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InovGrid

Benefits and New Business Models under a Smart Grid Context

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Abstract: InovGrid - Benefits and New Business Models under a Smart Grid Context

Over the next decades, Portugal will face the large-scale introduction of smart-grid technology. With new “smart” requirements, EDP Distribuição will eventually re-define its busines model. Consumption and energy efficiency data was analyzed, resulting in findings of cost and energy savings. To ensure the capture of those benefits and a smoothening of smart grid development, the new role of EDPD as an active distribution management system is presented. Last but not least, the consumer will be enlightened in his role and the reaction towards a dynamic pricing structure which will culminate in a new paradigm of an active Demand Response environment.

Keywords: Demand Response, Smart Grid / InovGrid, Dynamic Pricing, Active Distribution Management

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1 CONTEXT

In the following chapter, EDP Distribuição (EDPD) will be aligned in the Portuguese market regarding smart grid management. First, the company will be described with its core activities, second EDPD will be characterized in its Portuguese market of grids concession management. Furthermore, the current situation of EDPD under a smart grid context will be elaborated resulting in a definition of challenges, EDPD might face in the future smart grid environment.

1.1 Overview of EDP Distribuição

EDP Distribuição (EDPD) belongs to the EDP Group, a global energy company which is the largest generator, distributor and supplier of electricity in Portugal. EDPD is Portugal's major electricity Distribution System Operator (DSO), managing the grid market with its major tasks in (1) planning, construction, operation and maintenance process of the National Electricity Distribution Network; (2) public lighting investment and maintenance; (3) compliance of Quality of Service and other regulatory requirements (ensuring safety and quality of supply in addition to network connections to any customer) as well as (4) the provision of market support when it comes to metering management and switching of suppliers. Moreover, it enables energy efficiency promotions, environment protection and sustainability in the use of resources. Regarding the remaining organization of the electricity sector, it is legally independent in the decision making process. (EDPD, 2015) EDPD is responsible for almost the whole market, having more than 6 million end-customers, corresponding to more than 99% of the total market in the mainland of Portugal.

1.2 Portuguese Market Overview within Grid Concession

As stated above, EDPD holds a monopoly position in the Portuguese market; it also operates in more than 20 countries, with a major foothold in Spain and Brazil. It is therefore the only electricity DSO in the mainland of Portugal with High Voltages (HV) and Medium Voltages (MV) concessions while having a market share of more than 99% of Low Voltages (LV) concession. Although EDPD manages the energy grids in Portugal, it does not owe them. HV/MV are granted by the government for a period of 25 years and will expire in 2043. 278 LV concessions are granted by corresponding municipalities for a period of 20 years, with most of the contracts ending until 2021. Therefore, EDPD has to ensure that it will get the rights to all the concessions when they will be renewed. It is important to have all the concessions remaining within the company to ensure its market power and an efficient grid management which can otherwise be negatively impacted if different concessions are managed by different DSOs. Besides distribution (DSO), the following market functions are involved in the energy system: Generation, transmission, supply, operation of the electricity market and the logistical operations that facilitate the switching of electricity suppliers for consumer. (EDP, 2015) The electricity generation is licensed to many generation plants from different endogenous and renewable sources (e.g. large hydro power plants in Portugal). It is carried out in a competitive environment. The electricity transmission (Transmission System Operators, TSO) is carried out through the national transmission grid, which is under an exclusive concession granted by the Portuguese government. With this, the TSO is responsible of planning, implementation and operation of the national transmission grid and its related infrastructure with relevant interconnections. The electricity supply is open to competition and is subject to licensing, granting the rights of buying and selling electricity. For this, supplier can access the national transmission and distribution grids upon a payment of access charges set by the Portuguese Energy Services Regulatory Authority. From the consumer perspective, they are free to choose the supplier (retailer). Switching supplier is possible without any additional fees and is overseen by a new entity of the regulator, ERSE. The Minister of Finance and the Minister for energy sector are responsible for the authorization of operations of organized markets for electricity.

1.3 Current Situation of EDP Distribuição regarding Smart Grid Context

Electricity grids that are used today by the majority of developed countries are older than 50 years and are more and more becoming outdated. Therefore, the current trend goes towards increasing the efficiency of energy production and a modernization of the use of grid assets, aiming towards a more reliable and secure network. Currently, new technologies are developed and employed, that will make the grids "smarter" (Gelazanskas et al, 2014). As defined by the European Technology Platform (European Commission, 2006) "A smart grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both in order to efficiently deliver sustainable, economic and secure electricity supplies." The goals of smart grids can be captured by economic and technical efficiency, increased sustainability, improved reliability of supply and increased customer services (Tan, 2011). With recent technological improvement, communication and sensing development, smart grids are more and more empowered in the world, with the United States, South Korea and Japan being pioneers. These countries are followed by the European countries, which are getting more and more encouraged by the EU regulations, aiming an overall 80% rollout of smart meters[1] until 2020. Traditionally, there has been a centralized generation of energy, pushed by one-way transmission and distribution networks to the end-customers. Nowadays, distributed renewable energy generation, distributed energy storage, utility scale renewables etc. are being integrated into the energy system. Moreover, a new communication layer is incorporating for the exchange of data information and control. Thus the whole grid landscape including the different stakeholders, such as customers, retailers, the DSO, the Transmission System Operators (TSO) are subject to change from the structure and business models, they have been facing historically. (Gelazanskas et al, 2014)

In line with this EDPD has developed InovGrid, a smart grid solution which has currently been installed in the city of Évora and 6 other locations in Portugal. Electricity grids are equipped with intelligent information system and equipment which focus on automated network management, improved service quality, reduced operating costs, fostered energy efficiency and a more sustainable environment (Matos et al, 2013). This is enabled by an integrated architecture and innovative tools composed of an *active Demand Response (DR) system*, providing information on energy consumption, an *integration with Smart Home*s, such as smart appliances, a *Smart Metering Data Processing*, a two-way data obtainment and communication of the InovGrid infrastructure, an *integration of Distributed Energy Resources* (DER), enabling coordination and synergy management of DER by responsive loads and distributed small-scale storage, *an Automation and Control of MV*, reducing the need of field teams and managing short time failures by an automated remote control device as well as an *Integrated Communication solutio*n (InovGrid, 2013). This creates a solution empowering energy efficiency, load and generation management, e-mobility, and energy storage by an optimal exploitation of synergies between the system tools. This whole system can be identified as an emerging smart grid ecosystem with multiple interfaces touching different stakeholders in the electricity value chain: From end-consumers, some of them being producers ("prosumer") at the same time, micro-generators, to electricity retailers, transmission system operators, electrical vehicles (EVs) and other companies that gain strengths from the new systems, have the possibility to create value and setup new business models benefiting the different stakeholders. (Matos et al, 2013)

[1] A smart meter is an electronic device that records electricity/energy consumption in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing. Smart meters enable two-way communication between the meter and the central system.

That being developed, the first results can be seen in Évora regarding energy efficiency and load management. As consumers are exposed to new information about their consumption by EDP boxes (smart meters), invoices based on real consumption and tariff simulation, energy buses, participation in sessions with small groups of clients, presence in both local and national press, energy efficiency tips via mailing, web access to EDP online energy management (alerts via sms, email etc.) and conferences/events about smart grids; energy efficiency has increased in 2014 with an overall reduction of about 4%.

