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Abstract:

This deliverable analyses the regulatory, energy security, social and ethical as well as business-model landscapes for the implementation of smart grids across the EU with particular focus on the existing legislation and both at the EU level and the national levels of the pilot sites for the WiseGRID project. The report discusses among other things the impact that the project will have on energy security as well as social and ethical considerations that ought to underpin projects of this nature. It also analyses and proposes workable business models for the implantation of the project.

Keywords:

Smart grid, Energy security, Renewable energy, Electricity, Demand response, Storage, Electric vehicle, Circular economy, Data protection, Privacy, Cyber-security, Legislation, Regulation, Smart meters, Wholesale Markets, Ancillary Services and Flexibility.

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EXECUTIVE SUMMARY

WiseGRID aims to demonstrate the real-life optimisation of intelligent electricity deployment, management, and consumption through the provision of a set of solutions and technologies that typify a smart, stable, secure and open, consumer-centric energy grid. The project is part of the European Union's Horizon 2020 research and innovation programme and will combine an enhanced use of storage technologies, a highly increased share of RES and the integration of charging infrastructure to favour the large-scale deployment of electric vehicles.

This report provides an analysis of the implementation of the WiseGRID project in the European Union (EU) with regard to a number of key areas in the context of WP1. It does so first by looking at the social, ethical implications of the project in Member States while considering the existing legislative and regulatory frameworks with the view of assessing the impact these might have on the strategic goals of the project. The report also presents the first steps toward the business modelling work of WiseGRID that aims to demonstrate the economic viability of the project and strengthen its exploitation potential. Moreover, the report also employs the selection of pilot sites by the project to demonstrate the specific implications of the project in different legal, socio-economic, political, market and geographic settings.

The first part of the report focuses on the impact the deployment of the future smart grid is likely to have on energy security and the electricity ecosystem as a whole. Given that the EU is not immune to the changing dynamic of global energy trade - the 'unpopularity' of reliance on fossil; the growing support for 'greener' sources of energy; the decentralization of energy production; the redefinition of energy governance structures; and the introduction of new energy players, the reconsideration of the remits of the energy security needs of the Union could not be more timely.

The evolution of the energy market is largely being spurred by the electricity sector and smart grids would undoubtedly have a large role to play in the new epoch of energy security. The expected growth in consumption in the next 30 year is likely to result in spill-overs into other sectors for which smart meters would be influential in amongst others; spearheading economically optimal performance; fostering energy market competition; managing energy consumption and efficiency; achieving maximum possible carbon emissions reductions; maximizing the network efficiency; fomenting system and technology safety, security and resilience; altering and cleaning the energy mix; creating storage capacity and new technologies in the storage sector; expanding to the transportation sector through electric, plug-in vehicles; democratizing the energy systems; and empowering citizens/customers.

The turn of the twentieth century heralded a change in the electricity market through the unbundling of vertically integrated electricity companies which controlled the generation, transmission and distribution of electricity. The roles of these previously monopolistic players, in the new era is yet to be seen. Particularly when viewed against the backdrop that, the new energy landscape has presented opportunities for new actors such as aggregators and prosumers. However, it is axiomatic to say that, the energy policy of national jurisdictions will play a pivotal role in determining the way forward. It is important that national policy makers recognize that, the existing philosophy underpinning electricity governance may not lend itself to the new smart grid. For instance, the dynamic nature of demand and supply in a smart grid, coupled with the intermittent nature of RES generation do not lend themselves to the existing supply-centric dispatch policies. Similarly, it would be important to re-evaluate current risk scenarios which do not factor in demand response into demand and availability curves.

EU energy policy has, for decades been pre-occupied with several issues, no mean of which includes energy security. Energy security concerns have been the fulcrum around which discussion about the Energy Union have revolved. Interestingly, the European Commission has called for a paradigm shift, with the view to placing citizens at the heart of energy security by encouraging self-consumption, distributed generation, and the creation of prosumers' markets and local energy communities. Given that these developments might bring uncertainty to energy production and consumption, it is important that measures are put in place to ensure optimal balance of electricity load.

Smart grids possess enormous potential for the promotion of sustainability in the energy sector. For instance, the integration of Information Communication Technology (ICT) systems into the electricity network would augment efficiency and benefits of RES. The architecture of smart grids would allow the creation of local energy communities and micro-grids, thereby reducing the economic burden of investing in transmission infrastructure.

Despite the advantages of smart grids, their full-scale rollout is impeded by important challenges. For instance, the further electrification of consumption systems may lead to higher energy consumption. Also, electricity markets in several EU Member States have failed to catch up with the pace of renewable energy production largely as a result of the fiscal implications of these developments. In States where there are policies which ostensibly promote RES production, the gains made by these policies, are whittled down by other 'unfriendly' policies, such as tax regimes, which ultimately operate as disincentives. Similarly, it is envisaged that the change from a fossil-fuel driven market to a "greener" market will be met with some resistance from the fossil-fuel industry. In the face of these and other challenges, the implementation of policies which promote clean energy, such as subsidies, becomes even more important. Although such policies do not come without their own challenges, they are necessary, if energy security would be maintained in the new energy paradigm.

The analysis of the issues discussed in the first part of the report culminates in amongst others, the following policy recommendations:

- Simplification of subsidies for renewable energy generation and perhaps replacing them with a carbon tax.
- Design and operational standardisation of smart grids.
- Wide-scale development of demand response mechanism.

The second part of the report examines the existing legal frameworks that impact on the project. It outlines existing EU laws and policies that apply to the key project objectives and assesses the level of implementation of these policies in various Member States, with particular emphasis on the States in which the pilot sites are located.

While the concept of smart grids is well understood in the energy industry, a precise definition has eluded both practitioners. The section starts by examining the legal definition of smart grids and the attempt by European energy regulators to provide guidance on the issue. It then examines the legal basis for the deployment of smart grids across the EU and the progress made by Member States in this regard. It concludes that while several Member States have adopted some kind of roadmap, or strategy for achieving smart electricity networks, very few have achieved commendable degrees of implementation. While acknowledging the nascent nature of smart grids, it also concludes that, the slow progress is attributable to the lack of regulatory reform which mirrors the reality of the changing technological landscape. Particularly, it advocates the adoption of incentives and support schemes, designed to reduce the financial burden of developing smart grid systems. Finally, it concludes by making recommendations for the design of future regulations that impact smart grids.

The report goes on to examine the legal framework affecting the development of demand response mechanisms. Although demand response is gaining prominence as a means of providing flexibility in the electricity network, its development is hindered by the attendant emergence of a new player in the electricity market – Aggregators. The regulatory treatment of this new actor and its relationship with existing players appears to be posing a challenge for many legal systems, with many not recognising it. With guidance at the EU level remaining relatively sketchy and foundational, demand response strategies are adopted on largely national basis. While in most EU Member States demand response is not yet actively deployed. In countries like Belgium, France and the UK, demand responsible has proven viable and participates in the electricity market. In the countries where demand response is not active, regulatory barriers such as technical and procedural requirements are identified as key challenges. In this regard, recommendations are made with the view to facilitating the wide-scale development of demand response mechanisms.

Despite the lack of technological advancement, energy storage is beneficial to all levels of the electricity market. Given that the project envisages the integration and management of electric vehicles as controllable loads in a smart grid, the second part of the report explores the regulatory frameworks for electricity storage and the electric vehicles in the EU.

The e-transport revolution has been propelled by the EU's ambitious target to reduce the use of internal combustion engine vehicles by 50% by 2030. In recent years, industry and governments have intensified actions aimed at improving the uptake of electric and hybrid vehicles. While the benefit of greenhouse gas emission reduction is not disputed, the imperceptible benefits to electricity management system, especially when coupled with storage technology, have only recently gained prominence.

In the electricity storage sphere, the main regulatory challenge is a conceptual and practical lack of consensus of what role storage plays in the electricity value chain - should it be treated as a generation asset, distribution asset or a consumption asset? Without a cogent answer to this question the regulation of electricity storage would remain uncertain. Currently, different Member States have adopted different approaches, none of which present a convincing solution to the problem.

Further, it is without question, that if e-mobility is to achieve its objectives of reducing GHG emissions and becoming a source of electricity flexibility, regulatory responses such as a revision of grid-fee structures and the implementation of incentives and support mechanism. Another important policy consideration which should be prioritised, is the possible increase in electricity demand which would result from wide-scale use of EVs.

The third part of the report provides the cornerstone for the business modelling activities of the WiseGRID project. To begin with, explains our holistic business analysis and evaluation methodology that comprises of 5 steps (see Figure 4):

Step 1. Generic value network generation
Step 2. Economic and business analysis of WiseGRID use cases
Step 3. Creation of archetype business models for the WiseGRID tools, services and actors
Step 4. Cost Benefit Analysis
Step 5. Final business models and guidelines for the successful exploitation of the WiseGRID tools

In the context of this report we present the results of the three first steps, whereas we set the ground for the next two, to be followed through in WP16 and WP17 respectively. The generic value network of Step 1 (see Figure 5) represents the main players of the Smart Grids and the likely, depending on the business case, interactions amongst them. Moreover, it introduces the main business roles involved and the contribution of each one of them in the delivery of a potential product or a service, as well as the flow of power, information and money between the participants.

Based on this network, the second step analysed thoroughly each HLUC of the project as these were defined in the context of *WP2,* identifying the participating business roles and which are the actors that assume them. Through this important process all WiseGRID partners explored the different business cases that could originate from their participation in WiseGRID and gained a more business-oriented understanding of the WiseGRID ecosystem that will help them produce sustainable business plans at the end of the project.

The analysis of the HLUCs resulted in the creation of 7 *archetype business models (BMs)*. These models present how the economic value is generated for the participating actors stemming from the WiseGRID core technological innovations and tools. The BMs are characterized as "archetype", because they aim to account for the entire set of services in which each tool may play a role. The archetype BMs are presented graphically using value networks and business modelling canvas' that describe the assets/products/tools (provided by the project) to be utilized for achieving the objectives and the anticipated economic gains for each core participating actor. The 7 archetype business models are the following and are presented in detail in as follows:

Archetype BM1. Promoting RES installations via RESCOs
Archetype BM2. Efficient monitoring and management of the distribution grid
Archetype BM3. Exploiting the integration of EVs in the grid
Archetype BM4. Prosumers driven energy storage integration
Archetype BM5. Exploiting co-generation in domestic and tertiary buildings
Archetype BM6. Exploiting the VPP assets
Archetype BM7. Supply-demand balancing by means of implicit DR events

For all the above, our analysis has provided preliminary insights for the state of the grid in the absence of the WiseGRID tools and the innovative technologies we will introduce, and consequently the actors' increased costs or the limited revenues due to the lack of their sophistication and the advanced capabilities that they will respectively provide. This process is a prerequisite for identifying the "business as usual case", which will be utilized as a comparison basis during the cost-benefit-analysis of the BMs later in the project, targeting to reveal the source of the added value and to quantify the potential benefits for the actors. Additionally, the description of the business models emphasized on the terms that must be clarified in the contractual agreements between the involved actors, for resolving conflicts of interests that may arise over the utilization of resources (e.g., RES generation, battery capacity), in case they participate in the realization of multiple services.

The report proceeds to evaluate the social and ethical implications of the project, drawing primarily on the EU context, as well international law and policy. The introduction of smart grids is presented as an innovation which not only heralds a transformation of the energy market, but also demonstrates the interlinkages between different sectors towards the attainment of sustainable development goals, in what has come to be known as the collaborative economy.

The collaborative economy has become a major phenomenon in recent years to due to increased business opportunities heralded by advances made in Information Communication Technologies (ICT). This new epoch in business activities possesses the potential of changing the way in which actors in the electricity value chain interact with one another, which represents a big change from the traditional market. While this may ultimately, be in the interest of consumers, if its dynamism is left unchecked, it may result in unexpected pitfalls. The implications of the sharing economy for law, regulation and policy making are only now being considered. The European Commission has taken the appropriate lead in this regard, albeit through a non-regulatory approach. However, as far as smart grids are concerned, both the European Commission and various Member States recognise its potential to improve consumer participation in the energy markets. This has led to the adoption of several legal frameworks, designed to incentivise the participation of consumers. Smart grids within the context of the collaborative economy, are also presented as a solution to the problem of energy poverty. The success of this objective would, however, depend on policy and regulatory decisions.

The adoption of smart grids can have a vast positive impact on EU policy on energy and climate. The link between energy and climate-related issues is a recent phenomenon within the EU, resulting in the recognition of the regulation of energy and climate as two sides of the same coin. While the coupling the regulation of both sectors is ideal, it is worth considering a transitional approach as an interim measure. Such a transitional approach would not only cater for the transformation of the regulatory landscape, but also for the movement towards greener economy, from the current fossil-fuel based economy. This transition would undoubtedly highlight the pervasive problem of waste management associated with technology, and countries need to undertake reforms of existing laws and also develop innovative policy and regulation to meet these challenges, and as it were, close the loop of the circular economy.

On the one hand, smart grids would potentially deliver improved reliability, resiliency, environmentally friendly generation, transmission and distribution. On the other hand, they will make energy management systems more complex, and heighten concerns such as the risk of cyber-attacks of critical infrastructure, energy and data theft, fraud, denial of service, hacktivism and their impacts of energy security. The regulatory requirements to address the necessary security and design measures to tackle these challenges will result in trade-offs that can impact both their performance and relative costs. An effective regulatory framework should manage both known and unknown risks, with the latter involving a precautionary approach. However, the interconnected nature of smart grids, presupposes and multilevel governance approach, which presents legal challenges for both lawyers and policy makers.

Of the many risks that smart grids pose, one of major concern, would be the protection of the large streams of personal data that would be generated by these technological systems. Unlike oil, which does not generate more oil, the product of data, will generate more data thereby posing a threat to the privacy and security of individuals. This perceived threat has for instance led to a resistance of smart meters by some citizens. The challenge, therefore, is to manage the relationship between these streams of data to ensure the privacy and security of data subjects. The requirement to protect citizens from incursions into private space, has long been an obligation at international law, and been promoted actively by the European Commission. Consequently, the processing of personal data by EU Member States is guided by seven cardinal principles which provide a foundation for the development of suitable legislation within the smart grid context.

While many of the findings of the report may be common to several EU Member States, they are contextualised by the different technical, climatological, regulatory, legislative and social conditions of project pilot sites – Belgium, Italy, Spain and Greece.

1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

The purpose of this report is to provide an analysis of smart grids in the European Union (EU). The WiseGRID project represents a significant milestone in the up-scaling of smart grid technology across the EU. Characteristic of such nascent technological advancement, the project pushes the frontiers of existing regulatory regimes. Thus, a detailed evaluation of EU and domestic legal frameworks is required in order to ensure both the successful realisation of the objectives of project in the jurisdictions of the pilot sites, and a smooth replication of the project in other Member States.

1.2 SCOPE OF THE DOCUMENT

The report assesses the regulatory; energy security; social, and ethical; as well as business-model aspects of smart grids in the EU. This report examines the existing regulatory frameworks by evaluating the legislation and policies that impact on the project both at the EU and national level. It outlines existing EU Directives that apply to the key project objectives and assess the level of implementation of these Directives in various Member States, particularly the WiseGRID project sites (namely, Belgium, Italy, Greece and Spain). It also assesses the extent to which the existing legislation facilitates the development of smart grids and proposes areas of further regulatory consideration.

1.3 STRUCTURE OF THE DOCUMENT

This report is primarily divided into six sections. After this short introduction which constitutes **Section 1**; **Section 2** studies the consequences that the deployment of smart grids entails in terms of energy security; **Section 3** analyses smart grid regulation both at the EU and Member State level; **Section 4** explores emerging business models for smart grids; **Section 5** outlines the social and ethical dimension of smart grids, with a particular focus on data protection. Finally, **Section 6** concludes the present document by summarising the main findings of the report. In addition to this, the report includes **ANNEX A – COUNTRY CASE STUDIES** which provides a comprehensive overview of the jurisdiction of each of the WiseGRID pilot sites. **ANNEX B - Business Modelling State-Of-The-Art** constitutes the final annex of this report.

2 SMART GRIDS DEPLOYMENT AND THEIR IMPACT ON ENERGY SECURITY

2.1 SETTING THE CONTEXT

2.1.1 The geopolitical context

The global energy market is still to a great extent monopolized by the production, trade and consumption of oil and gas [1]. The EU is no exception to this rule with a high import ratio of both oil and gas. Unreliable oil producers, geopolitical instability in many oil-rich countries, resource nationalism, transportation-related hazards and the high volatility of international oil prices are constraining importers to face significant risks [2].

In the gas sector, the EU is confronting a practically oligopolistic external market with Russia, Algeria and Norway supplying most of the imported gas [3]. Azerbaijan and more distant Liquefied Natural Gas (LNG) suppliers also contribute to the EU's import portfolio, without however changing the EU's dependence on a few exporters [4]. In particular, relations with the most important gas supplier, Russia, have become overtly problematic. This state of play must be borne in mind insofar as politics and international relations have a crucial influence in energy policies and international trade relations.

Diversification of sources, routes and suppliers has been high on the EU's agenda. The Southern Gas Corridor and a number of LNG initiatives are the only tangible steps towards this direction. Nevertheless, these efforts have not produced sea changes in Russia's pivotal market role [5]. The rationale of liberalization and competition is in accordance with the logic of diversification. This is so as both premises aim to create a level playing field for external actors in a market well-shielded from monopolistic structures and practices [6]. While the application of the Third Energy Package has blocked some of Russia's future investment moves, it cannot by itself substantially alter the EU's import portfolio [7].

This is mainly due to the fact that Member States and their energy companies are responsible for negotiating and signing supply contracts. Indeed, Gazprom traditionally retains strategic alliances with a number of European oil and gas companies (such as Italy's ENI, Austria's OMV, France's Gaz de France, and Germany's EON Ruhrgas and Wintershall) [8]. Indeed, Russo-German relations have been remarkably cordial over the last decades with energy cooperation being at the centre of this partnership. Interestingly, the recent fallout between Russia and Ukraine, and Russia's actions (invasion of Crimea and hybrid war in Eastern Ukraine) that evidently go against fundamental international law principles enshrined in a number of international treaties, have not resulted in any interruption of Russia-EU gas trade [9].

Having said this, a number of actors within the EU (especially, the European Commission, the European Parliament, together with the Member States located in Central and Eastern Europe) are striving to counter Russia's leverage in the EU energy market [7]. While liberalization and diversification can be considered significant roadblocks but no-game changers, the need remains for holistic, innovative energy policies that will curtail the EU's import dependence and ensuing energy insecurity [6].

2.1.2 The institutional context

The key issue to be considered is how, by whom, and in what ways energy is governed at the EU level. Energy governance can be defined as multi-level management and regulation of energy supply, calling for variable degrees of coordination and cooperation between several actors. In the words of Florini and Sovacool, energy governance refers to "collective action efforts undertaken to manage and distribute energy resources and provide energy services", and can hence serve as "a meaningful and useful framework for assessing energy-related challenges" [10].

With regard to EU energy governance, a definite dualism is at play. On the one hand, Member States implement energy policies at the national level. On the other, the European Commission sets the energy blueprint at the EU level. In particular, Member States retain their sovereignty in the energy sector on the grounds that energy is a strategic good. Consequently, decisions on the domestic energy mix should lie solely with national authorities [11]. Since the Lisbon Treaty, energy has come under the shared competences of the EU and the Member States. Indeed, energy, in its wide sense, is expressly referred to as a matter of shared competence between the EU and its Member States in Article 4 TFEU. National energy measures have to be designed in conformity with a number of EU policies. Examples of such strategies include the 2020 climate and energy package [12] and the 2030 climate and energy framework [13], for instance. The Commission has thus pioneered an ambitious climate-change mitigation agenda that is bound to impact on the Union's energy policy [11].

EU energy policy is driven both by Member States' governments and supranational institutions. It is within this institutional framework that the European Commission is currently fostering research on ground-breaking technologies; the elaboration of forward-looking regulation; the transformation of the traditional energy market towards low-carbon systems; and the establishment of prosumers' markets. Such schemes are deeply rooted in the EU's vision to revitalize its energy security.

2.2 SMART GRIDS: A MULTIVALENT INSTRUMENT

Smart grids, together with the promotion and integration of renewable energy generation in the electricity network, bear significant potential for achieving: low-carbon energy security; protection from the vagaries of international energy markets; affordable energy costs; enhanced access to energy; existent and future climate goals; empowerment of citizens; and enhanced competitiveness for the European economy [14].

As the International Energy Agency (IEA) underlines, the sweeping renewable energy generation revolution has propelled a profound debate over the design of the evolving power market and electricity security [1]. What makes the ongoing energy transition different to previous ones is the parallel change in both the energy and digital technology sectors. The contemporary energy transition is characterized by common changes in integrated systems. As such, the scope and scale of this transformation is ubiquitously potent and unprecedented.

This transition basically concerns the electricity sector. This industry expands exponentially at the cost of other sectors, and is projected to account from 25% in the last 25 years to close to 40% of the anticipated growth in energy consumption by 2040 [1]. The electricity industry fosters crucial spill-overs to other sectors as well. The transport sector, with the use of Electric Vehicles (EVs) as an inherent part of the grid, is an indicative example. Verbong, Beemsterboer and Sengers highlight the differences between the old and the emerging energy system as follows: "[it] will be more hybrid, in terms of the location and type of generation; lower carbon because of a larger contribution of renewable energy sources (RES); more complex and vulnerable; and less hierarchical" [15].

These changes are bound to profoundly impact on society at large and energy users in particular [15]. Indeed, smart grids can serve a multitude of goals, such as: spearheading economically optimal performance; fostering energy market competition; managing energy consumption and efficiency; achieving maximum possible carbon emissions reductions; maximizing the network efficiency; fomenting system and technology safety, security and resilience; altering and cleaning the energy mix; creating storage capacity and new technologies in the storage sector; expanding to the transportation sector through electric, plug-in vehicles; democratizing the energy systems; and empowering citizens/customers.

Smart grids are not being deployed only in the EU, but also in several other countries, most prominently in China, Japan, South Korea and the United States (US). It is important to stress that there are different drives for the roll-out of smart grids in each case. The frequent outages in the US electricity system, usually caused by ageing infrastructure, have motivated the substitution of the conventional grid with smart grids. China's main preoccupation has been with air quality and pollution. Smart grids have been part of the answer to this environmental question.

The EU is set to proceed with the large-scale roll-out of smart grids to fight climate change and improve energy efficiency in order to hit climate and energy goals set for the next decades [16]. In this context, smart grids are not per se climate policy instruments but speak to a wider set of goals [16]. As Eid, Hakvoort and de Jong put it, the way power markets evolve depends on "the innovators' and designers' imagination producing market designs and outcomes better aligned with their political and value preferences" [17].

2.3 THE OPERATION OF PROSUMER MARKETS

From the 1990s onwards, the EU electricity sector underwent a transition from vertically organized electricity companies that controlled the production, transmission, distribution and supply activities, to the unbundling of these services. In particular, TSOs were responsible only for the balancing of the load and its transmission from large electricity production plants at high voltage levels. From there, DSOs took up to distribute electricity to every corner. As we move to an electricity sector comprised of multiple large and small producers, Virtual Power Plants (VPP) and decentralized energy production, the role, rationale for and competences of the TSOs remain mired in uncertainty. DSOs, on the other hand, seem well-placed in the new energy setting. Indeed, according to the European Commission's proposed internal electricity market directive, their role will be significantly enhanced, principally when it comes to coordinating and managing the energy produced by the new decentralized energy producers. DSOs are anticipated to absorb the energy thus produced, manage the load, and efficiently distribute electricity to households and corporate premises. The digitalization of services through AMI will massively facilitate their upgraded role [18].

This having been, one could anticipate the TSOs' reaction and their pledge for a place in the sun. This potential friction raises a number of questions as to how the competences of the new actors are going to be divided in the new energy landscape [18].

Energy policy goals and ensuing national jurisdictions will play a pivotal role in moving the transition forward. Top-down, bottom-up and hybrid (both top-down and bottom-up) energy policy blueprints mandate variable leeway for different actors across the energy chain. Some aspects can be legally binding and perhaps commissioned to specific market players (*e.g.* smart meters roll-out). Another is allowing utilities, DSOs and consumers to decide the very ways, and pace, they move forward. What transpires for now is a hybrid model. In this architecture, climate goals have been set at the higher governance level but the smart grids transition is carried out at the lower governance level. This policy is in accordance with the EU law principle of subsidiarity, according to which Member States are given the discretion to decide for themselves how they are going to reach the goals mutually agreed at the top EU political level [16].

The previous reform of the electricity markets carries its important heritage to today's transition. Unbundling has taken place in different ways in the various Member States. In these cases where legal unbundling took place, corporate links between the generation and distribution network companies, albeit they now constitute two different legal entities, may well be maintained, thus creating benefits to actors in the retail market. This is not the case in ownership unbundling, where the generation and network companies are fully separated. A level-playing field is indispensable, if we are to avoid privileges of certain actors vis-à-vis others [16].

The specific market conditions also impact on the pace and scale of investments. For example, market players with dominant market shares naturally prioritize retaining their central position, rather than investing in new network infrastructure and smart grids roll-out, as the benefits that will accrue are unlikely to be a match with costs endured by reduced revenues due to a lessened market share. On the other hand, investments are very pertinent not only in light of legislation in place, but also to tackle, and anticipate, market competition. In this context, DSOs are keen to invest in AMI. Private investors can find a niche in investing in control boxes, downstream from the meter. A significant caveat to be issued here is that private investment can render customers captive in light of the long lead contractual times that are imposed so that costs are recovered. This in itself obstructs competition. Such issues have to be seriously taken into account when designating the new regulatory framework for smart grids deployment. Waiting games are also typical corporate tactics that should be anticipated and treated appropriately, since existing market power determines future over- or underinvestment plans [19].

In this new energy landscape, though, opportunities are opened up for new energy actors as well. One such type is energy aggregators. The rationale for their emergence is to provide flexibility and join the Balancing Responsible Parties (BRPs) in what will be a much more variable corporate electricity landscape. Such a role can also be taken up by incumbents. In the new market, however, flexibility services and packages will be crucial, and hence there seems to be much space for new corporate actors, services and associated innovation. These services revolve around collecting decentralized prosumers' savings and energy generation and selling it back to utilities and BRPs in the form of 'flexibility packages'.

Yet, another type of actors to emerge may be small storage providers. These can store the energy they have produced (in batteries or EVs, for instance) and resell it for a high premium in a market in dire need of flexibility, back-up capacity and last resort solutions. Such services can be developed at the community/district/neighbourhood level. In this case, the emergence of energy co-operatives may take shape. Integrated energy services companies are the key to the new electricity market [20].

At an even lower level, individuals, households and energy cooperatives are given the opportunity to become themselves energy actors. They can sell the energy they produce or conserve to utilities and/or aggregators. Both flexibility and network optimization are achieved this way. Distributed energy resources (DER) and storage facilities are central in the energy transition [21].

Whether storage capacity will be incorporated successfully in smart grids will be critical to their eventual performance. Leaving aside the contested debate over the likelihood of success, storage capacity will tackle peak consumption, reduce system-wide generation costs, and minimize network congestions, thereby optimizing the operation of the electricity network [16].

EVs are an option for storage capacity which is also highly contested. In particular, charging infrastructure costs, logistics and issues regarding charging time and efficiency both for the vehicle and for the grid have still to be resolved. Nevertheless, EVs have the potential to decarbonize of the transport sector. This would represent a huge leap forward in meeting the EU's climate targets and contributing to climate change mitigation [1].

The development of prosumer markets is based on two pillars. The first one regards its hardware (infrastructure); the other concerns it software (the associated legislation and regulation). In that vein, the European Commission made a handful of important steps forward. In particular:

- It recognized consumers' right to self-consumption. This will lead to all national jurisdictions gradually embracing self-consumption. Moreover, prosumers are explicitly encouraged to sell their energy surplus to other energy actors, this way adding to the energy market's resilience and becoming active stakeholders in the energy transition.
- It explicitly referred to energy communities, granting the right to prosumers to group together and join the market.
- It strongly recommended advancing energy performance-related information, as well as information regarding the sources of district heating and cooling systems. This will further empower prosumers and energy communities to improve on their energy performance (including production consumption and trading). On top of that, the quality of information that consumers obtain will come under the scrutiny of regulatory authorities. This also includes the refinement of the Guarantees of Origin system for energy resources [21].

The advent of prosumer markets entails the commercialization, rationalization and economization of consumers' behaviour. Through demand response, prosumers are expected to take full control of their energy usage. That is, prosumers will be able to adjust their patterns and be economical and efficient. The inflow of relevant information will allow them to adjust, conserve and chose flexible contracts. Switching off unnecessary appliances or turning down the thermostat in peak hours, not only provides monetary benefits, but it also contributes to balance the grid. Conversely, consumers are incentivized to use electricity when it's cheap (*e.g.* doing the laundry in late hours) [21].

Smart applications can substantially enhance energy efficiency. Instructing the washing machine to wash the clothes at the lowest price of electricity during the day can lead to optimal results for both the consumer and the grid. Dynamic price contracts are also a useful tool for demand management. In light of their consumption patterns, consumers are encouraged to negotiate suitable contracts with electricity suppliers. From the side of utilities, well-targeted, flexible contracts should become increasingly part of their corporate strategy in order to cater for customers' customized needs. Competition forces can work well in this sector and lead to a wave of easily adjustable contracts.

Moreover, a number of pricing mechanisms (*e.g.* real-time pricing, time-of-use pricing, critical-time pricing, and variable peak pricing) can be also be put into good use. Not only can they reflect market fundamentals, they also render consumers more aware of price variations according to market dynamics. Thus, last resort solutions like load-shedding and self-rationing can be altogether abandoned. However, dynamic pricing contracts encounter several difficulties. It is hard for utilities to create spot-on abstract models of "representative agents" taking into account the heterogeneity in patterns of energy use of different consumers. Devising effective contracts is also challenging from the supply side, since different utilities face different costs in the energy they buy, especially when it comes to buying flexibility packages themselves, to respond to their customers' needs. It is natural then to anticipate that they may remain averse to making even more sophisticated contract types [20].

An important aspect of the deployment of smart grids lies in revisiting the philosophy behind their function rather than to borrow the one underpinning the function of the conventional grid. The conventional grid has been premised on the worst case dispatch philosophy. With the supply side being *a priori* known, utilities focused their efforts on balancing it every second with demand. The danger lay in an imbalance occurring either due to a supply disruption (*e.g.* an accident in a generation plant), or an unpredictable surge in electricity demand (*e.g*. a heat wave). For such mishaps to be averted, large reserve capacity was retained to ensure that dispatch of electricity would still be possible in the case that demand exceeded predictions and supply was decreased. Such a policy was neither sustainable nor cheap but at least hedged against the danger of power cuts and load-shedding [22].

These principles and rationale fail to be suitable for smart grids. The dynamic nature of both supply and demand in the new electricity landscape calls for a new philosophy. The increase of intermittent solar and wind energy; the lack of storage capacity as of now; the development of micro-grids; the increased variability with regard to the preferences of consumers; and the way consumers will operate smart appliances result in increased uncertainty in both supply and demand ends. Smart meters, sensors and demand response mechanisms can mediate and, at least partially, manage the variability and unpredictability of power markets by providing both mechanisms for control of energy use as well as precise information on the state of the power system and the supply-demand equilibrium [20].

It is thus essential to redefine the risks in the operation of the power markets and their management. What is considered acceptable risk now has to be adjusted to the new operating conditions of smart grids and power markets. The demand response of all consumers will have to be factored into a probabilistic demand curve, which will be analogous to the generation availability curve of intermittent renewable energy [22]. The focus will continually lie the movements in the *net load,* the difference that is between aggregate demand (load) and variable generation. The capacity, ramp rate, duration and lead time for increasing or decreasing supply will have to be factored in such analyses as well to optimize the responses of the smart grids to the fluctuating supply-demand dynamics [20].

Finally, it is necessary to integrate cross-border markets and capacity into risk management analysis. The EU has managed to establish a functional cross-border power market through its day-ahead market, with many national markets being now coupled. This has been instrumental in fomenting price competition, providing further leverage for load balancing, optimizing back-up capacity and leading to increased resilience. Having said this, a handful of physical barriers (such as congestion, lack of transmission capacity and/or underutilization) remain, thereby leading to sub-optimal transmission returns and hub market differentials. These, in their turn, block, rather than enhance, cross-border trade. A further step regards the extension of such schemes into Energy Community members, which are not EU members, as well as to neighbouring states outside the Energy Community. A more critical challenge regards the adjustment of the cross-border market to the new reality of "real-time", intra-day trade [23].

2.4 SMART GRIDS AND ENERGY SECURITY

The transition to low-carbon energy systems is the crucial political economy issue for the EU, as it stands in the nexus of energy, politics and markets. With power markets developing into dynamic energy system integrators, smart grids emerge as the most suitable structures that can help the EU's achieve three principal energy security goals (sustainability, security of supply and affordability). Smart grids are power networks that utilize two-flow transmission of information to maximize the balancing capacity of the system and achieve optimal electricity transmission and services [22]. In doing so, they provide resilience *vis-à-vis* supply-demand disequilibria and power outages. Moreover, they also create new markets and commodities [19]. Smart grids therefore impact the electricity industry and carry the potential to 'smarten' houses and all kinds of premises in terms of energy use and efficiency [24].

Smart grids integrate renewable sources at the upstream level; advance overall renewable generation; including self-generation; enable energy efficiency and conservation; promise to achieve low carbon security; and hedge against the volatility of international energy markets. On the other hand, the establishment of smart grids requires high upfront investment costs; the creation of operational markets; promote the understanding of smart grids and their benefits; as well as an assortment of incentives for their optimal utilization. Demand response management is key in this process.

For decades, EU energy policy has been preoccupied with a number of issues, including threats of supply cuts; diversification schemes; mitigation of dependence on external producers; fluctuating prices; and pressing to provide dynamic responses to a warming planet [25]. The deliberations around the establishment of an Energy Union naturally focus on these aspects in an effort to effectively provide security of supply; integrate the energy market; enhance demand-side policies; de-carbonization of the economy; and further research and innovation [26].

Interestingly, the European Commission has been calling for a paradigm shift. This lies in placing EU citizens at the heart of energy security by means of self-consumption, distributed generation, and the creation of prosumers' markets and local energy communities [18]. Having said this, such far-reaching developments could also bring about uncertainty in energy production and consumption. Hence, it is imperative to create mechanisms that will ensure the optimal balance of the electricity load at all times.

2.4.1 Sustainability prospects

2.4.1.1 Advantages

Smart grids play a decisive role in the proliferation of indigenous renewable energy generation. Priority dispatch mechanisms ensure that RES enter the grid [27]. High-efficiency photovoltaics installations bear the highest energy return factor, as well as the largest life-cycle carbon emissions offsets, assuming that land availability is not an issue [28]. Consequently, the integration of Information and Communications Technologies (ICT) systems into the network would only serve to augment the efficiency and benefits of RES.

The introduction of digital technology is promising since it will enable European consumers to be aware, adjust and optimize their energy consumption [29]. Therefore, one can reasonably anticipate that energy consumption would be rationalized and reduced. Smart meters convey all the information regarding supply, demand, transmission and real-time consumption, so that prosumers are able to consume energy in an optimal manner [24]. Additional AMI, such as in-home automation and in-home displays, will serve the same goals [16]. The use of use sensors by utilities so that voltage in the consumers end remains low also results in optimized energy conservation [29].

Smart grids are a striking development in that they provide consumers the possibility to generate energy themselves. This will lead to an exponential increase of overall renewable energy production. Together with the anticipated increase of energy savings and efficiency, this can translate in a significant reduction of oil and gas imports. Belgium features here as an excellent case in point. Enhanced incentives for the installation of solar panels have rendered private households producers of their energy. This releases pressure from the grid and supplies renewable energy to the grid [30].

The architecture of smart grids allows the creation of local energy communities by means of distributed generation (micro-generation). In turn, distributed generation reduces the associated costs of investments in new traditional large power generation plants. Moreover, energy can also be consumed at the point of its production, which minimizes not only leakages but also logistical problems. Another effect of self-consumption and distributed generation is that they release pressure off the transmission grid and effectively prioritize the use of renewable energy. [31] In this context, the European Commission has been encouraged to propose the escalation of the EU's energy efficiency target for 2030 from 27% to 30%.

