.

## 5.2. Simulations

At the moment of writing this deliverable, there is no connection to the houses and the rest of the system through the middleware. The plan is to document the functionalities in deliverable D5.4 The energy management system. This documentation will be done by simulation based on real data from the houses.

# 6. Conclusion

This deliverable is divided into these parts:

1. Describing the existing power trading and distribution system in a number of European countries. Chapter 2, 3.
2. The normal Energy brokerage methods used by the Wholesale electricity markets and by the Retail electricity markets are described in Chapter 4.
3. Based on that the energy brokerage module is designed in Chapter 5.

1): In general, the energy trade regulations in the European countries are based on a liberal market. In many countries, these regulations don't open up for implementing of local microgrid where individual small energy producer can trade energy with their neighbours. This means that the energy trading system developed in this deliverable will, in many countries, requires a new set of regulations, before it is possible to implement it in real life.

2): Market price of electricity is typically formed in the day-ahead market. The strategy is to balance the generation and consumption during the following day. This market price is found by some international power exchange markets like e.g. the Nord Pool Spot marked for the Nordic countries. On the Retail market there are a number of price models in Europa. Some of them are:

***Time-of-use (TOU)***
Different unit prices are defined for usage during different time periods within a day.

***Critical Peak Pricing (CPP)***
The consumers can be charged a much higher electricity price during specific time period.

***Real-time pricing (RTP)***
Pricing based on real-time movements in electricity prices based on trade in spot markets.

***Combinations***
Some utilities have implemented pilots that combine the elements of both CPP and TOU or RTP and CPP [18].

***Fixed prices***
The price will be fixed for a specific time period.

The Retail market prices shall secure that all the involved parties, in the local trading system, will have a benefit of the system. I.e. The buying price from the microgrid shall be lower than the buying price from the utilities. Like vice the selling price to the microgrid shall be higher than the selling price to the utilities. This leads to the main assumption: The buying price from the utilities shall be higher than the selling price to the utilities. This is not the case in all countries in EU.

3): There has been developed a new module for local energy trade. This module are an autonomy unit and consist of four sub module, the Marketplace sub module(MP), the Regulating Power sub module(RP), the Load Distributer sub module(LD) and the Local Price calculator sub module(LP).

- MP: This sub module, coordinate the trade of energy where the selling parties are cells with a surplus of energy and the buying parties are cells with a need/demand for energy.
- RP: This sub module comes into play if there is a mismatch between the production and the consumption with in a microgrid. The task for the RP sub module is to utilize the flexibility of the individual cells, and by that mean, try to minimizing the selling and buying form the main grid.
- LD: This sub module will, depending on the strategy chosen for the MP sub module, secure that every part are treated according to a queue based strategy.
- LP: This sub module will, on an hourly base, calculate the local energy price. This are be done based on the prices from the utilities. The MP selling and buying price are the same and set to the mean of the utility selling and buying price. The Up regulation price is the utility buying price and the down regulation price is the utility selling price.

At the moment of writing this deliverable, there is no connection to the houses through the middleware. Simulations that show the functionality of the local energy trading system will be descript in deliverable D5.4 The energy management system.

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