1.4 Challenges under a Smart Grid Context

With an increasing smart grid environment and on-going initiatives for Renewable Energy Sources (RES) and DER integration, the current business model for stakeholders is facing challenges as new roles have to be assigned and existing roles have to be re-defined aiming a smoothening of the evolution.

With smart grid technology, information is the lever for managing distribution systems efficiently and cost-effective by enabling the deployment and management of more distributed resources. EDPD is taking on new roles with regard to balancing and ancillary services, flexibility and data management while remaining a neutral market facilitator. Currently, EDPD is designed according to a "networks follow the predicted demand" paradigm and follows the "fit and forget" approach (by solving operational problems in the planning phase) (Farmad et al, 2012). Its core roles include the following: energy flows are delivered by EDPD in one direction from stations to end-users; local constraints are prevented (e.g. peak loads) by planning network investments and by adjusting the grid configuration. The "new generation" of EDPD will face challenges: (1) consumers are getting into the center of attention: smart grid technologies, especially Demand Response[2], is embraced by and dependent of consumers from different size (companies, home owners etc.). The trend of efficient energy management is increasing as consumers want to take advantage of flexible options, micro generation and cost savings. (2) There will be a rapid technological development in the areas of metering, sensing, data management, control of resources enable faster and more pro- and re-active approaches. (3) Due to the variability of power flows (integration of variable generation/ load capacities and peak demand), the "network follows demand" approach will result in high investments in network expansion and operational

[2] Demand Response is a consumer-centered program offering a direct source of revenue to residential, commercial and industrial customer by lowering or adjusting the energy consumption at strategic times (peak loads) with control signals or financial incentives.

activities (e.g. maintenance). A new system needs to improve connections in order to reduce costs and delays. Thus, the new generation of EDPD has to find solutions with regard to *regulations and funding* (e.g. regulatory support and definition of rules for new services to support the emergence of new business models), *people* (e.g. increased customer engagement), *process* (e.g. management of increasing volumes of data and large automation of operations) as well as *technology* (e.g. hardware and software of smart grid in end-to-end integration).

2 REFLECTION ON THE WORK DONE

In this chapter, we discuss the impact and the future role of EDPD in a smart grid operation context with more actively engaging electricity demand (Demand Response). Beside the role of EDPD, the system in which it operates will be aligned, assessing the potential benefits of smart grids. Lastly, recommendations to EDPD will be enlightened, integrating the active engagement of the system as a whole with a focus on consumer participation regarding Demand Response.

2.1 Problem definition

Although smart grid implementation is emphasized by the European Union with more than 450 European smart grid projects being undertaken, Portugal has not yet relocate levers to deploy smart grid technologies over the whole country. EDPD is expecting to face an investment of more than 600 million Euro in order to deploy smart grid technology due to the *replacement of current LV meters with electronic devices* called EDP Boxes, integrating automated meter management; *the installation of local control equipment in MV/ LV transformers* for measuring, actuation, processing, interface, communication; *the acquisition of equipment and technologies* for information transmission; and *the integration of systems and applications* for management and central data processing (Giordano et al, 2012). Moreover, as stated in 1.4 the deployment of smart grids will impact the current role of EDPD, as it will face new challenges such as increased data management and smart metering development. Therefore, the problem can be defined as the following: ***Besides a high initial investment for smart grid deployment, EDPD is not able to capture smart grid benefits with its current functionalities and business model in a smart grid environment.*** Therefore, the research topic we will focus on, addresses the following question: *How can EDPD capture value from smart distribution grids, taking the system and stakeholder interaction into account?*

2.2 Methodology

It is hypothesized in 2.2.1 that EDPD is in need of a business model change in order to ensure a smoothening of smart grid deployment in Portugal. It is assumed that EDPD as well as the system can only capture the benefits analyzed in 2.2.2 if the new business model approach is applied. The work plan including data handling will be described in 2.2.3.

2.2.1 Hypothesis: Business model change of EDPD

With an increase in energy demand, the penetration of electric/hybrid vehicles, the deployment of renewable energy sources, peak load increase, aging grid asset infrastructure and the increased environmental awareness and possibilities of self-sufficient energy supply, smart grid deployment is unstoppable (Heinen et al, 2011). With developing political and public expectations, EDPD has to deal with the pressure on reliable, flexible and affordable distribution. Currently, the regulator (ERSE) is limiting the revenues through a tariff code (fixed tariffs) and regulation parameters (e.g. regulated gross profit for EDPD of 1.194M € for electricity distribution in 2015) (EDPD Investor Briefing, 2015). Consequently, it becomes important to justify any expenditure by showing that it either prevents a larger expenditure in the future, or that it is an efficient way of serving the goals of a DSO as a "smart grid enabler". Thus it is hypothesized, that with an investment of 600M €, the justification of smart grid is in heavy need of taking into account a change in the business model of EDPD in order to capture value from the new system. As the whole system will be affected by a change in the business model, it is important to assume and stimulate the change of business model within all stakeholders. As stated in the 4.4, the "fit and forget" approach is outdated in a smart grid environment because the whole system and stakeholder interaction is getting more dynamic. This arises especially from Demand Response, as the encouragement of consumers by programs and activities to change their electricity usage pattern is one of the major characteristics of smart grid technology. Timing and level of electricity demand are modified and can be changed to increased energy efficiency by using time-of-use and dynamic rates in pricing, reliability programs such as direct load control of devices, and other market options for demand changes, such as demand side bidding (Article 15, Energy Efficiency Directive, European Commission).

By looking at this factor, it can be assumed that EDPD is in need of business model changes regarding (1) network planning and operation processes (2) TSO cooperation (3) dynamic reaction in electricity markets (4) data management and (5) customer interaction as to Demand Response. With these changes, EDPD might capture potential benefits of smart grids.

2.2.2 Analysis: Benefits of smart grid deployment

This section will analyze the benefits of smart grid deployment. To ensure consistency, the following assumptions for smart grid technology are defined:

- The system is based on interaction within the distributed architecture, including embedded sensors and control elements.
- The grid operation is self-configuring and self-healing. It is able to detect, control and change energy operations regarding failure detections.
- The system is participative regarding Demand Response. Customers can actively participate, control and overlook their energy consumption.
- Data is dynamic. The information flow is based on real-time. Automated distribution (changes) and mobile computing are assumed.
- Two-way communication is enabled within the system and enables net metering, remote connections and real-time pricing options.

Currently, daily demand and consumption peaks are determined by historic data. Grids experience peaks on a daily base and on a seasonal base. For Portugal, the highest daily peak can be found at 9 P.M. (Exhibit 1) and the season with the highest energy consumption can be found in winter (Exhibit 2, red colored lines). These behavior patterns can be explained by the fact that residential (as opposed to commercial) consumer are the main contributor to peak consumption: Portuguese people come home from work very late, doing their household and preparing dinner at a time around 9 PM. As winter is cold and isolation of buildings are in poor conditions, a lot of energy is used especially with old, energy inefficient heating systems. These numbers are different compared to other countries. For examples, Germany is facing its peak hours between 12-4 PM as commercial and industrial activities are outweighing household effects. The U.S. grid for example, is expecting its seasonal peak in summer due to a high usage of air conditioning (Bergaentzlé et al, 2014). According to the load duration curve, the top 6% of top peak energy capacity was only used by 1,3% of the year (Exhibit 3). Therefore, two questions remain: can energy be shifted on a daily basis so that load is shifted to off-peak times and can energy be shifted on a seasonal basis?