Increased production of renewable energy, self-consumption and distributed generation can substantially clean the mix and dwindle imports of fossil fuels [32]. A recent study has convincingly shown that: *"utilizing existing infrastructure such as existing building roofs and shade structures does significantly reduce the embodied energy requirements (by 20–40%) and in turn the EPBT [energy pay-back time] of flat-plate PV systems due to the avoidance of energy-intensive balance of systems (BOS) components like foundations … [while] a greater life-cycle energy return and carbon offset per unit land area is yielded by locally-integrated non-concentrating systems, despite their lower efficiency per unit module area"* [28].

The increase of renewable energy generation, in tandem with the need to continually balance the electricity load raises the issue of storage. EVs that can be plugged into the grid and serve as batteries hold high promise for extending the benefits of the electricity sector to transportation, a sector that accounts for a significant percentage of total EU carbon emissions [33].

2.4.1.2 Risks and challenges ahead

Smart grids and their full-scale roll-out do face important challenges. The further electrification of consumption systems with the view to promoting energy efficiency may lead to higher energy consumption. Indeed, requiring less energy for one particular function or service does not necessarily lead to lower overall energy usage. For instance, a "smart" household, which uses an EV with a fast charging point might find that, despite having a technology to help reduce its everyday consumption, owing to the high voltage requirements of the EV's fast-charger, its net consumption is still relatively high. Hence, energy efficiency as an end by itself is not enough to bring energy consumption down. Additional policies and market support measures are required if this goal is to be achieved [15].

Furthermore, electricity markets and their regulation have failed to catch up with the pace of renewable energy production. It is surprising that Greece and Spain two Mediterranean countries that enjoy substantial solar irradiance have only recently established a regulatory framework for self-consumption. Spain did so in 2015 while Greece had done so previously in 2014 [34]. Even if this constitutes a positive step, it hardly balances the priority given to larger solar and wind parks via financial mechanisms [30]. Conversely, the regulation and policies in place fail to promote self-consumption. In Spain, small-scale investors have to pay an obscure tax, dubbed "tax on the sun" to be allowed to carry these activities. On top of that, the most common type of self-consumer is not entitled to any remuneration should they wish to export their electricity surplus to the domestic grid. As a result, such self-consumers have no incentive to do so. Efforts to encourage a cleaner energy mix and lower emissions are hampered by such provisions [35]. In other Member States, such as Belgium and Germany, self-consumers are charged for exporting electricity to the national grid. Such policies represent a substantial disincentive for promoting clean energy production [36]. What is more, RES were not used due to the failure of the network to accommodate the energy produced [24]. Micro-LNG grids have emerged as the first significant market response and challenge to renewable energy-run smart grids. Micro-LNG grids can surpass conventional smart grids as they feature the critical advantage of storage capacity [37].

For now, Member States maintain back-up capacity through capacity mechanisms, which allow coal and gas-fired plants to operate and provide energy when needed. These constitute a backdoor to the perpetuation of energy derived from fossil fuels throughout the energy transition [16]. In particular, the EU has legislated that all new generation plants (launched from 2020 onwards), as well as every generation plant after 2025, will have to comply with an emission performance standard of 550 grams per kilowatt hour in order to be permitted to be included in the capacity mechanism. Modern gas plants meet this threshold. Coal-fired plants are also likely to meet it in case they follow appropriate carbon abatement techniques [23]. These numbers contrast sharply with the IEA's projected carbon intensity of electricity generation, which brings performance standards to 335 grams in the baseline scenario and to only 80 grams in the most optimistic deep de-carbonization scenario in 2040 (in comparison with 515 grams today) [1]. The more prices remain at reasonable levels, the more reliance on fossil fuel plants decreases. This entails a greener energy mix and the reduction of CO_2 emissions. In this context, one should also anticipate the fossil industry's resistance regarding the substitution of the capacity mechanism with a profusion of other schemes, such as clean energy storage capacity (including EVs and batteries); cross-border functional interconnections; and market-based real-time congestion management [22].

While the transition to clean energy has discouraged oil and gas imports, it has brought about an increase in coal use. Germany's *Energiewende* is a good case in point [38]. More generally, the electrification of the energy sector means that the sources feeding it become even more significant for climate change mitigation. In this context, electric heating makes sense if it is powered by the sun and the wind rather than coal. The same holds true for the transport sector. While petrol emissions are significant, emissions from coal-fired electric cars will be even more harmful to the environment [17].

This brings us to the fundamental importance of policy to prioritise clean energy in order to foster green smart grids. Two instruments that enhance renewable generation have come under criticism. The first is the RES-E (Electricity from Renewable Energy Sources) scheme that subsidizes renewable energy generation in the form of either feed-in tariffs or premiums. The second is the RES dispatch priority mechanism. The main argument underpinning their censure is that these schemes unwittingly favour the least competitive forms of energy generation, this way compromising other sounder investments, and increasing the bill. The situation in the UK is illustrative of this trend. Criticisms to feed-in tariffs have led to revised tariff rates that are projected to yield lower returns, especially compared to those in other EU Member States. Accordingly, the dangers of depressed investments in renewable generation seem rather likely [39]. On the other hand, smart grids bear the potential to render renewable energy more profitable through proper energy management which should result in energy conservation [22]. Smart grids are very promising but may also impinge on the three main dimensions of energy security (sustainability, security of supply and affordability).

Another argument against subsidies schemes for renewable energy derives from the existence of the Emissions Trading System (ETS). The ETS is supposed to deliver on the climate front and thus renders renewable energy feed-in tariffs redundant. However, the ETS addresses climate policy goals appropriately only under determined circumstances which hardly apply in practise. Firstly, energy technology choices are distorted by market and policy failures, which tilt the advantage towards business-as-usual solutions rather than facilitating the emergence of new technologies. Subsidies on renewables can be understood as mechanisms to counter these distortions that perpetuate technological lock-in. Feed-in tariffs increase availability of renewable energy, thereby allowing for stricter caps to be set in the ETS. Secondly, subsidies on renewables have the potential to reach other goals beyond climate change mitigation; such as achievement of renewable energy targets; provision of other environmental benefits; improved air quality; strengthening of security of supply; and boosting of industrial policy and economic competitiveness [22].

Contemporary emphasis on extensive gas infrastructure clashes with the EU's agenda on smart grids deployment. This friction can generate profound lock-in effects by obstructing a faster transition to low-carbon energy systems [40]. The fact that half of the funding of the Connecting Europe Facility (CEF) scheme is directed to two gas projects deemed to be of strategic importance is revealing of this dichotomy [41]. The ongoing gas glut equips gas proponents with important arguments for its significance for the energy mix. Nevertheless, horizontal fracking constitutes a nocuous practice for the environment and produces higher emissions than conventional gas [42]. The globalization of gas markets, facilitated by the shale revolution, meddles with global gas supply-demand equilibria. Such turn of events are contributing to an increased gas import portfolio.

2.4.2 Strengthening supply security

While smart grids' impact on sustainability, energy efficiency, affordability and competitiveness has been considerably examined, security of supply remains an unexplored topic in relevant academic debates [43].

2.4.2.1 Advantages

The new energy architecture with smart grids at the centre aims at strengthening security of supply and resilience of the energy markets. A mix of solar, wind and other renewable sources constitutes a much more decisive diversification policy than pressing for gas imports from alternative suppliers [6]. The planned connection of EVs to smart grids can provide added resilience by means of enhancing congestion management [33]. While the modern centralized electricity grid has been exposed to terrorist attacks in terms of physical security, the decentralized nature of smart grids makes any meaningful attack on the energy infrastructure impossible [31]. Even though the decentralized grid increases the level of resilience, it also increases the number of potential targets. Furthermore, new threats are emerging such as cyber and cyber physical threats taking into account the massive use of ICT in network management.

Energy poverty remains an urgent issue to tackle in the EU. Indeed, smart grids seem to be a spot-on response to this problem. Self-consumption directly combats energy poverty at the root. Poor households can produce their energy and consume it rather than having to pay volatile prices.

In introducing smart energy systems, the Member States are faced with a set of strategic choices. Firstly, Member States can decide whether to embark on a "make" or "buy" choice. The first choice ("make") refers to the option for the Member State in question to produce electricity itself. The second choice ("buy") is to import energy supplies. If a Member State is able to produce its own energy, this eradicates any dependencies. Further, favouring energy which is generated nationally will cascade into much needed domestic investment and generate new employment. Having said this, the "make" option entails higher costs (at least for most Member States). The "buy" option offers efficiency and flexibility but retains some dependencies to external suppliers. What is more, the "buy" option will burden national economies.

Secondly, the states can opt for a centralized or a de-centralized architecture of energy production. This boils down to Member States having to "*decide whether they prefer centrally or decentrally produced electricity and whether to rely on incumbent energy companies and grid operators or empower households and local communities with their own production and distribution networks (connected to the grid or not). If the distributed option is chosen, energy markets become locally oriented, likely to involve a mix of private and communal companies. This choice in generation capacity adds a strategic consideration within the make or buy context*" [44]. An important caveat regards flexibility and, in particular, whether the reversion of the initial decision is likely and possible in the "make" option. For the Member States that will opt to produce their own energy, a centralized architecture is more flexible since it can accommodate reversion to the 'buy' option, in case the 'make' option underperforms. This is so because central grids can be connected to grids of other countries and hence carry imported energy from third countries. This is less functional and practical in the case of locally produced energy [44].

The exact shape of smart grids deployment is significantly contextualized and contingent upon both local conditions and national regulation. A one-size-fits-all approach hence is unfeasible. In Greece, for example, geography plays a critical role with the energy security of the mainland on the one hand, and the myriad of islands on the other calling for different treatment, as is reflected in the institutional energy structure and the associated regulatory provisions [45]. The existence of a big number of small islands in the Aegean Sea create a strong rationale for autonomous energy generation, since connection to the main grid is rather costly. Utilizing the rich potential of energy generation through strong winds and abundant solar irradiance could substantially boost indigenous energy generation. A smart grids architecture that would interconnect the grids of several adjacent islands, and then create interconnection points for these different groups of islands (most probably on the basis of existing administrative divisions) could also provide for the appropriate scale, as well as offer interconnectivity options necessary to ensure strong security of supply.

2.4.2.2 Risks and challenges ahead

The evolution of smart grids, on the other hand, also presents formidable challenges. The load in the electricity networks has to be continually balanced. This can be achieved in two ways. Either through the maintenance of the supply and demand balance via market mechanisms, or by means of adequate storage capacity. The low carbon transition has been based on the proliferation of solar and wind energy, both of which are intermittent in nature, thus raising the issue of what happens at the times when they underperform. As the transition moves on, and renewable energy starts to play a central role in the energy mix, the continual supply-demand balancing is anticipated to take centre-stage. Sophisticated weather forecast tools will assist in predicting with increasing accuracy the supply side, thus providing benchmarks and minimizing uncertainties.

These notwithstanding, in case of balancing failure, the end result will be either load-shedding, in other words a power cut, or increased electricity prices. Load-shedding amounts to failure to provide supply security, while increased electricity prices accentuate energy poverty and contravenes the affordability goal. A concerted demand response management program is being developed to correct such mishaps in time and avert negative outcomes. Demand response management includes decentralized control automation, real-time and scarcity pricing, self-rationing, intra-day markets and flexible, targeted contracts [19]. At the same time, it allows consumers to take full control of their energy usage and optimize both the services they entertain as well as the operation of smart grids.

While the emphasis remains on the capacity mechanism, the further development of cross-border trade and the optimization of the available electricity across borders is a key issue. Poor data availability; sub-optimal coordination; and limited infrastructural interconnection have as a result that prices are not set at the right level. Thus, participants do not receive the adequate market signals which leads to the suboptimal delivery of electricity [23]. Member States' emphasis on national measures and tools to tackle security of supply risks only accentuates the problem of loosely coordinated national electricity markets [23]. Assuming the capacity mechanism is not ruled out in the following decades, it makes sense to move from national assessments to an EU adequacy assessment and design multiple cross-border flows of electricity accordingly [23].

The European Commission aims to deal with these shortcomings by introducing "a wider regional and European aspect first into the assessment of capacity needs" and seeking "to better coordinate national capacity mechanisms" [46]. Under the new rules, all Member States are free to set their desired level of security of supply. However, these rules should be transparent and verifiable. More importantly, capacity mechanisms will be governed not just by state aid guidelines but also by a European framework which will mandate and regulate cross-border participation and eventually lead to integrated capacity markets in the EU [46].

The premise that smart grids and smart meters necessarily equate to quasi-automatic energy savings is not supported by recent research surveys. Indeed, these studies have moderate expectations. On the one hand, smart meters are found to provide wealth of information to the consumers. On the other, this AMI develops over time into a normal background monitor fully embedded in household routines and practices. Consequently, smart meters fail to continuously nudge consumers to further economize on energy. Usually, supplementary savings are hard to materialize beyond a certain threshold. The potential for additional energy savings is frustrated due to the absence of wider policy and market support [47]. In light of the above, security of supply is in practise only marginally improved.

2.4.3 Affordability and competitiveness gains in prosumer markets

2.4.3.1 Advantages

Europe's energy systems require investments. There is evident discordance when it comes to which projects have to be financed and which will be left out of the agenda [48]. This is a fundamentally political conflict which impacts on the allocation of funding and the distribution of benefits across corporate sectors.

On the affordability front, smart grids can bring two positive results. Firstly, a reduction of energy bills should arise from self-consumption and demand management. In turn, these will lead to lower energy quantities being transmitted from the grid. Secondly, prosumers have the possibility to install the infrastructure to generate their own energy. Prosumers can then sell their electricity surplus to aggregators, DSOs and other energy services companies.

An important benefit of smart grids *vis-à-vis* fossil fuel imports is the resulting predictability of prices. Fossil fuel prices are renowned for their volatile nature as opposed to the price of renewable energy. Abrupt increases in fluctuating energy prices create severe hurdles for the poorest citizens within the EU. There is a considerable disparity between the decreasing costs on renewable energy generation and the frequent boom and bust cycles of global energy markets [49]. Smart grids may lead to higher prices in the case of ineffective load balancing. This raises the importance of the development of effective demand response mechanisms that will optimize the benefits accruing from digital technologies [50].

2.4.3.2 Risks and challenges ahead

In the absence of reliable electricity storage technologies, reserve capacity is ensured through capacity mechanisms. This policy tool puts a premium in electricity prices. The same is true of the priority dispatch mechanism, which prioritizes the utilization of renewable energy even when this is not the most competitive option. Therefore, it is safe to say that "structural changes to the design and operation of the power system are needed to ensure adequate incentives for investment and to integrate high shares of variable wind and solar power" [1].

In light of the underperformance of the ETS, the question of carbon tax is of notable importance. The need to somehow put a price on carbon means that fossil fuels will be more expensive in the near future. With the above in mind, there is hardly any rationale for investments on new coal-fired power plants to materialize. While one could argue that carbon pricing has been successfully kept at bay by influential fossil fuel corporations, two points have to be considered. Firstly, certainty is key in markets in general. It is for this reason that a price on carbon – one that can create a level-playing field and guide corporate policies for the future decade – may transpire. Secondly, there are reasons for optimism in the wake of the open letter that six major energy companies signed asking for a carbon tax to be established prior to the Paris Agreement [51]. The setting of sub-national and regional emissions trading schemes around the world is arguably paving the way for such a tax [52].

The above is illustrative of the complexity of policy-making in terms subsidy mechanisms. This task is even more challenging considering that subsidy schemes can lead to significant market distortions. In turn, these distortions thwart adequate market signals to the detriment of consumers. A suggested course of action boils down to the gradual phase-out process that would naturally culminate in a carbon tax. This carbon tax should incentivize renewable energy generation instead of fossil fuels imports [23]. Alternatively, a feed-in premium tariff for renewable energy production should be placed as the only subsidy to further encourage renewable energy production when needed.

The European Commission is renowned for its tough stance regarding subsidies and ensuing market distortions. In this context, it aims to replace capacity mechanisms by scarcity pricing. Not only would supply-demand dynamics not be tampered with, but scarcity pricing would also lead to the optimal operation of the electricity market [23]. Indeed, demand response management maximizes network efficiency and minimizes associated costs (including capacity mechanisms). Such a development would constitute "a triple win – encouraging investment, enabling demand response and lessening the need for capacity mechanisms" [23].

Having said this, potential weakness to effectively manage the electricity load at all times will lead to higher prices, thus jeopardizing the access to affordable energy. Energy politics are also against “perfect markets”, as controlled electricity markets are more conducive to governments’ interests. This is so as markets may lead to higher prices to reflect the state of supply and demand. However, this conflicts with the political aspirations of governments who want to meet their citizen’s expectations. Low electricity prices are a way to achieve this.

More importantly, the advent of prosumer markets will mean that the same actors will have conflicting interests in their dual roles. On the one hand, prosumers will seek high prices for selling their electricity surplus, while on the other, they will prefer low prices for their energy usage. This contradiction may lead to suboptimal profits from demand response schemes. At the same time, aggregators and other actors who can obtain significant market power may be able to reap the benefits of higher prices, by passing them to consumers, thereby neutralizing the benefits of demand response. A way out of this impasse may be increasing the emphasis placed on self-consumption. Hence, a fraction of the energy needs of households are covered by the energy they produce themselves, thereby mitigating the importance of prices. This will indeed mark the democratization of the energy system. Energy access will be, at least in part, directly provided without the mediation of market mechanisms that may yield adverse results.

Broadly speaking, the rationale for prosumer markets draws from neo-classical economic presuppositions. However, such premises hardly apply in practical terms. Mainstream economics regard prosumers as rational actors that will endeavour to reach optimal energy consumption. After all, prosumers have access to the necessary information in order to take the best decisions. Nevertheless, these abstract expectations are usually frustrated in the practical plane. This is so as the average prosumer tends to display a limited capacity to process all the information thereby falling short of maximising his energy consumption [53]. In light of the above, expecting prosumer markets to perform automatically is wishful thinking. Educating prosumers is necessary to reap all the benefits tendered by smart grids. Specific emphasis should be given to the social groups that are likely to need the most guidance (such as senior citizens, for instance).

Bradley, Leach and Torriti subject the success of smart grid deployment on the trust between prosumers and other actors across the energy market. In particular, they assert that “to maximise benefits from DR [demand response], it must be ensured that implementation of smart metering and other technologies is done in such a way as to ensure trust, maximum customer acceptability and satisfaction as well as education along with implementation” [50].

The costs associated to the deployment of smart grids will be contingent on the degree of customer engagement and trust. Should customers fail to recognize the benefits offered by smart meters, it will be harder for customers to engage with the process and trust the corporate players implementing the roll-out. This would certainly lead to a suboptimal roll-out of smart meters. Higher costs, limited benefits and a hugely mismanaged opportunity will be the end results [50].

The new architecture of smart grids currently leaves the competences of the amalgam of actors in a policy vacuum. For example, while DSOs are anticipated to invest, there are hardly any incentives in place for them to do so. Conversely, the benefits of such investments accrue predominantly to suppliers and consumers as well as local and national authorities that can meet their climate targets. Providing a compensation to DSOs to upscale the development of smart grids is hence the first necessary step [16]. Rationalizing these compensation schemes in terms of access to energy being tantamount to a public good may enhance the reception of such schemes among citizens [54]. What has to be considered in-depth is the question of who pays for hedging against emergencies. Peak prices and scarcity pricing places costs on consumers. The development of storage capacity (*e.g.* EVs) adds a further layer of costs which can either be funded through tariffs or be passed on to retail prices. Hence, taxpayers pay for this. The same is true for capacity mechanisms.

3 SMART GRID REGULATION

3.1 SMART GRIDS: PAVING THE WAY FOR SMARTER GRIDS

3.1.1 Background

"Smart grids" can be defined in a variety of ways. The following definition is proposed by the European Regulators Group for Electricity and Gas (ERGEG), and used also by the Council of European Energy Regulators (CEER) and the Commission: "A smart grid is an electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power systems with low losses and high levels of quality and security of supply and safety" [55] [56] [57] [58]. It might be interesting to note that this definition does not define smart grids by the kind of technology used. The term describes the complex connection between electricity generation, transmission, distribution, utilization and information communication platforms via a system of sensors and other equipment across various levels of the electricity market [59]. One major purpose of smart grids is to target future behaviour of the most important grid user, namely consumer, with the view to finding more means to use energy when and where necessary, and under more convenient conditions.

Smart metering issues are of course related to smart grid issues. Yet, while smart meters are enablers for smart grids, they are merely one of many components of a smart grid. The ERGEG suggests that it is technically possible to develop smart grids and to roll out smart meters independently of each other [56]. Indeed, smart grids represent an amalgam of existing energy infrastructure and new information technology. Consequently, smart grid regulation transcends energy law and policy; it represents a balance between promoting the development of new technologies aimed at promoting the development of renewable energy, and the need to protect consumers and consumer interests.

3.1.2 The EU legal basis

According to the Third Energy Package adopted in 2009, Member States shall, subject to a positive cost-benefit analysis, ensure the roll-out of smart meters. The aim of implementing intelligent metering systems is to facilitate the active participation of consumers in electricity markets. Directive 2009/72/EC in particular, states that subject to an economic assessment of all the long-term costs and benefits to be conducted by September 2012, Member States or any competent authority they designate shall prepare a timetable with a target of up to 10 years for the roll-out of smart meters. Where the assessment is positive, at least 80% of consumers shall be equipped with smart meters by 2020 [60].

While the Directive is not an obligation on Member States to introduce smart grids, Article 3 (10) and (11) represent the legal foundation on which Member States can facilitate the development and deployment of smart grids. The Directive also includes rules designed to benefit European energy consumers and protect their rights. One of these rights is the right to choose or change suppliers without extra charges. In order to make this a reality, a review of the existing technical and operational landscapes, together with their attendant regulatory framework is required.

3.1.3 Current status in Europe

According to a 2014 study conducted in 27 European states by the CEER, 42% of the participating countries already had a strategic roadmap to implement smart grids [58]. Expressed in absolute numbers, 10 countries had established such plans, while 17 had not. Table 1 provides an overview of smart grids implementation plans across European States. Specifically, Austria, Cyprus, Denmark, Finland, France, Greece, Luxembourg and Norway published national implementation plans. In 11 of the countries, these plans were established at the national level; while in Belgium, this plan is being developed at local levels. For instance, the Flemish government approved the concept note "Digital meters: roll-out in Flanders" on 3 February 2017. The Flemish regulatory body VREG was asked by the Flemish government to update its earlier cost-benefit-analysis on the basis of the principles of the new concept note. VREG concluded that the roll-out of the smart meters in

Flanders would be a correct policy decision [61]. Implementation plans were not created, for example, in the Czech Republic, Slovenia, and Spain. In Great Britain, although an implementation plan was not established, a high level route-map has been developed, which is the responsibility of the national GB Smart Grid Forum [58]. There is no convergence across Europe in terms of timeframe for the implementation of smart grids. In most of them, national governments and DSOs are responsible for implementation, while National Regulatory Authorities (NRAs) have monitoring functions [58].

As far as actual implementation is concerned, Italy is to be considered a forerunner. Smart metering implementation has been completed, covering 99% of electronic metering points [62]. The DSO is the owner and responsible party for implementing the smart grid and for guaranteeing power quality. Remarkably, the Italian implementation is not merely aimed at achieving a roll-out of AMIs, but it envisages a progressive improvement of AMIs. For instance, given that the low voltage remote control meters which were first rolled out in 2001 have a lifespan of fifteen years, the first replacement campaign was launched in 2016. These first generation (1G) meters have since reached their end-of-life, and true to the expectation, some companies have started installing 2G meters. The Italian experience is also a regulatory paragon because the law laid down functional specifications for 2G meters and identifies some crucial criteria. The requirements include: 2G meters, once installed, shall remain in operation, presumably, for another 15 years; over this period, they must be able to support every electric system transformation, such as the new distributed production paradigm and the changes of the electricity market [63].

Other countries, such as Spain, have not developed an implementation plan for smart grids. Yet, the roll-out of smart meters is ongoing and is planned to be completed by 2018 [64].

Member State	National or local level	Details
Austria	National level	National Smart Grids Technology Platform (www.smartgrids.at), published roadmap in 2010
Belgium	Local level	Wallonia: http://www.cwape.be/?dir=4&news=122 Flanders: http://www.vreg.be/nl/nieuws/kosten-batenanalyse-slimme-meters
Croatia	No	
Cyprus	National level	
Czech Republic	No	Under construction.
Denmark	National level	http://www.kebmin.dk/sites/kebmin.dk/files/klima-energi-bygningspolitik/dansk-klima-energi-bygningspolitik/energiforsyning-effektivitet/smart/smart%20grid-strategi%20web%20opslag.pdf
Finland	National level	http://energia.fi/sites/default/files/haasteista_mahdollisuuksia___ja__hiilineutraali_visio_vuodelle_2050_20091112.pdf and http://www.emvi.fi/files/Tiekartta%202020%20-%20hankkeen%20loppuraportti_15_11_2011%20(2).pdf
France	National level	Published by the Energy Agency (ADEME), current version is available at: current one is available here : http://www2.ademe.fr/servlet/getDoc?sort=-1&cid=96&m=3&id=84680&ref=&nocache=yes&p1=111
Germany	No	
Great Britain	No	High-level route map has been developed.
Greece	National level	
Hungary	No	
Italy	National level	Incentives were deliberated by the energy authority (AEEG-SI) in 2010: http://www.autorita.energia.it/it/docs/10/039-10arg.htm The latest update concerns the second generation of smart meters, published in August 2016: http://www.autorita.energia.it/it/docs/dc/15/416-15.jsp
Lithuania	No	

Member State	National or local level	Details
Luxembourg	National level	For smart meters: http://www.eco.public.lu/documentation/etudes/2012/Etude_ComptageIntelligent.pdf
Norway	National level	www.nve.no/ams
Poland	No	
Portugal	No	
Romania	National level	http://www.anre.ro/ro/legislatie/smart-metering
Slovenia	No	Under construction.
Spain	No	
Sweden	National	A roadmap with recommendations on how to stimulate the deployment of smart grids for the years 2015 to 2030 is currently under construction by the Swedish Coordination Council for Smart Grid (http://www.swedishsmartgrid.se). Due date December 2014.
Switzerland	No	
The Netherlands	No	There is a vision document from the Taskforce Smart Grids established by the Ministry of Economic Affairs http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/

Table 1 – Development of smart grids implementation plans in European Member States [58]

With the view to promoting smart grids, many Member States have adopted regulatory incentives. In the CEER study, 79% of the countries were found to use tools for price regulation and 63% use performance indicators. In contrast, tools to regulate the provision of information, charges and licensing are used significantly less. In most of the countries (76%), regulatory instruments will need to be adapted in order to facilitate the deployment of smart grids [58]. For example, in Belgium, from 2018, ATRIAS will provide a new clearing house with new MIG6 market protocol implementation. This means that from 2018 onwards, new market models for prosumers with PV<10 kW peak will be established, making dynamic tariffs and sale of injection possible [65]. In Great Britain, the value of demand side flexibility for the electricity system will have to be reflected in the incentives to invest in smart grids [58]. In Lithuania, reaping the benefits of smart grids and managing related data privacy issues will require amendments to the current regulatory framework. In Italy, "input-based" type of incentive regulation has been used for the transmission network as well as to support smart grid pilot projects in distribution networks. In Poland, in order to assess the benefits of smart metering for consumers, two new performance indicators were introduced. In Spain, the deployment of smart meters is ongoing, and it is viewed as a necessary step towards the development of smart grids. As part of Spain's efforts, the low voltage code has been proposed to be changed and a new discriminatory tariff that, thanks to smart meters, promotes charging of EVs at times of lower demand and prices has been established [58]. Despite what appears to be wide-spread attempts at regulatory reform within the continent, some actors in some of these market are of the opinion that regulatory reform may not be necessary as the current regime already provide an enabling ground for smart grids [58]. While this may be true in some cases, the reality is that the existing regimes for electricity regulation are skewed towards the traditional grid and do not take into account the dynamic nature of smart grids. Consequently, if smart grids are to be afforded an opportunity to enter what is currently, often an oligopolistic market, regulatory reform would be quintessential.

Given that smart grids are largely experimental, demonstration projects have played a pivotal role in the development and deployment of the new technologies developed. Different countries in Europe have adopted various approaches towards promoting these demonstration projects. 61% of countries which participated in the CEER study, use a combination of sources for funding [58]. 56% of the countries, in particular, have been funding demonstration projects through industry funding, public funding institutions, the European Commission and integrated municipal energy suppliers. In 61% of the countries, governments are responsible for making decisions about granting funds. For example, Finland passes costs through to consumers to a certain extent, but also adopts efficiency targets for companies. Italy uses a cost-benefit indicator to select projects. Austria finances demonstration projects through a combination of funding from industry, public institutions and the national budget. The federal government established the Climate and Energy Fund

(Klima- und Energiefonds - KLIEN) to support the implementation of the climate strategy. KLIEN is responsible most of funds for demonstration projects. Remaining costs are audited and covered through network charges during the regulatory period, with the application of efficiency targets. Great Britain does not apply efficiency targets to demonstration projects. However, a key criterion for awarding funding is the project's value for consumers and its long term efficiency. The NRA, rather than the government, is responsible for most decisions [58].

With regard to more general incentives to encourage DSOs to adopt smart grid innovation projects and how they are funded, most European countries use a combination of regulatory mechanisms, national government initiatives and European initiatives. 63% of the countries assessed by CEER, use general incentives not specific to smart grids to promote the development of smart grids [58]. For example, Austria incentivises cost reductions through efficiency targets which do not distinguish between traditional and smart grids. As a result, regulated companies favour smart solutions when they are more cost efficient than other alternatives. Belgium still has to specifically define incentives, while Cyprus has currently no incentives in place. In majority of countries, incentives for DSOs to innovate are funded through distribution network charges. National and European funding is also used to a significant extent. Many Member States adopt a combination of sources of funding. For instance, Austria, Finland, Italy and France use network charges, national funding as well as European funding. The Netherlands, Poland and Norway use network charges as well as national funding. Lithuania and Slovenia use network charges and European funding. Greece and Spain use European as well as national funding [58].

Finally, with regard to the smart grids related issues of data privacy and security, it is a commonly held view that the technology associated with smart grids pose significant risks to data privacy and cyber security; both of which require concerted regulatory reform, of these risks are to be adequately managed. However, according to the CEER status review on European regulatory approaches enabling smart grids solutions, there is no clear consensus about whether NRAs for the energy sector will and should be responsible for data security regulation in relation to smart meter data. [58] Be that as it may, different proposals and approaches are being considered by different countries for dealing with the problem of data protection and security for smart grids. For example, in the UK, data aggregation plans will be proposed by the DNO and then approved by the NRA, and data privacy requirements will be regulated in the context of license conditions [58]. In Slovenia, a cost benefit analysis carried out by the NRA will also look at security issues [58]. In Spain, energy suppliers are precluded from having access to any information, other than that of their own customers [66]. In contrast, in the Czech Republic the Office for Personal Data Protection to be responsible for data security. Similarly, in France there is a separate and dedicated agency with competence over data security. In Germany, this is the responsibility of the Federal Office for Information Security. Finally, in countries such as Belgium and the Netherlands, the NRA for the energy sector and the Data Protection Authority will work jointly on data security issues [58].

The ERGEG Guidelines of Good Practice on regulatory aspects of smart metering recommend that "it is always the customer that chooses in what way metering data should be used and by whom, with the exception of metering data required to fulfil regulated duties and within the national market model. The principle should be that the party requesting information shall state what information is needed, with what frequency and will then obtain the customer's approval for this. [Furthermore] Full transparency on existing customer data should be the general principle" [67]. Table 2, from the CEER status review of regulatory aspects of smart metering, shows that many European countries indeed provide customers with information about, and ensure control over their metering data, free of charge. However, the same table also shows that, in a number of countries, customers are not given control over their own data [58].

	In control and informed	In control and not informed	No control over data	Not available
Free	AT, BE, DK, FI, FR, DE, GB, IE, IT, LU, NO, PL, NL, EL		CY, CZ, EE, IS, RO, SI, ES, SE	LT, PT
Not free				

Table 2 – Data privacy and security regulation in European Member States [58]

3.1.4 Towards regulatory policy recommendations

The most relevant issues at the moment revolve around network planning, priorities about grid reinforcement, and the ways DSOs are incentivised by national regulation to invest in smart grids. In simplified terms, a crucial issue concerns how to convince DSOs to test and innovate more. The 'obvious' answer seems to lie in the regulatory incentives set by the NRAs. Yet, these agencies also have to protect consumers from potentially excessive charges that natural monopolists such as DSOs could charge. This problem might be made even more acute when DSOs are state-owned and a major sources of public revenue. Therefore, a balance has to be struck between incentivising DSOs to invest in smart grids and avoiding the imposition of high tariffs on consumers. Another important concern is the possibility of conflicts of interest between DSOs and, for instance, self-producers. The desire of DSOs to optimize the economic benefit of grid utilization, inherently conflicts with the idea of self-production. Consequently, without regulatory interventions, DSOs would be opposed to the development of technology which potentially affects their bottom line.

The European Commission as well as the CEER and the ERGEG, hold the position that DSOs should be "market facilitators" [58] [55]. The notion of market facilitator in this context means that DSOs should play a crucial role in setting up and managing the infrastructure necessary to perform new services, for example, demand side and load aggregation functions. But they should not be directly involved in the provision of such functions, which instead should be left to actors competing against each other (*e.g.* suppliers, aggregators, ESCOs).

An additional set of regulatory challenges relate to the use of, and access to, smart meter data for smart grids. In most Member States, smart grids will make use of, and indeed rely on smart meter data and infrastructures. In general, how consumers' data will be managed and by whom will have to be clearly explained. Otherwise, an anxiety about privacy issues will be inevitable. Indeed, access to, as well as ownership of data appear to be the key issues. These are not specific to energy sector alone, but represent challenges that have been discussed thoroughly in other domains from which lessons may be drawn, such as "big data". While the regulatory nature of data protection for smart grids still remains unclear, it seems likely that national bodies (*e.g.* independent regulatory agencies for energy), will play a central role. Regulators and policymakers more generally can learn from other sectors which had to face already similar issues (*e.g.* internet, search engines).

It would also be important to consider the standardisation of smart grid technology with the view to improving security and integrity of the infrastructure. Although the various components of smart grids are at various levels of development, the concept envisages the interconnection of various components. Consequently, the absence of minimum technological requirements might result in, or facilitate the development of vulnerabilities such as cyber-attacks. Similarly, it is not inconceivable to envisage situations where sub-standard assets which interface with a smart grid network inhibit the smooth operation of the network or damage it. Granted that standardisation may occur at different levels, it may be prudent for the Agency for the Cooperation of Energy Regulators (ACER) to take lead on standardisation efforts to provide an international framework to guide national, local or enterprise based standardisation and perhaps delineate the relevant levels of standardisation.

Furthermore, a significant barrier to smart grid deployment would be insufficient/lack of consumer demand for such technology. Given fears associated with cyber security, government espionage and data protection, as well as public scepticism on the utility of such technology, concerted action has to be taken to create sufficient awareness to tackle this barrier. It is therefore critical that more information is provided to citizens about the benefits of smart grids, and more specifically about why smart meters are being deployed. This would increase consumers' awareness and engagement in energy markets, and, in turn, facilitate the development of smart grids.

3.2 DEMAND RESPONSE

3.2.1 Background

Demand response is defined by ACER as "changes in electric usage by end-use consumers from their normal load patterns in response to changes in electricity prices and/or incentive payments designed to adjust electricity usage, or in response to the acceptance of the consumer's bid, including through aggregation" [68] [69]. It has increasingly gained prominence as one of the means by which energy efficiency can be improved, and improve the reliability of grids through the lowering of demand, especially during peak periods.

Demand response programmes can be distinguished in two types: implicit and explicit demand response. In price-based (implicit) demand response, consumers choose to become exposed to time-varying prices which reflect the value and cost of electricity at different time periods. Thus, consumers do not pay constantly fixed prices but rather respond to wholesale market price variations and/or dynamic grid fees. Such flexible prices for consumers do not necessarily require "aggregators" [70].

In contrast, in incentive-based (explicit) schemes, consumers receive direct payments to change their consumption patterns upon request. This can be triggered by, for example, activation of balancing energy, differences in prices of electricity or grid constraints. Consumers may earn from their consumption flexibility by acting individually, or rather by contracting with an aggregator, which in turn might be either a third party or the customer's supplier. Aggregated demand side resources are then traded in the wholesale, balancing, and/or capacity markets.

Aggregators are new actors within European electricity markets. They are service providers that employ a number of demand facilities to sell pooled loads of electricity. As their name suggests, they perform the function of "aggregating" flexibility; they agree with industrial, commercial and/or residential consumers to aggregate their capacity to reduce energy and/or shift loads on short notice. They then create a "pool" of aggregated controllable load, made up of a number of smaller consumer loads. Finally, they sell the pooled load as a single resource to system operators, which use it for their technical needs. It should be noted that while load aggregators are new actors emerging in a number of power markets in Europe, load aggregation is a service, which might be performed by a variety of actors, well beyond load aggregators but including, for example, 'traditional' suppliers or other new companies (*e.g.* ESCOs). It is important to further note that the two distinct forms of demand response are not necessarily substitutes. Indeed, customers might well participate in incentive-based demand response through either an aggregator or a 'traditional' supplier and, at the same time, participate in a price-based demand response programme based on time-varying prices [70]. Beyond "aggregating" consumers (demand), aggregators also have a role to play in "aggregating" prosumers (consumption, production and storage).

Given that demand response gives rise to complex relationships between energy suppliers, customers, aggregators, and BRPs. A critical examination of the implications of these relationships for, amongst others, grid planning and customer protection is necessary. Based upon which a suitable regulatory framework, which enables and facilitates market participation for these actors and ensures that the full benefit of demand response mechanisms are reaped.

3.2.2 The EU legal basis

The Third Legislative Package laid the foundation for the development of demand response in Europe. Article 3(10) in particular, enjoined Member States to adopt amongst others, "demand-side management" measures as part of efforts to combat climate change and improve energy security. Further progress was made with the Energy Efficiency Directive (2012/27/EU). Article 15(4) of which requires Member States to "ensure the removal of those incentives in transmission and distribution tariffs that are detrimental to the overall efficiency (including energy efficiency) of the generation, transmission, distribution and supply of electricity or those that might hamper participation of demand response, in balancing markets and ancillary services procurement" [71]. It also requires Member States to "ensure that network operators are incentivised to improve efficiency in infrastructure design and operation, and, within the framework of Directive 2009/72/EC, that tariffs allow suppliers to improve consumer participation in system efficiency, including demand response, depending on national circumstances" [71].

Furthermore, Article 15(8) of the Directive, establishes that "Member States shall ensure that national regulatory authorities encourage demand side resources, such as demand response, to participate alongside supply in wholesale and retail markets. Subject to technical constraints inherent in managing networks, Member States shall ensure that TSOs and DSOs, in meeting requirements for balancing and ancillary services, treat demand response providers, including aggregators, in a non-discriminatory manner, on the basis of their technical capabilities. Subject to technical constraints inherent in managing networks, Member States shall promote access to and participation of demand response in balancing, reserves and other system services markets, inter alia by requiring national regulatory authorities […] in close cooperation with demand service providers and consumers, to define technical modalities for participation in these markets on the basis of the technical requirements of these markets and the capabilities of demand response. Such specifications shall include the participation of aggregators" [71].

The importance of promoting demand response is also emphasised by the set of rules ("network codes") drafted by European Network of Transmission System Operators for Electricity (ENTSO-E), based on Framework Guidelines from the ACER, in turn based on priorities set by the European Commission. Specifically, the ACER Framework Guidelines on Electricity Balancing provide that "These terms and conditions, [...] including the underlying requirements, shall, in particular, be set in order to facilitate the participation of demand response, renewable and intermittent energy sources in the balancing markets" [68].

Finally, the Commission Guidelines on State aid for environmental protection and energy 2014-2020, in clarifying the conditions under which Member States are allowed to introduce "capacity remuneration mechanisms", requests Member States to consider alternatives such as demand response. [72] Specifically, the Guidelines state that "Member States should therefore primarily consider alternative ways of achieving generation adequacy which do not have a negative impact on the objective of phasing out environmentally or economically harmful subsidies, such as facilitating demand side management and increasing interconnection capacity". [72] Furthermore, "the measure should be open and provide adequate incentives to both existing and future generators and to operators using substitutable technologies, such as demand-side response or storage solutions". [72] In addition, "the measure should be designed in a way so as to make it possible for any capacity which can effectively contribute to addressing the generation adequacy problem to participate in the measure, in particular, taking into account the following factors: the participation of generators using different technologies and of operators offering measures with equivalent technical performance, for example demand side management, interconnectors and storage" [72].

These supranational frameworks are designed to ensure that fundamental modalities required for a successful deployment of demand mechanisms can be made possible. These modalities can be categorised into three; namely: the legal recognition of demand response, thereby allowing consumer loads to compete with other generation assets in all markets; the legalisation and enablement of aggregation services in the markets; and the adjustment of technical specification in recognition of consumer capabilities and requirements.

[73]. The transposition period for the Energy Efficiency Directive (EED) expired on the June 2014. The expectation was that, by this date, the necessary modalities necessary for implementation across Member States would have been put in place.

3.2.3 Current status in Europe

The CEER's study on regulatory approaches for smart grids revealed that, in order to promote demand response, 71% of the European countries that were sampled, use static time of use tariffs and 58% of them use load control to incentivise demand side response. In countries such as Italy, load control is limited to large industrial customers through remote means [58]. In countries such as Belgium, different types of load control are used by the TSO in the tertiary reserve ancillary services of TSO Elia. In countries such as Greece, there are differential tariffs for peak and off-peak consumption for households [74]. However, not all European States apply "price signals" to induce customers to change their consumption patterns.

Figure 1 maps the current status of development of incentive-based (explicit) demand response in Europe as of 2015. The assessment carried out by the Smart Energy Demand Coalition (SEDC) [70], was based on the following four criteria: enabling consumer participation and aggregation; appropriate programme requirements; fair and standardised measurement and verification requirements; and equitable payment and risk structures [75]. Overall, the SEDC suggests that, in Europe, incentive-based (explicit) demand response is still in its early developments, and in a few cases, the markets do not permit consumer participation and are therefore 'closed' to explicit demand response. Member States have largely varying regulatory frameworks, each with its own participation requirements and rules. There are generally no standardised contractual arrangements governing the roles and responsibilities of the distinct actors involved. Furthermore, it is often impossible in practice, or even not allowed by the law, to aggregate consumers' flexibility [70].

In some countries, demand response is a commercially viable product. For example, in Belgium, demand response can participate in a number of balancing markets, namely the primary and tertiary reserves. However, a key obstacle is the requirement for aggregators to get the prior agreement of the customer's supplier/balancing responsible party in order to be able to contract with the customer [70]. There are at least two private aggregators active on the market ("Restore.eu" and "Actility"), as well as a tertiary off-take reserve scheme specifically for aggregators ("Dynamic Profile").

Great Britain is deemed to have competitive energy markets and open balancing markets, though uncertainties for demand response have been cast by the emerging capacity market. Great Britain was the first EU Member State to open to the demand side many of its electricity markets. Currently all balancing markets allow the participation of demand response in general and aggregated load in particular. However, according to the SEDC, measurement, baseline, bidding and other procedural and operational requirements are not appropriate. Thus, even though the markets are formally open, in practice, results in terms of demand-side participation have been worsening over time. Furthermore, the capacity remuneration mechanism introduced in 2014 is said not to place demand-side resources on a "level playing field" with generation resources. Indeed, only one demand-side aggregator out of around 15 operating in the market managed to secure a contract in the first capacity market auction [70].

France and Switzerland have redrafted their programme requirements and defined clear roles and responsibilities precisely to allow independent aggregation [70].

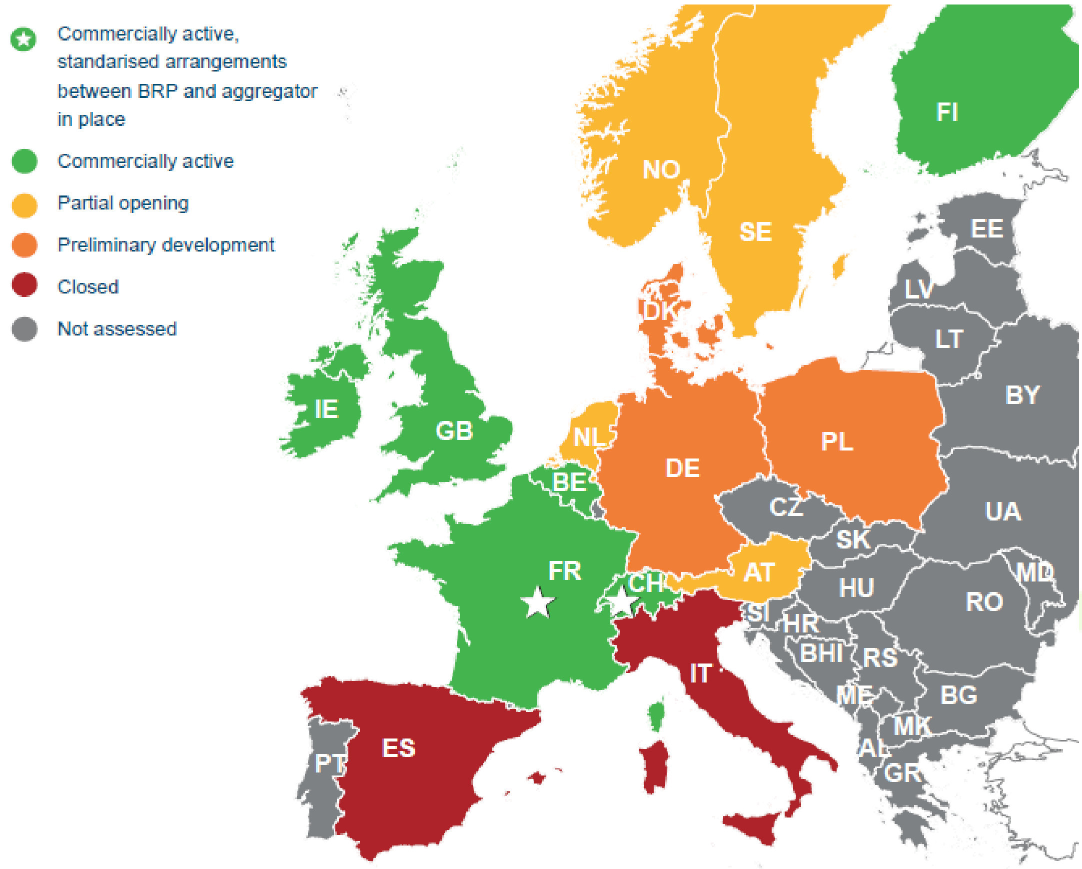


Figure 1 – Map of incentive-based (explicit) demand response development in Europe today [70]

Other European countries still present important regulatory barriers, notably programme participation requirements not yet tailored for both generation and demand-side resources. For example, Austria requires consumers to install a secured and dedicated telephone line in order to participate in the balancing market. Norway requires TSO signals to be delivered over the phone, thus making the minimum bid-size high. As a result, the participation of consumers other than large industrial consumers is hindered [70]. Similarly, technical and organisational rules do not consider some of the requirements for the provision of balancing services in sufficient detail [70]. Such as the negative impact of complex and lengthy approval procedures, and their associated costs, on market entry and participation.

In still other Member States, aggregated demand response is either illegal or its development is seriously hindered due to regulatory barriers. For example, in Italy, the notion of load aggregator is not formally recognised and no regulatory framework currently exists. Poland and Spain do not seem to be taking the required steps to foster the development of incentive-based (explicit) demand response [70]. Indeed, load aggregators do not exist in every EU Member State. The analogous consideration applies to regulatory frameworks governing their operation.

The remainder of this section provides a brief discussion of demand response in a limited number of Member States. They were selected on the basis of the data currently available and the nationality of the consortium partners with higher input in WP1. In Belgium, demand response can participate in a number of balancing markets, namely the primary and tertiary reserves. However, a key obstacle is the requirement for aggregators to get the prior agreement of the customer's supplier/balancing responsible party [70] in order to be able to contract with the customer [70].

Italy relies mostly on hydro and gas generation to satisfy its flexibility requirements, while the framework governing consumer participation in balancing markets has not been set up yet, the partial exception of interruptible contracts which constitute a dedicated demand response programme [70]. Load aggregation is not allowed, nor is there currently, any regulatory framework in place to govern such activity. Yet, the strategic guidelines for the period 2015-2018 published by the NRA included an evaluation of demand-side mechanisms and hence might reflect the possible opening of balancing markets to demand response [76].

Like Italy, Spain also uses mainly hydro and gas generation for its flexibility needs. Even though some smart grid pilot projects are currently being developed, incentive-base (explicit) demand response is currently modest. Even though there is one interruptible load programme that allows incentive-based (explicit) demand response, the scheme is only open to large consumers and has not been used for a number of years. Importantly, load aggregation is illegal. Yet, proposals to open balancing markets to demand response could prompt changes in 2016-2018, especially in the light of the smart meter roll-out expected by 2018 [70].

3.2.4 Towards regulatory policy recommendations

Overall main regulatory barriers found repeatedly across Member States include:

1. **Demand response might not be accepted as a flexibility resource:** in a number of European countries wholesale, balancing and/or capacity markets do not accept aggregated demand as a flexibility resource [70].

2. **Inadequate and/or non-standardised baselines:** in a number of European countries standardised measurement and baseline methodologies are absent. Current methodologies are designed for generators and, as a consequence, do not accurately measure changes in consumption. This could hinder demand response, because consumers might not receive adequate payment for their flexibility. [70]

3. **Technology biased programme requirements:** programme participation requirements, historically designed for national generation, might not include demand side resources. [70] Power markets more in line with demand response timeframes have to be established (*e.g.* based on 15 rather than 60 minutes timeframes).

4. **Aggregation services are not fully enabled:** prequalification, registration and measurement may still be conducted at the level of individual consumers rather than at the level of pooled load brought together by the aggregator, hence hindering entry by placing heavy administrative and legal burdens on individual consumers. [70] Moreover, there is often no real definition of load aggregators. To promote the possibility for consumers to contract with aggregators, load aggregators must be legally acknowledged as facilitators of demand side flexibility.

5. **Aggregators, where existing, are currently active at the high and medium voltage levels, rather than the low voltage level:** load aggregators exist in some countries, such as France and Belgium. Yet, at the moment their activities are focused on the high and medium voltage levels, namely at transmission and dealing with TSOs. We therefore must learn how these activities might be translated, if at all, at the low voltage level, namely at distribution and when dealing with DSOs.

6. **Lack of necessary infrastructure:** while there is much discussion about the emergence of load aggregators, it must not be forgotten that, in order for aggregators to provide load aggregation services, they will have to rely on certain infrastructures. The key reference here is to install smart meters, which in most of the European member states are not yet deployed.

7. **Lack of standardised processes between consumers, balance responsible parties and aggregators:** it is important that standardised processes protect the relationship between customers and aggregators, and govern bidirectional payment of sourcing costs as well as compensations between the balance responsible parties (often the traditional suppliers) and the aggregators. [70] In other words, it is crucial to put in place contracts between, for example, DSOs, load aggregators and customers. For example, it is crucial that on the one hand the right of consumers to offer their flexibility on the market is acknowledged, while on the other that guarantees are put in place so that consumers maintain their rights when they sign up for demand response. For instance, there should be a provision for the network side to ensure some minimum balancing support through demand response schemes. Thus, demand response schemes could really contribute in reducing other capacity mechanisms.

8. **Provision of information to consumers:** this relates not only to energy prices and how much customers could save by changing their consumption patterns, but also to other kinds of information. For example, consumers could feel more motivated to engage in demand response programmes and choose among suppliers/aggregators depending on the mix of energy sources from which the electricity they consume is produced. Consumers could, for instance, prefer a programme and service provider that produces energy from cleaner sources, even if the monetary gains they could make were limited.

9. **Financial incentives as well as making it easier and less costly for consumers, especially through automatic adjustments within comfort levels**: it is now well-known, especially thanks to studies from the discipline of economics, that the efforts of policymakers to empower consumers are often frustrated by the fact that consumers do not react to efforts to alter their consumption patterns. Ironically, perhaps this is because they do not see the financial gain as sufficient to reward altering their consumption. In light of this difficulty, in addition to increasing financial incentives and promoting more cost-reflective tariffs that provide price signals for customers to adjust their consumption patterns, regulation could also consider providing fiscal incentives. That is to say, governments might consider putting in place policies which, through taxation, support demand-side adjustments. Another aspect that could be considered is a stronger use of 'negative' financial incentives. That is to say, increases in the penalties rather than rewards for changing consumption patterns, which might be more effective than 'positive' incentives.

10. **Automatization of demand response mechanisms**: Furthermore, demand response programmes should be made as easy as possible for consumers to participate. That is to say, in addition to concentrating on the rewards side of the equation, attention should be devoted also to the cost side; consumers will have to invest as little time and effort as possible, so that they might engage in demand response even if the financial rewards are not very high in absolute terms. In this context, automatization of responses appears to be crucial: consumers will not have to do anything, because adjustments in their consumption patterns will be automatic. In particular, the North American market is more experienced in the automatization of changes in consumption patterns within customers' 'comfort zone'. That is to say, for example, changes in the intensity of lighting within a flat which will not be noticed by its residents and will be activated automatically when appropriate. The US power markets are also more experienced with regard to load aggregators. Hence it appears desirable to look at these experiences and learn from them.

3.3 ELECTRICITY STORAGE AND ELECTRIC VEHICLES

3.3.1 Background

While solutions to the problem of large capacity energy storage are still in experimental stages of development, the importance of energy storage in future energy management systems cannot be underestimated. Current storage systems meet the temporary storage needs of small to medium-scale generation, usually from RES. Despite the lack of technological advancement, energy storage is beneficial to all levels of the electricity market. First, they provide an option to redress the problem of the intermittence of RES generation [77]. Further, the ability to store energy when prices are low and possibly sell when prices increase present an opportunity for arbitrage [78]. However, the nearest term benefit, is evident at the consumer level where it can contribute to the integration of decentralised production [79]. This benefit is further augmented when Electric Vehicles (EVs) are integrated into a smart grid design. EVs have traditionally been lauded as climate-friendly alternatives to internal combustion engines which emit greenhouse gases. However, more recently, the lithium-ion batteries used in EVs have been recognised as a potential storage device that can be used to provide reserve capacity to a grid, under what has come to be known as the Vehicle to Grid (V2G) system. Further, the integration of EV charging infrastructure with the appropriate management systems will allow the charging of EVs to become a controllable load which would go a long way to improve the reliability of the distributed power system, while ensuring that the EV is charged at the most convenient time. Despite the inability to store large volumes of electricity to meet traditional modes of supply in traditional electricity markets, the current storage technology could play an important role in Virtual Power Plants (VPPs).

VPPs aggregate energy produced by diverse distributed generation sources, including small scale generators. Consequently, unused electricity stored in batteries from small scale RES could be fed-into a VPP. Similarly, energy stored in the lithium-ion batteries used in EVs could also be fed-into VPP, or indeed grids under the so-called V2G system.

3.3.2 The EU legal basis

The legal framework governing electricity storage in Europe is provided, at the EU level, by the Third Energy Package. At the same time, at national level there are laws under development which will regulate electricity storage applications [80].

It is important to note the Directive 2009/72/EC [60] does not expressly mention energy storage. However, the proposal for a new directive on common rules for the internal electricity market of February 2017 does regulate energy storage. For instance, the text of the proposal clarifies that DSOs should not be allowed, directly or indirectly, to own storage facilities [81].

In respect of EVs the EU has set for itself an ambitious target of reducing the use of internal combustion engine vehicles by 50% by 2030, and phasing them out entirely by 2050 as part of efforts to reduce GHG Emissions. [82] Further to this, the alternative fuels directive [83] encourages Member States to develop systems which enable EVs to feed power back into the grid. In addition, the Commission has recently published a strategy for low-emission mobility, which amongst others, seeks to promote the removal of obstacles to the scaling up of the use of EVs [84].

3.3.3 Current status in Europe

When conducting an overview of the distinct electricity storage technologies used in Europe at the end of 2012 and their expected increase in the ensuing five years, the CEER memo on development and regulation of electricity storage applications concluded that hydro-pumping storage is, at the moment, the most commonly used electricity storage technology. This picture is not expected to change considerably over the next years. Although other distinct technologies will be employed (*e.g.* flywheels, compressed air electricity storage –CAES– and electrochemical storage), they will still represent less than 3% of the installed power. Even if they increase in number of applications, the associated growth in energy capacity will be minor. For example, it is expected that electrochemical storage will increase by up to 100MW thanks to new demonstration projects. However, this stands in contrast with hydro-pumped, which represents about 37GW in storage capacity in the CEER member states. Of course, the situation might change, even dramatically, thanks to breakthrough technologies [80].

The regulation of storage assets faces many conceptual and practical challenges. Conceptually, there is no consensus on the definition of storage assets. Particularly, whether they should be treated as generation assets or consumption units. This lack of clarity stems from the fact that, while storage assets can generate electricity in the literal sense of 'generation', the amount of electricity generated is typical not enough to provide a net positive flow to the electricity system [85]. On the other hand, they cannot be properly classified as consumption units because they do not actually consume the energy that they take up. Could they also be classified as part of a transmission or distribution network, given that they can be a bridge asset between generators and final consumers? The answers to these question is fundamental to the development of an appropriate regulatory regime as they impact on *inter alia* ownership, pricing and the imposition taxes and levies.

With regard to issues of ownership, the CEER memo shows that in most European countries storage applications are owned by generators, even though in some countries network operators may, to a certain degree, own storage applications. In most European countries, storage can provide services to both network operators and generators, and its primary users are its owners [85]. The ownership of storage assets is one of the challenges that impinges the development of the appropriate regulation. While there is no doubt that market operators such as TSO would benefit from owning storage assets, their unique position in the market presents an information asymmetry which would operate unfairly to their advantage against other market players particularly if stored energy is participating in the balancing and ancillary markets. It is in response to this problem that current proposals for the Electricity Directive seek to proscribe the ownership of storage assets by the owners or operators of network infrastructure [60]. The proposed proscription is in keeping with the EU's unbundling policy, in a bid to prevent counter-competitive activity in electricity markets.

In Spain, although there is no general regulatory framework for electricity storage, there are hydro-pumped storage power plants which perform the function of providing power during hours of peak consumption. The only exception relates to regulation of storage for small self-consumption systems. Under the Electricity Sector Law 24/2013, battery owners are not allowed to reduce the maximum power they have under contract with their supplier [86]. While it may be argued that this is intended to maintain grid integrity, when coupled with the high self-consumption tax, the regulatory regime for self-consumption and storage appears to be ill-considered.

In some cases, the regulatory framework not only does not promote, but rather, hinders the development of storage. For example, in some countries taxation is not favourable to storage, as typified by the 'Grid Fee System'. Ordinarily, grid fees are paid by the final consumers of power, as a fee for the transportation of electricity through the grid network. In the case of storage, operators of storage assets are first charged for charging the storage asset and then also for discharging it, because of the notional double flow of electricity. In real terms, the storage asset is neither a producer nor consumer therefore the strict application of the traditional grid fee model should not extend to storage assets. Often, this double taxation is higher than power prices, resulting in a very strong disincentivisation of electricity storage.

Regarding EVs, the European Environment Agency (EEA) reports that in 2015, 150,000 new EVs were sold in the EU. However, 90% of these sales were in the Netherlands, the United Kingdom, Germany, France, Sweden and Denmark [87]. Despite a steady growth in the number of EVs sold in the EU over the years, the 2015 numbers represent only 1.2% of total vehicle sales in the EU. Figure 2 shows the trend of EV sales since 2010.

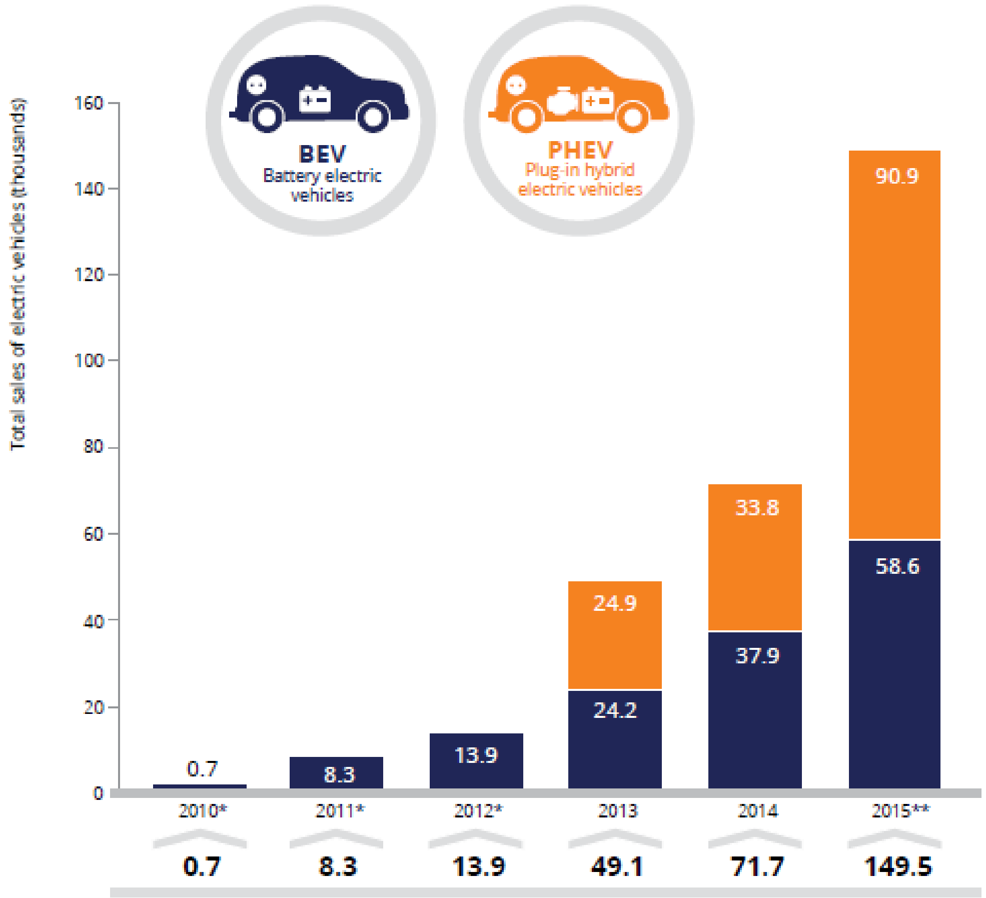


Figure 2 – EV Sales in the EU [87]

Note: * In 2010, 2011 and 2012, only statistics for BEVs are available. ** The data for 2015 are provisional.

In countries such as Norway and the Netherlands, where EV sales are very high, regulatory incentives have played a large role in promoting consumer interest [88] [89]. These incentives include tax exemptions on EV purchases, one-off grants, and the imposition of taxes on fossil fuels. Figure 3 summarises the use of incentives for EVs across Europe. In Belgium, Greece, Hungary, Latvia and the Netherlands for instance, there is a full registration tax exemption on EV Purchases, while Denmark and Finland provide a partial exemption [87]. Other financial schemes employed by governments are fixed grants, as employed in France and Portugal for the replacing of an end-of-life vehicle with a new electric vehicle.

Beyond promoting consumer interest, many countries also support research and development with the view to promoting innovation in the EV sector. Finland for instance instituted the Electric Vehicles Systems Programme (EVE) in 2011 with a budget of EUR 100 million, to support the growth of the EV sector [87].

Governments have also taken various actions to support the development of infrastructure, particularly charging points. France for instance set up a special fund, for the construction of charging infrastructure, which led to the construction of 5.000 charging points in 2015. In Sweden, individuals who installed charging points in their homes obtained a tax reduction for the associated labour cost [87]. However, an emerging barrier to the large scale deployment of charging infrastructure is that, new fast charging technology is not only expensive to install, but also requires high voltage input therefore the associated consumption fee is high [87].

Non-financial measures, particularly at the local government level have also been instrumental towards the promotion of EVs in Europe. In the UK for instance, some local councils have adopted a procurement policy which requires at least one EV amongst their fleet of vehicles [90]. In Bulgaria, the National Action Plan for the promotion of EVs gave EVs free parking in all its cities [91]. In other countries like Spain and Norway road toll exemptions and discounts apply to EVs [87].

As national response to climate change and air pollution continue to increase in response to EU Directives, it is expected that many more countries will adopt policies that would enhance EVs and storage technology.

	PURCHASE SUBSIDIES (purchase-related tax exemptions or reductions, registration tax, import tax, co-funding or other finantial purchase support)	**OWNERSHIP BENEFITS** (annual tax exemption, reduction of electricity or energy costs)	**BUSINESS AND INFRASTRUCTURE SUPPORT** (business development or infrastructure support)	**LOCAL INCENTIVES** (free parking, access to bus lanes, no toll fees, free charging, access to restricted areas in city centres)
AUSTRIA	✔	✔	✔	✔
BELGIUM	✔	✔	✔	
BULGARIA	✔	✔		✔
CROATIA	✔		✔	
CYPRUS		✔		✔
CZECH REPUBLIC	✔	✔	✔	
DENMARK	✔	✔	✔	✔
ESTONIA			✔	✔
FINLAND	✔	✔	✔	
FRANCE	✔	✔	✔	✔
GREECE	✔	✔		✔
GERMANY	✔	✔	✔	✔
HUNGARY	✔	✔		✔
ICELAND	✔	✔	✔	✔
IRELAND	✔	✔	✔	✔
ITALY	✔	✔	✔	✔
LATVIA	✔	✔		✔
LIECHTENSTEIN				
LITHUANIA	✔			✔
LUXEMBOURG	✔		✔	
MALTA	✔	✔	✔	✔
NETHERLANDS	✔	✔	✔	✔
NORWAY	✔	✔	✔	✔
POLAND		✔		
PORTUGAL	✔	✔	✔	✔
ROMANIA	✔	✔		
SLOVAKIA		✔		
SLOVENIA	✔			✔
SPAIN	✔	✔	✔	✔
SWEDEN	✔	✔	✔	✔
SWITZERLAND	✔	✔	✔	✔
TURKEY	✔	✔	✔	
UNITED KINGDOM	✔	✔	✔	✔

Figure 3 – Use of incentives for EVs across Europe [87]

3.3.4 Towards regulatory policy recommendations

Given the importance of unbundling of energy suppliers under the Third Energy Package, a definition of storage is necessary. Particularly a clear delineation of which operators in the market can own, operate or control these assets.

Regulatory intervention would also be required to incentivise investment in the development of storage technologies. Particularly in the case of prosumers, the need for investment incentives must be coupled with favourable policies related to demand response mechanisms and self-generation/consumption of renewables.

A review of grid fees structure is also necessary to avoid the situation where storage assets pay double grid fees. Better consideration should be given to the kind of service provided by storage assets in determining the applicability or otherwise of grid fees or other similar taxes. In the grander scheme of facilitating the development of smart grids and electricity markets, the regulatory framework should not discriminate between DERs, thereby ensuring that storage resources are granted equal access to flexibility markets to enable them to compete equally with fossil-fuel based generation units.

Policy makers should create incentives for the consumers as well as companies to use EVs, as well as the construction and operation of electric vehicle charging facilities. Such incentives might include lower taxes for EVs, higher taxes for vehicles using gasoline, the possibility for EVs to use exclusive taxi or bus lanes, as well as support to research and development activities.

Consideration should also be given to a number of potential concerns. One is how realistic it is to expect states under financial and budgetary distress to pursue measures such as the above. Another is whether pursuing such measures could go against the state aid regime at EU level, and hence under what conditions these support measures could be accepted and/or whether it would be desirable to amend the current state aid regime (*e.g.* through state aid guidelines that the Commission regularly produces over time across a number of domains).

It is also worth noting that the increase in the use of EVs will contribute to the increase in demand for electricity. Therefore, it is critical that EV deployment is done as part of a larger smart grids strategy to ensure strategic low-cost vehicle charging.

4 SMART GRID EMERGING BUSINESS MODELS AND WISEGRID BUSINESS MODELLING ANALYSIS

4.1 METHODOLOGY AND NOMENCLATURE

Figure 4 depicts the five steps of the methodology to be followed for the definition, analysis and evaluation of the WiseGRID business models. This deliverable includes the results from the first two steps and additionally provides preliminary insights of the material needed for Step 3, while the remaining process will be covered extensively in the context of:

- WP16 Technical evaluation and socio-economic impact assessment
- WP17 Business models and overcoming local barriers

The graphical representation of our approach is presented here, aiming for the reader's holistic view and understanding of WiseGRID's innovative approach to economic and business analysis and impact creation.

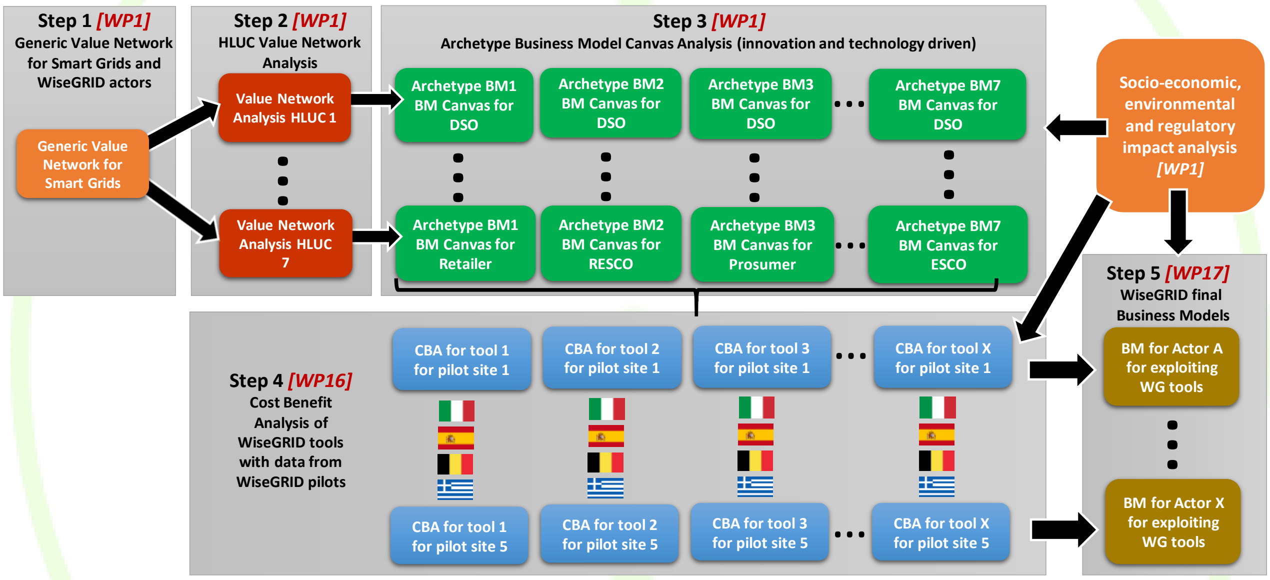


Figure 4 – The overall methodology for the WiseGRID business and economic analysis and evaluation

In what follows, we provide a brief description of each step.

- **Step 1: Generic value network generation**

  It is the starting point of the analysis and refers to the design of the generic value network, which will represent the main players of the Smart Grids and, depending on the business case, the interactions amongst them. This network will introduce the main business roles involved and the contribution of each one of them in the delivery of a potential product or a service. More specifically, it will present the flow of power between the participants, the exchange of information which is necessary in order to compose any new service and the money flow pertaining to their business relationships. The generic value network will represent all of the WiseGRID particular use cases that we will analyse subsequently. However, note that its aim is not to account for all possible cases in future Smart Grids (since this is impossible due to the high complexity and wide context) but focus on the WiseGRID objectives and core technologies (storage, EVS, DER integrations, DR, etc.).

- **Step 2: Economic and business analysis of WiseGRID use cases**

  Based on the generic value network, this step will analyse thoroughly each HLUC of the project, including primary and secondary use cases as these are defined in the context of *WP2: WiseGRID Use* *cases, requirements and KPIs definition.* This process will identify the participating business roles according to the scenario of the HLUC and determine which role is undertaken by each of the involved actors. Have in mind that depending on the scenario, an actor may perform multiple roles and inversely one role may be undertaken by various actors; for example, the power may be generated by the traditional fossil-fuel power plants and residential prosumers. The ultimate target of this step is for all WiseGRID partners (and especially those involved in the pilots and tools development) to explore the different business cases that could originate from their participation in WiseGRID and gain a more business-oriented understanding of the WiseGRID ecosystem that will help them produce sustainable business plans at the end of the project.