A seasonal load shifting is considered to be rather unrealistic. For example, for cold and rainy days in winter, heating will stay constant, and it is impossible to shift heating consumption into another season, such as summer. Thus no seasonal load shifting is possible. But intra-daily changes might affect energy load shifting. EDPD currently plans grid usage based on historic annual peak demand. As 25% to 37% energy production is based on hydro-electric generation and is therefore dependent on changing climate conditions, historical data is rather volatile. Thus, the difference between used and available grid capacity is unstable. If more energy is transported outside peak times, the installation of expensive generation capacity, usage from old polluting plants and maintenance costs can be avoided. Moreover, as energy prices are dependent on a demand and supply equilibrium, lower energy consumption and better forecast methods can decrease energy prices for retailer, which then can be passed on to consumers. With smart grid technology and an active network management (real-time information, decision and controls of load flexibility), the utilization of grids can be changed towards a more effective approach. Demand Response therefore enables load flexibility, as consumers can switch energy consumption to lower price times during a day. With the smart meter being an essential element of two-way data exchange and digital on-time information, EDPD can get insights into the usage patterns of the distribution grids. Based on this information, EDPD can control the connected generations and loads and optimize the energy flow between the grids, resulting in a better and more efficient utilization of the assets. Control means that consumers can voluntarily respond by changing their energy consumption behavior dependent of information about electricity prices and other incentives (Zhu et al, 2011). Consumers do not have to give up their comfort of using electrical appliance, but rather benefit from innovative energy management systems and smart meters that support Demand Response on a voluntary basis. Nevertheless, increased energy usage awareness due to the provision of information might lower the overall energy consumptions. As defined in the InovGrid project at Évora, the use of technology such as EDP online energy management, education and dynamic tariffs will have an impact on energy demand. EDPD can profit from Demand Response by shifting the capacity utilization peak time to off-peak times (Tan, 2011). Thus, EDPD will have to be in contact with consumers by trying to influence their personal load shifting. These might affect usage patterns such as operating the washing machine at a different time than before during a day.

Load shifting is expected to decrease the need of grid capacity during peak time and therefore lowers grid need, especially when it comes to older, polluted grids, which might only be operated in peak times. Thus EDPD investment of grid reinforcement can be deferred or even be eliminated.

Although EDPD only holds concessions or LV, HV and MV networks, EDPD is responsible for the investments into those networks. Annual investments within the last five years have ranged between 278M € and 330M € and are expected to be in the same range within the next 5 years. These investments can be divided into mandatory investments (e.g. investments associated with consumption capacity needs due to increased peak capacity), structuring investments (e.g. improvement of network performance regarding Quality of Service), current investment (e.g. grid refurbishment and LV grid development) and urgent investment (e.g. fault detections). When looking into the future, EDPD is expecting annual grid development investments related to the overall investments from 12M € to 19,2M €. Due to load shifting, a reduction in investments for peak power plants and subsidies for reserve capacity can account for about 20% of the grid development investment, resulting in savings of about 2,5M € annually.

Besides load shifting benefits in grid investments, EDPD has a potential to decrease operations costs as more and more of the system is automatically managed (Giordano et al, 2012):

- Due to the EDP Box and automated meter management, local meter readings and local failure service will become redundant, as it can adapt automatically to changes and the system is self-healing. The EDP box is able to measure, control, react and communicate energy consumption and performance automatically.
- Distribution maintenance costs of transformers and stations can be avoided as site visits become more obsolete. This results from remote controls and the self-healing factor.
- Distribution operations costs can be reduced as it is not necessary anymore to send line workers to switch locations for operations. Capacitor banks and feeder switch automatically or remotely control the operations.
- Power outage field service can be reduced as outages are located automatically and can self-reconfigure and self-heal.

Moreover, EDPD is able to ensure reductions in losses and protect revenue:

- The EDP box is able to automatically detect energy thefts due to the identification of patterns that indicate energy diversion in customer usage by meter data. Thus losses will be reduced.

- Also, energy losses due to power transport are expected to be reduced. Due to more efficient peak load management and closer electricity production based on real-time information, reactive power will be minimized.
- Outage times will be reduced. Currently, outages are mainly recognized if customers report them. With smart grid technology, real-time monitoring and network information, anomalies are detected faster and thus can reconfigure more quickly.
- Congestions can be balanced out as Demand Response tools enable grid operations to manage the electricity flow around constrained interfaces.

These loss reductions and operational costs cannot be quantified at the moment as no data can be found on it. However, when looking at regions with a fully-integrated smart grid roll-out such as California, operational expenses of 58% within those cost factors (e.g. distribution maintenance, local metering service etc.) can be avoided (California Smart Grid, 2015). However, the above stated assumptions of smart grid technology are different to the ones in California, as the smart meter rollout is based on deviating technologies and responsibilities. Moreover, other operational costs such as IT maintenance cost, data transfer costs and network management costs will emerge.

Until now, we have seen that a 600M € investment will not be balanced out by an increase of benefits for EDPD by the same amount. Thus, when only looking at EDPD individually, it is not possible to reach the conclusion that this investment will have a positive value for EDPD. But as stated above, it is not only about the DSO by its own. The system has to be regarded in a broader perspective. As Confucius has said "If your conduct is determined solely by considerations of profit you will arouse great resentment" and this also holds true for the deployment of smart grid technology. To this effect, the benefits of the overall system has to be taken into account in order to enlighten the benefits of smart grids.

Regarding Demand Response, the system can benefit from energy efficiency and load shifting. As explained above, load shifting is dependent on price signals and a dynamic pricing model. Dynamic tariffs are based on the consumption and the energy offered at a distinct moment. With a current fixed tariff, demand is inelastic, as there is no incentive to change the demand. As long as energy is needed, it will be consumed. The supply curve is inflexible, as energy supply is dependent of external / environmental changes and cannot be influenced. Thus, when demand is high, there will be a high on-peak clearing price. With a flexible tariff structure, the price is adjustable and thus, demand is more elastic. Customers are incentivized to change their consumption pattern depending on the price. Therefore, demand will change when higher prices are offered resulting in lower demand and thus lower peak loads. When it comes to the tariff structure, it is important that dynamic pricing reflects the availability of grid capacity. Dynamic pricing can be achieved by two different DR models (which can also be applied together): Price-based Demand Response and Incentive-based Demand Response. Price-based DR focuses on time-varying rates, reflecting the value and cost of electricity in different time periods, such as Time-of-use rates (dependent on time of day), Real-time pricing (dependent on on-time available consumption data and grid capacity usage) and Critical Peak-time pricing (Real time price with critical event/peak price). Incentive-based DR is paying to participating customers in order to reduce their loads at times requested by the program sponsor, triggered either by a grid reliability problem or high electricity prices. (Cooke, 2011) When lowering the dynamic tariffs, the value of load flexibility can be passed on to the consumer.