- **Step 3: Creation of archetype business models for the WiseGRID tools, services and actors**

  The analysis of the HLUCs of the previous step will result in a number of archetype business models. These models will present how the economic value will be generated for the participating actors stemming from the WiseGRID core technological innovations and tools. The produced models will be aligned with the capabilities as described in the relevant HLUCs and present composite services that may be realized from the joint utilization of their functionalities. The BMs are characterized as "archetype", because they aim to account for the entire set of services in which each tool may play a role. The archetype BMs are presented graphically using value networks and business modelling canvas' that describe the assets/products/tools (provided by the project) to be utilized for achieving the objectives and the anticipated economic gains for each core participating actor. This step in the context of WP1 will be executed at a preliminary level (not all the details of the canvas will be entered) and elaborated further later in the project where the exploitation of the partners and the functionality of the products would have been crystalized.

- **Step 4: Cost Benefit Analysis**

  This step will be performed in the course of *WP16: Technical evaluation and socio-economic Impact assessment* and will produce a cost-benefit analysis (CBA) of each WiseGRID tool, with respect to a set of well-defined KPIs and by utilising evaluation data from the WiseGRID pilots. This will be based on the Smart Grid Cost-benefit analysis (CBA) [92] methodology developed jointly by the EUs' Joint Research Centre (JRC)[1] and the US Department of Energy (DoE). This impact-assessment methodology provides the scientific framework for the CBA section of the EC recommendations on smart metering deployment [93] and is in accordance with the Commission's 'Proposal for a Regulation of the European Parliament and of the Council' for the implementation of Smart Grid projects in line with the priority thematic area 'Smart Grids deployments'. The procedure followed firstly analyses the baseline scenario, "State A" which corresponds to the current state of the market, i.e., in the absence of the products proposed by the project and compares them via standard econometric techniques (like the Net Present Value) to "State B" i.e. the market state for the actor after adopting the WiseGRID tools. The results are utilized as a comparison benchmark for the evaluation of each case. The CBA will consider metrics for the evaluation of the whole spectrum of objectives that the WiseGRID project aims to achieve, including economic ones (e.g., peak demand reduction) but also environmental (e.g. the increased portion of energy produced by RES), ethical (e.g. the reduction of energy poverty) and finally those related with the collaborative economy (e.g. the fair share of gains among the participating actors).

- **Step 5: Final business models and guidelines for the successful exploitation of the WiseGRID tools**

  This step will be performed in the course of *WP17: Business models and overcoming local barriers.* Based on the CBA analysis of the previous step and the archetype BMs defined in the course of Steps 1-3 will produce the final, complete business model canvas for each WiseGRID core actor, targeting

[1] https://ec.europa.eu/jrc/en

to reflect the particular context of the pilot sites under consideration. In that context it will include the quantification of the various parameters affecting the viability of the proposed business model. For instance, it will provide an accurate estimation of the cost and revenue streams of each participant, the population of the group which any new product/service targets and its minimum expected period to remain in the market. Moreover, it will suggest (if necessary) variations of the basic business model, such as the vertical integration of multiple roles by a single actor, and the revision of the regulatory rules that would increase the profitability of the participants and will discuss incentive compatibility issues amongst the different players in each BM scenario.

Next, Section 4.2 will present the WiseGRID generic value network (Step 1) followed by the definition of the archetype BMs (Step 3) in Section 4.3 Section 4.4 will present an overview of the main characteristics of the models in a table. Finally, ANNEX B - Business Modelling State-Of-The-Art will provide a SOTA review (summarized and based on WiseGRID relevance and importance) of related business models from the industry that we analysed during the course of this task. The SOTA was included in an Annex to reduce the extent (size) of the current report and improve its readability. For the same reason the results of Step 2 are not presented, however are used as input to Step 3.

4.2 GENERIC VALUE NETWORK FOR SMART GRIDS AND WISEGRID ACTORS

Figure 5 presents the WiseGRID generic value network for Smart Grids. It depicts ten key business roles and their between interaction in terms of power, information and money flows. This generic value network does not aim to represent all the business roles and all the possible interactions between the various stakeholders, as this is not possible due to the composite and rapidly evolving nature of the Smart Grids. However, it represents a vast number of scenarios and the most important players, especially with regards to the WiseGRID use cases and scenarios. Its purpose is to serve as a guideline/template for creating and analysing various business cases and scenarios primarily for the project as well as for the larger energy community, where it will also be publicly disseminated as a WiseGRID outcome.

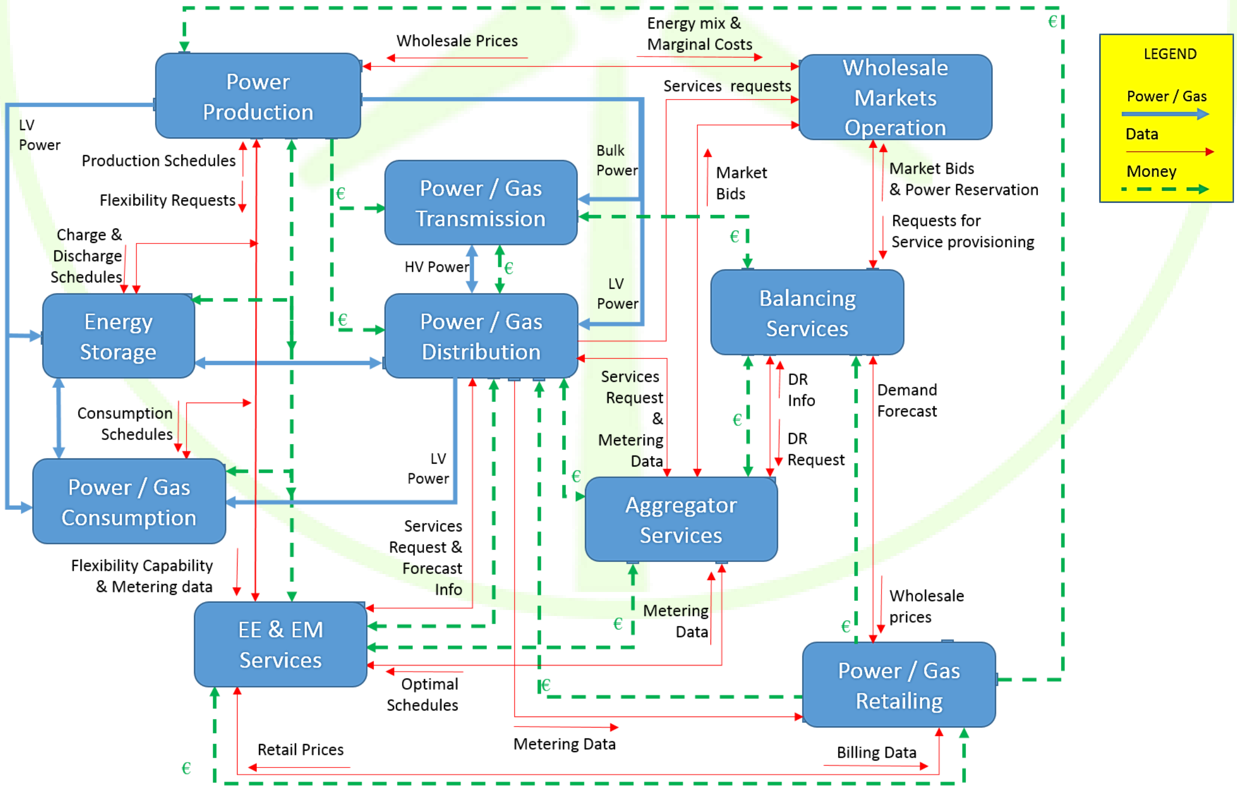


Figure 5 – The archetype value network for smart grids

In its current form, the generic value network includes the following “core” business roles:

1. **Power Production** that is responsible for the power generation, using either fossil fuels or RES. This role may include multiple actors independently of their size, i.e. from large power plants to small residential prosumers.
2. The **Power Transmission** grid is operated by the TSOs, and provides High-Voltage transmission from the generation units and interconnection services between the distribution grids. The TSO is responsible for the maintenance of the transmission system and must also take the necessary actions (capacity development) to guarantee its ability to satisfy the evolving demand.
3. The **Power Distribution** grid is operated by the DSOs. It is connected with the transmission grid and provides Low (or Medium) Voltage power to end users. The DSO is responsible for operating the transmission system and planning the necessary capacity expansion which is adequate to satisfy the future demand. His role is also crucial for the incorporation of distributed generators in the smart grid.
4. The **Wholesale Market** Operation combines the information of the production cost and demand forecasting, to compute the wholesale prices and propagate them to the generators, the retailers and the aggregators.
5. The **Power Retailers**, perform the final sale of power to end users. These agents try to forecast in accuracy the future demand and reserve the adequate amount in the wholesale market, which resell to their customers.
6. The **Balance Services**, provided by the Balancing Responsible Party, who operates as an intermediator between the Wholesale Market and the Retailers. This agent is responsible to guarantee that the quantity reserved by the retailers is actually consumed.
7. The **Aggregators** offers intermediate services between the end users and the other participants in the Smart Grid. They are responsible to design and provide the sophistication for the orchestration of multiple appliances, such that their collective consumption scheduling results to benefits for their owners and a remarkable positive effect for the grid. The appliances may belong to multiple individual users with personal interests or to a single entity (for instance a fleet of EVs).
8. The **Energy Efficiency and Management Services** role, may be undertaken by the relevant companies or organizations, such as the EV Fleet manager, the Battery Operator, the ESCOs and RESCOs. These agents, operate as intermediators between the aggregator and the end-users and offer the necessary equipment (e.g., EVSE, smart meter, BMS) and automated operations (e.g. ERP), which allow a consumption schedule to be realized (e.g. Automated DR event).
9. **Power Consumption**, refers to all electrical appliances that consume power for their real time operation. As it becomes apparent below, we choose to distinguish between power consumption and energy storage, because the latter term refers to appliances (batteries) which consume power for supplying energy for other devices or inserting it to the grid.
10. The **Energy Storage,** refers to the means which capture/store the produced electricity for some future use. We choose to assign a separate role for energy storage even though it could be also represented as a combination of consumption and production. This is because batteries do not literary produce new power but may inject the previously consumed power in the grid, targeting for example to smooth out the negative impact of peak loads. Additionally, this assignment is aligned with the emphasis that the WiseGRID project attributes to the storage means, towards the achievement of the objectives in the Smart Grid context. As the relevant power-arrows indicate, the energy may be stored directly from the production units (e.g., when a residential consumer owns RES) or via the distribution grid (in terms of consumption). In the opposite direction, the stored energy may be utilized for local consumption (e.g. in the case of residential storage), or it may be injected in the grid, to be used by other consumers (e.g. VPP).

The aforementioned actors may undertake a single business role, or they may undertake a combination of multiple such activities in the market. For instance, an end-user is a consumer when relying on the grid for the operation of its appliances, but is also a provider when offering electricity to the grid for the harmonization of the demand. In this latter case, this agent is considered as a prosumer, a term that may refer to multiple scenarios. More specifically:

- A prosumer may be a consumer who does not produce new power but participates in a DR event and accepts to curtail her demand during peak hours.
- A prosumer may also generate power from a small-scale PV infrastructure (residential) and inject it (feed in) in the grid.
- A prosumer may own storage means (e.g. EV Company or residential end-user with batteries) and utilize them either for self-consumption or for supplying devices of another agent.
- Any combination of the above cases.

<u>Further actors may arise by the combination of the basic roles</u>. For example, a retailer may decide to build its own generation plant, aiming to reduce its dependency form the fluctuating prices in the wholesale market and the consequent risks. In this scenario the resulting role is referred as a pretailer. Additionally, a retailer may decide to undertake aggregation services, aiming to take advantage of the existing customer basis.

The graph does not include a role for the regulator, because this agent does not offer a distinct contribution to the composition of a service but is responsible for the supervision of the whole system (to guarantee the 'level playing field', i.e. that all actors are imposed the same set of rules and have access to equal volume of information). The impact of this role may be implicitly included in the Business Model Canvas, by means of the entrance barriers due to the regulatory framework in the considered market.

An example value network that presents both the roles and the actors that could undertake them is presented below. This particular case, assumes that the prosumer has installed RES and batteries at its premises and therefore undertakes three roles, i.e., the power production and consumption (either from the local RES or from the grid) and the energy storage. The role of power production is undertaken by two actors, the prosumer and conventional generators.

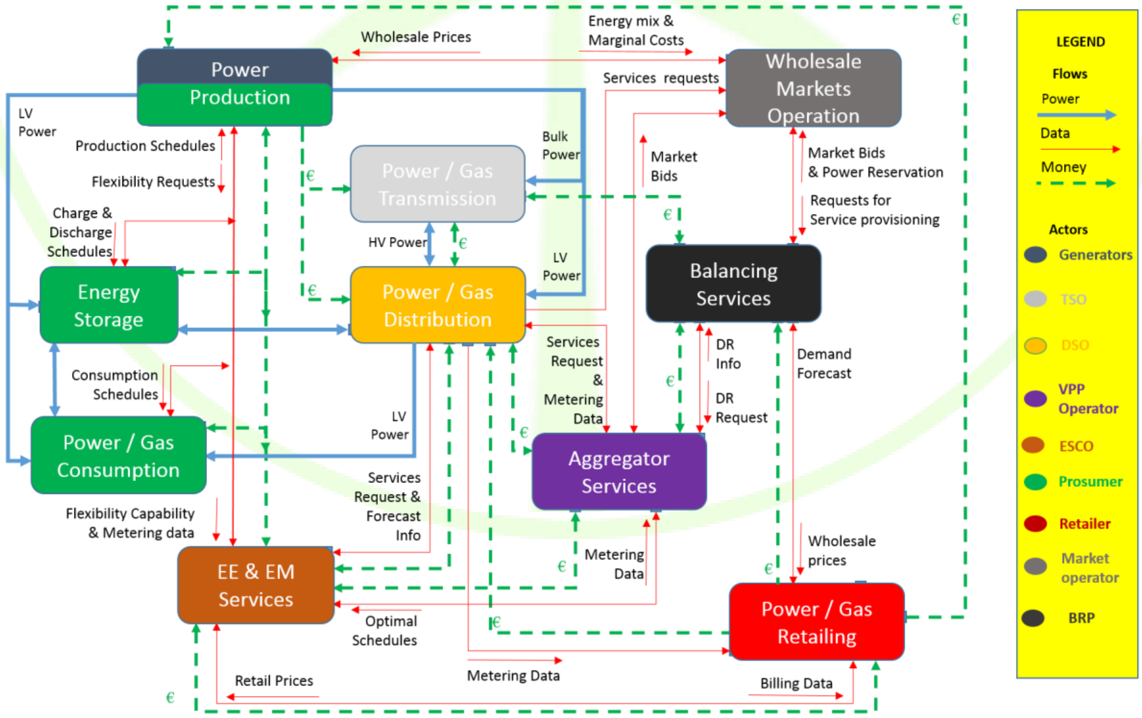


Figure 6 – An instance of the WiseGRID for a particular business model – Roles and actors included

4.3 WISEGRID ARCHETYPE BUSINESS MODELS AND VALUE NETWORKS

This section introduces a set of archetype business models which investigate the commercial exploitation of the tools that will be developed in the context of the WiseGRID project. To this end, the considered models are totally aligned with their capabilities as described in the relevant HLUCs (as these are defined in the context of *WP2: WiseGRID Use cases, requirements and KPIs definition)* and present composite services that may be realized from the joint utilization of their functionalities. The objectives of the scenarios are economically oriented, in the sense that they target to maximize the potential profits for the participating actors. As it will become apparent next, the tools are designed to meet this target by achieving (among others) the optimal utilization of the existing generation resources, suggesting the least costly consumption schedules and contributing to the smooth integration of innovative technologies (EVs, CHP systems, batteries) in the smart grid. Before proceeding, we mention that the BMs are characterized as “archetype”, because they aim to cover the entire set of services in which each tool may participate.

The analysis attributes great importance in defining the added value provided by each individual tool for each specific actor who participates in the value network. This process firstly requires to determine their ownership, i.e., who actor bears their development and operational cost (or pays the relevant licence to a third party) and gains the revenues from their management. In most of the cases, each involved actor manages a single tool, and their matching is determined according to the objectives of the project. This approach is followed because we want to demonstrate the highest possible granularity of the value networks and investigate if such conditions allow for lucrative business models to appear. We mention beforehand that this approach may be extended to capture hybrid cases, when one actor undertakes multiple roles and consequently bears the cost and gains the profits related with the management of more than one tools.

Particular focus is given to the commercial exploitation of the WiseHOME and the WiseCORP tools, which are located at the premises of domestic and tertiary buildings and their sophistication provides the optimal consumption and production schedules at the local level. According to the basic business model, these tools are managed by an ESCO which elaborates the necessary data (may vary according to each scenario) and provides the optimal suggestions to the prosumers. The ESCO receives as payment a portion of the prosumer’s savings due to the decreased electricity bill or a part of their compensation (provided by other actors, e.g. the VPP Operator) for their participation in the considered services (e.g. an explicit DR event). This form of revenues is aligned with the report of the European Commission [94], which suggests the “Energy Performance Contacting” (EPC) as the financial model between the ESCOs and the prosumers. Essentially, the EPC model implies that “remuneration of the ESCO is directly tied to the energy savings achieved”, thus it transfers the risk of the investment to the ESCO and encourages the market competitions between such companies.

In the following sections, we describe the potential risks that may arise from this form of revenues which make the engagement of the ESCO questionable, and propose further candidate revenue schemes aiming to prevent a possible market failure. Furthermore, we propose alternative options for their cost-coverage, driven by the objectives of the involved actors to gain indirect benefits from their operation. This approach is reasonable because these tools participate as components for the provision of composite services and thus their functionalities are necessary for the successful realization of such services. For instance, a retailer may offer them free of charge to its clients, aiming to convince them for their exposure to dynamic pricing schemes. In this way the retailer may indirectly utilize their functionalities and reduce his costs, by performing implicit DR events. We mentioned that our propositions are aligned with the context of each BM and compatible with the interests of the participating actors. Of course, in the simplest case, the prosumers (domestic or energy manager in the case of tertiary buildings) may buy these two tools and gradually amortize their cost by means of the provided functionalities.

A similar rationale is also followed for the actor(s) who should bear the capex cost of the innovative technology and equipment, since this factor may be beneficial for multiple participants in the value network. For instance, BM5 considers the case when the cost of the Combined Heat and Power equipment is totally covered by the prosumers, but also its subsidization by the GAS-DSO who aims to gain indirect revenues by the expected increase in the gas consumption. We emphasize that the inclusion of such capex costs in the cost streams of the participating actors, strongly depends on the investigation objectives in each BM. For example, the BM1 includes the capex cost for the RES installation as part of the RESCO's cost stream. On the contrary, BM6 assumes that the prosumer has already installed the RES equipment (e.g. PV panels), since it aims to investigate the added value provided by the more efficient utilization of their generation if the relevant prosumer participates in the VPP. Similarly, the BM3 does not include the capex cost of buying the EVs, because it targets to investigate the added value that the WiseEVP tool provides to the fleet manager by suggesting the EVs' "smart charging" schedules. For completeness reasons, we clarify that the findings with respect to the aforementioned objectives, may be utilized for investigating also the amortization of the capex cost. For instance, the quantification of the potential benefits by the EVs' "smart charging" may provide useful insights for the fleet manager on how to overcome their higher purchase price compared to the conventional counterparts.

For all the BMs, our analysis provides preliminary insights for the state of the grid in the absence of the WiseGRID tools and the innovative technology, and consequently the actors' increased costs or the limited revenues due to the lack of their sophistication and the advances capabilities that they respectively provide. This process is a prerequisite for identifying the "business as usual case", which will be utilized as a comparison basis during the cost-benefit-analysis of the BMs, targeting to reveal the source of the added value and quantify the potential benefits for the actors. Additionally, the descriptions of the business models emphasize (when necessary) the terms that must be clarified in the contractual agreements between the involved actors, for resolving conflicts of interests that may arise over the utilization of resources (e.g., RES generation, battery capacity), when the actors participate in the realization of multiple services that may require them.

Concerning the graphs of the value network, they include only the flows of information and money which are directly related with the service under investigation. For instance, a prosumer's self-consumption will lead to a decreased electricity bill both due to the lower grid-consumption and network charges. In this case, the graph only includes the money-arrow from the prosumer to the retailer and not the one from the retailer to the DSO, because the former includes both types of costs. Additionally, the graphs present direct payments between the actors, even though their agreement for the provision of a service may be feasible only via the energy markets. Furthermore, they depict the flow of money assuming that the relevant service is actually realized. For example, in the case of an explicit DR event the graphs include the compensation provided from the VPP Operator to the prosumers for successfully meeting its requirements, but not the non-conforming penalties that are imposed in the opposite case. Finally, they do not depict payments which occur only once and are a prerequisite for any service, such as the participation-fee paid by the prosumer to the VPP Operator. Still, these parameters are considered in the cost/revenue streams of the relevant actors.

Finally, it is mentioned that the complex environment of the smart grid with multiple interacting actors, allows to design additional and more complicated scenarios than those described. Some of these possible alternatives are documented in the following sections, along with the basic scenario that is considered. We emphasize that our methodology is suitable for capturing such extensions and the value network graphs may be appropriately modified to depict the flows of money and information that correspond to each case.

4.3.1 Archetype BM1: Promoting RES installations via RESCOs

4.3.1.1 Description

This section investigates the BMs concerning a RESCO (HLUC1_PUC5) renting the rooftop of domestic or tertiary buildings and installing RES when the occupants of the buildings cannot afford the investment cost. In this context, the following scenarios mainly target to investigate the added value provided by two WiseGRID-tools, namely the WG RESCO and the WiseCOOP. The former estimates the RES generation with respect to various technical parameters and provides monitoring and control capabilities of the installed equipment, while the latter may be used by the RESCO for identifying the most profitable utilization of its production. Additionally, the scenarios describe the necessary exchange of information with the tools that manage the occupants' consumption (WiseHOME, WiseCORP), such that the target for the efficient utilization of the RES generation can be realized.

More specifically, the WG RESCO tool monitors and forecasts the RES production (HLUC1_SUC5_2) and receives forecast information for the occupants' consumption (HLUC1_SUC5_3) by means of the WiseHOME and WiseCORP tools, for the residential and tertiary buildings respectively. Based on the contract between the two parties, the RES production may be used to meet the local needs (self-consumption or self-sufficiency) and the production surplus will be traded by the RESCO in the wholesale markets (HLUC1_SUC5_4). For simplicity reasons the BM assumes that the RESCO has installed many RES and does not need an aggregator for having access to the market. In this way, the occupants reduce both their consumption and distribution charges, while the RESCO receives revenues from selling the energy.

The BM may also be extended to include more dynamic synergies between the RESCO and the occupants of the buildings. For instance, the RESCO may forecast a higher production surplus than the maximum which is allowed to inject in the grid according to its agreement with the DSO (HLUC1_SUC5_2). In this case, the RESCO may require from the occupants to increase their consumption/storage, aiming to avoid a RES curtailment. The RESCO may incentivize the occupants to do so, by offering to them lower prices (for their additional consumption compared to the one mentioned in their initial agreement) than those propagated by the retailer. A similar situation may occur during periods of high prices in the wholesale energy market. Then the RESCO, aiming to utilize the production more profitably, may request a shifting/shedding from the occupants (consume less than what is agreed in the contract) and should offer them a portion of the additional revenues for their contribution. As mentioned in HLUC1_SUC5_4, the RESCO utilizes the functionalities of the WiseCOOP tool for making the optimal decisions for the utilization of its generation, in terms of profit maximization.

The aforementioned synergies may be considered in wider geographical terms, in the case when the RESCO and the consumers jointly form a cooperative. In this case, the production of RES should be consumed by the members of the cooperative who are located closely to them, but not necessarily in the same building. In this way the cooperative has higher flexibility in utilizing the RES generation and may additionally negotiate with the DSO for lower network charges because they contribute to the smooth operation of the grid. Depending on the national policy, both generation (as mentioned in Section 2.4.1.2) and consumption may be subjected to network charges, thus their cooperation is expected to be beneficial for both parties. This scenario is not further analysed here, but the business model and the value network graph may be suitably expanded to include it, if it will be implemented at the pilot sites.

The need of synergies becomes a prerequisite if the RESCO aims to install RES in island mode (HLUC1_SUC2_4), because the production surplus cannot be injected in the grid and consequently it must always be consumed locally. This scenario may occur if the DSO rejects the RESCO's investment plan to integrate RES in a particular area of the grid due to the saturation of the grid capacity. Still, the RESCO may proceed with the investment targeting to cover (even partially) the needs of local consumers, by providing them the suitable economic incentives that should make the consumption of RES production less costly compared to the charges of their retailer. Please note that the options of the DSO i.e. to integrate the RES or not may be subject to the local/national policies complementary to the technical restrictions.

Here also, the BM considers a RESCO which has installed PVs on the rooftop of a domestic or tertiary building. In a similar fashion, the scenario may consider that the RESCO has installed PVs on the rooftop of a parking which also offers EVSE infrastructure. Thus, the potential customers of the RESCO are the domestic prosumers, the building facility manager (as mentioned in HLUC4_SUC1_4) and the EVSE provider. In the two former cases, the customers utilize the RES production for self-consumption, while in the latter the EVSE provider may communicate the prices to the fleet manager who is interested in charging economically its EVs. For clarity reasons, we mention that the scenario including the EVSE provider is extensively analysed in section 4.3.3.1 , in a similar context when the lower prices are due to a DR event requested by the DSO and is not further considered here.

The RESCO may initiate consumption flexibility requests to its customers, aiming to shift their consumption such that it follows the RES generation. Then, the tools residing in the customers' premises (WiseHOME, WiseCORP) may reschedule their consumption pattern, targeting to benefit from the lower prices offered by the RESCO, than those offered by their retailer (if they consume from the grid). The rescheduling and optimization algorithm should take into consideration the consumer's preferences, as described in HLUC7_SUC1_1 for the tertiary building and should guarantee that they are satisfied.

The WG RESCO tool will include the appropriate KPIs described in HLUC1_SUC5_5 (KWh/m2, KWh/occupancy, KWh/production unit, KWh/ shift, KWh/EUR invested) for evaluating the economic viability of the aforementioned business cases. The analysis will include the initial financial investment along with the operational and maintenance costs and will compare them with the expected revenues from the production selling (either to the wholesale markets or locally in the case of an island topology). This process will estimate the return on investment time and the expected profits thereafter till the end of the installed RES lifecycle.

In all the aforementioned scenarios, the basic business model considers that an ESCO operates the WiseHOME and WiseCORP tools and utilizes their sophistication for providing the optimal consumption schedules for the occupants of the buildings at the local level. For its services, the ESCO receives as payment a portion of the prosumer's savings due to the decreased electricity bill, or a portion of the payment provided by the RESCO due to his alignment with the consumption shifting requests. As already mentioned, the analysis will investigate alternatives for the commercial exploitation of these tools. For instance, in the context of the aforementioned scenarios, the tools may be provided by the RESCO as part of contractual agreement with the consumers, aiming to help them understand the potential revenues from their consumption rescheduling and encourage them to follow the optimal consumption patterns that are beneficial for both parties. In this case, the RESCO undertakes also the role of the ESCO.

4.3.1.2 Generic BM Canvas

WiseGRID products	• **WG RESCO** • **WiseCOOP** **Information exchange with (via the WG IOP):** • **WiseHOME** • **WiseCORP**
Actors involved	• Prosumer (consumer with batteries) • RESCO • ESCO
Roles involved	• Power Consumption and storage: (Role performed by domestic and tertiary consumers who own batteries). • Power Production: (Role performed by the RES units, managed by the RESCO) • EE & EM Services (Role performed by the ESCOs managing the functionalities of WiseHOME and WiseCORP tools)
Value proposition	**Prosumer (consumer with batteries / EV fleet manager)** • Decrease the electricity bill of the retailer. • More efficient utilization of the batteries and flexibility capabilities. • Their convenience constraints are satisfied. **RESCO** • More efficient utilization of the RES production – higher usage rate of the installed capacity. • Proceed with RES investments even in island mode. **ESCO (WiseHOME, WiseCORP)** • Provide better and more profitable services for their customers. • Increase their penetration in the market.
Revenue streams	**Prosumer (consumer with batteries)** • Reduced electricity bill from the retailer.

	• Revenue from response to consumption shifting/shedding request by RESCO, to purchase energy with better prices. **RESCO** • Income from selling the produced energy in the wholesale markets. • Income from selling greater volume of energy to its customers due to the reduced curtailment. • Income from occupants in the case of island mode. **ESCO (WiseHOME, WiseCORP)** • Increased revenues from their services due to the reduction of the prosumers' electricity bill. • Flat-fee received by the prosumers, according to the contract between the two parties. • Receives a portion of the compensation offered by the RESCO to the con/prosumer for its response to flexibility requests during high wholesale energy prices.
Cost streams	**Prosumers(consumer with batteries)** • A portion of the energy savings (or/and a flat fee) is given to the ESCOs for providing the optimal consumption schedules. • Also a portion of the compensation provided by the RESCO for his flexibility capabilities is given to the ESCO. **RESCO** • Capex and maintenance cost for the RES installation • Costs for the forecast of RES production. • Cost for the monitoring equipment. • Initial economic investment on software (WG RESCO) and communication channels and technologies with WISEHOME / WiseCORP. **ESCO (WiseHOME, WiseCORP, WiseEVP)** • Initial economic investment on software (WISEHOME / WiseCORP, WiseEVP tool) and communication channels and technologies with WG RESCO

Table 3 – Generic BM canvas for archetype BM1

4.3.1.3 Value network graph(s)

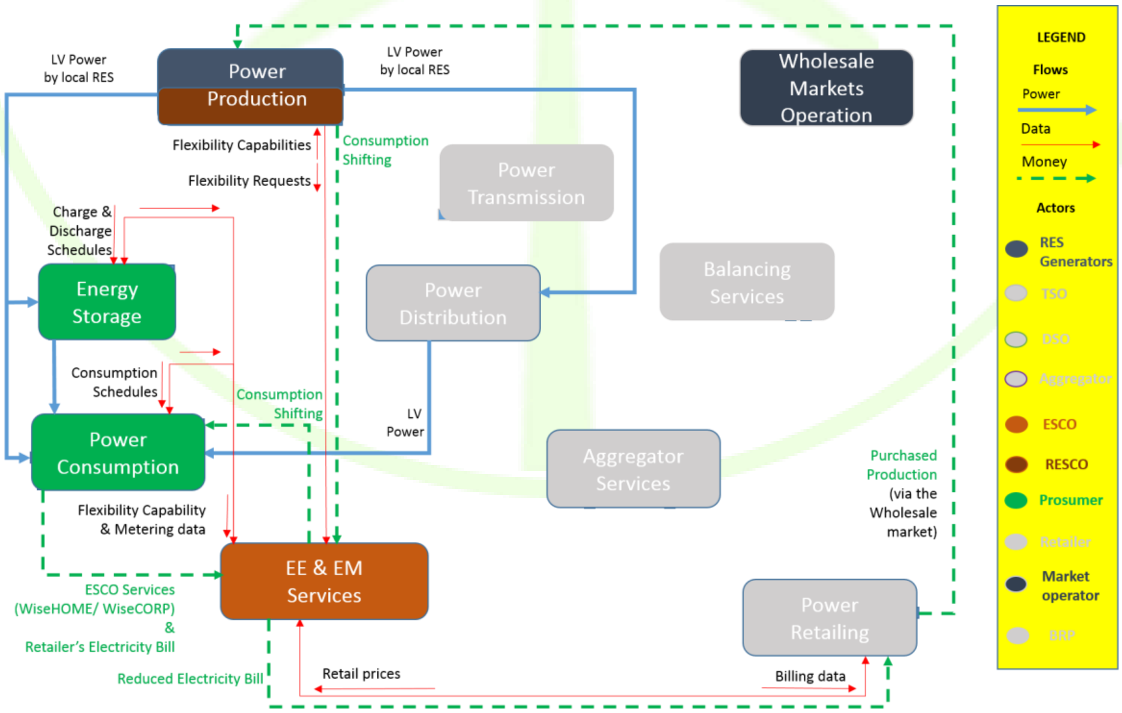


Figure 7 – Promoting RES installation by RESCOs (with injection of production in the grid)

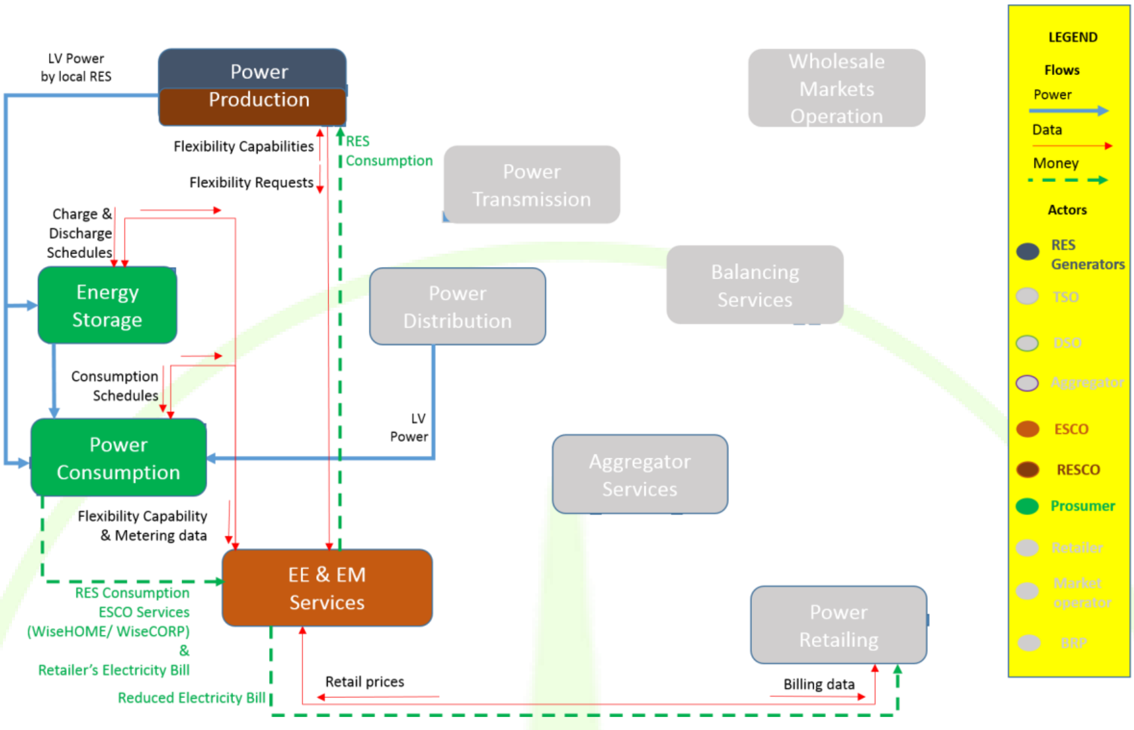


Figure 8 – Promoting RES installation by RESCOs (in island mode)

4.3.1.4 Preliminary business modelling canvas for the RESCO

Key Partners	**Key Activities**	**Value Propositions**	**Relationships with other partners**	**Customer Segments and Communication.**
• Prosumer • ESCO • Wholesale energy market • DSO	• RES installation. • Forecast of the RES generation. • Set-up the infrastructure for the real time monitoring of the RES generation. • Integration of new RES infrastructure with other IT systems. • Decide the most profitable utilization of RES generation (self-consume or sell). • Select optimal auxiliary services (e.g., maintenance, request flexibility from prosumers).	• Increase production from renewable sources, in line with national and European targets for RES integration. • Efficient utilisation of the RES production in order to meet the prosumer's and the power grid needs. • Supporting the energy grid balancing avoiding or at least reducing energy curtailment situations. • Proceed with the investment in island mode.	• Data from Energy market (e.g., Prices, exchanged quantities) • Receives from the ESCO the flexibility capabilities of the consumers. • Receives from the ESCO information about the retail prices (in the case of island mode). • Receives Information from the DSO about the grid conditions (e.g. congestion, injection limits).	• Low-Voltage households, domestic and businesses prosumers/consumers, EVSE operator. • Direct (face to face contact for the e.g. PVs installation), and indirect communication channel (on line focused promotion e.g.: towards environmentalist). • During the service, the communication of the actors is feasible via the WiseGRID tools (WiseHOME / WiseCORP, WG RESCO, etc.)