In relation to the described dynamic pricing model (incentive based and price-based), the following analysis evaluates the economic benefits of smart grids within Demand Response, more specifically load management. For the analysis, data of hourly consumption of 2014 was used to evaluate load shifting. Based on the price elasticity on different pricings during the day, the willingness to switch to lower price and change in the demand was calculated. Therefore, consumption has been reduced during peak hours, thus between 8 PM and 11 PM as marginal cost of energy production is higher and thus consumer reduce their consumption level. During business hours (9 AM to 5 PM) the consumption will stay relatively stable, meaning that consumption will only marginally decrease (Exhibit 4). Although it is possible to switch consumption usage patterns in the commercial/industrial part, we will assume that for that price elasticity is higher on residential consumers. Moreover, there is no need for decreasing the consumption during these hours. The on-peak load will mainly shift towards off-peak periods, as the energy price is on the lowest level. By looking at how much savings could have been reached (price of energy x consumed energy), the total benefit in 2014 accounts for 27M €.

Furthermore, energy efficiency has a major impact on cost savings. Based on the Évora InovGrid project, an overall reduction of 4,4% per hour in consumption was calculated in 2014. This is due to energy saving awareness resulting in reduced electricity costs, reduced CO_2-emission, deferred distribution capacity investments and reduced oil usage. Upon this calculation, 84M € would have been saved in 2014 by the system.

With this economic value of smart grids in the system, an appropriate tariff structure can be determined, as insights in the amount of expenditure savings and the compensation for load flexibility are given. The question of how feasible load management itself is, is beyond the scope of this research. As it can be seen, there are major cost savings within the system, most of them will be skimmed by the consumer themselves, as they are the figures in the system who will have to change their behavior/model to the highest extent and will also benefit from the absorption of the lower prices.

2.2.3 Work plan: From DSO centric towards system approach

The original approach of the analysis was to find benefits of a smart-grid system itself for EDPD. After analyzing the present role of EDPD, reviewing the smart grid environment, benchmarking European and pioneer countries with a focus on DSO activities, there were two major findings identified which will influence the potential of smart grid deployment in the future: while the DSO bears high investment costs, the major benefits fall to the end-consumer. The DSO (here EDPD) has a high impact on how "smoothly" smart grid will be deployed within a country as it works as the market facilitator. On the other hand, smart grid benefits are to a high extent dependent on an efficient Demand Response system. The impact of how smoothly this runs, is however more dependent on the consumer and the willingness to "interact" or "respond" to energy consumption patterns. These findings have been challenging as we assumed to find the benefits only within the DSO, in order to be able to directly contrast investment costs with potential benefits (e.g. cost savings, revenue protection and profitability increase). Nevertheless, a direct comparison was not feasible as we have realized that smart grid technology has to be approached by the overall system. To put it in an easier metaphor: although building a highway might be expensive for the government, the overall benefits might overwhelm a high cost on one single player in the system. Especially with the encouragement of the European Union, inter-country competition, energy awareness of consumers, increasing renewable energy consumption and old grid utilization, changes are unstoppable. Therefore, it was required to understand not only the position of the DSO and its benefits but also (and even more) to analyze of how the DSO can mostly benefit within high investments and also ensure the highest possible benefits to the overall system by looking at the business model.

Moreover, data management and handling during the analysis were unfortunately not as easy available as we hoped it would be. For example, investment data for annual grid development was given; but there were no data of how many of the new investments were due to peak consumption. Therefore, a deep and mature analysis of how much investment savings could be done was not possible. Therefore, the data was only based on a five-year outlook which resulted in the loss of a long-term perspective.

2.3 Recommendations: Active distribution management & customer participation

The benefits of smart grid technology and Demand Response can be exploited to the fully extent, if and only if, the DSO enlarges its role as smart grid manager. Only the DSO will allow the system to become more flexible, efficient and customer-centric with the right tools. Therefore, the following questions need to be reflected:

- What new roles and services must EDPD assume to adapt to the changing energy paradigm? / How should the scope and responsibilities evolve within the new roles?
- What new tools/methodologies must be developed to support the new roles?
- How must regulation and markets be adapted to support the smart grid environment?
- How can Demand Response evolve over time? How can customer participation be ensured?

First of all, it is important to emphasize that the current core roles of EDPD, such as the development, operations and maintenance of network will remain in the future. Besides that, EDPD will have to manage a much more complex network, resulting from two-way communication, increased data handling and real-time information. In order to provide those services, the "fit and forget" model needs to be changed towards a role of an active distribution management system, thus the traditional role of "building and connecting" will move towards "connecting and managing" (especially data). The new management system has to address the improvement of network planning and operations process, the provision to contract and activate flexibilities, an advanced cooperation with the TSO, a facilitation and enabling of the electricity market to react dynamically, the provision of services based on data management and the empowerment of the customer. (Six, 2014)

Network planning and operation process are now being dominated by EDP boxes and smart metering processes enabling EDPD to control and supervise the whole network, supported by an increased and more precise data collection and storage. This will enable the improvement of grid development while limiting network costs. Moreover, advanced analytics and real-time supervision enables EDPD to anticipate faster and earlier operational problems such as outages.

The provision to contract and activate flexibilities allows temporarily limitations of feed-in or consumption power to enable a DR incentive based and pricing based systems. With real-time operations, energy generation can be modified fast and flexible.

An advanced cooperation with the TSO (responsible for the overall grid system) ensures an optimal constraints management, such as reactive power exchange. This provides a more cost-efficient way to management the power system at different levels.

As integrated in all changed roles, **data management** is not only a requirement for these responsibilities but can also be a key driver for future, newly created responsibilities of EDPD.

The end user potential flexibility and Demand Response participation can be exploited by EDPD aiming the optimization of the distribution network management. Therefore, EDPD cannot only benefit for itself in data gathering (e.g. due to better network planning) but also has to feed the market with the data to optimize the system benefits: Smart meters are in need of the data for DR activities, and thus an effective consumption and production. Load and generation forecasts need to be provided to stakeholders to increase planning forecasts (and to develop calculations of losses and possible constraints). Data related to quality of supply such as outages and failures will be important for the TSO as well as for EDPD. With the provision of the data to other stakeholders an efficient energy consumption, an increase in social expectation and an on-going technological revolution can be assured. Moreover, EDPD can develop new services within smart grid management and data. As the DSO is the one, to whom data is transferred first, it has the responsibility to collect, store and manage data within a regulated and secured frame. Although it is important to underline that EDPD is a neutral market facilitator and thus should be able to provide technical data in a non-discriminator way, it could enable the provision of additional data as an additional ancillary revenue part. With more and faster real-time data, retailers increase data reliability which in turn decreases costs of imbalances with regard to forecast changes during the daytime to meet actual demand. Access to timely and accurate information is crucial for the dynamics and innovation for the electricity retail market. It is important that information about the location of customers, their energy consumption value, their nature and usage pattern are known to develop more innovative products and services that eventually will empower the customer choice and deliver a greater competition benefit to end-customers, aiming an ultimate maximization of Demand Response and flexibility.

On the other hand, DR enables increased data reliability in the sense of improving energy efficiency and decreasing consumption costs. Moreover, other stakeholders such as national regulators and local authorities could be provided with additional data aiming to support sustainable development, an enhancement in the transition to carbon free economies, urban planning and Smart City demands. Thus, there will be a provision of free and on-time technical data depending on the data confidentiality and stakeholder profile. The non-discriminatory data, which is provided freely to retailers and the TSO, consists of aggregated consumption, energy flows in the network, voltage profiles and information about interruptions. Besides that, additional services and revenues can be made by the provision of commercial data, such as real-time individual data, a pricing forecast algorithm depending on real-time consumption and other third party data such as weather forecasts, which in turn can affect the forecast algorithm regarding the pricing structure due to an increased use of hydro-electric generation. As EDPD is acting as a monopoly, it is easy to create a competitive advantage, as no other stakeholder has the information available on such a real-time condition.

Furthermore, data management is only beneficial as long as stakeholders, especially consumers, are willing to change their consumption pattern. Therefore, the empowerment of the customer to create active market participation is a key determinant in driving smart grid environmental change. Transparency of pricing and incentives is important to stimulate customer's response. It is therefore important that energy management tools are created which support an easy and reliable connection, a simple understanding and fast response.

When it comes to regulatory requirements, a removal of price regulation is required to create a greater product differentiation and innovation, aiming to stimulate the entrance of new retailers into the market, which again will result into more innovation and more choice for the customer. Also, the risk of price coordination and tacit collusions might be mitigating by an increased transparency, diversity and innovation in tariffs ("smart" combination of price- and incentive-based Demand Response). Regulated prices would delay the development of dynamic and innovative energy markets, resulting into higher economic costs for consumers and loss potentials in effective energy choices for customers and Demand Response (Cooke, 2011). At the moment, retail prices in Portugal distort the market in the way that it hinders the development of an efficient and flexible Demand Response system as prices are fixed and even below costs. It results in an encouragement of overconsumption, placing grid systems under stress and increasing expensive network investments. Contrarily, it is important that tariff competitions are carefully overlooked by the regulation to ensure that customers are treated equally and fairly and are empowered to make the right choice in an open energy market.

2.4 Concerns regarding data shortcomings and Demand Response implementation

One shortcoming of the mentioned analysis is the determination of the economic value according load shifting possibilities. There are different local peaks, maxima and capacity constraints, as some regions have more available grid capacity than others. Therefore, different locations/areas might lead to different prices assuming a dynamic tariff structure. It is questionable whether price discrimination according to the consumer's location is acceptable. Participation incentives are lowered if it is chosen to socialize the overall benefits of the joint grid users. In line with the location differences, the analysis assumes that load shifting can be done within the whole Portuguese market. Here, different locations will have different load capacity and thus it is not possible to just shift load to off-peak periods when some grids might not be able to even transport that much energy. Therefore, assumptions to be made are that grids have the same capacity in the whole country and that consumption is on an equal level independent of the region.

Moreover, the consumption shift assumes that load shifting will happen within the same day while the shift is relative to the weighted daily price average (by consumption). It is therefore limited to the day's current highest or lowest consumption and does not take into account, shifts to other days (e.g. it might be cheaper for an industrial company to use non-human machines on the weekends rather than on weekdays). The analysis is based on an average demand elasticity of -0,28; which is determined as the international estimated short-run elasticity for energy consumers. Dependent on the activity and customer (e.g. commercial, industrial, residential) elasticity might be different and thus, it is only an average of elasticity value. Furthermore, in the long-term with smart grid awareness and an efficient Demand Response system, elasticity might increase as consumers will learn how to shift consumption and will also be stimulated by energy consumption innovations.

Within the analysis and recommendation part, it is assumed that consumers are willing to participate in the Demand Response system. For this purpose, a total smart grid deployment must be ensured eliminating the current system, as the fixed tariff structure with its low prices does not stimulate consumers at the moment to change to a smart grid technology with a on average higher tariff structure. It is therefore very important to increase consumer awareness of electricity overconsumption by educating them in commercials, seminars and online tools. Furthermore, a key characteristic, which has to be deployed in the best possible way, is the transparency of pricing and incentive structure. Real-time information, monitoring and control have to be consistently available. This might not be the case at the moment, as there is a lack of technology and experience in that field.

Finally, it will eventually be all about the consumer's acceptance of a ubiquitous system[3] which will be able to make programmed decisions based on the real-time information and consumer settings. As Milon Gupta has phrased it: "In a way, it is quite a relief to know that all things in your home (...) are dumb. They give you the feeling that you are always in control. This feeling is in danger, if (they) suddenly turn smart." Great efforts in both, technology development and social policy & marketing will be necessary.

3 REFLECTION ON LEARNING

Regarding the analysis, previous knowledge of my Master studies could be applied as well as new knowledge referring to the business content. Moreover, this part will contain insights into my personal experience within the project and benefits of hindsight.

3.1 Integration of previous knowledge

With regard towards Demand Response and dynamic pricing, I was able to integrate my knowledge of the course "Pricing strategy" I attended during my second Master semester as an exchange student at Aarhus University. This concerning, I was able to apply the concept of the strategic pricing pyramid (Exhibit 5). This concept says that the creation of an efficient and profitable pricing structure is a system-wide and step-to-step approach, taking into account dynamic and customized strategies: the first step is to determine value creation (1), e.g. what is the economic value for the customer / for the system? What are the key drivers (e.g. energy saving/pollution awareness)? Then, also the price structure (2) is to be determined, this has been a focus in our project since the dynamic pricing configuration is based on it: a segmented pricing purchase was created dependent to "time of purchase". Higher prices will be charged at time where capacity is constrained, assuming that only less price sensitive buyers will then consume the same amount of energy as planned. It reflects the fact that price sensitivities can change due to the time of the day, the week or the season. One sub-concept is "Peak Load Pricing" which is used to segment the markets by the "cost of serving at different times" and it is based on the segmented pricing for a "product or service" with fixed capacity which we can find in our

[3] A ubiquitous system or computing is a system, which can appear everywhere and anywhere, using electric devices in any format and in any location. A user interacts with the computer, here via the online tool and smart meter, in everyday objects such as a fridge or a pair of glasses to "smarter" steer objects.

example, as grids have a constrained capacity. The third step is value communication (3) which implies that a price structure is in need of a good communication to the consumer to ensure that customers participate in the Demand Response system. With a good energy management system via online tools and smart metering, dynamic pricing can be communicated. Moreover, consumer awareness has to be created. This can be seen as a good example in the Évora example with energy buses and lectures/information papers about how to use smart grid. Furthermore, the pricing policy (4) needs to be ensured with a reliable price setting procedure taking real-time data and regulatory tariff frameworks into account. Eventually all these steps will build up the price level and only with these pre-determined criteria, it is possible to implement a dynamic pricing strategy. For the analysis I was able to use the concept of price elasticity, based on demand and supply as well as its flexibilities. (Nagle et al, 2013)