Value network graph	Barriers
Figure 7 and Figure 8.	• Reduction of the price of fossil fuel energy. • Authorization for the sale of energy by RESCO. • Excessive bureaucracy or lack of regulatory framework for prosumers. • The involvement of the con/prosumers creates an uncertainty about their flexibility capabilities. Accurate models for the flexibility calculation are required. • Possible conflicting interests with other actors (e.g., VPP Operator) who aim to utilize the consumer's flexibility. • Lack of awareness among residential customers and small businesses. • High initial capital investment.
Cost Structure	**Revenue Model**
• Development and operational cost of the WG RESCO / WiseCOOP tool, or alternative the license - cost paid to a third party. • Installation and maintenance cost of the RES units and the monitoring equipment. • Taxes (e.g. "tax on the sun" for small scale investors as mentioned in Section 2.4.1.2) and fees for the market participation and the connectivity to the grid. • Charges for exporting electricity in the grid (Belgium, Germany), as mentioned in Section 2.4.1.2. • Operational expenses (payroll, etc.). • A portion of the revenues from selling energy to the wholesale markets is given to the consumers as a compensation for their response to the flexibility request.	• Revenues from energy selling to the wholesale energy markets. • Revenues from energy selling to the consumers in the case of island mode.
Societal and Environmental Costs	**Societal and Environmental Benefits**
• Purchase of new technology and disposing of older (but still functional) equipment.	• Lower overall carbon emissions, result to reduced effects on climate change and pollution. • The RES penetration results to higher self-consumption and thus to fewer power losses, while it may reduce or eliminate the need for grid-capacity reinforcements. • Increased resilience of communities. • Reduce or eliminate the energy poverty.

Table 4 – Preliminary business modelling canvas for the RESCO

4.3.1.5 Preliminary business modelling canvas for the ESCO (WiseHOME, WiseCORP)

Key Partners.	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• Prosumer • RESCO	• Receives consumption flexibility requests from the RESCO, according to the RES generation and the wholesale energy prices. • Computes the flexibility	• The optimal consumption rescheduling, creates revenues for the ESCO, pay receiving a portion of the prosumer's	• Receives from the retailer	• Energy-conscious residential electricity

	capabilities of the prosumers. • Reschedules the consumption of the prosumers, such that the flexibility requests of the RESCO are met, while maintaining the comfort zone (e.g., temperature) and satisfying all the prosumer's convenience constraints. • Manages the control boxes downstream from the smart meter.	savings due to the reduced electricity bill, or a portion of the compensation provided by the RESCO for the flexibility capabilities. • The provision of optimal services, provides an advantage in a competitive environment and increases its penetration in the market, and thus its revenues.	information about the retail prices • Elaborates real-time and historical consumption data of its clients (con/prosumers)	consumers & prosumers • Tertiary building owners/ occupants. • Citizens approached via ad campaigns (e.g. online) • Niche communities.

Value network graph Figure 7 and Figure 8.	**Barriers** • Lack of confidence from the users in this new business model, may lead to a limited portfolio. • Uncertainty about inherent demand flexibility available in various building typologies and relevant activities/operations.
Cost Structure • Development and operational cost of the WiseHOME / WiseCORP tool, or alternative the license - cost paid to a third party. • Energy management strategy definition per customer. • Operational expenses (payroll, etc.) • Communication, measurement & control infrastructure (depending on agreement with customer)	**Revenue Model** • Benefits from their clients due to their services that provoke a reduction of the prosumers' electricity bill. • Flat fee from its clients, depending on the contractual agreement between the two parties. • Keeps part of the compensation provided by the RESCO for accepting the flexibility request and selling energy in high wholesale prices.
Societal and Environmental Costs • Demand flexibility may incur inconvenience or operations degradation, if not properly managed.	**Societal and Environmental Benefit** • As described for the RESCO.

Table 5 – Preliminary business modelling canvas for the ESCO

4.3.1.6 Preliminary business modelling canvas for the Prosumer (domestic/tertiary)

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• ESCO • RESCO	• Inform the ESCO about his convenience constraints (e.g., temperature comfort zone). • Inform the ESCO about the capabilities of the installed equipment (e.g., batteries' capacity). • Follows the optimal consumption schedules as proposed by the ESCO.	• The con/prosumer may reduce the electricity bill, while avoiding to undertake the risk of the initial investment for the RES installation. • Further revenues are possible by responding to the flexibility requests by the RESCO, while maintaining his comfort zone.	• Purchasing electricity from the retailer • Receives retail prices, contracts and energy bills from retailer (via the ESCO). • Receives schedules, set point data, historical operation data and billing information from the ESCO	According to the described scenario the con/prosumer is the customer of the ESCO and the RESCO.

Value network graph	Barriers
Figure 7 and Figure 8.	• The limited flexibility capabilities may prevent the synergies with the RESCO to appear.
Cost Structure	**Revenue Model**
• Provide a portion of his savings or/and a flat-fee to the ESCO. • Communication, measurement & control infrastructure (depending on agreement with the ESCO)	• Local consumption of RES generation results to lower electricity bill, both due to the decreased consumption from the retailer and to reduced network charges. • Additional revenues from responding to the RESCO's flexibility requests (receives a portion of the amount gained by the ESCO from purchasing the energy surplus in the wholesale markets).
Societal and Environmental Costs	**Societal and Environmental Benefits**
• As described for the ESCO.	• As described for the ESCO and RESCO.

Table 6 – Preliminary business modelling canvas for the Prosumer

4.3.2 Archetype BM2: Efficient monitoring and management of the distribution grid

4.3.2.1 Description

The archetype BM in this section focuses on the WG Cockpit tool, which will be developed in the context of the WiseGRID project, targeting to the efficient monitoring and management of the distribution grid. The WG Cockpit tool is extensively utilized by the DSO in the case of emergency conditions, for requesting services by other actors (e.g., DR event "as a service to the grid" (HLUC2_SUC3_2) or frequency control), who pool and control the loads of multiple small prosumers. The actors offering the service may be the VPP operator (HLUC6_SUC3_2 and HLUC7_SUC2_6) or the EV fleet manager / EVSE Operator (HLUC3_SUC4_2) who communicate the suitable incentives to the prosumers for rescheduling their consumption or production patterns. In the aforementioned cases, the DSO pays the contributing actors and the latter allocate these revenues to the prosumers according to their participation in the DR event. The flow of information and money which allow for such types of services to be realized are analytically described in Sections 4.3.3.1, 4.3.4.1 and 4.3.6.1.

Thus, the primary aim of this BM is to investigate the contribution of the WG Cockpit tool, in reducing the cost of the aforementioned services. To this end, it will specify the added value provided by the sophisticated algorithms that collectively compose its functionality, in terms of preventing an emergency condition or limiting the required compensations by the contributing actors when the request for a service is unavoidable. In this sense, this BM differs from the others mentioned in this deliverable, which consider the value chain of composite services consisted by multiple actors.

The development of the algorithms within the WG Cockpit tool, targets to reduce the cost related with the grid observability and to provide more accurate estimations of the grid state. More specifically, the DSO needs to place measuring devices (smart meters and sensors) at strategically chosen locations, for monitoring in real time the operating conditions of the distribution network (HLUC2_PUC1). The algorithm performing the observability analysis (HLUC2_SUC2_3), determines the optimal placement of such devices and consequently minimizes the cost of the required equipment while ensuring that the adequate level of accuracy becomes available. The collected data are provided as input to the "state estimator" algorithm (HLUC2_SUC2_5) which combines them with the network topology (HLUC2_SUC2_2) and provides the optimal estimate of the grid state. After each estimation cycle, the derived results are "filtered" by the bad-data detection algorithm (HLUC2_SUC2_6), avoiding possible misleading conclusions for the grid state (false-positive or false-negative emergency events). In the case of an identified emergency case, e.g., an imbalance between the generation and the demand or the frequency being out of the permissible ranges, the DSO needs to take the optimal corrective actions that prevent or minimize the consequences and restore the grid operation to the normal state. Thus, the optimization algorithm (HLUC2_SUC3_3) is activated to define the optimal strategy for the DSO: either to overcome the emergency by reconfiguring in real time the network topology (e.g., by changing the state of sectionalizing switches – HLUC2_SUC3_4) or to request a DR (or frequency control) event from other actors. Finally, the "asset management" component (HLUC2_SUC1_5) contributes to the efficient maintenance of the grid assets and informs for their proactive replacement before their possible failure, preventing emergency condition from occurring.

In conclusion, the WG Cockpit tool is expected to define the necessity for a DR event and specify its details in terms of the location, its duration and the magnitude of the load which needs to be rescheduled (increased, decreased or shifted). Consequently, its deployment cost will be compared with the benefits attained by the DSO, which are quantified as the reduced cost required for the management of an emergency (take a less costly corrective actions or reduce the payment to other actors offering the service).

Additionally, this archetype BM may investigate further actions (other than the "DR as a service") to be taken by the DSO, in the direction of the secure and stable operation of the grid. These alternative options refer to the load control of conventional generation units which are directly connected to the distribution grid. As mentioned in HLUC2_SUC3_1, the management and operation of such units is under the responsibility of the DSO, due to the large-scale production and their technical characteristics. The DSO has bilateral agreements with the owners of such units and may require to reschedule their production either during the day-ahead planning or in real-time. For instance, the "load flow calculation" functionality (HLUC2_SUC2_4) of the WG Cockpit tool, may inform the DSO that part of the grid is congested. If both conventional units and RES are connected at this part of the grid, then the DSO may request from the former to reduce their production, targeting to avoid the RES generation curtailment and the consequent penalty by the regulator. If the conventional units reschedule their production according to the DSO's requirements, then their owners receive a compensation, while in the opposite case they pay a non-conforming penalty to the DSO. In this case also, the role of the optimization algorithm (HLUC2_SUC3_3) is crucial for determining the optimal resource scheduling, i.e. the least costly solution which guarantees the smooth operation of the grid.

The WG Cockpit tool is utilized by the DSO for further operations related with the management of the distribution grid both in short and long terms. Under normal conditions, the "network reconfiguration" (PUC2_SUC3_4) refers to mid or long-term planning for the dimensioning of the grid capacity and the design of its topology. This process results in a more stable grid performance and is especially important for the RES penetration, due to their varying production. Additionally, the WG Cockpit tool provides to the DSO the set of optimal actions for the management of the grid after an intentional or unintentional islanding event (HLUC2_SUC3_5). These operations are documented for completeness reasons, but the evaluation of the WG Cockpit tool with respect to them is out of the scope in the Wise Grid project, because they cannot be easily demonstrated or tested in a real network.

For clarity reasons, we mention that according to the primary investigation objectives of this BM, the DSO is the only participating actor and thus the value network graph is pointless in this case.

4.3.2.2 Generic BM canvas

WiseGRID products	• **WG Cockpit**
Actors involved	• DSO
Roles involved	• Power Distribution (role performed by the DSO, managing the WG Cockpit tool)
Value proposition	**DSO** • The WG Cockpit tool, provides real time observability of the grid state and contributes to the cost-effective management of the distribution grid.
Revenue streams	**DSO** • The WG Cockpit tool, reduces the necessary costs related with the grid monitoring and identifies the least costly corrective action in the case of an emergency condition (analytically described in the canvas).
Cost streams	**DSO** • Economic investment for the development and operation of the software (WG Cockpit tool) and communication channels with the monitoring equipment for the necessary data collection and elaboration.

Table 7 – Generic BM canvas for archetype BM2

4.3.2.3 Preliminary business modelling canvas for the DSO

Key Partners	**Key Activities**	**Value Propositions**	**Relationships with other partners**	**Customer Segments and Communication.**
• • The DSO is the only participating actor in this BM.	• Places monitoring equipment at strategically chosen positions of the grid, targeting to its real time observability. • Collects and elaborates data from the monitoring devices for identifying the state of the grid. • Decides the least costly corrective action in the case of an emergency.	• The real time observability of the grid state allows the DSO to prevent an emergency condition from arising, reduce its impact and decide the least costly action for restoring the grid back to its normal operation state.	• Collects the generation forecast from large RES and conventional units Operators. • Collects the demand forecast from retailers/BRPs. • Utilizes the WG Cockpit tool for identifying in real time the location and the intensity of the problem (e.g., congestion) in order to compute the details of the requested services or to define alternative corrective actions.	According to the considered scenario, the DSO is not selling or buying anything. The BM aims to investigate the added value provided by the WG Cockpit tool to the DSO, in terms of the cost-effective monitoring, management, maintenance and expansion of the distribution grid.

Value network graph	Barriers
The network graph cannot be composed in this scenario because the DSO is the only actor involved.	• No barriers identified.
Cost Structure	**Revenue Model**
• Development and operational cost of the WG Cockpit tool, or alternative the license - cost paid to a third party. • Cost for the data-collection equipment (smart meters, sensors). • Operational expenses (payroll, etc.) • Specialized equipment (computers) with high computational capabilities, due to the volume of data and the increased complexity of the algorithms which determine the optimal option for the DSO.	• Cost savings by the optimal placement of the monitoring devices (sensors, smart meters) and the reduced equipment needed for such operations. • The proactive replacement of equipment before the end of its lifecycle reduces the emergency conditions. • The bad data collection algorithm eliminates the case of false positive/negative emergency alerts and consequently the operation costs of the DSO. • The optimization algorithm provides alternative options, such as the real-time reconfiguring of the network topology and the DSO does not need to pay a compensation to a third party (in order to overcome an emergency). • In the request of a service form a third party is unavoidable, the DSO achieves cost savings by determining in precision its parameters (such as the location, the duration, etc.) • The collected data may be utilized for the accurate future distribution needs and thus contribute to the long-term scheduling of the capacity expansion and the reconfiguration of the grid structure. • Using WG Cockpit the DSO could achieve better quality of service to the customers and thus reduce the possibility of relevant penalties paid to the Regulatory Authority
Societal and Environmental Costs	**Societal and Environmental Benefits**
• No societal or environmental costs identified.	• The cost efficient monitoring and management of the distribution grid allows the DSO to contribute in the social policy for the elimination of the energy poverty. • Further social and environmental benefits are analytically documented in all the BMs in which the DSO is a participating actor.

Table 8 – Preliminary business modelling canvas for the DSO

4.3.3 Archetype BM3: Exploiting the integration of EVs in the grid

4.3.3.1 Description

This section analyses the business cases originating from the electrification of the transportation sector, i.e., the integration of the Electric Vehicles (EVs) and their charging infrastructure in the smart grid. The following business models mainly focus on the added value to be provided by the WiseEVP tool and to this end the relative scenarios are aligned with its functionalities and consider services that require the aggregation of multiple EVs for their realization. More specifically, the scenarios consider an EVSE Operator, managing a charging station and an EV fleet manager who owns many EVs and aims to charge them economically, meaning that the latter actor undertakes the role of the prosumer. The EV fleet manager also owns and operates the WiseEVP tool, which takes into consideration the charging constraints of each individual EV (HLUC3_SUC2_2) and computes their collective flexibility capabilities (HLUC3_SUC3_3).

The EV fleet manager, may use the consumption flexibility to provide DR services to the DSO (as described in HLUC 3_SUC_4_1 and SUC4_2). The DSO may request such services aiming to control the power flow at the specific regulation area where the EVSE is located (this information is provided by the WG Cockpit tool as mentioned in HLUC3_SUC3_1). Multiple reasons may trigger such an event including the avoidance of RES production curtailment (DR for consumption increase) or the smooth-out of the grid congestion (DR for consumption decrease). More specifically, the DR requests may refer only to the G2V process where the consumed energy is used to cover the needs of the EVs. For instance, part of the DSO's grid may be congested and consequently the DSO will initiate a DR request, aiming to maintain the RES production within a specific area closely to the RES (HLUC 3_SUC_4_2). Otherwise, the DSO should prevent the RES from injecting power in its grid and consequently should pay the relevant compensation to the generators for the curtailment. Alternatively, <u>we may consider the case when the distributed RES connected with the grid of the DSO produces more than the demand and thus the DSO must pay to the TSO the regulated transmission tariffs.</u>

Aiming to avoid the aforementioned potential costs, the DSO initiates a DR request, targeting to increase the local consumption within the regulation area. The DSO requires the consumption of a specific volume of energy during a specific time period and provides an amount for each consumed unit. It is reasonable to consider that the total offered amount of money must be less than the potential costs of the DSO. Additional services are possible, including also the V2G process. For instance, the DSO may require a bidirectional DR event, i.e., both the consumption of a volume of energy but also its injection back to the grid at some specific future period. Apart from the DR services, the DSO may request the provision of ancillary services which may be supported by the EVs' batteries, such as the voltage regulation and frequency control. All the aforementioned processes will be supported by the WiseGRID FastV2G charging points, which will be developed within the project and will enable the load shifting or injection, following the directives of WiseEVP.

Aiming to offer such services that increase their revenues or decrease their costs, the EVSE provider and the prosumers (in our case the EV fleet manager) may participate in the value network as members of a Virtual Power Plant. The VPP operator bids aggregated bundles of services from EVSE provides (potentially along with services from other providers) in the relevant balancing and ancillary service markets and offers them part of his revenues (paid by the DSO) for their contribution in realizing the requested services. Then, the EVSE may propagate to the EV fleet manager lower charging prices during the DR event period (than those offered by the retailer) and the EV fleet manager may reschedule the charging pattern of the EVs (by means of the WiseEVP tool), achieving to reduce his operational costs. Alternatively, the business model may consider bilateral agreements between the DSO and the EVSE Operator, skipping the intermediary role of the VPP Operator. This is feasible because the DSO has knowledge about the location of the EVSE infrastructure by the WG Cockpit tool, and may directly request a service from the suitable actor who is located at the regulated area of interest. For simplicity reasons and without loss of generality, in what follows we consider the latter scenario. All the extra functionalities that the EVSEs provides to the smart grid, respect the preferences of the EV user, meaning his constraints (e.g. charge required to be completed within a certain time frame) will be prioritised in the charging sessions scheduling process.

Concerning the actor who bears the purchase, installation and maintenance cost of the EVSE infrastructure, the BM assumes a liberalized competitive market and consequently assumes that the EVSE Operator undertakes the aforementioned investment. For completeness reasons we mention that according to the strategy in some Member States, the DSO may lead this investment aiming to stimulate the penetration of EVs in the market, while its incurred cost is included in the policy of the regulated assets. Once the market develop, the DSO may sell this infrastructure to market parties (e.g. via auctions), aiming to cover the remaining cost and open the way to competition.

An extended scenario could also consider <u>owners of a single EV who charge them at a public charging station (operated by the EVSE provider) and aim to achieve benefits by participating in the aforementioned services.</u> In this case, the contractual agreement between the EV Fleet manager (who provides the sophistication of the WiseEVP tool) and the owner of the EV must be mutually beneficial. For instance, if the vehicle is planned to be charged during a DR event (requiring increase of consumption, as described above), then the EV fleet manager should receive a payment by its owner for advising this less costly schedule, while the latter actor is still favoured by the lower prices. In the case that the EV participates in the provision of ancillary service (e.g., the frequency control), then the EV fleet manager should keep a portion of the compensation that corresponds to this specific EV, according to its contribution.

The added value of an EV at the unitary level, e.g., a domestic prosumer owning a single EV who charges it with his private EVSE, may be incorporated in the next section which investigates the relevant benefits from the batteries integration in the grid. Indeed, the EV may be considered as a battery with intermittent availability, a parameter that may be formulated as a constraint in the relevant local-level optimization objectives, as described in the next section.

Finally, we mention that the sophistication of the WiseEVP tool may be also utilized in the case when the retailer or the DSO propagates dynamic prices to the EVSE Operator (as mentioned in Section 3.1.3 for the Spanish case, where a discriminatory tariff aims to incentivize the EVs' charging during the low demand). In this context, its functionalities should define the least costly charging schedule subject to the aforementioned constraints.

4.3.3.2 Generic BM canvas

WiseGRID products	• **Wise EVP** • **WG FastV2G** **Information exchange with (via the WG IOP):** • **WG Cockpit**
Actors involved	• Prosumer: EV Fleet Manager • EVSE Operator • DSO
Roles involved	• Power consumption (Role performed by EV Fleet manager by means of the EVs that manages). • EE & EM Services (Role performed by EVSE Operator providing the EVSE). • Power distribution (Role performed by DSO through WG Cockpit)
Value proposition	**EV Fleet Manager** • His charging preferences will be met. • Will provide flexibility to the system only when he wants to. • Will reduce his operational cost by utilizing the inherent flexibility capabilities and the storage equipment of the EVs. **EVSE Operator** • Will be able to offer more competitive prices to its customers (EV fleet manager) • Will be able to cover sooner the investment on EVSE infrastructure. **DSO** • Will have additional tools (participation in the flexibility market) to operate the distribution network. • Will improve his quality of supply indexes.

Revenue streams	**EV Fleet Manager** • Will decrease its charging cost by utilizing the EVs' flexibility and shifting their consumption during the DR events • Will receive revenues from the participation in V2G services, allowing (e.g.) the injection of energy from the EVs' batteries in the grid. **EVSE Operator** • Will increase its clientele and thus have increased revenues for using the EVSE. • May receive a portion of the compensation provided by the DSO for the provision of ancillary service. **DSO** • If quality of supply indexes improve, the DSO will avoid punishments and investment costs for the grid maintenance and capacity expansion.
Cost streams	**EV Fleet Operator** • Economic investment in software (WiseEVP) and communication channels and technologies with the other participation tools. **EVSE Operator** • Economic investment in the EVSE infrastructure. **DSO** • Economic investment for the development and operation of the software (WG Cockpit tool) and communication channels and technologies with the WiseEVP (via the IOP), to send service requests.

Table 9 – Generic BM canvas for archetype BM3

4.3.3.3 Value network graph(s)

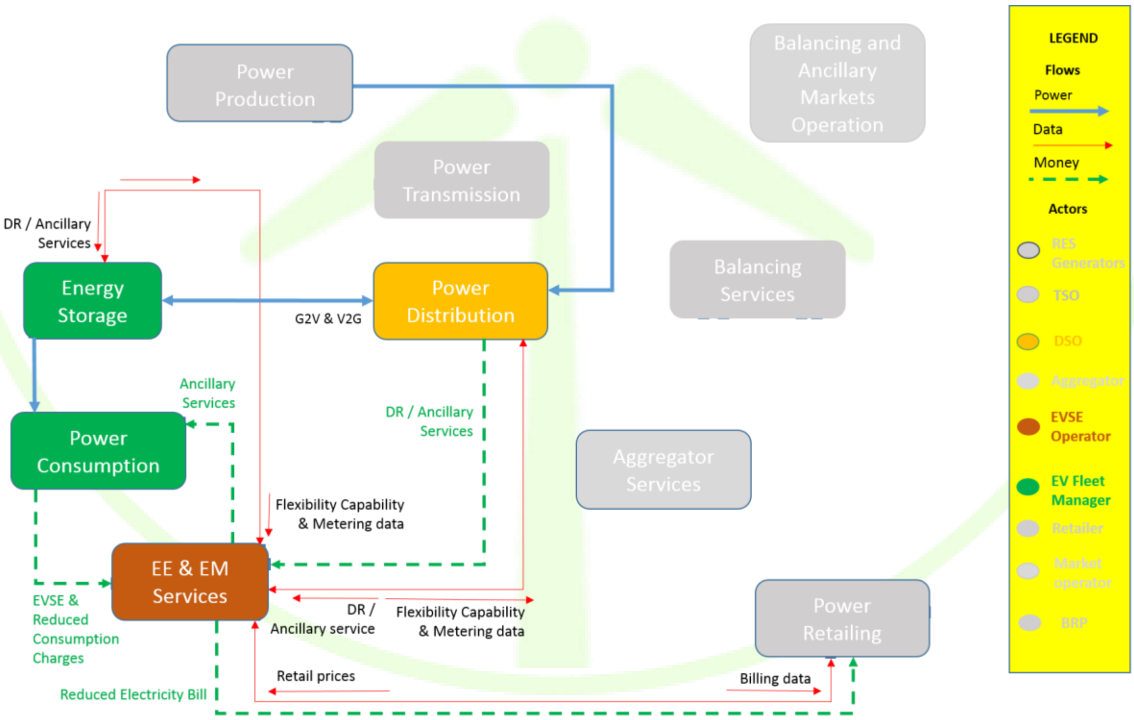


Figure 9 – Integration of EVs in the grid

4.3.3.4 Preliminary business modelling canvas for the DSO

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• EVSE Operator	• Monitors the distribution grid and foresees the risk of congestion, RES curtailment, or the frequency being out of the acceptable bounds. • Requests the relevant V2G and G2V services from the EVSE Operator, targeting to the smooth operation of the grid.	• The successful provision of the V2G and G2V services relieves in the short-term the DSO from penalties due to a RES curtailment and may reduce or eliminate in the long-term the need for capacity reinforcements.	• Collects the generation forecast from large RES units Operators. • Collects the demand forecast from retailers/BRPs. • Utilizes the WG Cockpit tool for identifying in real time the location and the intensity of the problem (e.g., congestion) in order to compute the details of the requested services.	According to the considered scenario, the DSO is the client of the EVSE Operator, requesting G2V and V2G services. During the services, the communication of the actors is feasible via the WiseGRID tools (WG Cockpit, WiseEVP, WG FastV2G)

Value network graph	Barriers
Figure 9.	• The high purchase price of EVs and their limited autonomy, causes their low penetration in the market. • Also, the barriers as referred for the other two actors.
Cost Structure	**Revenue Model**
• Development and operational cost of the WG Cockpit tool, or alternative the license - cost paid to a third party. • Cost for the data-selection equipment (smart meters, sensors). • Operational expenses (payroll, etc.) • Cost for the establishment of communication channels with the EVSE Operator. • Compensation given to the participating actors for the provision of the requested services.	• Reduced compensation to the RES unit owners, by decreasing or eliminating the RES curtailment. • Increased power quality by the frequency control (V2G) relieves the DSO from penalties imposed by the regulator. • The scheduling of RES consumption from EVs closely to the units, prevents or reduces the need for costly investments in capacity expansion.
Societal and Environmental Costs	**Societal and Environmental Benefits**
• As referred for the EV fleet manager.	• Lower overall carbon emissions, reduced power losses, reduced effects on climate change and pollution • Postponed investments in the local electricity grid. • Better use of public infrastructure results in more secure stable and smarter grid. • More awareness/direct link between energy consumption and production. • Maximisation of the share of renewable energy, i.e. pushing the energy transition.

Table 10 – Preliminary business modelling canvas for the DSO

4.3.3.5 Preliminary business modelling canvas for the ESCO (EVSE Operator)

Key Partners	Key Activities	Value	Relationships	Customer Segments and

• DSO • EV fleet manager • Retailer	• Provides the EVSE infrastructure. • Booking of EVSE's and assigning the EVSEs channels to EVs. • Authentication of the EV users. • Provides to the EV fleet manager the prices for using its infrastructure and for consuming electricity. • Provides to the EV fleet manager the V2G services, as requested by the DSO.	**Propositions** • The collaboration of the EVSE Operator with the DSO for the smart operation of the grid, allows this actor to announce lower charging prices (during a DR event) compared to its competitors and increase his market share. • The provision of equipment supporting also V2G services may attract the EV fleet manager and individual EV owners who aim to gain benefits form their participation in such services.	**with other partners** • Receives the propagated charging prices from the retailer. • Receives requests for DR and V2G services from the DSO. • Computes the billing details of each EV according to the usage of its infrastructure.	**Communication.** • The DSO is a customer of the EVSE Operator, requesting G2V and V2G services. We should consider face to face communication between these two actors for determining the place and the scale of the EVSE infrastructure (before it is built) due to its importance for the smooth operation of the grid. • The EV fleet managers and individual EV owners are also customers of the EVSE Operator. • The communication between the actors for the service provisioning is feasible by means of the WG Cockpit and the WiseEVP tools via the IOP.

Value network graph Figure 9.	**Barriers** • The high investment cost of EVSE may cause less than the necessary infrastructure in the market and may lead to suboptimal utilization of the inherent storage capacity. • The charging infrastructure requires high voltage input and therefore it is associated with high consumption fees (as mentioned in Section 3.3.3)
Cost Structure • Development and operational cost of the EVSE infrastructure. • Communication channels with the DSO and the EV fleet manager. • Maintenance cost of the EVSE infrastructure. • Operational expenses (payroll, etc.). • Electricity bill. • Real estate (parking spots or store room).	**Revenue Model** • Charges its clients (individual EV owners or EV fleet managers) for using the EVSE and for consuming electricity. • Increases its clients, due to the more competitive prices that propagates. • In the case of V2G services, the EVSE provider may keep a portion of the compensation offered by the DSO for the service provisioning.
Societal and Environmental Costs • No societal or environmental costs where identified.	**Societal and Environmental Benefits** • A park of charging EVs offers opportunities for social work in fleet services (cleaning, technical support), avoiding bad air quality. • Increase usage of EVs for the human mobility, reducing CO_2 emissions and noise pollution into the cities.

Table 11 – Preliminary business modelling canvas for the ESCO

4.3.3.6 Preliminary business modelling canvas for the Prosumer (EV Fleet Manager)

Key Partners

- EVSE Operator
- Prosumer (Individual EV owners)

Key Activities

- Computes the potential flexibility of EVs according to their charging preferences and constraints.
- Provides the optimal consumption schedules both for its own fleet and also for individual owners, aiming to benefit from the price fluctuations and from the participation in DR and ancillary services.

Value Propositions

- The optimal charging of its fleet allows the EV fleet manager to efficiently utilize the inherent flexibility capabilities of the EVs and reduce his operational cost.
- Further profits are possible by offering V2G services.
- May utilize the sophistication of the WiseEVP, for offering services to individual EV owners or other fleet managers.

Relationships with other partners

- Receives and elaborates the propagated charging prices from the EVSE Operator.
- Receives requests for V2G services from the EVSE Operator (as propagated by the DSO).
- Collects and elaborates the charging constraints and preferences of each EV/user.

Customer Segments and Communication.

- May manage its own fleet or may offer services to the following agents.
- Individual EV owners.
- EV car sharing companies.
- EV taxi fleet
- EV business fleet (e.g. postal services, courier services, municipality fleet)
- Customers are reached via promoting WiseEVP tool, on specialized events, brochures, bundles with new EV installations.

Value network graph

Figure 9.

Barriers

- Limited idle time of the EVs during the day to allow dynamic charging or V2G, because the batteries of the vehicles take long to be fully charged.
- Idle time of the vehicles is mostly at night, thus not much opportunities appear to answer grid requests.
- Rapid aging of batteries if too many recharge cycles are applied, leading to faster replacement costs.
- Schedule of the EVs is too unpredictable due to uncertainty of traffic, causing the scheduling not be accurate enough (delays, cancellations).
- Too many different types of EVs in the fleet, which are not interchangeable, increase the scheduling complexity.
- The limited potential revenues may not adequately incentivize individual EV owners to participate in such services.

Cost Structure

- Development and operational cost of the WiseEVP tool, or alternative the license - cost paid to a third party.
- Operational expenses (payroll, etc.).
- Charges paid to the EVSE Operator for the electricity consumption and the usage of the supply

Revenue Model

- Lower cost for charging his own fleet, due to the peak demand avoidance or due to charging during a DR event (consumption increase).
- Additional revenues from utilizing its own fleet for the provision of (V2G) ancillary and balancing services.
- Revenues from individual EV owners who aim to use

equipment. • It not managing its own fleet, a portion of revenues from the provision of V2G services is given to the EV owners.	the sophistication of the Wise EVP tool.
Societal and Environmental Costs • Matheus effect, whereby the fruits to be reaped depend on the size of the EV fleet, causing small EV fleet managers not to be able to gain from the flexibility, leading only big players to reap the fruits. • If the grid stability is really dependant on the behaviour of big EV fleet managers, they have big power over society, which might eventually lead to high costs. There need to be extensive legislation accompanying this system.	**Societal and Environmental Benefits** • Active participation of citizens in smart grid services. • Lower charging costs and V2G services may overcome the higher purchase price of EVs and result to the easier electrification of the transportation sector.

Table 12 – Preliminary business modelling canvas for the Prosumer

4.3.4 Archetype BM4: Prosumers driven energy storage integration

4.3.4.1 Description

This section analyses business cases and potential business models driven by the integration of energy storage systems at the prosumers' premises, in either domestic or tertiary buildings and focusing on the added value of the potential services that may arise from their utilization. The analysis clusters the services according to the level of their implementation, a parameter which also determines the involved actors. On the local level, the batteries are used to optimize the revenues of a single prosumer, while on the aggregation level the VPP Operator (aggregator) pools the storage capabilities of multiple individual prosumers, targeting to offer more demanding (in terms of storage capacity) services to further actors of the smart grid (e.g., the DSO).

More specifically, on the prosumer level the integration of batteries can result to consumption patterns which are less dependent of the energy prices. For instance, the prosumer may be exposed to dynamic prices propagated by the retailer (either time-of-use or real-time schemes). Then, the storage unit operation may be scheduled according to the prices' fluctuations; charged when energy prices are low and discharged when energy prices are high (HLUC4_SUC1_2). In this manner, the prosumer may achieve a reduced retailer's bill, while limiting the impact of consumption shifting on his convenience preference. An extended scenario (still on local level), may consider a prosumer who has also installed RES on his rooftop (HLUC4_SUC1_1). In this case, the prosumer may decide the most profitable strategy, in terms or revenues maximization: either store the self-production to meet his own future needs, or inject it in the grid and receive the relevant payment. The monitoring and configuration of the storage units at prosumer level will be mainly supported by the ESCO which owns and operates the WiseHOME and WiseCORP tools, for the residential and tertiary buildings respectively. According to the basic business model, these companies receive a portion of the prosumers' savings or profits, as a revenue for the provided services.

The individual prosumers may achieve additional benefits from the installed storage systems, by their collective participation in a Virtual Power Plant (VPP). The VPP Operator bids in the ancillary and balancing markets for services requested by the DSO, which contribute to the smooth operation of the grid. Such services may be frequency-control, reactive power and voltage control, back-up service, and peak shaving for grid congestion management. The VPP Operator aims to expand its portfolio with prosumers owning batteries, because such members may participate more actively in DR events and more importantly are necessary for provisioning a subset of the aforementioned services. To this end, the VPP Operator must invest in the communication, metering and control infrastructure needed for the data collection from the batteries and use such data as input for developing sophisticated algorithms for their scheduling in the market participation. Furthermore, the VPP Operator collects by means of the WiseCOOP tool, data from the markets related with the requests for the services provisioning. Then the VPP Operator combines these types of data, aiming to decide the most profitable utilization of its assets. More specifically, when the VPP Operator receives simultaneous requests for multiple services, the algorithms of the WG STaaS/VPP tool (manages by the aforementioned actor) determine which batteries (prosumers) should participate in each one (HLUC4_SUC3_2). This decision is based both on the batteries characteristics, such as their availability and cost functions with respect to their aging and losses (HLUC4_SUC4_2) and also on the forecast of the local production and consumption such that the prosumers' convenience preferences are not violated (HLUC4_SUC3_1). On the aggregation level, the VPP Operator allocates the monetary amount paid by the DSO to its customers according to their contribution in the service realization, while keeping a reasonable portion for its own services. Additionally, the VPP Operator may gain revenues by requiring a participation fee from his members. In this scenario also, the ESCO suggests the optimal consumption patterns at the local level, which satisfy the request of the VPP Operator, and receives a portion of the offered compensation for its services.

For all the aforementioned services, the BM will analyse two alternatives with respect to the batteries ownership. The former assumes that the prosumer pays and owns the batteries, i.e. the batteries are considered as a capex cost for this actor. In this case, the BM will compute the added revenues that the prosumer attains by the batteries due to the more economic coverage of his own needs and his more active participation in ancillary services (compared to a consumer who does not own batteries). The added revenues should exceed the initial investment (the cost of the batteries) within a reasonable time interval (e.g., ten years) and provide income to the prosumers thereafter, till the end of their lifecycle.

The second case considers an additional actor in the value chain, namely "Storage Unit Operator" (SUO), who bears the capex cost of the batteries and installs them at the prosumers' premises, aiming to offer storage services. This actor may allocate only a portion of the batteries' capacity for meeting the prosumer's needs and his revenue-maximization strategies at the local level, while the rest may be assigned for providing services that are requested by the VPP Operator. For its former contribution, this actor may receive revenues in the same form as for the ESCOs which manage the WiseHOME and WiseCORP tools, i.e., it exploits a portion of the added value created for the prosumers due to the batteries presence. We mention that in this case, the contractual agreement between the two parties must explicitly specify the portion of the capacity which is associated with the local needs. Since its revenue streams are identical with those of the ESCO, in what follows we assume for simplicity reasons that the ESCO undertakes also the role of the "Storage Unit Operator".