Another aspect which I was able to integrate in a modified version, was "Managing Digital Business", which I was able to attend during my CEMS joint degree at London School of Economics. During this class I have written a paper called "From Building Cars to Selling Ubiquitous Computing Systems - A Socio-Technical Approach towards Connected Cars in Light of Human-Computer Interaction" which will be published in the ICT-Journal of LSE (iS Channel Volume 10). The paper dealt with the topic of smart cars within a technological revolution ("Pervasive/Ubiquitous Computing"), analyzing the impact of consumer empowerment and how smart cars shaped their behavior within the issue of social interactions and information control flow. Major issues such as security, privacy and the loss of autonomy need to be taken into account when modeling a smart/connected car. In conclusion, it was proven that with the right social adaptation to the driver and its environment, Ubiquitous Computing will be a key success factor of Original Equipment Manufacturers in the future. When looking at a smart grid ecosystem, data management and two-way communication will also become "ubiquitous" in the future, as incentive and price-based Demand Response will be programmed according to consumer's needs and preferences. Moreover, data weaves itself into the fabric of ever day life, allowing smart and connected technologies a maximum of control. Consumers will act more and more autonomous, monitor their behavior patterns and they will be able to control and optimize it individually. Whilst the autonomy in terms of knowledge-based monitoring, analyzing and planning has constantly increased and finds itself on the verge of (semi-)absolute autonomy, the autonomy considering the exposure of data and personal information is constantly decreasing.

This is an outcome we also expect in the deployment of smart grid technology, as increased data management within different stakeholders will require more individual data sharing.

3.2 Adaptation of new knowledge

The energy market as a whole is a topic which I have never worked in before. Therefore, I was able to gain a lot of insights into this market, especially within the supply chain of energy. The energy supply chain is characterized by many different dependent and interactive stakeholders: roles can be defined as generation, transmission and distribution, retail and the customer while responsibilities can be defined as storage and demand shifting (e.g. network grid based storage); electricity/heat generation (e.g. RES); sensing, control and integration (e.g. smart meters) as well as other infrastructures (e.g. substations). Especially with regard to the retailer-DSO relationship, it was not obvious for me to understand why there was a separation between those two, as to a joint company would enable faster data and energy management. Then I understood that it is important that the DSO was a neutral market facilitator in order to ensure that every customer is able to consume energy. While the DSO focuses on ensuring the quality of supply by keeping the voltage and power level in the network within the set limits, retailers are competitive in their structure and are interested in maximizing their profits as a difference between sold and bought energy costs. To keep these two roles separated is important, as a neutral market facilitator should not simultaneously be a profit maximizer (Belonogova et al, 2011). Although we recommend that EDPD should be able to generate some ancillary revenues with extra data management and provision, the main responsibility of EDPD should always stay neutral, open and free to the market. Moreover, the bilateral-way and dynamic interaction between consumers, retailers and the DSO within Demand Response management, is complex and is in need of a reliable technology to ensure real-time information and operational changes.

Furthermore, I have learned a lot about different tariff structure and pricing methods where incentive-based and price-based structures can be combined and so, increase the range of products and services. The combination of different tariff structures has the potential to provide consumers with the tools they need for an effective Demand Response flexibility at each step in the process up to the moment before dispatch (Cooke, 2011).

Another aspect which was basically never included in business studies during my master studies, is the inclusion of regulatory frameworks. Often they are left beside, as regulations are left to the "legal department". The major responsibilities of the regulator (ERSE) are efficiency of the regulated activities, economic regulation and tariffs, consumer protection, commercial relations' regulation, quality of supply, market supervision and sanction power. With focus on Demand Response, the current tariff structure is not in favor of increasing smart grid deployment as mentioned in 2.3. Therefore, smart grid implementation from the point of view of retailers and the DSO have to take into account regulatory requirements. Moreover, when it comes to changes as proposed in 2.3 it is important to approach ERSE as soon as possible in order to elaborate further on the plan. Since a DSO member is a representative in the tariff board of ERSE, changes can be implemented and it is not impossible to change the current regulatory framework within the new smart grid technology. It is therefore important to ensure regulatory and commercial frameworks that enable and support the deployment of smart grid technologies and new commercial practices by the elimination of fixed tariffs and the inclusion of price control process. It is also important that the framework enables dynamic tariff approaches and enables investments in monitoring and communication system to successfully introduce Demand Response.

From a broader perspective, technology enables changes not only in the energy sector but also in other sectors. This affects often more than one stakeholder group, and even a whole system. With this in line, technology modifies behavioral patterns, such as consumption, and leads to new responsibilities and roles of stakeholder groups. To ensure that new technologies will be implemented in the right way and to the most favorable conditions, it is important to study a whole market. This means, even if one stakeholder group, such as EDPD, has to clarify its own objectives and benefits first, innovative technologies should be looked at in a broader perspective, e.g. benefits for the whole system and long-term changes and improvements. Therefore, it is important to analyze benefits for the whole market and to define how these benefits can be guaranteed, e.g. which behavioral patterns need to be changed. From this point on, one can come back to its own stakeholder position, aiming to achieve the right conditions and responsibilities to enable changes in the system, e.g. behavioral patterns of another stakeholder group such as the consumer. Moreover, as technological innovations can lead to dramatic changes in the market, it is not only about a profitability analysis but also about how a whole process change can be smoothened and how it can enable even more technological changes.

From the perspective of project management, I have learned a lot regarding business meetings in Portugal. Due to the several business meetings as well as the email communication with our business advisors at EDPD, I have learnt how differently structured and much more welcoming the communication level is in Portugal compared to the German one which I am used to. These affected different levels such as writing style (from calling them by their first name towards ending with “Abraço” instead of “Yours sincerely”) or even the structure of a meeting. I had often made myself a structure in advance to where I had already scheduled my questions. In the environment of EDPD and also with my business project colleagues who have different cultural backgrounds than mine, meetings were more open. Changes were often made and it was no problem to switch from one to the other topic and back.

3.3 Personal experience

In the business project, one of the key strengths I realized was that I often took on a leading position within the team members. I often divided the work, came up with deadlines and put an effort to find solutions when we were discussing topics. Moreover, I always gave feedback in order to integrate my understanding and reinforce others in their work.

Due to my internships in several consulting companies, I found it easy for me to create clear, well-structured slides.

From the perspective of weaknesses, I have made the mistake of diving too deep into the benefit analysis at the beginning without understanding the whole market structure of EDPD as well as the different responsibilities and roles within smart grid technologies.

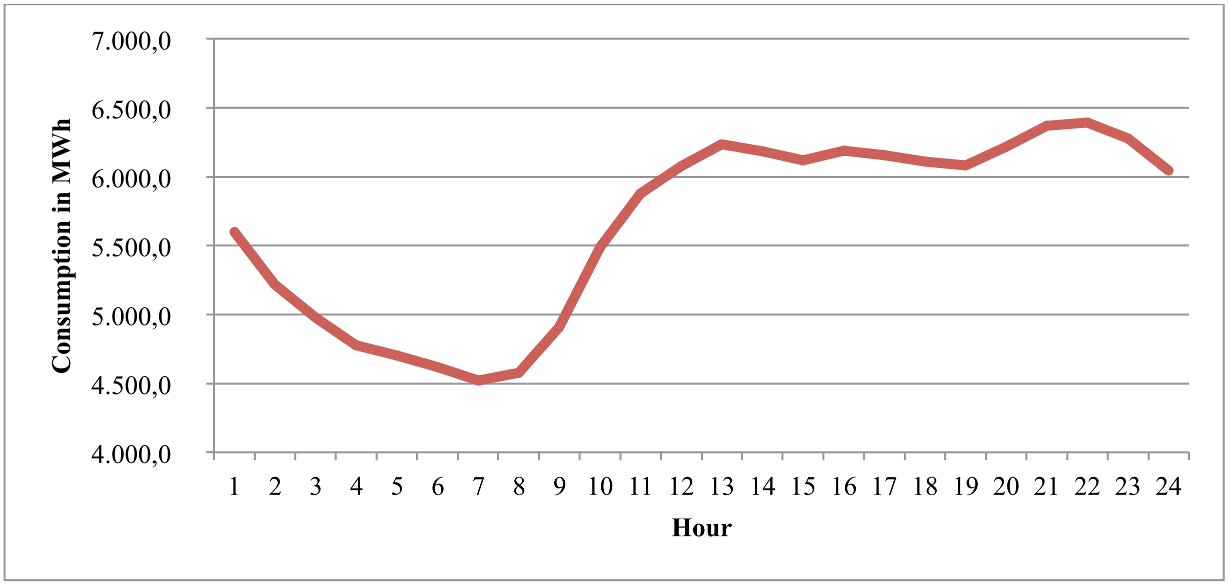
When looking at the storyline, it was not easy for me to find the right one from the beginning. I have therefore learnt that I will research more at the beginning before starting to create a storyline.

3.4 Benefit of hindsight

I believe that the most added value to our business project was the strong relationship within our team members and the different background we had (Economics, Management, Finance focus in my Bachelor). This gave us different views on topics which I would have not seen without them. It also was always a great pleasure to work with the team and the communication between us was always very pleasant, although we were from very different cultures. Moreover, I valued the support of our academic advisor who gave us hints especially when we were lost in our storyline. For the last weeks, where we were “lost in data”, our company representatives always replied very quickly and helped us as much as they could. Those different synergies gave me a feeling of support on all levels. When looking back to the business project, I have realized that our team waited too long to get answers from EDPD regarding data. This actually put us under pressure as we could not get the data we expected to get. The topic of our business project changed several times in the beginning when having meetings with EDPD. This created a certain confusion after every meeting; not knowing how to change the structure for the project. I have learned however that discussions sometimes need to be ended and it would have been recommendable if one of our team members would have tried to end discussions about new topics in returning back to the topic we had chosen in the beginning.