The aforementioned model which considers the presence of the "Storage Unit Operator" may also account for the scenarios where this actor installs batteries at strategically chosen parts of the grid, targeting to participate in services that are not feasible to be offered (in their entity) by domestic prosumers (e.g. black start – HLUC4_SUC2_2 and backup power for a residential area during a grid outage – HLUC4_SUC2_4). These types of services are not considered here for simplicity reasons, but the value network may be appropriately modified to include them, when they will be fully specified at the pilot sites.

As already mentioned in the previous section, this business model may be extended to investigate the added value gained by the prosumers from the integration of EVs, due to their inherent storage capabilities. The main difference with a conventionally battery may be its capacity limitations but also its availability when any of the aforementioned services needs to utilize its battery, with the latter parameter strongly depending on the prosumer's lifestyle pattern. Moreover, the EV mainly consumes electricity targeting to cover its own transportation needs and secondarily for supplying other devices. Thus it is expected to significantly increase the consumption of the households. Consequently, in this case the role of the ESCO is even more crucial in terms of providing the optimal consumption schedules according to the varying prices within the planning horizon, while also meeting the other objectives at the local (V2H) and aggregation (V2G) levels as described above.

4.3.4.2 Generic BM canvas

WiseGRID products	• **WG STaaS / VPP** • **WiseHOME** • **WiseCORP** **Information Exchange with (via the IOP):** • **WG Cockpit** • **Wise COOP**
Actors involved	• Prosumer (consumer with batteries and RES) • ESCO acting also as Storage Unit Operator. • DSO • VPP Operator
Roles involved	• Power consumption and production (Role performed by domestic / tertiary consumer with installed RES units) • Energy Storage (Role performed by prosumer with batteries or by the ESCO acting also as "Storage Unit Operator") • EE & EM Services (Role performed by the ESCO which operates the functionalities of WiseHOME / WiseCORP tools). • Power distribution (Role performed by the DSO, operating the functionalities of WG Cockpit tool) • Aggregator services (Role performed by the VPP Operator, operating the functionalities of WG STaaS / VPP tool)
Value proposition	**Prosumer** • Will be able to increase its self-consumption • Will be less dependent to the fluctuations of the retail prices and thus will reduce his electricity bill. • Will be able to meet its energy demand at all times. • Will be able to monitor its own production and consumption • Will be able to provide services to the VPP Operator (aggregator) and thus generate additional income. **ESCO** • Will be able to offer new and better services to its clients, by the more efficient utilization of their flexibility and self-production. • Acting also as SUO, will be able to provide multiple services (even at the same time) and thus generate additional income streams • Will increase its customers and its penetration in the market. **DSO** • Will be able to use storage units for grid services. • Will be able to react fast on situations occurring in the grid through low response times of storage units. • Will be able to locally solve grid congestions. • Will profit from grid investment deferral when storage units are deployed in a larger scale. **VPP Operator** • Will be able to provide services and flexibility to the market and thus generate additional income. • Will be able to monitor and control decentralized storage units via WG STaaS/VPP.
Revenue streams	**Prosumer** (consumer with batteries and RES) • Reduction of the energy bill through time-of use management and enhanced self-consumption. • Additional revenues from its more active participation in DR events, and other services that require the batteries installation. **ESCO** • Receive a portion of the prosumers' revenues for providing the WiseHOME /

	WiseCORP service (optimal batteries scheduling at the local level). • Acting also as SUO, receives a portion of the prosumers' revenues for providing the storage capabilities and gains additional income from the VPP Operator for its contribution in DR events and ancillary services. **DSO** • Lower cost and thus higher profit through grid investment deferral when storage units are deployed or pooled in a larger scale. **VPP Operator** • Payment received by the DSO (or other actors) for providing ancillary services and flexibility to the relevant markets. • Receives participation fee from the prosumers who aim to become members of the VPP.
Cost streams	**Prosumer** (consumer with batteries and RES) • The investment cost for buying and installing the batteries • A portion of the achieved added value (revenues for participating in DR events and offering ancillary services, or decreased electricity bill of the retailer) is given to the ESCO for its services provision. • Participation fee to the VPP Operator. **ESCO** • Initial economic investment on software (WISEHOME / WiseCORP tool) and communication channels and technologies with WG STaaS/ VPP. • Acting also as SUO, bears the capex cost of the storage equipment and the relevant monitoring and control devices. **DSO** • Initial economic investment on software (WG Cockpit tool) and communication channels and technologies with WG STaaS/ VPP. **VPP Operator** • Initial economic investment on software (WG STaaS/ VPP tool) and communication channels and technologies with WISEHOME / WiseCORP. • Participation fee to the ancillary and balancing markets.

Table 13 – Generic BM canvas for archetype BM4

4.3.4.3 Value network graph(s)

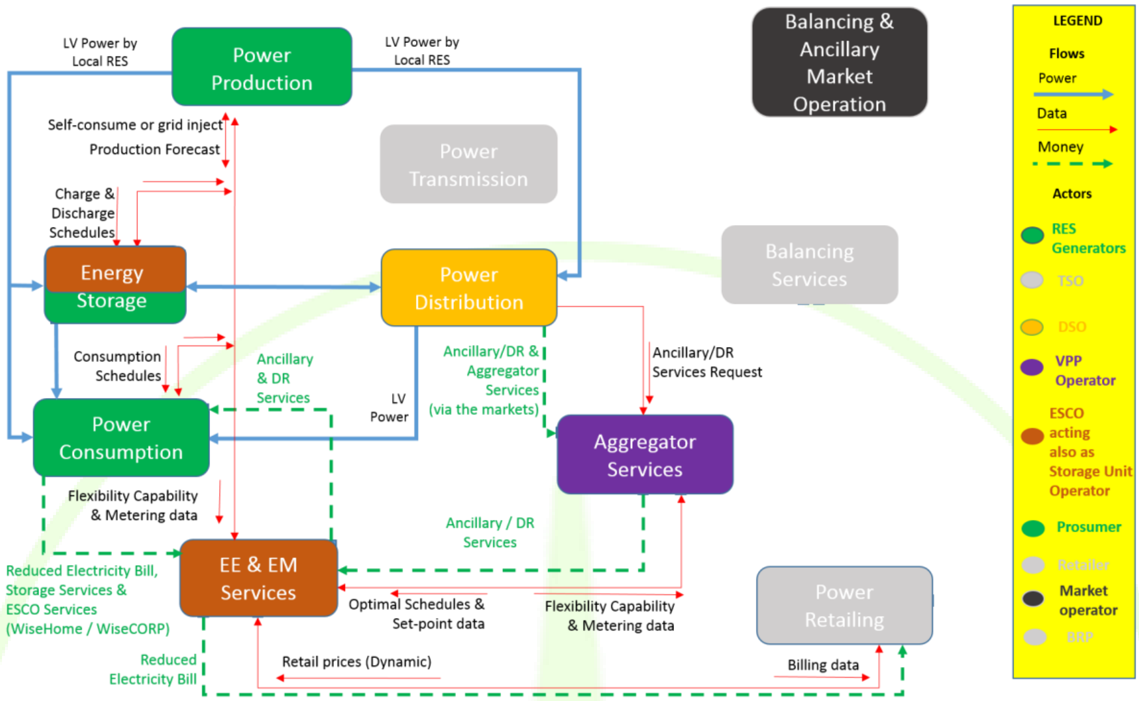


Figure 10 – BMs for prosumers driven energy storage integration

4.3.4.4 Preliminary business modelling canvas for the VPP Operator (Aggregator)

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• Prosumer • ESCO	• Intermediate between the prosumers and the markets. • Provides ancillary services /DR to the DSO. • Decides the optimal assignment of the requested services to its assets • Set-up of communication channels with its members. • Collects technical characteristics and capabilities, supports the monitoring of storage facilities. • Asset mapping. • Performs the bidding in the relevant markets. • Computes the compensation for each member according to its participation in the	• The pooling of storage and flexibility capabilities allows the VPP Operator to offer multiple services to the DSO for the grid support , i.e. power quality disturbance compensation, peak shaving and load harmonization, black start capabilities, back-up power for residential area. • Offers the opportunity to the prosumers to participate in the balancing and ancillary services market and	• Receives the details of the service by the DSO. • Receives the payment for providing the service and allocates it to its members. • Communicates the service request to its members. • Collects metering data via WG StaaS/VPP, to validate the participation of its members. • Informs the retailer/BRP for the provided	• DSO, through the participation in ancillary services and DR requests from DSO. • Low-Voltage households and businesses for pooling their storage and flexibility capabilities. Targeted online promotion or face to face communication. • During the services, the communication of the actors is feasible via the WiseGRID tools (WG STaaS / VPP, WiseHOME/WiseCORP, WG Cockpit, etc.)

	services.	generate additional income.	services.	

Value network graph Figure 10.	**Barriers** Possible barriers related with the role of aggregator and the function of the related market affecting it: • Not clear definition of the regulatory framework for storage units in all European countries. • Not clear regulatory definition of the role, rights, obligations, function of Aggregator in all European countries, as mentioned in Section 3.2.3. • Not an extended scaling up of advanced smart meters enabling fast response to DR requests. • Not enough prosumers with storage units installed in their premises. • Even in countries where load can participate in markets, existing market codes require aggregation of an extreme number of small electricity end-users to reach the required load volume thresholds for participation
Cost Structure • Development and operational cost of the WG STaaS/VPP and WiseCOOP tools, or alternative the license - cost paid to a third party. • Acquisition and maintenance cost for ICT infrastructure. • Tariff customization strategy definition per customer. • Operational expenses (payroll, etc.) • Fee for his participation in the balancing and ancillary markets. • A portion of his revenues is allocated to its members for their contribution in the service provisioning.	**Revenue Model** • Income through the provided ancillary services and flexibility to the relevant markets. • Fee paid by its members who aim participate in the VPP.
Societal and Environmental Costs • Batteries can contain toxic materials, which are not in abundance in nature (depending on the technology used). • Life-cycle management with special measures for disposal or recycling needs to be in place. • The production and the operation of Storage Units lead to ecologically harmful emissions. The exact impact (e.g. CO_2 footprint of a storage unit) is still part of investigations. • The high penetration of decentralized Storage Units, may result in decreasing the importance of classical business models related with conventional power stations, which might also have an impact on the employees working in this business area.	**Societal and Environmental Benefits** • Increased energy efficiency and grid investment deferral, since with integrating energy storage facilities, the peak demand can be covered without adding additional power plants or using the thermoelectric plants at their maximum, thus reducing the environmental impact and CO2 emissions. This reduction can be further improved, as RES penetration could be also increased with storage facilities installed in the network. • Improved investment exploitation because of the flexibility on managing the system and the various services provided by storage systems. • With the growing business of storage units, new jobs are created not only related to the manufacturing and installation of storage units but also in the field of aggregation and operation.

Table 14 – Preliminary business modelling canvas for the VPP operator

4.3.4.5 Preliminary business modelling canvas for the ESCO (WiseHOME/WiseCORP)

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• Prosumer • VPP Operator • Retailer	• Local generation forecasting • Human-centric demand and flexibility forecasting • Battery modelling & management at the local level (capacity over lifetime, optimal usage management) • If acting as SUO, bears the capex cost of the batteries.	• The optimal scheduling of local consumption/storage and production, maximizes the ESCO's revenues. This process may include the following actions: • Human-centric energy management for cost minimization. • Self-consumption scheduling for reduced reliance on the grid and the fluctuating retail prices. • Further profits from the provision of services to the VPP Operator, if acting as a SUO.	• Receive and elaborate the energy prices & forecasts from retailer. • Communicates the storage and flexibility capabilities to the VPP Operator. • Metering data from the consumer/ prosumer • Sensor information for context awareness • Building operational boundaries (e.g. comfort preferences, machinery/process constraints) via WiseCORP/ WiseHOME.	• Energy-conscious residential electricity consumers & prosumers • Tertiary building owners/ occupants • Individual residents to be informed via ad campaigns (e.g. through the internet) • Tertiary building managers to be informed via ad campaigns in trade events and press

Value network graph	Barriers
Figure 10.	• Acceptance of dynamic prices is rather low around the EU. Consumer's reluctance to join such programs is prevalent. Such conditions do not bring about the potential savings in the electricity bill, therefore the engagement of the ESCO becomes questionable. • Uncertainty about inherent demand flexibility available in various building typologies and housed activities/operations. • Reluctance of end-users to shift their demand sufficiently, due to the lack of sufficient economic incentives. • Regulatory provisions may render business model non-profitable, e.g., by maintaining network charges on storage (charged for the double flow of electricity as mentioned in Section 3.3.3). • Not satisfying prices offered for the provision of ancillary services.

Cost Structure	Revenue Model
• Development and operational cost of the WiseHOME / WiseCORP tool, or alternative the license - cost paid to a third party. • Energy management strategy definition per customer. • Operational expenses (payroll, etc.) • Communication, measurement & control infrastructure (depending on agreement with	• Receives a portion of the prosumer's savings due to the reduced electricity bill. This portion must be higher in the case that the ESCO acts also as the SUO. • Receives an additional flat-fee by the prosumers, depending on the contract between the two parties. • Receives a portion of the compensation provided by the VPP Operator for the contribution of the prosumer in the realization of aggregated services. In the case

customer) • Capex and maintenance cost of the storage equipment, if acting also as a SUO. • Participation fee paid to the VPP Operator in order to become its member, if acting also as a SUO.	that the ESCO acts as a SUO, it receives the whole compensation.
Societal and Environmental Costs • Demand flexibility may incur inconvenience or operations degradation, if not properly managed. • Suboptimal demand shifting and energy storage may lead to increased energy costs and energy poverty.	**Societal and Environmental Benefits** • Flexible loads can further reduce emissions and reduce wholesale energy prices by avoiding generation from expensive and polluting fossil-fuel plants • Increased public awareness about green energy, the energy transition and the internal energy market.

Table 15 – Preliminary business modelling canvas for the ESCO

4.3.4.6 Preliminary business modelling canvas for the Prosumer

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• ESCO • VPP Operator	• Informs the ESCO about the capabilities of the installed equipment (RES generation, batteries capacity) and his convenience constraints. • Provides to the VPP Operator the market qualification of its assets. • Follows the optimal suggestions provided by the ESCO.	• The presence of storage equipment at the prosumer's premises, will allow this actor to utilize more efficiently his self-production and become less vulnerable to the fluctuating retail prices. • Will be able to gain additional revenues by providing services to the VPP Operator, without affecting his comfort preferences.	• Purchases batteries from battery manufacturer. • Purchases electricity from the retailer. • Receives retail prices, contracts and energy bills from retailers. • Receives schedules, set point data, historical operation data and billing information from VPP Operator and/or the ESCO.	According to the considered scenario, the prosumer is the customer of the ESCO and the VPP Operator.

Value network graph Figure 10.	**Barriers** • Lots of different intermediaries between citizen and the energy market could increase the complexity of participation in such markets. • Complexity in implementing these services and entering the market, which discourages the prosumer to participate. • The cost of batteries are still high, although they have dropped dramatically in recent years and are about to decrease further in the future. • A lack of standardization regarding performance and safety of the storage equipment. • The regulatory framework may not allow the potential savings to appear and consequently hinder the development of storage (e.g., Section 3.3.3 mentions

	that in Spain the battery owners are not allowed to reduce the maximum power under contract with their retailer)
Cost Structure • Capex cost for purchasing and installing the batteries. • The maintenance cost of the storage system. • Communication, measurement & control infrastructure (depending on agreement with the ESCO). • Self-generation losses within the storage system. • Cost for non-fed energy into the grid (in some countries remunerated with specific feed-in tariffs). • A portion of the achieved added value (revenues for participating in DR events and offering ancillary services, or decreased electricity bill of the retailer) is given to the ESCO for its services provision and for the storage system if the latter agent acts as a SUO. • Flat-fee paid to the ESCO for service provisioning, depending on the agreement between the two parties. • Flat-fee paid to the VPP Operator for becoming its member and participating in the relevant markets.	**Revenue Model** • Reduction of the energy bill through time-of use management, the efficient utilization of the storage systems and the enhanced self-consumption. • Additional revenues from its active participation in DR events and ancillary services, as a member of the VPP.
Societal and Environmental Costs • Not advanced mechanisms in place for the disposal of the storage systems at their end-of-lifecycle, may cause cost burden to the prosumer. • Elder people or people who are not familiarized with new technologies and apps would be excluded from this market.	**Societal and Environmental Benefits** • The prosumers could participate in the energy market (ancillary services) by installing energy storage equipment that could have additional benefit for the management of their own energy consumption.

Table 16 – Preliminary business modelling canvas for the Prosumer

4.3.5 Archetype BM5: Exploiting co-generation in domestic and tertiary buildings

4.3.5.1 Description

This section analyses business cases and potential business models driven by the integration of Combined Heat and Power (CHP) in domestic and tertiary buildings and the control of the HVAC systems in such buildings, in order to exploit the synergies between the thermal and electrical needs. The management of the available thermal potential of the buildings allows using them as a form of thermal storage, in order to take advantage of their flexibility and contribute to reduction of the cost for covering the local needs but also to the smooth operation of the distribution grid.

More specifically, the scenario considers domestic and tertiary buildings, which are connected both with the gas and electricity networks and consequently have two options (and their combination) for meeting their thermal and electricity needs. The gas consumption is used to supply the CHP equipment and the produced heat may be either used in real time or stored at the buildings premises (thermal storage), while the electrical power may be consumed only in real time (electric energy storage is not considered).

According to the basic business scenario, at the local level the consumption patterns of the prosumers are under the responsibility of an ESCO which operates the WiseHOME or the WiseCORP tool, for domestic and tertiary buildings respectively. The ESCO combines the thermal monitoring in each individual building

(HLUC5_PUC1) with models for their thermal behaviour (HLUC5_PUC3), aiming to forecast their thermal needs (HLUC5_SUC2_1), i.e., the potential of thermal energy that can be shedded/shifted in a building without affecting the thermal comfort of the occupants. The connection of the buildings with the two networks, along with the thermal flexibility and the storage capabilities, may be utilized to cover more economically the local needs. For instance, as the prosumer is exposed to the prices propagated both by the gas and the electricity retailer, the ESCO should advise the most efficient consumption mixture (gas or electric energy) and scheduling (shifting/shedding) that minimizes the consumer's bills from the gas and electricity retailer (HLUC5_SUC2_2). The computed schedules are realized by the device management component of the tool, which communicates the optimal set-points to all the participating devices (HLUC5_SUC2_3). In this business case, the ESCO receives a portion of the prosumers' savings as a revenue for the provided services by means of the tools that it operates. As already mentioned, in the context of the WiseGRID project alternative business models will also be investigating, concerning the ownership and operation of the WiseHOME and WiseCORP tools. For instance, in the aforementioned environment these tools may be provided by the gas retailer (or the gas DSO) to the prosumers at a price equal to their development cost or even lower. It is obvious that in this case the involved actor (e.g., gas retailer) does not anticipates direct revenues from selling these tools, but aims to stimulate the gas consumption and consequently increase its income.

In addition to the pre-described potential benefits at the local level, the prosumers owning the CHP equipment may exploit their thermal flexibility and storage capabilities, aiming to generate further profits. To this end, they may participate as members in a Virtual Power Plant and contribute to the realization of DR events. For instance, the (electricity) DSO may request a DR (load shifting / shedding) from the VPP Operator (operating as an aggregator), aiming to alleviate its grid from a period of severe congestion. Notice that a prosumer owning the CHP equipment may participate more actively in such services, because he may meet the thermal or electricity needs by switching to gas consumption and remain within his comfort zone. Furthermore, such a prosumer may offer additional services compared to those who lack the relevant system, such as the provision of power to the grid. The VPP Operator computes the optimal set of its assets (prosumers) for participating in the service, according to their potential in satisfying its requirements (HLUC5_PUC4). Then the VPP Operator, communicates the details of the DR event (magnitude of load shedding, duration of the event) that are assigned to each individual member, by means of the communication between the tools at the aggregation and local level, i.e., the WG STaaS/VPP and the WiseCORP respectively (the WiseHOME tool is not mentioned here, because in the context of WiseGRID project it is considered that only domestic buildings may participate in explicit DR events due to their considerable capabilities in load shedding). After receiving the relevant request, the ESCO computes at the local level the optimal set-points for each device such as their joint rescheduling satisfies the requirements. In this case also, the thermal behaviour of the building plays a crucial role, because the ESCO may utilize their thermal inertia and use them as virtual storage means for preheating before the DR event is activated. In the aggregation case, the VPP Operator allocates the received revenues (the amount paid by the actor requesting the service, e.g., the electricity DSO) to its members according to their contribution in the service realization. Here also, the ESCO receives a portion of the compensation offered by the VPP Operator to the relevant prosumer under its responsibility. All the documented services are provided subject to the satisfaction of the comfort preferences of the occupants and the technical constraints of the devices that should be considered with the highest priority due to safety reasons.

Besides the added value provided by the participating WG-tools in the realization of the aforementioned services, the BM will also investigate financing schemes for covering the cost of the CHP system. The simplest case is to consider that the prosumers pay for it, and compare it with the received revenues (or decreased electricity costs) from their participation in the services within a reasonable time interval. Alternatively, the gas DSO or retailer may subsidize its cost, aiming to stimulate the penetration of such systems in the market and consequently increase the gas consumption and their profits.

4.3.5.2 Generic BM canvas

WiseGRID products	• **WiseHOME** • **WiseCORP** **Information Exchange with (via the IOP):** • **WG STaaS / VPP** • **WG Cockpit**
Actors involved	• Prosumer (domestic and tertiary occupants with CHP equipment and thermal storage capabilities) • Gas Retailer • Gas DSO • Electricity DSO (managing the WG Cockpit tool) • VPP Operator • ESCO
Roles involved	• Electricity/heat Production (role performed by the prosumer with CHP) • Gas/electricity Consumption (role performed by the prosumer with CHP) • Energy/thermal Storage (role performed by the prosumer with CHP) • Gas Retailing (role performed by the gas retailers) • Gas Distribution (role performed by the gas DSO) • Electricity Distribution (role performed by the electricity DSO, managing the WG Cockpit tool) • Aggregator Services (role performed by the VPP Operator managing the WG StaaS/VPP tool) • EE and EM Services (role performed by the ESCO managing the WiseHOME / WiseCORP tools)
Value proposition	**Prosumer (Facility Manager)** • Will achieve cost reduction of the electricity and gas bills. • Will gain additional revenues by providing DR to the VPP Operator • Will achieve efficient management of CHP. • Will ensure acceptable comfort level in building • Will improve the energy effectiveness by using more accurate commands provided by the ESCO (WiseCORP / WiseHOME). **Gas Retailer** • Will be able to do better forecasting by using more accurate demand information provided by the ESCO. • Will increase their revenues due to the increase in the use of CHP/gas consumption. **Gas Distribution Company** • Will have additional revenues as the increase in the use of CHP will increase the gas consumption and distribution network use. • Will be able to make better asset management. **Electricity DSO** • May utilize additional resource (CHP) for DR services. • Will be able to do better forecasting by using more accurate information concerning the DR schedule. • Will enhance its flexibility and efficient operation. **VPP operator** • Will improve his existing services by using the excess energy provided for ancillary and DR services. • Will be able to do better forecasting by using more accurate information concerning the list of available assets and the requested services schedule. **ESCO** • Efficient management of customers/CHPs. • Increase its penetration in the market. • Will be able to do better forecasting and energy management by using more accurate

	data concerning the energy use and production of the CHP unit. • Additional revenues by scheduling the prosumer's consumption and production for their participation in services requested by the VPP Operator.
Revenue streams	**Prosumer** • Will reduce his power consumption cost by using the thermal energy produced as a by-product from the CHP. • Will reduce his consumption by receiving more accurate energy management services. • Will reduce its electricity and gas retailers' bills by following the optimal consumption schedules. • Will receive a compensation for his participation in the services requested by the VPP Operator. **Gas Distribution Company and Retailer** • Additional profit due to the increase usage of gas distribution network and gas consumption respectively. **Electricity DSO** • Decrease its cost penalties by utilizing the additional capabilities for DR requests and achieving the smooth operation of its grid (congestion relief). **VPP Operator** • Fee received by the prosumers for participating in the VPP (depends on the type of contract between the two actors). • Increase its revenues by providing further services to the DSO, due to the participation of additional members in the VPP. **ESCO** • Receives a portion of the prosumer's savings due to the reduced electricity and gas retail bills. • Receives a flat fee by the prosumers for providing the optimal schedules (depends on the agreement between the two parties. • May receive a portion of the compensation provided by the VPP Operator to the prosumers for the utilization of their assets in the energy markets.
Cost streams	**Prosumer** • Partially or totally cover the cost of the CHP equipment. • Part of their revenues (income due their contribution in DR or decreased retailers' bill) is given to the ESCO for providing the optimal schedules. • Membership fee to the VPP Operator for becoming its member. • Flat fee to the ESCO (depends on the contract). • Cost of metering and control equipment (depends on the contract with the ESCO) **Gas Distribution Company** • Cost possibly needed to improve or expand the existing distribution network. • May partially cover (subsidize) the cost of the CHP equipment. **Gas Retailer** • Additional charges by the gas distribution company due to the increase usage of the distribution network. **Electricity DSO** • Economic investment for the development and operation of the software (WG Cockpit tool) and communication channels and technologies with the WG STaaS/VPP for sending request for services. • Compensation provided to the VPP Operator for the provision of the requested services. **VPP Operator** • Economic investment for the development and operation of the software (WG WG STaaS/VPP) and communication channels and technologies with the Cockpit and WISEHOME / WiseCORP tools for receiving requests by the DSO and assigning them to its assets (members).

	• A part of the compensation received by the DSO is allocated to its members according to their contribution in service realization. **EE&EM Services** • Economic investment for the development and operation of the software (WISEHOME / WiseCORP tool) and communication channels and technologies with the WG STaaS/VPP for receiving request for services. • Cost of metering and control equipment (depends on the contract with the prosumer)

Table 17 – Generic BM canvas for archetype BM5

4.3.5.3 Value network graph(s)

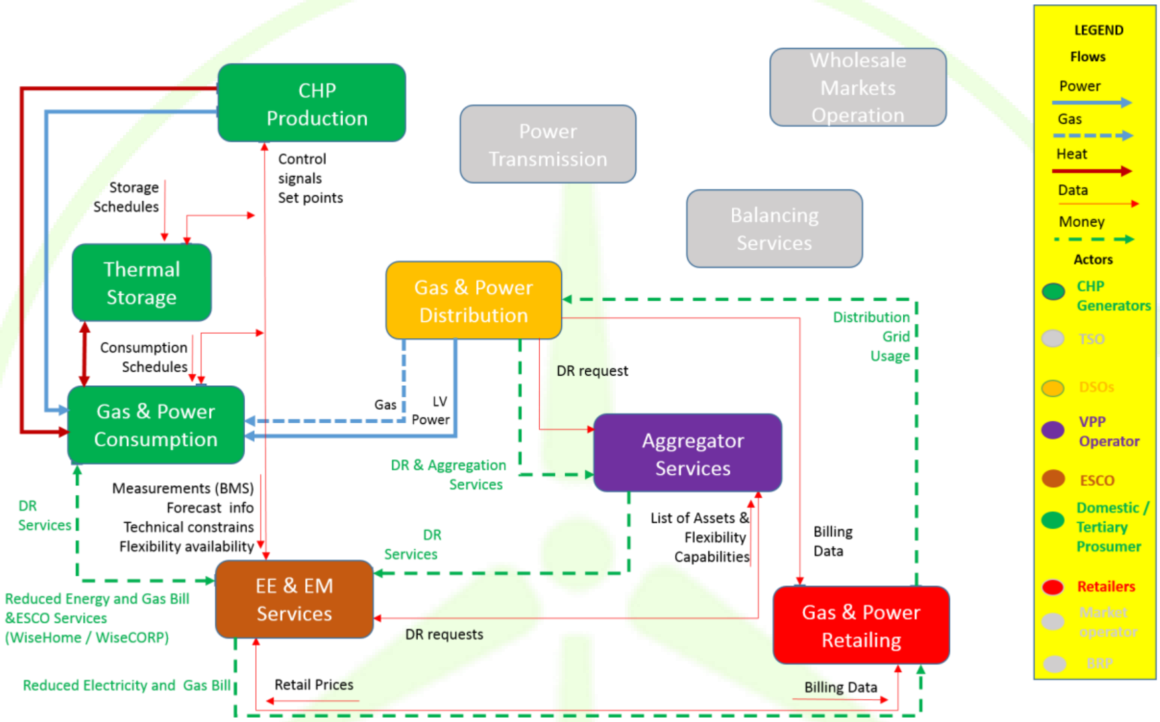


Figure 11 – Co-generation in domestic and tertiary buildings

4.3.5.4 Preliminary business modelling canvas for the Gas DSO

Key Partners	**Key Activities**	**Value Propositions**	**Relationships with other partners**	**Customer Segments and Communication.**
• Gas Retailer • Domestic / Tertiary Prosumer with CHP equipment (via the ESCO).	• Distributes gas to the Prosumer (CHP premises). • Provides grid use services to the Gas Retailer.	• Will have additional revenues as the increased usage CHP will in turn increase the gas consumption and distribution network use. • Will be able to make better asset / grid management.	• Receives revenues from Gas Retailer for the provision of distribution services. • Receives schedules and needs from Gas Retailer. • Provides billing information and operating data to Gas retailer.	• All thermal energy users • All gas users • All gas retailers • Communication through marketing campaigns • Promoting CHP installation through energy and building experts.

Value network graph	Barriers
Figure 11.	• Availability of the distribution grid at the prosumer's premises. • Necessary space and infrastructure
Cost Structure • Cost possibly needed to improve or expand the existing distribution network. • May partially cover (subsidize) the cost of connection in the gas distribution grid. • May partially cover (subsidize) the cost of the CHP equipment.	**Revenue Model** • Additional profit due to the increased usage of the gas distribution network.
Societal and Environmental Costs • Installation of CHP, HVAC and necessary infrastructure leads to CO2 emissions • With high penetration of decentralized co-generation units classical business models related with conventional power stations loose of importance which might also have an impact on the employees working in this business area.	**Societal and Environmental Benefits** • New jobs can be created not only related to the manufacturing and installation of CHPs but also in the field of aggregation and operation. • More jobs related to grid expansion.

Table 18 – Preliminary business modelling canvas for the Gas DSO

4.3.5.5 Preliminary business modelling canvas for the Gas Retailer

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• Gas DSO • Domestic / Tertiary Prosumer with CHP equipment (via the ESCO)	• Provides gas to the ESCO (prosumer) for the operation of the CHP by using the gas distribution network.	• Will be able to do better forecasting by using more accurate demand information provided by the ESCO. • Will increase their revenues due to the increase in the use of CHP and gas consumption.	• Provides retail prices, contracts and energy bills to ESCOs (prosumer). • Receives revenues from the ESCO (prosumer) for providing gas. • Receives scheduled gas/energy needs from ESCO. • Provides scheduled gas needs to Gas DSO. • Receiving billing information and operating data from Gas DSO. • Provides revenues to Gas DSO for providing distribution services.	• All thermal energy users • All gas users • Communication through marketing and advertising campaigns. • Promoting CHP installation through energy and building experts.

Value network graph	Barriers
Figure 11.	• As referred for the Gas-DSO.

Cost Structure	Revenue Model
• Additional charges by the gas distribution company due to the increased usage of the distribution network. • May partially cover (subsidize) the cost of gas used by the CHP equipment.	• Additional profit due to the increased gas consumption.
Societal and Environmental Costs • As described for the Gas DS	**Societal and Environmental Benefits** • Lower energy costs due to the use of more efficient thermal energy systems • Possible future savings from reduced (or postponed) electricity wires infrastructure.

Table 19 – Preliminary business modelling canvas for the Gas Retailer

4.3.5.6 Preliminary business modelling canvas for the ESCO (WiseHOME / WiseCORP)

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• Prosumer • VPP Operator	• Formulates the thermal behaviour of the buildings under its responsibility. • Computes human-centric forecasts of flexible loads according to the prosumers' convenience constraints (e.g. comfort preferences, air quality, machinery/process constraints). • Provides the optimal (gas and electricity) consumption and generation schedules according to the economic criteria of cost minimization or revenues maximization. • Always meets the convenience constraints of the citizens.	• The optimal consumption and generation scheduling (provided by WiseHOME / WiseCORP) allows the ESCO to maximize its revenues by reducing the prosumer's bills and by utilizing its assets for the provision of aggregated services. • The ESCO will improve its market position and increase its clientele.	• Receives and elaborates the retail prices, from the gas and electricity retailer. • Informs the VPP Operator for the capabilities of the prosumer to offer aggregated services. • Receives requests for services by the VPP Operator.	• Tertiary building owners/ occupants. • Citizens informed via ad campaigns (e.g. online) • Tertiary building managers to be informed via ad campaigns in trade events and press.

Value network graph	Barriers
Figure 11.	• Measuring and billing efforts. • The limited penetration of CHP systems in the market. • Uncertainty about thermal inertia of the buildings and the accurate demand flexibility that may be achieved by flexibility actions, such as preheating.

Cost Structure	Revenue Model
• Development and operational cost of the WiseHOME / WiseCORP tool, or alternative the license - cost paid to a third party. • Personalized management for each customer, aiming to cover the individual convenience preferences. • Operational expenses (payroll, etc.) • Communication, measurement & control infrastructure (depending on agreement with customer).	• Receives a portion of the prosumer's electricity and gas bill savings. • Receives an additional flat-fee from the prosumers (based on the contractual agreement between the two parties). • Receives a portion from the compensation provided by the VPP Operator for the contribution of the prosumer in the realization of aggregated services.
Societal and Environmental Costs	**Societal and Environmental Benefits**
• Demand and thermal flexibility may incur convenience degradation, if not properly managed.	• The active participation of citizens in the energy markets becomes feasible. • Lower CO_2 emissions through effective management (electric + thermal) and the deployment of thermal storage.

Table 20 – Preliminary business modelling canvas for the ESCO

4.3.5.7 Preliminary business modelling canvas for the Prosumer

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• Gas Retailer • ESCO	• Informs the ESCO about his convenience constraints (e.g., temperature comfort zone). • Informs the ESCO about the capabilities of the installed CHP equipment. • Follows the optimal consumption and generation schedules as proposed by the ESCO. • Allows the market qualification of its assets by the VPP.	• Will achieve cost reduction of the electricity and gas bills. • Will have additional revenues by providing services to the VPP Operator • Will ensure acceptable comfort level in building • Will improve the energy effectiveness by using more accurate commands provided by the ESCO (WiseCORP / WiseHOME).	• Purchases gas and electricity from the retailer • Receives retail prices, contracts and energy bills from retailer. • Receives schedules, set point data, historical operation data and billing information from the ESCO.	According to the considered scenario, the prosumer is the customer of the ESCO, targeting to utilize in the most efficient way his CHP equipment.

Value network graph	Barriers
Figure 11.	• Legal and regulatory aspects regarding the integration and operation of CHPs within buildings. • Necessary space and infrastructure (ICT, pipes) within building.

Cost Structure	Revenue Model
• Capex cost for the CHP, the HAVC system and for thermal storage devices (the CHP equipment may be subsidized by the GAS DSO or the retailer) • Maintenance cost of its equipment • Communication, measurement & control infrastructure (depending on agreement with the ESCO) • Part of its saving in the electricity and gas bills (and a flat fee) is given to the ESCO for providing the optimal advices. • Part of the compensation provided by the VPP Operator is given to the ESCO for the same reason. • Flat fee to the VPP Operator for becoming a member of the VPP.	• Will reduce his power consumption cost by using the thermal energy produced as a by-product from the CHP. • Will reduce its electricity and gas retailers' bills by following the optimal consumption schedules. • Further revenues by its participation in the VPP and his contribution in the realization of aggregated services.
Societal and Environmental Costs	**Societal and Environmental Benefits**
• As described for the Gas DSO.	• As described for the ESCO.

Table 21 – Preliminary business modelling canvas for the Prosumer

4.3.6 Archetype BM6: Exploiting the VPP assets

4.3.6.1 Description

The archetype BM in this section exploits the functionalities included in HLUC6 for the optimal operation of the Virtual Power Plant (VPP) and the subset of those in HLUC7, which refer to the scheduling of an explicit DR event. The reason for this documentation is to provide the complete value chain of the services offered by the main actor in this BM, i.e., the VPP Operator.

More specifically, the VPP represents a basic component of an interactive and dynamic distribution network, as a system that integrates many resources, such as: Renewable Energy Sources (RES), energy storage systems and flexible/controllable loads of domestic and tertiary prosumers. According to the basic business scenario, at the local level (for each individual household or tertiary building), these resources are scheduled by the responsible ESCOs that manage the WiseHOME and WiseCORP tools respectively, aiming to optimally meet the needs of the occupants. At the aggregation level, the production capacity and consumption flexibility of these heterogeneous resources can be pooled and the energy surplus can be utilized to offer additional services. In that sense, the VPP operator represents an intermediary between the prosumers and the energy markets.

The VPP Operator can participate in the Day-ahead and Intraday wholesale market for selling the energy surplus (HLUC6_SUC2_1) and in the balancing markets (HLUC6_SUC2_2) for offering consumption flexibility and DR services to other actors of the grid, e.g., the DSO. Aiming to maximize the revenues of its participants while satisfying their convenience constraints, the VPP Operator firstly selects (by means of the WiseCORP and WiseHOME tools) the forecasts of the RES production, and combines it with the forecasted demand of its members aiming to compute their surplus (HLUC6_PUC1). Then, the VPP Operator compares the potential revenues from the two markets and decides the most profitable schedule for its assets: either sell the consumption surplus or store it to cover future local needs and additionally the member that will participate in the DR events (HLUC6_SUC2_3). The VPP Operator's tool (WG STaaS/VPP) sends the optimal strategies to each individual prosumer, using the communication channels with the relevant tools (WiseHOME, WiseCORP).

In the case of a DR event, the VPP Operator explicitly requests from a subset of its members their consumption shifting/shedding of a specific volume of power within a specific time duration. In the context of the

WiseGRID project, such requests refer only to tertiary prosumers (not to domestic) due to the considerable volume of power consumption that may be controlled at the HVAC equipment and the larger-scale storage capabilities (compared to a domestic prosumer). For instance, the DSO may request the self-consumption (or storage) of the RES production to avoid a curtailment, or a consumption shifting that would relief its grid from congestion.

Depending on the contracts with its members (HLUC6_SUC4_1), the VPP Operator may offer a payment for the consumption rescheduling, or may apply direct load control. In the former case, the VPP Operator firstly chooses the most appropriate prosumers to participate in the DR event (HLUC7_SUC2_2), according to their potential in satisfying the DR requirements and the level of compensation that they request. The DR signal along with the payment level is sent to the WiseCORP tool, which computes the optimal rescheduling of the local devices, such that the relevant request is met. In the case of direct load control (HLUC7_SUC2_6) the VPP Operator computes and sends the optimal schedules for the devices in the tertiary building, while the role of the WiseCORP tool is limited to their implementation. In both the aforementioned schemes, the participation of the prosumers in the DR is quantified by comparing their actual consumption during the event with their individual baselines (consumption under normal conditions, in the absence of DR request), which are derived by elaborating historical data. The VPP Operator manages the compensations for its members according their involvement and contribution to demand response campaigns and the energy surplus provided (HLUC6_SUC4_2). Concerning his revenue stream, the VPP Operator may require a participation fee from each individual member and also keep a portion of their profits from their participation in the wholesale markets and the DR events.

Concluding, the aim of this BM is to investigate the added value gained by the prosumers from their participation in the VPP, due to the more efficient utilization of their production and consumption-shifting capabilities both at local and aggregation level, according to the advices of the VPP Operator. As mentioned above, the additional potential revenues will be gained by purchasing their production surplus in the wholesale market (compared e.g., with the regulated feed-in tariffs or premiums as mentioned in Section 2.4.1.2 and in Section 3.1.3 for the participation of small scale producers below 10KW in the markets) and by participating in DR events. Furthermore, the BM will investigate the added value that will be provided by the WG STaaS/VPP tool to the VPP Operator. The potential additional revenues are expected to be realized mainly due to the optimization functionalities of the tool, which allow the agent to decide the optimal assignment of the requested services to its assets and consequently increase the set of services that may be offered (e.g. increase the magnitude of demand shifting that the VPP Operator can offer in the balancing market). Additionally, the optimal advices to the prosumers are expected to extend its clientele (more prosumers willing to become members of the VPP) and thus its revenues. The role of the ESCO in the aforementioned scenarios is aligned with those in the other sections, i.e., to reschedule the consumption of the devices at the local level, such that the consumption pattern communicated by the VPP Operator is met.

For clarity reasons, it is mentioned that this archetype BM assumes that the prosumers own the RES. Nevertheless, the BM and the relevant value network may be appropriately modified to include also the case when a RESCO owns and operates the RES, when this parameter is clarified in the pilot sites. In this case, the relevant contracts must be carefully designed to resolve conflicting interests between the involved parties. For instance, we may consider a contract between a consumer and the RESCO (renting his/her rooftop), which specifies the portion of generation that may be consumed locally on hourly basis. Then, if the VPP Operator require from the consumer an explicit DR lasting for a shorter interval (e.g., half an hour), the prosumer may require from the RESCO to consume all the agreed portion of the local generation during the event, aiming to avoid the inconvenience cost while earning the compensation by the VPP Operator. This action may be against the interests of the RESCO if at the same time the wholesale price is high, because it misses the opportunity to maximize the profits from its generation.

4.3.6.2 Generic BM canvas

WiseGRID products	• **WG STaaS/VPP.** • **WiseHOME** • **WiseCORP** **Information exchanged with (via the WG IOP):** • **WG Cockpit**
Actors involved	• Prosumer • ESCO • VPP operator • DSO
Roles involved	• Power Consumption / Production and Energy Storage: (Role performed by either domestic or tertiary consumer with batteries and RES installed) • Aggregator Services (Role performed by the VPP Operator managing the WG STaaS / VPP tool) • EE & EM Services (Role performed by the ESCO, managing the WiseHOME / WiseCORP tools) • Power Distribution (Role performed by the DSO, managing the WG Cockpit tool for sending the DR requests)
Value proposition	**Prosumer** • Will be able to schedule its consumption, production and storage capabilities more efficiently. • Will be able to sell its production surplus to the wholesale market. • Will receive additional revenues from its flexibility capabilities and its participation in explicit DR events. • Will have the opportunity to give its contribution for the environment protection, when participating in explicit DR events for the RES curtailment avoidance. **ESCO** • Will decide the optimal schedules of the devices at the local level and thus increase its revenues (as a portion of the prosumer's profits) **VPP operator** • Will provide a combination of services, thus utilizing more efficiently the assets of its members. • Will provide optimal schedules and thus increase its clientele. • Will manage better its internal resources in order to decide more efficiently if it is more profitable to store or sell the energy surplus. • Will be able to provide explicit DR services, thus increasing its earning. DSO • Will be able to receive in an easier way support for balancing the grid by means of the DR services provided by VPP operators.
Revenue streams	**Prosumer** • Revenues by selling its energy surplus to the wholesale market. • Payments from the aggregator for its contribution in the explicit DR events. **VPP operator** • Revenues for operating as an intermediary between the prosumers and the energy markets (receives a portions of the prosumers' profits). • Revenues for providing DR services to the DSO. • Receives flat-fee from the prosumers for their participation in the VPP. **EE&EM** • Revenues for providing the sophistication of the WiseHOME and WiseCORP functionalities. Their revenues may be either a portion of the compensation provided to prosumers for their participation in explicit DR events, or a fixed fee paid by the prosumers (or their combination). **DSO**

	• Decreased operational costs by avoiding the grid congestion and RES curtailment.
Cost streams	**Prosumer** • Part of its revenues will be given to the ESCO for the optimal schedule of the local devices. • Payment to the VPP Operator for becoming a member of the VPP. **VPP Operator** • Economic investment for the development and operation of the software (WG STaaS / VPP tools) and communication channels and technologies with the WiseHOME / WiseCORP and WG Cockpit tools, aiming to receive and send flexibility requests and compute the optimal schedules at aggregation level. • Payments to VPP participants for their involvement in the DR services realization and for their power production. • Payments to the markets operator for market participation (not appearing in the value network). **ESCO** • Economic investment for the development and operation of the software (WiseHOME / WiseCORP tools) and communication channels and technologies with the WG STaaS / VPP, aiming to receive flexibility requests and compute the optimal schedules at local level. **DSO** • Economic investment for the development and operation of the software (WG Cockpit tool), and communication channels and technologies with the WG STaaS / VPP, aiming to send flexibility requests. • Payment to the VPP Operator for provisioning the DR services.

Table 22 – Generic BM canvas for archetype BM6

4.3.6.3 Value network graph(s)

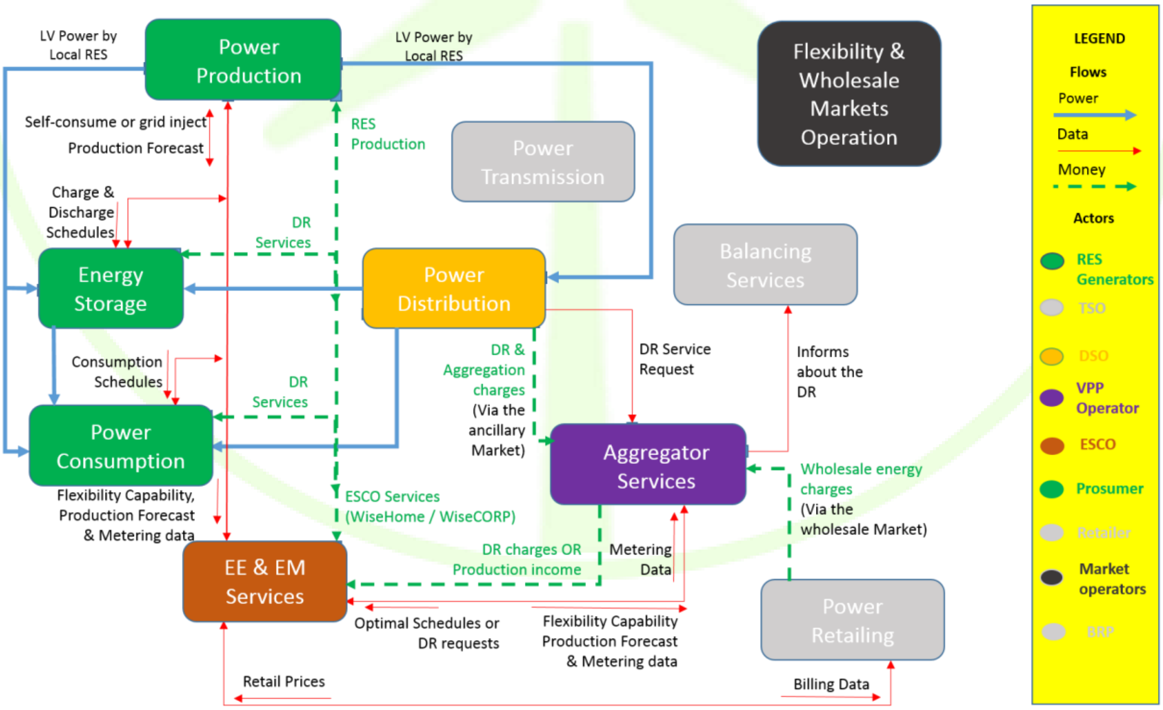


Figure 12 – Exploiting the VPP assets

4.3.6.4 Preliminary business modelling canvas for the DSO

<table>
<tr>
<td>Key Partners
• VPP Operator
• Flexibility Market Operator</td>
<td>Key Activities
• Monitor the distribution grid and foresee the risk of congestion or RES curtailment.
• Flexibility request from the VPP Operator, targeting to the smooth operation of the grid.</td>
<td>Value Propositions
• The smoothing of congestion and avoidance of RES curtailment, lead to the less costly management and operation of the distribution grid.</td>
<td>Relationships with other partners
According to the considered scenario, the DSO communicates only with the VPP Operator via the flexibility market (or alternatively with bilateral agreements).</td>
<td>Customer Segments and Communication.
According to the considered scenario, the DSO is the customer of the VPP Operator. Their between communication is feasible by means of the WiseGRID tools (WG Cockpit and WG STaaS / VPP).</td>
</tr>
<tr>
<td colspan="3">Value network graph
Figure 12.</td>
<td colspan="2">Barriers
• Regulatory gaps in the operation of the VPP and the provision of the relevant flexibility services.</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• Development and operational cost of the WG Cockpit tool.
• Cost of the advanced metering infrastructure (smart meters, sensors) needed in order to specify the details of the required DR event (duration, area, etc.)
• Payment to the VPP Operator for the provision of the DR services.</td>
<td colspan="2">Revenue Model
• Better management of the peak demand leads to decreased need for investment in grid capacity.
• Avoidance of potential penalties that would arise in the case of RES curtailment.</td>
</tr>
<tr>
<td colspan="3">Societal and Environmental Costs
No societal or environmental costs identified.</td>
<td colspan="2">Societal and Environmental Benefits
• Better use of public infrastructure.
• More secure and stable grid.
• Less investment costs needed by the DSO in bigger cables and prolonging the useful life of the infrastructure. The money saved can be used by the DSO for other socially relevant purposes, targeting to eliminate the energy poverty.</td>
</tr>
</table>

Table 23 – Preliminary business modelling canvas for the DSO

4.3.6.5 Preliminary business modelling canvas for the VPP Operator (Aggregator)

Key Partners	**Key Activities**	**Value Propositions**	**Relationships with other partners**	**Customer Segments and Communication.**
• DSO • Prosumer (by means of the ESCO) • Wholesale and Flexibility Market Operator	• Operates as an intermediate between the prosumers and the wholesale / balancing markets. • Aggregates the consumption / production loads of the prosumers and offer flexibility services balancing markets. • Provides the optimal suggestions to the prosumers for the utilization of their assets at the aggregation level.	• The pooling of generation units and flexible consumption loads leads to their more efficient utilization. • The utilization of its assets for providing services in two markets leads to more profitable decisions for the VPP members and thus also for the Operator. • The optimal assignment of services to specific assets (prosumers) allows the VPP Operator to offer further services and thus increase its revenues.	• Receives flexibility requests from the DSO. • Collects the flexibility capability and production forecast of the prosumers (by means of the ESCO). • Provides to the ESCO the optimal utilization of RES generation and instructions for the explicit DR. • Informs the retailer/BRP about the explicit DR events.	• The DSO is a customer of the VPP Operator as the former requests flexibility services. • VPP members, such as low-voltage households and businesses with or without RES production and storage capabilities. • Communication through marketing campaigns. • The provision of the services is feasible by means of the communication between the participating WiseGRID tools.

Value network graph	**Barriers**
Figure 12.	• Must have enough members in a specific area to be able to offer significant flexibility. • Uncertainty about inherent demand flexibility available in various building typologies and relevant activities/operations. • Aggregators must get the prior agreement of suppliers/BRP, before contracting with their customers (e.g., the case of Belgium, as mentioned in Section 3.2.3). • In some member states no regulatory framework currently exists for the operation of the aggregator (e.g., in Italy as mentioned in Section 3.2.3). • Absence of methodology for the accurate definition of the baseline consumption, as mentioned in Sections 3.2.3 and 3.2.4.
Cost Structure	**Revenue Model**
• Development and operational cost of the WG STaaS/VPP tool, or alternative the license – cost paid to a third party. • Fee paid to the market Operators for its participation in the markets.	• Flat-fee paid by the prosumers for their participation in the VPP. • Keeps a portion of the prosumer's income by selling their energy in the wholesale market. • Keeps a portion of the amount paid by the DSO (bidding process in the market) for the flexibility

	request (the rest is given to the prosumers).
Societal and Environmental Costs • Manufacturing and operation of VPP assets leads to CO_2-emissions, especially when non-renewables are included in the VPP asset pool. • VPPs are in competition with conventional power stations which might be pushed out of the market affecting employees working in this business area.	**Societal and Environmental Benefits** • More awareness/direct link between energy consumption and production • Maximisation of the share of renewable energy, i.e. pushing the energy transition • Encouragement of citizens' active participation. • New jobs can be created related to the setup and operation of VPPs. • DR reduces the need for reserved capacity, which results to a premium in electricity prices (as mentioned in Section 2.4.3.2), thus the associated costs are expected to be minimized.

Table 24 – Preliminary business modelling canvas for the VPP Operator

4.3.6.6 Preliminary business modelling canvas for the ESCO (WiseCORP/WiseHOME)

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• Prosumer • VPP Operator	• Local RES generation forecasting • Human-centric demand forecasting • Forecast of flexible loads according to the prosumers' convenience constraints (e.g. comfort preferences, machinery/process constraints). • Optimal consumption rescheduling.	• The optimal consumption rescheduling during the explicit DR event and the efficient utilization of the RES units at the local level maximize the ESCO's revenues.	• Sends to the VPP Operator the forecasts about the local generation and flexibility capabilities. • Receives explicit DR requests and price signals from the VPP Operator • Receives the optimal suggestions for the utilization of the RES generation by the VPP Operator.	• Energy-conscious electricity consumers & prosumers • Tertiary building owners/ occupants • Tertiary building managers to be informed via ad campaigns in trade events and press. • Information via Internet, seminars/trainings, fairs, magazines/newspapers, and architects.

Value network graph	**Barriers**
Figure 12.	• Uncertainty about inherent demand flexibility available in various building typologies and relevant activities/operations • Limited remuneration from participation in DR campaigns may not provide sufficient incentive for the hassle for electricity end-users. • Large electricity prosumers may prefer to in-house this expertise and capacity rather than hiring a third-party (ESCO).

Cost Structure	Revenue Model
• Development and operational cost of the WiseHOME / WiseCORP tool, or alternative the license - cost paid to a third party. • Energy management strategy definition per customer. • Operational expenses (payroll, etc.) • Communication, measurement & control infrastructure (depending on agreement with customer)	• Receives a portion of compensation given from the VPP Operator to the prosumers for their participation in the explicit DR events. • Receives a flat fee from building owner/manager or from the domestic prosumers for the provision of the WiseHOME and WiseCORP services.
Societal and Environmental Costs	**Societal and Environmental Benefits**
• Demand flexibility may incur inconvenience or operations degradation and to higher prices (as mentioned in Section 2.4.3.1), if not properly managed.	• Flexible loads can further reduce emissions and reduce wholesale energy prices by avoiding generation from expensive and polluting fossil-fuel plants • Increased public awareness about green energy, the energy transition and the internal energy market • Increased participation of citizens in the energy markets.

Table 25 – Preliminary business modelling canvas for the ESCO

4.3.6.7 Preliminary business modelling canvas for the Prosumer

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• ESCO • VPP Operator	• Informs the ESCO about his convenience constraints (e.g., temperature comfort zone). • Informs the ESCO about the capabilities of the installed RES equipment. • Follows the optimal consumption and generation schedules as proposed by the ESCO. • Allows the market qualification of its assets by the VPP Operator.	• The participation of the prosumer in the VPP, will result in more efficient utilization of his consumption, production and storage capabilities due to his participation in the wholesale and flexibility markets. • The management of his devices by the ESCO will contribute in the realization of the efficient schedules.	• Purchases electricity from the retailer • Receives retail prices, contracts and energy bills from retailer. • Receives schedules, set point data, historical operation data and billing information from the ESCO	According to the considered scenario the prosumer is the client of the ESCO and of the VPP Operator.

Value network graph Figure 12.	Barriers • Legal and regulatory aspects regarding the operation of VPP assets. • A lack of standardization (e.g. communications interfaces of VPP assets). • The offered compensation for the participation in explicit DR events, may not offer be enough incentives (compared to the potential inconvenience cost).
Cost Structure • Part of its compensation for participating in explicit DR events (or a flat fee) will be given to the ESCO for the optimal schedule of the local devices. • Part of its revenues from energy selling will be given to the VPP Operator for the provision of the optimal utilization schedules of the local generation. • Payment to the VPP Operator for becoming a member of the VPP	**Revenue Model** • Revenues by selling its energy surplus to the wholesale market. • Payments from the aggregator for its contribution in the realization of the explicit DR events.
Societal and Environmental Costs No societal or environmental costs identified.	**Societal and Environmental Benefits** • As described for the ESCO

Table 26 – Preliminary business modelling canvas for the Prosumer

4.3.7 Archetype BM7: Supply-demand balancing by means of implicit DR events

4.3.7.1 Description

The following identified archetype BM investigates the added value provided by the WiseCOOP tool to the retailer, for meeting its obligation of a balanced portfolio by means of implicit DR events. Recall that the implicit DR refers to the propagation of dynamic prices by the retailer to its clients aiming to incentivize them to reform their consumption pattern. Thus, the BM investigates also the added value provided by the tools that manage at the local level the consumption and production of the prosumers (WiseHOME / WiseCORP), in terms of mitigating the risk of high electricity bills due to their exposure in dynamic pricing schemes.

The scenario assumes that the retailer handles by its own the aforementioned balancing responsibility (does not delegate it to another company), meaning that undertakes also the role of the Balancing Responsible Party (BRP). Focusing on the functionalities of the WiseCOOP tool (to be mentioned below), we consider that the retailer/BRP does not manage generation units and consequently has not the option of production re-scheduling. Thus, a balanced position consists to the equalization of its clients' consumption with the volume of energy purchased (reserved) in the wholesale market. In what follows we consider the case when the retailer's forecast about the demand of its clients and consequently the volume of energy purchased in the day ahead wholesale market does not match the actual consumption. In the case of a negative imbalance, i.e., when the reserved energy is not adequate to cover the actual demand, the retailer/BRP may purchase further energy in the intra-day market, but such a choice may be particularly costly. In the opposite case, the retailer/BRP has to pay an imbalance penalty to the TSO for its inaccurate estimation [95].

The scenario assumes that the retailers' customers have already signed contracts that expose them to dynamic pricing schemes (in what follows we describe the potential benefits from accepting such an exposure). The retailer's tool has gathered all the necessary data from each individual prosumer (by means of the communication between the relevant tools) that let this agent know how they adapt their consumption with respect to the prices, environmental conditions and social events (HLUC7_PUC_1 & PUC_3). The retailer elaborates this knowledge and computes their response with respect to the aforementioned parameters (HLUC7_SUC2_1, & SUC2_3). Utilizing this information, the WiseCOOP tool (that will be implemented in the context of HLUC7) allows the retailer to know the appropriate level of the prices, which should cause the desired collective modification in the demand profile of its clients (load shifting/shedding) and will result in a balanced energy portfolio. The aforementioned calculation may either refer to personalized prices for each individual client or to common prices for all the members of its clientele.

The dynamic prices are propagated both to residential prosumers and tertiary buildings via the WiseHOME and WiseCORP tools respectively, which compute the optimal consumption schedule at local level, according to the price sensitivity of the prosumer and its convenience constraints or preference. The BM considers prosumers who have installed batteries and may store energy from the grid during periods of low prices and consume it when the electricity is more expensive. Additionally, the prosumers have installed RES and may compare their revenues from the injection of their production in the grid, with the savings from a reduced electricity bill if they choose to self-consume/store. The optimal schedules of the assets at the local level will be presented in a user-friendly way by means of the "Enriched Information Visualization" components of the WiseHOME and WiseCORP tools (HLUC7_SUC1_2 & SUC3_1). This presentation will allow the prosumers to easily adopt the proposed schedules and understand their potential revenues. Apart from the economic incentives, the response of the domestic prosumers to dynamic prices may be stimulated by social and ethical parameters, such as the feeling of working together toward a common purpose and the impact of comparisons and competition with other peers of the communities. Such functionalities will be provided by the WiseHOME tool (HLUC7_SUC3_2).

From the retailer's/BRB's perspective this BM will exploit the added value offered by the WiseCOOP tool stemming from better demand side management, in terms of reducing or eliminating the cost that is related with an imbalanced portfolio. From the prosumer's perspective it will exploit the added value provided from the WiseHOME and WiseCORP tools. To this end, it will compare the case of prosumers who follow the optimal schedules provided by their functionality, with those that maintain their flat-fee consumption pattern despite the propagation of dynamic prices by the retailer. Additionally, it will investigate the possibility provided to the prosumer to accept favorable contracts offered by the retailer. For instance, a candidate contract between the retailer and a prosumer may combine dynamic pricing scheme in the form of critical peak pricing during the peak periods, and flat rates for the rest of the time. Then, the prosumer may accept such a contract if the level of the flat prices are lower than those in a contract that does not include any dynamic scheme. The optimal consumption-suggestions of the tools should guarantee that such a choice will result to lower electricity bill for the prosumer. Concerning the operation of these two latter tools, the basic business scenario considers that it is performed by an ESCO, which receives revenue streams as a portion of the prosumer's bill savings.

We clarify that this type of DR event is characterized as implicit, because the retailer does not require a specific volume of consumption curtailment but provides economic incentives for consumption shifting/shedding via dynamic pricing, while the prosumers voluntarily respond to such signals. But, this voluntary nature of implicit DR makes the intervention of an ESCO questionable. Indeed, the prosumers may not always accept to appropriately shift their consumption according to ESCO's suggestions. As a direct results the anticipated savings in the retailer's bill will not (or partially) be realized and the ESCO will lose its source of revenues. Aiming to overcome the aforementioned risk, the business model will investigate alternative forms of revenue streams for the ESCO. For instance, it could require a flat fee from the prosumers for providing its optimal suggestions, along with the portion of their bill savings. Additionally, the ESCO should strategically choose the suitable subset of prosumers to offer its services, based on an analysis for their price sensitivity which reflects its potential revenues. But still, the revenues of the ESCO may not justify its business role, especially for domestic prosumers whose payback from their participation in the implicit DR events are not expected to be noteworthy. To this end, the business model will suggest alternative options for the commercial exploitation of the WiseHOME and the WiseCORP tools. For example, in the context of the current scenario these tools may be provided free-of-charge (or at the price that equals their development cost) by the retailer to its clients, aiming to help them participate more efficiently in the implicit DR events, while protecting them from their exposure to the dynamic pricing schemes. In this case, the retailer objective is not to achieve direct revenues from selling the tools, but aims to utilize them for meeting a balanced portfolio, while keeping its clientele satisfied from the offered service and preventing them from switching to any of its competitors. We emphasize that such services are of particular importance in a liberalized market, since the consumers have the right to change their supplier without any extra charges (see also Section 3.1.2)

For completeness reasons, it is mentioned that the case of an explicit DR event is investigated in the arche-type BM 6 (Section 4.3.6.1) that can be extended to account for the retailer as the actor that requests such a service. Finally, it should be noted that the dynamic pricing schemes may be applied from the retailer for other purposes as well, such as to reduce the possible need for more expensive and non-friendly environ-mentally assets to be activated, expose consumers to the actual energy cost and raise their awareness. In the table that follows, we document them for completeness reasons, nonetheless we consider them out of scope in this BM as they don't provide a direct benefit for the retailer.

4.3.7.2 Generic BM Canvas

WiseGRID products	• **WiseHOME** • **WiseCORP** • **WiseCOOP** **Information exchange via the WG IOP**
Actors involved	• Prosumer • Retailer • ESCO/ (EE&EM)
Roles involved	• Power Consumption & Production, Energy Storage : (role performed by domestic and ter-tiary prosumers) • EE and EM Services (role performed by the ESCO which manages the functionalities of the WiseHOME and WiseCORP tools) • Power Retailing (role performed by the retailer)
Value proposition for involved actors	**Prosumer** • A prosumer who participates in the implicit DR events, may negotiate favourable contracts with the retailer (as described above). • Prosumers who have installed RES and generate electricity can utilize self-balancing to generate added value through the difference in the prices of buying, generating, and selling electricity. • Prosumers who have installed batteries in their households/premises may adapt their electricity consumption profiles according to the dynamic prices with a lower inconvenience cost and utilize to higher extent renewable energy sources. • Will be able to follow more accurately the optimal schedules by means of their visualization, while they remain within their comfort zone. **Retailer** • Implicit DR enables retailers to adjust their portfolio demand profile so that it better matches the profile of energy purchased from the wholesale energy markets, therefore reducing chances of imbalance (the value proposition considered in this BM). • Retailers can employ dynamic pricing tariffs, such as time-of-use, critical-peak-pricing and real-time-pricing, to better represent market prices, expose consumers to the real electricity cost and raise their awareness (out of scope). • Retailers can use load flexibility, through dynamic prices, to reduce peak demand and benefit from stability in the network. At the same time, they reduce the possible need for more expensive and polluting assets to be activated, thus keeping emissions and wholesale electricity prices lower (out of scope). **ESCO** • Energy Service Companies can benefit from the dynamic supply/demand interplay by offering suitable services to prosumers and retailers, such as forecasting information and prediction models, remote maintenance and support, and on- or offsite energy management.

	• Energy cost management or tariff comparison, can be offered by ESCOs to facility managers and/or residential consumers, opening up new lines of business.
Revenue streams	**Prosumer** • Reduced electricity bill by means of load shifting/shedding and the use of batteries. • Better utilization of RES by comparing the consumption prices (retailer) with the potential revenues from grid injection, to make the optimal decision: either self-consume or sell. **Retailer** • Reduced cost or penalties due to its portfolio imbalance (main source). • Dynamic tariff schemes and related enhanced information services can increase the supplier market share, via consumer engagement and improved brand image. **ESCO** • Revenues for providing the sophistication of the WiseHOME and WiseCORP functionalities. Their revenues are a portion of the electricity bill reduction combined if necessary with a flat-fee.
Cost streams	**Prosumer** • Part of their saving are given to the ESCO for providing the optimal consumption and RES generation schedules. **Retailer** • Economic investment for the development and operation of the software (WiseCOOP tool) and communication channels and technologies with the WiseHOME and WiseCORP tools. **ESCO** • Economic investment for the development and operation of the software (WiseHOME / WiseCORP tool) and communication channels and technologies with WiseCOOP. • Potential charges paid to prosumers and/or aggregators for not providing suitable services and/or accurate information (out of scope).

Table 27 – Generic BM canvas for archetype BM7

4.3.7.3 Value network graph(s)

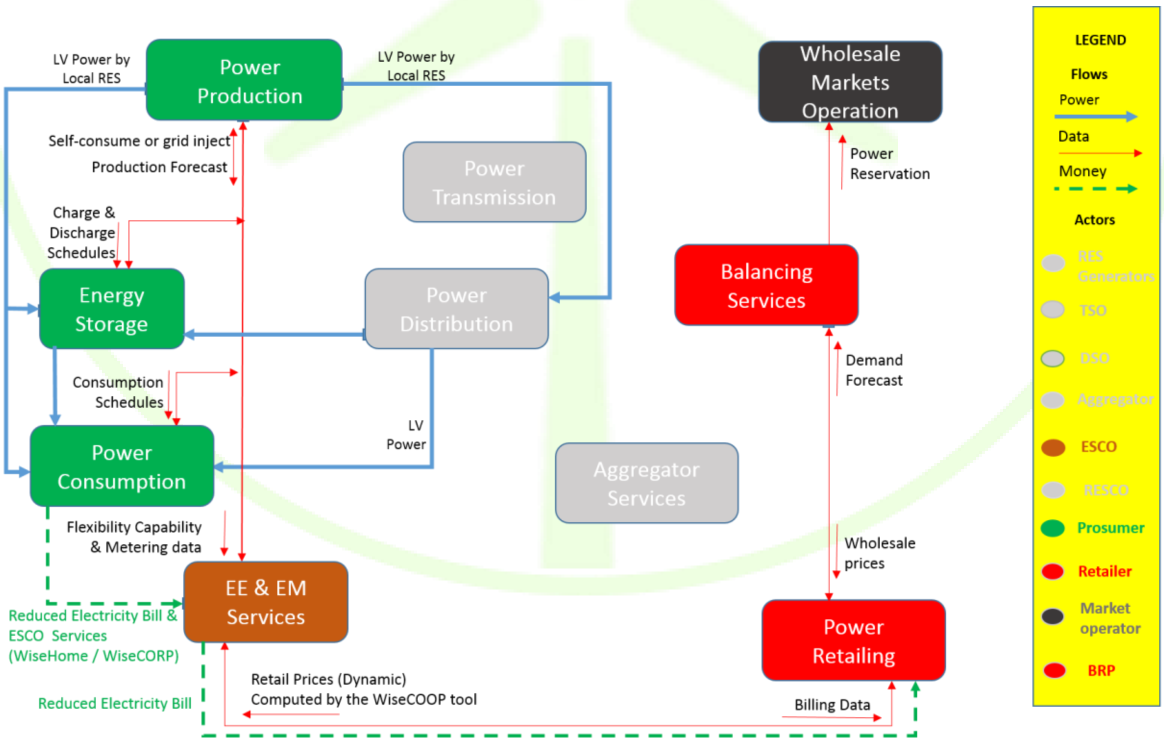


Figure 13 – Supply and demand balancing by means of implicit DR events

4.3.7.4 Preliminary business modelling canvas for the Retailer/BRP

<table>
<tr>
<td>Key Partners
• Prosumer
• Wholesale market operator</td>
<td>Key Activities
• Portfolio demand forecasting
• Price risk hedging strategies
• Electricity wholesale price forecasting
• Retail electricity pricing strategies to customers per type (residential, commercial, industrial, LV, MV, etc.)</td>
<td>Value Propositions
• Dynamic electricity tariff schemes reduce or eliminate the penalties or costs related with an imbalanced portfolio.</td>
<td>Relationships with other partners
• Receives metering data from the metering responsible party (DSO).
• Collects and elaborates data from the electricity market.
• Propagates the retail prices to the prosumers.</td>
<td>Customer Segments and Communication.
• Electricity end users (Segmentation and niche can be decided based on specific retailer strategy).
• Residential customers informed via ad campaigns (e.g., TV, the Internet).
• Tertiary building managers to be informed door-to-door or during trade events.
• During the service, the communication between the actors is feasible via the WiseGRID tools (WiseCOOP and WiseHOME/ WiseCORP)</td>
</tr>
<tr>
<td colspan="2">Value network graph
Figure 13.</td>
<td colspan="3">Barriers
• Legislative frameworks in some Members States still do not allow dynamic retail prices for all customer tiers (Section 3.2.3 mentions that not all Member States apply “price signals and the 71% of the European countries use static time-of-use prices which may restrict the space of the retailer’s activities).
• Reluctance of residential consumers to be exposed to dynamic prices in fear of energy cost increase.
• Uncertainty about inherent demand flexibility available in various building typologies and relevant activities/operations.</td>
</tr>
<tr>
<td colspan="2">Cost Structure
• Development and operational cost of the WiseCOOP tool, or alternative the license - cost paid to a third party.
• Tariff customization strategy definition per customer.
• Operational expenses (payroll, etc.).
• Smart meters (usually another actor assumes this investment).</td>
<td colspan="3">Revenue Model
• Improved profit margin from electricity sales due to better sales forecasting and wholesale purchasing decisions.
• Customised tariffs improve differentiation and personalization of service offering leading to increased market share.</td>
</tr>
</table>

Societal and Environmental Costs	Societal and Environmental Benefits
• Suboptimal computation of the level of dynamic prices may lead to increased energy costs, if another demand peak appears due to consumption shifting. • Dynamic prices may lead a subset of prosumers / consumers to conditions of energy poverty if they can't efficiently adjust their consumption patterns.	• Flexible loads can reduce emissions and reduce wholesale energy prices by avoiding generation from expensive and polluting fossil-fuel plants. • Increased public awareness about green energy, the energy transition and the internal energy market due to visibility of end users to wholesale market dynamics.

Table 28 – Preliminary business modelling canvas for the Retailer/BRP

4.3.7.5 Preliminary business modelling canvas for the ESCO (WiseHOME, WiseCORP)

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• Prosumer • Retailer	• Local generation, forecasting • Human-centric demand and flexibility forecasting • Intelligent, human-centric energy management. • Indoor air quality and comfort management.	• The optimal consumption rescheduling during the implicit DR event maximizes the ESCO's revenues. This process may include the following actions: • Human-centric energy management for cost minimization • Always meet the convenience constraints of the citizens.	• Metering data from the consumer/ prosumer • Building and operational boundaries (e.g. comfort preferences, machinery/process constraints) via WiseCORP/ WiseHOME • Receives and elaborates the energy prices & forecasts from retailer.	• Energy-conscious residential electricity consumers & prosumers • Tertiary building owners/ occupants. • Citizens approached via ad campaigns (e.g. online) • Tertiary building managers to be reached in trade events and press.