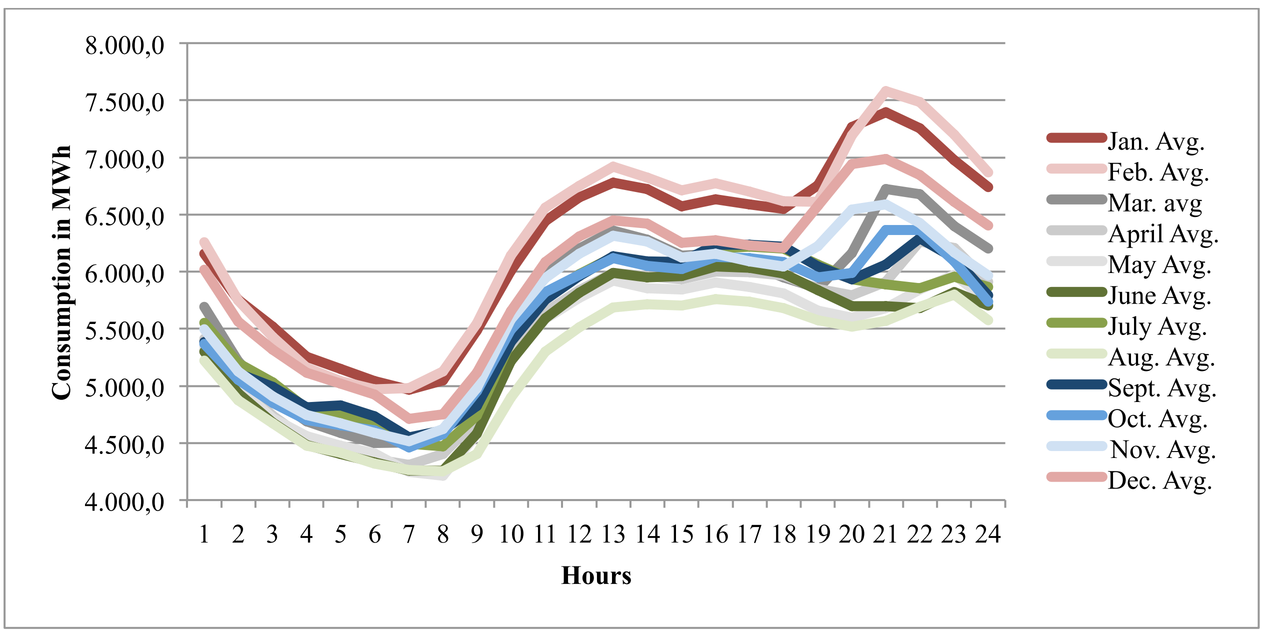
Exhibits

Exhibit 1: Annual average hourly peak consumption of 2014



Source: Data from mercado.ren.pt Energy Portugal; Daily market hourly market

Exhibit 2: Average hourly peak consumption per month of 2014

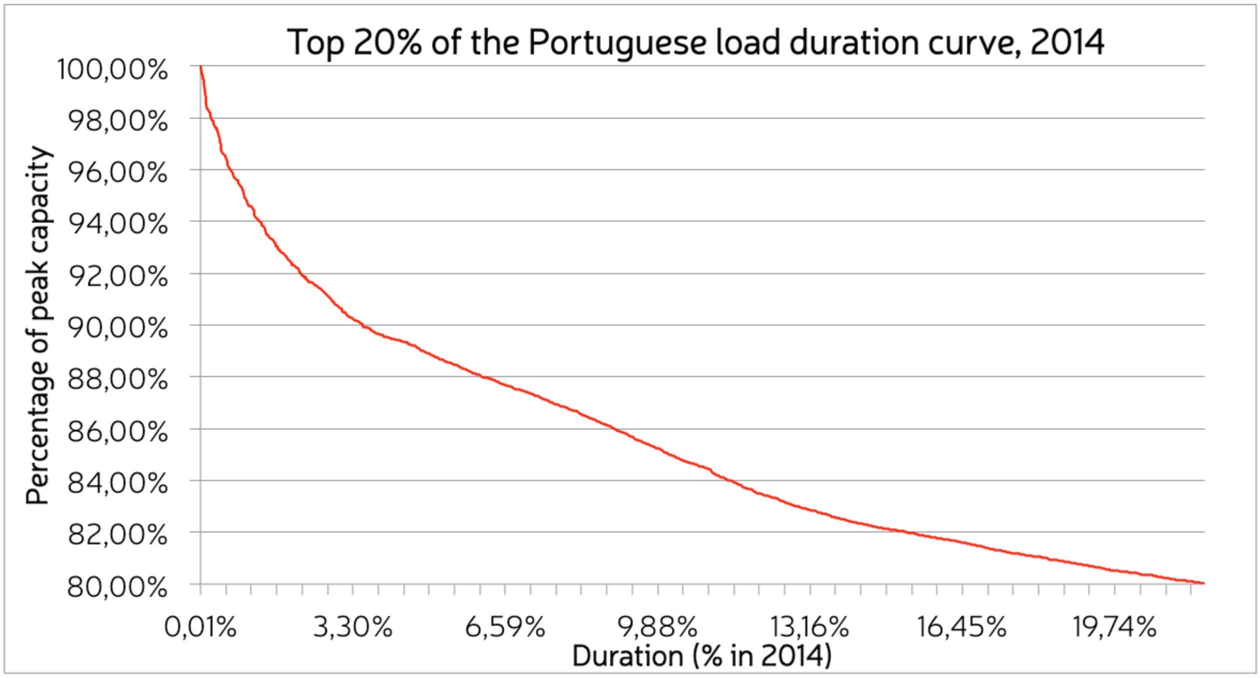


Seasonal Overview:

- Winter: red colors
- Spring: grey colors
- Summer: green colors
- Autumn: blue colors

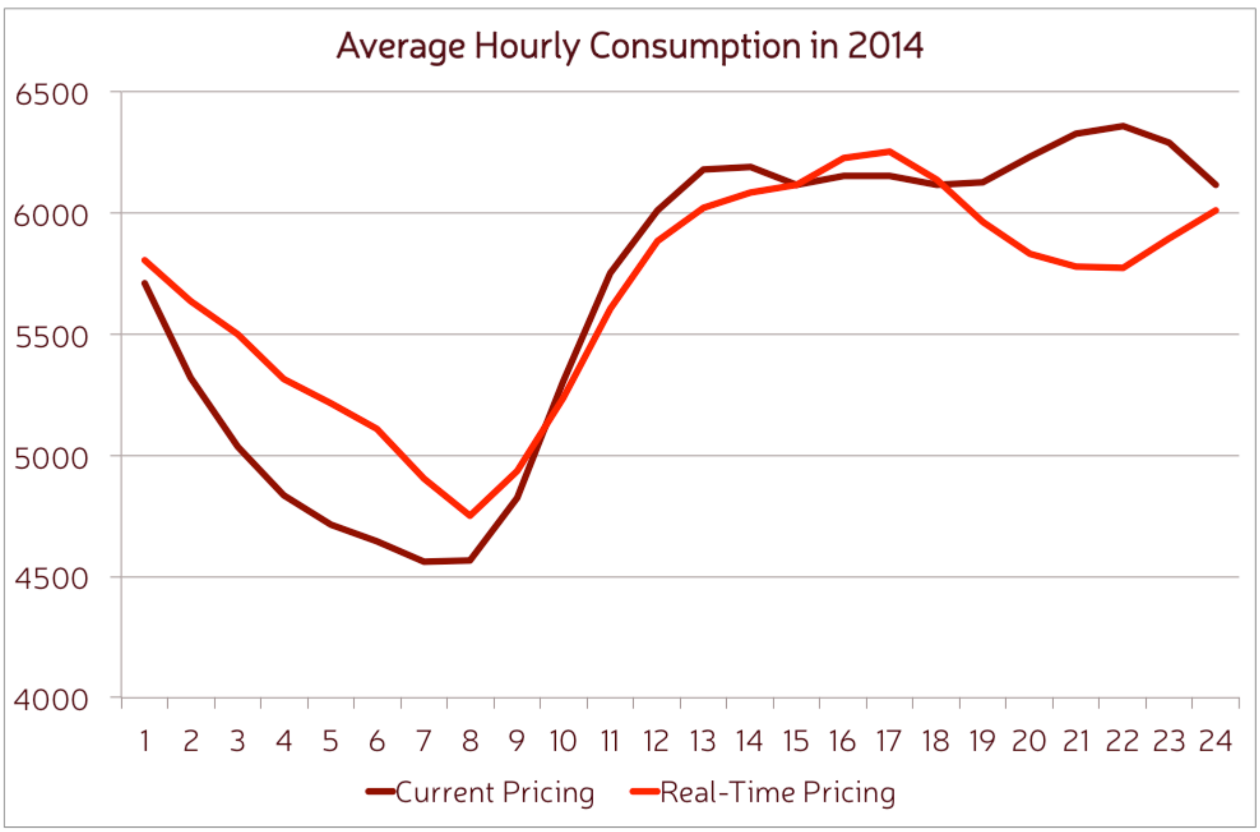
Source: Data from mercado.ren.pt Energy Portugal; Daily market hourly market

Exhibit 3: Load duration curve, 2014



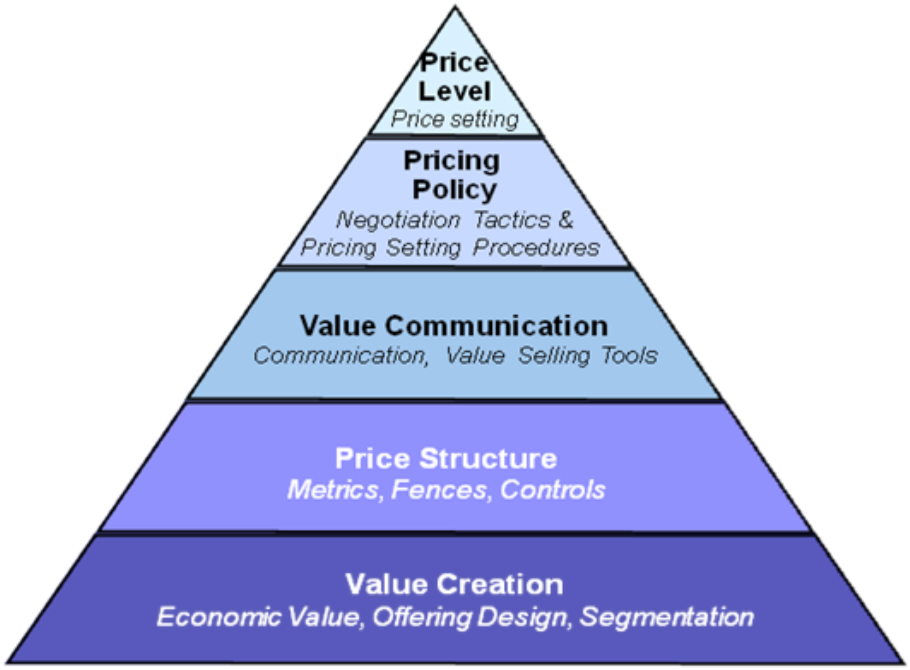
Source: Data from omie.es Energy Portugal; Monthly Scope, Daily market hourly market

Exhibit 4: Load shifting for the average hourly consumption of 2014



Source: Data from mercado.ren.pt Energy Portugal; Daily market hourly market

Exhibit 5: The strategic pricing pyramid



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