Value network graph	Barriers
Figure 13.	• Reluctance of residential consumers to be exposed to dynamic prices in fear of energy cost increase • Uncertainty about inherent demand flexibility available in various building typologies and relevant activities/operations. • Limited paybacks (especially from domestic prosumers) make the engagement of the ESCO questionable. • Questionable revenues because the prosumers may not always follow the optimal suggestions.

Cost Structure	Revenue Model
• Development and operational cost of the WiseHOME / WiseCORP tool, or alternative the license - cost paid to a third party. • Energy management strategy definition per customer. • Operational expenses (payroll, etc.) • Communication, measurement & control infrastructure (depending on agreement with	• Receives a portion of the prosumer's electricity bill savings. • Receives an additional flat-fee from the prosumers (based on the contractual agreement between the two parties).

customer).	
Societal and Environmental Costs • Demand flexibility may incur inconvenience or operations degradation, if not properly managed. • Suboptimal demand shifting may lead to increased energy costs and energy poverty.	**Societal and Environmental Benefits** • As described for the retailer/BRP actor.

Table 29 – Preliminary business modelling canvas for the ESCO

4.3.7.6 Preliminary business modelling canvas for the Prosumer

Key Partners	Key Activities	Value Propositions	Relationships with other partners	Customer Segments and Communication.
• ESCO • Retailer	• Inform the ESCO about his convenience constraints (e.g., temperature comfort zone). • Inform the ESCO about the capabilities of the installed equipment. • Follow the optimal consumption and generation schedules as proposed by the ESCO.	• Efficient consumption shifting/shedding according to the dynamic energy prices. • Efficient utilization of the RES units and batteries. • His convenience constraints are not violated.	• Purchases electricity from the retailer • Receives retail prices, contracts and energy bills from retailer. • Receives schedules, set point data, historical operation data and billing information from the ESCO.	The prosumer is not selling something in the implicit DR scenario (he/she is the customer of the ESCO and the retailer/BRP)

Value network graph Figure 13.	**Barriers** • Reluctance of residential consumers to be exposed to dynamic prices in fear of energy cost increase • The potential paybacks from the participation in DR events may not be enough for the prosumer to accept the inconvenience cost.
Cost Structure • Provision of a portion of the savings and a flat-fee to the ESCO. • Communication, measurement & control infrastructure (depending on agreement with retailer, DSO).	**Revenue Model** • Reduced electricity expenditure due to shift of demand to times of lower prices.
Societal and Environmental Costs • As described for the retailer/BRP and the ESCO.	**Societal and Environmental Benefits** • More efficient utilization of the RES units at the local level, may reduce or eliminate the need for grid reinforcement and to lower CO2 emissions from fossil-fuel plants. • As described for the retailer/BRP and the ESCO.

Table 30 – Preliminary business modelling canvas for the Prosumer

4.4 REFERENCE TABLE FOR ARCHETYPE BUSINESS MODELS

The table below summarises, as a reference for the reader, the key components of the BMs described above.

Archetype BM	Related HLUCs	Key energy technologies	Main actors involved	Candidate pilots for evaluation	WiseGRID products
1. Promoting RES installations via RESCOs	HLUC1, As extension in: HLUC3, HLUC4, HLUC6, HLUC7	Solar, Wind, Storage,	Prosumer with batteries, RESCO, ESCO/ EE&EM	Crevillent, Ghent, Terni, Mesogia, Kythnos	WG RESCO, WiseCOOP, WiseCORP, WiseHOME
2. Efficient monitoring and management of the distribution grid.	HLUC2 Utilized for services request in: HLUC3, HLUC4, HLUC5, HLUC6	Observability devices for data collection (smart meters, sensors)	DSO	Crevillent, Terni, Mesogia, Kythnos	WG Cockpit
3. Exploiting the integration of EVs in the grid	HLUC3 As extension in: HLUC4	EVs, Storage, EVSE for G2V and V2G services, Sophisticated "smart charging" software	EV Fleet Manager ("Intelligent" Prosumer), Individual EV owners, EVSE Operator, DSO	Crevillent, Ghent, Terni, Mesogia, Kythnos	WiseEVP, WG FastV2G, WG Cockpit
4. Prosumers driven energy storage integration	HLUC4	Solar, Storage, Smart home energy systems	Prosumer with batteries and RES, Storage Unit Operator, ESCO/ EE&EM, DSO, VPP Operator	Crevillent, Ghent, Terni, Mesogia, Kythnos	WG STaaS/VPP, WiseHOME, WiseCORP Information Exchange with: WG Cockpit, WiseCOOP
5. Exploiting co-generation in domestic and tertiary buildings	HLUC5	CHP, Thermal storage, HAVC system	Prosumer with CHP, DSO, Gas Retailer or DSO, Aggregator/VPP Operator, ESCO/ EE&EM	Mesogia	WiseCORP WiseHOME Information Exchange with: WG Cockpit, WG STaaS/VPP
6. Exploiting the VPP assets	HLUC6 As an extension in: HLUC4, HLUC5	RES, Storage	Prosumer, ESCO/ EE&EM, VPP operator, DSO	Crevillent, Ghent, Terni, Mesogia, Kythnos	WG STaaS/VPP, WiseHOME, WiseCORP Information Exchange with: WG Cockpit
7. Supply-demand balancing by means of implicit DR events.	HLUC7 As extension in: HLUC3, HLUC4, HLUC5	RES, Storage, Smart home energy systems	Prosumer, Retailer, ESCO	Crevillent, Ghent, Terni, Mesogia, Kythnos	WiseCOOP WiseHOME, WiseCORP

Table 31 – Summary table of the archetype BMs

5 SOCIAL AND ETHICAL ISSUES OF SMART GRIDS

5.1 INTRODUCTION

In this section, the development of smart grids will be analysed with regard to its implications on social and ethical matters. This section draws primarily on the EU context, although it has its conceptual background in international law and policy. The ethical framework is founded indeed on international human rights law as incorporated into the Treaty on the Functioning of the European Union (TFEU). The primary aim of considering the ethical framework when dealing with the development of smart grids is to ensure that smart grids contribute to the further realisation of economic and social rights within a period of transition to a low-carbon society. Society needs to be engaged and should benefit from the technological transformations occurring in energy generation and consumption. This report highlights opportunities and potential downsides of the path towards the achievement of such goals.

In Section 5.2, the report focuses on how smart grids can contribute to a broader economic transformation. It considers the economic transition occurring globally towards collaborative economics and how the EU aims to incorporate new market exchange models into smart grids energy systems. Attention is paid to the potential social and environmental benefits, but also the challenges that lie ahead in realising the future policy goals.

Section 5.3 explores how the EU is working towards fostering more flexible, open, transparent and dynamic policies within the energy sector. To achieve a low-carbon sustainable society that is fair and equitable for all, the new model has also to reduce the use of resources and to use them efficiently. The section also outlines the importance of new concepts in the management of resources, such as circular economy, which aims at closing the loop on waste and inefficiency throughout the whole product lifecycles, including the design phase.

In section 5.4, the report takes up issues relating to ICT and smart grids. The first two sections give an overview of the key issues raised by the integration of ICT into energy systems, and address the cyber security and privacy issues of smart grids. The next section considers international and EU legal responses to those issues, focusing, in particular, on privacy and data protection and on Digital Systems Security.

5.2 SMART GRIDS: CONTRIBUTING TO THE EU COLLABORATIVE ECONOMY

The introduction of smart grids into the EU energy grid heralds a crucial transformation. The EU is in the process of investing in radical reform of the economic foundations upon which it depends. At the national level, some European countries are already implementing strategies for the change. In Germany and Denmark, for example, most wind power is locally or co-operatively owned, or, sometimes, both [96]. Also, at the international level, different projects are developing communities around smart grids. Brooklyn Microgrid projects, for example, aim to: “increase the amount of clean, renewable energy generated in the community by members of the community; develop a connected network of distributed energy resources which will improve electrical grid resiliency and efficiency; manage these distributed energy resources during power outages and emergencies to protect the community and local economy; create financial incentives and business models that encourage community investment in their energy future, creating energy and jobs that boost the local economy” [97]. At any level, the strategic decisions adopted are driven by many interconnected factors and there is an increasing social and community acceptance of some of the concepts that the smart grids refer to, such as renewable energy [98]. The main difficulties seem to be found not only and not much within the technical aspects, but more within the policy-related and regulatory issues [99].

The approach to the transition to a low-carbon economy that the European Commission has embraced is based on flexible, dynamic, digital and resource efficient new economic models [100]. This will increase the reuse of materials to add value to each product’s life-cycle and reduce dependency on sourcing natural resources externally. Such moment of transition could be a substantial opportunity to overcome existing inequalities throughout the EU Member States, while the EU economy continues to recover from the 2008 economic crisis [101].

This section highlights the interlinkages between the different policy and governance approaches to sustainable development, and resource efficiency within a collaborative economy. It considers such approaches to emphasise the role that smart grids could play towards achieving the EU policy goals.

An introduction to the concept of the collaborative economy will be provided in section 6.2.1. Section 6.2.2 focuses on the EU context, while section 6.2.3 specifically links the potential of a collaborative economy with a smart grids energy system. The final section focuses specifically on energy poverty, as an example of the social benefits that the collaborative economy can provide.

5.2.1 The Collaborative Economy: A 'Disruptive Innovation'

The collaborative economy has become a major phenomenon in recent years due to increased business opportunities made possible by advances in digital information communication technologies (ICT). The digital economy has opened up new innovative ways for people to engage in the market exchange of goods and services that circumvent the existing institutional economic structures [102]. The collaborative economy provides the opportunity for individuals and/or communities to offer their assets, time and skills within the digital market place [103]. This is particularly relevant to those looking to develop market mechanisms to tap into low-carbon energy generation and distribution from decentralised energy communities [104].

The collaborative economy is a phenomenon which can profoundly change the way consumers buy or rent goods and services. It can also allow consumers to enter the market in order to provide goods, services, time or skills themselves and become prosumers. Within such business models, the traditional business-to-consumer relationship is no longer the norm. A trilateral relationship is created instead: a consumer, a provider of a service or good, and the intermediary platform with anyone being one or more of these actors [105]. The collaborative economy business models, unlike traditional markets, are based on relationships of trust, reputation and reviews systems.

The advent of the collaborative economy, also referred to as the sharing economy, is what economists call a "disruptive innovation" while some even talk of it being, alongside the digital economy, "the fourth industrial revolution" [106]. Despite the concept of sharing goods and services is not without historical precedence, what differentiates traditional collaborative economic activities with the proper collaborative economy is that the sharing/collaborative model "has progressed from a community practice into a profitable business model" [107]. The concept has a certain dynamism that fits within the advent of artificial intelligence, big data and 3D printing [106]. The collaborative economy represent a big change from traditional markets as it brings operators to make their offer and business models more modern. This competition is generally good for consumers [108]. It can indeed make consumer markets more efficient as it brings down transaction costs and it is able to offer cheaper products and services.

As the phenomenon penetrates more into the everyday lives of people, in order to provide essential services, such as energy, it is important that appropriate regulatory frameworks are adopted. This has to be done in such a way that the dynamism and flexibility of the exchanges between new small scale enterprises providing services is not undermined. Indeed there are many benefits the collaborative economy offers to consumers and prosumers, but also risks. Advantages and disadvantages of the collective economy will be analysed in the following sub-section, which focuses on the European context.

5.2.2 The EU and the Collaborative Economy

Supporting consumers, businesses and public authorities to participate and contribute to the success of a collaborative economy is central to the future economic strategy of the EU, and the EU sees the collaborative economy as a new opportunity [100]. Commission Vice-President Jyrki Katainen even stated that "Europe's next unicorn could stem from the collaborative economy", stressing the innovative potential that might be revealed from the collaborative economy in the area of products or services [108]. When considering such a new business model, the EU is also aware of the scale of challenges that exist to deliver such benefits [109]. The new economic model should, indeed, happen without undermining existing consumer and employment rights, alongside other regulations on health, safety and the environment. The European Commission cautions that a “fragmented approach to new business models creates uncertainty for traditional operators, new services providers and consumers alike and may hamper innovation, job creation and growth” [109].

The implications of the sharing economy for law, regulation and policy making are only beginning to be considered [110]. The European Commission, national competition authorities, and consumer protection regulators in Europe are currently in the process of formulating their regulatory approach to some idiosyncratic issues raised by the sharing economy. When adopting the Single Market Strategy in 2015, the European Commission, announced that it "will develop a European agenda for the collaborative economy, including guidance on how existing EU law applies to collaborative economy business models" [111]. At the moment, the non-regulatory approach currently followed by the EU relies on many pre-existing legal concepts, often ill-adapted to this new model of doing business, thus bearing the risk of extreme fragmentation along national lines [112]. This will frustrate efforts to incorporate the collaborative economy into the (updated) Single Market Strategy, including the European Energy Union.

The collaborative economy expansion and success is intrinsically linked with new technologies. Cloud computing facilities, for example, are considered integral by the European Commission to create new opportunities to foster innovative business models, including the collective economy, because many new innovations depend on access to data at reduced costs [113]. Special Rapporteur Hans Graux notes that “small businesses in particular can benefit from the cloud, as they can gain access to high-performance IT solutions, which will help them to adapt quickly to new market developments and to innovate and grow their businesses faster” [114]. Given this perspective, the cloud has an enormous role to play in delivering decentralised energy provisions in the EU energy generation, as it will open up opportunities for new, small and medium scale actors, so to manage data from wireless and internet applications that increasingly constitute smart grids.

5.2.3 Smart Grids: A Platform for the Collaborative Economy

The smart grid is an “an integrated system that includes technologies, information (availability, accessibility, utility), human and social influences, organizational and managerial supporting arrangements, and political (policy) constraints as well as facilitation considerations” [115]. Smart metering systems are one stepping stone towards smart grids, empowering consumers to actively participate and influence the energy market. Under Directive 2009/72/EC and Directive 2009/73/EC of the European Parliament and of the Council, EU Member States are required to “ensure the implementation of intelligent metering systems to assist the active participation of consumers in the electricity and gas supply markets.” That would expand the dynamic characteristic of the market, making possible time safe reactions from consumers that would levelized and harmonise associated costs. It is also an initiative to increase the number of energy providers within the European Energy Union network [116] that would only improve the balance between generation and consumption.

The European Commission explicitly acknowledged its Energy Union as a strategy “with citizens at its core, where they take ownership of the energy transition, benefit from new technologies to reduce their bills, participate actively in the market, and where vulnerable consumers are protected” [117]. Local energy consumers are crucial to deliver a new power market design that enables consumers to participate in the market through demand-side response, auto-production, smart metering and storage. In the Winter Package proposed by the European Commission in 2016, EU Member States are required to provide an enabling regulatory framework for local energy communities and users [18].

With the appropriate regulatory and legal frameworks to incentivise the participation of consumers, the energy economy has the potential to switch from a traditional supply-side driven system controlled by energy cartels into a demand led decentralised model that fosters competition from localised providers [19]. This potentially opens up economic and societal space for the emergence of the energy ‘prosumer’ at a level that is truly transformative. To achieve this, political priority will need to support decentralisation, countering decades of investment of political capital – and the requisite law legal infrastructure – for large-scale energy business, including national companies. This demonstrates that decentralisation can deliver secure, affordable and sustainable energy supplies and could potentially provide the necessary persuasion to governments and citizens alike to embrace new energy systems.

5.2.4 Delivering Social Benefits in a Collaborative Economy

The relationship between new technologies and social changes are at the core of the energy/climate debate [118]. There is an overwhelming belief that informed individuals will make rational choices that will benefit society and the environment. Nonetheless the embedding of new technologies within society can have also unforeseen consequences. It is very interesting to consider the unplanned consequences, and perhaps even the distorted incentives, that the up-scaled adoption of new technologies into the very structure of society and our economy can have. Therefore, there is a need to question the "smart utopia" being offered [119].

One goal underpinning energy reforms is to address energy poverty across Europe. On average, 11% - over 54 million - of the EU citizens experienced some form of energy poverty (being unable to keep homes at ambient temperatures, having difficulty with bill payments and/or living with inadequate energy infrastructure services) [120]. The situation is especially pervasive in Central Eastern and Southern European Member States [121] but due to recent significant climate phenomena, that could expand to other parts of Europe as well.

In addition to the cost on economic terms, the negative social and environmental impacts of energy poverty severely deteriorate the quality of life for vulnerable individuals and communities. Despite this, only a few EU countries (namely, the UK, Ireland, France and Cyprus) have adopted legal definitions recognising energy poverty [120]. The causes of energy poverty are multiple. A key issue is the structure of energy markets which impacts energy pricing and determines, to some level, incentives for more efficient energy use. Investments in upgrading and incorporating modern digital ICT into the energy system need to tackle energy poverty at the forefront of its ambitions.

The potential of smart grids to contribute in addressing energy poverty in the EU will be determined by key policy and regulatory decisions. Policy design needs to take account of the interconnections with other related strategies being pursued by the EU. The Digital Single Market Strategy is central to smart grids achieving economic value. Such a strategy focus is on maximising the growth of Digital Economy potential by boosting competitiveness [122]. It is clear that ICT is already leading to new business models – as part of the new collaborative economy – and there is great speculation that, with the appropriate regulation, such new models could facilitate a more social, just and equitable economy within Europe, as well as globally [123]. Nonetheless, whether these models can actually play a role in tackling some of the energy poverty issues remains to be seen.

To determine how to ensure energy poverty is best addressed, a distinction needs to be made between the traditional consumers and those who are active service providers in the collaborative economy. The demographic affected by energy poverty and new service providers within the collaborative economy are by no means aligned. Energy poverty occurs largely in marginalised, vulnerable and poorer communities, often in rural areas and small towns [120]. The actors driving the collaborative economy tend to be from urban and affluent communities [124]. Individually, the profiles also differ from those being active in forming and benefitting from the opportunities of the collaborative economy, coming from well-educated, younger and technology literate cohorts of the population [125]. However, it is argued that the collaborative economy opens up opportunities to young marginalised communities, who can enter the business sector without the need to meet professional cultural standards [124]. There are also concerns that transnational corporate players within the collaborative economy could appropriate emergent micro entrepreneurs. Such companies have actively sought to lobby the law-making process within the EU. In a 2016 open letter to the Netherlands Presidency of the Council of the European Union, 47 commercial sharing platforms, including Uber and Airbnb, urged the EU Member States to "*ensure that local and national laws do not unnecessarily limit the* *development of the collaborative economy to the detriment of Europeans*," by citing the benefits stemming from sharing services [126]. It is integral that "benefits" are understood to be social ones and not just "commercial" benefits. In order for the collaborative economy to be socially sustainable, these benefits need to be available not just to those who can become market providers, but also to service users [127].

The collaborative economy as a fluid, flexible organising market, will not per se result in affordable energy pricing targeting at those most in need [128]. However, it can deliver opportunities in terms of efficiency and affordability to consumers. Such a potential depends on the structure of the energy market. Decentralisation to increase competition, although part of the EU energy reform packages, has actually resulted in limiting competition even amongst large-scale providers. The intention under EU energy strategies of increasing energy cooperatives, which are able to deliver energy locally with the greatest efficiencies, requires clear policy incentives. This will need government intervention to ensure that the social opportunities are realised. Delivering social and environmental benefits to all must be at the core of the pathways to achieve a low-carbon energy transition. The next section considers how the EU is approaching the challenges.

5.3 LOW-CARBON TRANSITION PATHWAYS AND SMART GRIDS

5.3.1 Conceptualizing issues

The adoption of smart grids can have a vast positive impact on EU policy on energy and climate. The 2015 Paris Agreement has provided a significant boost to deliver the policies agreed by the EU countries on energy and climate. The Agreement is a global driver to invest in technology, law and policy to achieve a low-carbon world. The potential pathways to achieve this energy transition are many, but principles of justice, equity and fairness should inspire the whole approach to the change.

The maximum increase of the global average temperature that the UN Paris Agreement is aiming at is between 2^{0}C and 1.5^{0}C above pre-industrial levels [129]. A 2°C warming will result in a new climate regime, particularly in tropical regions, whilst 1.5°C warming will bring the Earth to a climate at the outer edge of historical experience for human civilisation [130]. The risks associated with the rising global temperature are driving action that will have political, economic, environmental and social impacts [131]. Either temperature outcome under the Paris Agreement will have impacts on existing energy systems, especially the infrastructure for generation and distribution [132]. It has to be considered that both of the targets of the 2°C and 1.5°C are likely to be reached, given the gap from the existing intended nationally determined contributions submitted by the Parties. Maintaining security and resilience requires engineers, policy-makers and regulators to create future climate-proofed energy systems as part of the process towards a low-carbon new model.

The EU has recognised the scale of the task. The EU Sixth Environmental Action programme identified that climate change was the "outstanding challenge of the next 10 years and beyond" [133]. It has deliberately interlinked climate change policy with energy policy in order to develop pathways towards a low-carbon economy. To encourage the transition to a more secure, affordable and decarbonized energy system [134], the EU adopted climate and energy targets to be achieved in the coming decades. In 2007, the "Europe 2020 Strategy" set three key targets: 20% cut in greenhouse gas emissions (from 1990 levels); 20% of EU energy from renewables; 20% improvement in energy efficiency [135]. In 2014, the EU set the target to reduce greenhouse gas emissions by at least 40 per cent by 2030 from 1990 levels [136]. The EU also adopted a long-term goal aiming at reducing EU greenhouse gas emissions by 80–95 per cent below 1990 levels by 2050 [137]. The steps to be followed towards green policy and energy union need to be monitored and controlled to avoid dangerous imbalances that could dramatically affect the market prices. In February 2015, the Energy Union Strategy was launched, with the goal of leading to a sustainable, low-carbon and environmentally friendly economy [113], the steps to be followed towards green policy and energy union need to be monitored and controlled to avoid dangerous imbalances that could dramatically affect the market prices.

In spite of such ambitious targets, the link of energy with climate-related issues is relatively new within the EU. Although energy issues have always been at the heart of European integration, energy related topics (such as climate change policy, renewable energies, energy planning energy security of supply) have only gained growing importance on the EU's policy and regulation agenda following the increasing importance that the concept of sustainability has gained at the European (and also international) level [138]. Such a different approach has resulted in considering the three dimensions of sustainability (economic, environmental and social), within any EU policy. It is encouraging that energy and environmental regulations are now clearly understood to be two sides of the same coin, when, previously, they were perceived as separate competences [139]. Developing strategies to achieve both climate and energy targets will require effective institutional management and good multilevel governance, involving existing and new actors. A new transitional approach will help to achieve such a goal from an institutional point of view.

Until quite recently, the concept of transitional justice has been associated only with post-conflict truth and reconciliation processes [140]. However, an increased number of justice scholars are seeing the value of applying the concept to other political and legal developments related to human rights, natural resources management and climate change law [141]. A multidisciplinary approach to explore the discourse and practice of transitional strategies within EU climate and energy policy can offer a conceptual foundation for understanding the justice dimension of the dynamic normative transition within other jurisdictions and contexts. A transitional justice approach to the transformation from carbon-dominant energy systems to one's based on smart grids and renewables could offer the EU a methodological pathway that will help addressing pressing social issues such as energy poverty, which exists to varied degrees in all European countries, as discussed above (see Section 5.2.4).

It is evident that the EU is seeking to undertake a transformation towards a low-carbon economy that can meet these challenges. The EU is increasingly seeking to include such principles within those laws and policies that aim at achieving resilient economic, social and environmental systems [142]. The intersection between social, economic, environmental and political rights across all communities of energy users, including marginalised and vulnerable groups, needs to be explored as part of a more interconnected examination of every action of the EU, also considering its forefront position of addressing environmental issues adopting a more inclusive, holistic and integrated approach [142].

The Fifth Environment Action Program (EAP) (1993) was a reaction to the perceived failure of regulatory measures to achieve environmental goals, adopting innovative regulatory models that differed from the traditional "command-and-control" approach, in favour of an approach that implied to "shared responsibility between various actors: government, industry and the public" [143]. The EU has welcomed the principle of sustainable development, combining economic, social and environmental aspects, in 1997, when EU Member States adopted the Amsterdam Treaty, which came into force in 1999. This is now incorporated in Article 3(3) of the Treaty on European Union (TEU) and it can be considered a "constitutional objective" of the EU. In 2001, the European Council adopted the EU Sustainable Development Strategy, "a long-term strategy dovetailing policies for economically, socially and ecologically sustainable development" [144]. After this important step, the EU Sixth EAP (2002) advocated "a more inclusive approach including more specific targets and an increased use of market-based measures" [145]. This aims at strengthening the integration of environmental concerns into other policies, in an attempt to foster greater engagement and implementation by EU Member States [145]. The most recent EAP, the Seventh EAP (2013) [146], has an emphasis on decoupling economic growth from carbon emissions and establishing a circular economy [147]. To achieve the Seventh EAP goals, the Programme commits to a better integration of environmental concerns into other policy areas and ensures coherence when creating new policy. Strategic initiatives feeding into the Programme include the Roadmap to a Resource Efficient Europe [148] and the Roadmap for a low carbon economy by 2050 [149].

The EU Climate and Energy Package focuses on the fact that some contradictions could be encountered between the instruments for reducing greenhouse gases emissions and the protection of the environment. Although it is still not sure whether the package succeeds in balancing climate change mitigation with other environmental protection goals, it succeeds in supporting climate change mainstreaming [150]. The EU's climate policy and the EU leadership on the sustainability governance is in contrast with the complexities of the internal energy market. It is still rather underdeveloped, regardless of the abused existence of the term 'sustainability' within a significant number of legal instruments advocating for it [151]. Meeting renewable energy demand within a low-carbon economy will need to be done in a manner that does not result in negative impacts on the environment [152].

The EU, as a governance body, continues to invest in advancing innovative approaches to policy-making, in its pursuit of realising sustainable development [153]. In the 1990s, Collier observed that environmental policy integration is necessary for "achieving sustainable development and preventing environmental damage; removing contradictions between policies as well as within policies, and realizing mutual benefits and the goal of making policies mutually supportive" [154]. Given today's challenges of energy security of supply, climate change and biodiversity conservation, with the growing awareness towards an equitable allocation of resources, sustainable development perceived as a new constitutional paradigm is even more essential as part of the regulatory frameworks than when the concept was coined in 1987 [151]. The adoption of the Sustainable Development Goals by the international community at the UN General Assembly in September 2015 provided the EU with an opportunity to take forward the key principles within the TFEU and incorporate them into the very fabric of the policy-making, both substantively and procedurally [155].

As part of the 2030 Agenda for Sustainable Development [156], the EU is keen to reform the policy-making approach to ensure that it takes into account long-term impacts. In measuring progresses towards sustainable transitions and human well-being within the physical limits of the Planet, it is necessary to assess environmental sustainability. The so-called "Planetary boundaries" [157] for carbon emissions, water use and land use are being modelled to determine the ecological space available for sustainable development. "Growing scientific evidence for the indispensable role of environmental sustainability in sustainable development calls for appropriate frameworks and indicators for environmental sustainability assessment" [158]. Most decision-support systems and recommendations developed to analyse trade-offs between low-carbon energy generation and other interests have focused on single energy sources such as biomass, wind energy and hydropower. A way to represent the pressure that humanity exerts on the Earth's ecosystems, is to measure the environmental footprint. Recently, a growing list of such footprints has been created: the ecological footprint, the carbon footprint and the water footprint, for instance [159]. The anthropogenic impact on the Planet needs to be taken up by policy-makers, economists and lawyers when designing long-term strategies for pathways to a low-carbon world, including those working on smart grids energy systems.

The debate on sustainability has increasingly been complemented by the concept of building resilience into the system [160], and focused on long-term solutions. The European Environmental Agency has called for *"increased use of foresight methods, such as horizon scanning, scenario development and visioning [which] could strengthen long-term decision-making by bringing together different perspectives and disciplines, and developing systemic understanding. Impact assessments of the European Commission and EU Member States, for example, could be enhanced if they were systematically required to consider the long-term global context*" [161].

Technologies can either undermine or enhance resilience of systems [162]. The energy/climate debate is one infused with a faith in the positive relationship between the introduction of new technologies and social change [118].

It is not only the technological system, but also the social-ecological systems that need to be resilient to reduce the chances of exposure to shocks. "Social-ecological systems and socio-technical systems are understood to display complex, dynamic, multiscale, and adaptive properties; recommendations for their sustainable governance emphasize learning, experimentation, and iteration" [162]. The transition phase is one where multiple pathways are being pursued and the social-ecological ecosystem is at its most dynamic, but also most vulnerable stage [163].

Research into the slow uptake of smart grids has emphasised the importance of developing a diverse approach and establishing multiple pathways for transformation amongst all stakeholders to build resilience within the system [164]. There is the need for flexible, responsive regulatory frameworks that are fit for purpose in a transforming social-economic system. This requires lawyers and policy makers to recognise uncertainties within systems – in this case smart grid-based energy systems, as well as a more adaptive approach to governance, where incomplete knowledge of social-ecological systems is acknowledged and taken into account.

The transition to a low-carbon world will need the EU Member States, amongst other States, to carefully balance the new opportunities arising from ICT, alongside societal and environmental needs in a just, fair and equitable manner, delivering integrated sustainable outcomes across all sectors. One area where this is most necessary is the use and disposal of resources.

5.3.2 Smart Grids within a Circular Economy

A threat to EU economic security and growth is the access to raw materials. Increasing energy efficiency is part of a broader goal to increase resource efficiency in the EU [165]. One strategy is to develop a circular economy. This section outlines the concept and the reason why it is needed, especially in relation to the smart grids. The discussion covers themes of design obsolescence, extended product responsibility and e-waste management. The section considers how responsibilities should be allocated and to whom during the life cycle and value chain of products in a decentralised digital energy system.

The transition to a low-carbon economy will not be without waste. It is imperative that forethought goes into business modelling and resource management for the entire lifecycle of the product, in order to limit impacts on the environment, also contributing to increase energy efficiency.

The global growth in renewable energy capacity will soon bring end-of-life cycle waste management issues to the fore. Planning ahead is necessary to, firstly, manage the existing waste stream from established renewables, and, secondly, to also promote a circular closed loop approach to the whole life-cycle of products and contribute to a green economy [166]. Countries need to undertake reforms of existing laws and also develop innovative policy and regulation to meet these challenges. The risks are high, primarily because renewable energy is far from being 'clean'.

The EU energy targets promote energy efficiency, renewable energy, as well as decentralisation, but these goals also need to fit within the broader 2030 EU Agenda for Sustainable Development [167] and the Circular Economy Action Plan to increase resource efficiency and decrease waste [168]. The rising costs, driven by the growing demand for primary resources, including those needed for smart grid systems, requires new approaches to resource management along the entire life cycle value chain. The EU is increasingly recognising that the current economic model dependent on the linear use of materials is no longer viable, and this is the reason why closing the material loop is being prioritised [169].

5.3.2.1 The Circular Economy Concept and the EU

The circular economy, also known as a "closed loop" economy, aims to reach holistic sustainability goals and it is based on the concept of "no waste" [170]. In a circular economy, the end-of-life stage of products and materials must be replaced by restoration [170]. Reducing waste is therefore at the core of the circular economy model [168]. It is a concept that recognises the continuous potential value of materials, in an effort to reduce resource inefficiency in both production and consumption. These have to be the objective of a profound transformation. Consequently, the standard approach to creation, fabrication, and commerce of products has to change as well.

The EU is heavily dependent on imported raw materials, especially metal ores and non-metallic minerals that are found in electrical and electronic equipment (EEE) [171]. Since the design of a product directly influences the way a value chain is managed, building circular, globally sustainable value chains inevitably implies a fundamental change in the practice of design [170]. Recently, the EU waste law has become part of a wider policy discourse on sustainable production and consumption, moving towards the adoption of a circular economy. For example, as part of the Circular Economy Package, the European Commission has proposed the addition of an obligation to ensure that, by 2030, the amount of municipal waste put into landfill is reduced to 10% of the total amount of such waste [172].

The EU Commission has committed to analyse the current situation of critical raw materials in the context of the circular economy, with a focus on material-efficient recycling of electronic waste, waste batteries and other relevant complex end-of-life products [168]. With the transition to renewable energy systems sets by the 2020 EU Climate and Energy Package and the 2030 EU Climate and Energy Framework, greater efforts need to be made to incorporate the Circular Economy principles into systems infrastructure design. The implications of this new approach are yet to be fully appreciated. It is clear, however, that existing waste regulation needs to be revised and all actors throughout the supply chain of products need to assume new responsibilities to change the EU current production system and accomplish to close the loop, as required by the circular economy.

5.3.2.2 EU Waste Regulation: Key Principles for Renewable Energy and Smart Energy Grids

The EU has an extensive legal framework on waste management [173]. The 1975 Framework Directive on Waste (FDW) lays the foundation for the EU waste law. It defined key concepts, established major principles such as the waste hierarchy, and allocated responsibilities between different actors: authorities, producers and households [174]. Another important Directive is the 1999 Landfill of Waste Directive which introduced the end-of-life cycle principle. Such a Directive requires EU Member States to draft a national strategy for the implementation of measures aiming at developing a whole life-cycle approach to waste management and landfills [175]. It "sets targets to progressively reduce the level of biodegradable waste going to landfill and bans the landfilling of certain hazardous wastes, such as liquid waste, clinical waste and used tyres" [176]. The overall goal within the EU is to reduce the percentage volume of waste being discarded in landfills. Additional Directives included the Packaging and Packaging Waste Directive [177], the End-of-Life-Vehicles Directive [178], and the Waste Electrical and Electronic Equipment (WEEE) [179]. Each of these Directives took forward the FDW waste hierarchy and extended responsibility principles.

In 2008, a new FDW developed the waste hierarchy and extended responsibilities, especially for producers [180]. The Directive was based on Article 192(1) of the Treaty Framework of the European Union, which aims "to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use" [179]. The 2008 Directive incentivizes the concept of life-cycle of products and materials, encourages the recovery of waste and the use of recovered materials and develops end-of-waste criteria for specified waste streams [180]. Under the 2008 FDW, top priority should be given to prevention, followed by preparing for re-use, recycling, and other recovery, including energy recovery. Disposal is the least desirable option and it is at the bottom of the hierarchy.

Furthermore, the principle of responsibility is expanded. The FDW places responsibility for waste treatment upon the original waste producer. Under Article 15 of the FDW, EU Member States can specify the conditions of responsibility and decide in which cases the original producer is to retain responsibility for the whole treatment chain or in which cases the responsibility of the producer and the holder can be shared or delegated among the actors of the chain [180]. This includes that the original waste producer bears the cost of waste management.

The trend in the EU is towards recognising an extended producer responsibility to new products, product groups and waste streams, such as electrical appliances and electronics [181]. However, the effectiveness of extended producer responsibility within the EU Member States is variable. Different national applications of the extended producer responsibility principle lead to substantial disparities in the financial burden on economic operators. Having different national extended producer responsibility interpretations for waste electrical and electronic equipment hampers the effectiveness of recycling policies. For this reason, in 2012, the Commission proposed that essential criteria needed to be decided by the EU and minimum standards for the treatment of waste electrical and electronic equipment should be developed [182].

The EU is taking steps to address the impacts of renewable energy and smart grids – including the upscaling of solar PV, wind turbines and batteries for EVs. One substantive initiative in this regard is the amendment of the WEEE Directive for the collection and recycle of solar PV panels [182]. Most of the EU Member States have revised EEE waste regulation to include solar PV in national law (*e.g.* Spain [183] and Italy [184]).

The principle of producer responsibility could be extended for manufacturers to recycle wind turbine blades in the same way it has so effectively been done with the WEEE Directive amendment [176]. If legislation is introduced within the wind energy industry, it is likely to be similar to the end–of–life vehicles legislation that introduces set recycling and recovery targets for manufacturers, therefore requiring the producer to have more responsibilities. Some EU Member States have adopted measures to deal with the problem of wind turbine blades landfill dumping. Consequently, materials with a high organic content (e.g. wind turbine blades) need to find different end-of-life routes. R. Cherrington *et al.* stated that "landfill bans effectively divert waste from landfill and drive towards energy recovery" [176]. EU legislation increasingly discourages the disposal of waste to landfill, setting steeper reduction targets, for example the reduction of 10% by 2030 included in the Circular Economy Plan [172]. Wind turbine manufacturers could take the initiative. Investing in solutions now will provide time to develop efficient systems and reduce technology costs [185].

The amendments to the WEEE Directive to increase recycling of solar PV panels and proposals to limit the discarding of wind turbine blades in landfills are important steps to manage the end-of-life waste from these renewable energy sectors.

5.3.2.3 New Concepts and Principles to Close the Smart-Grid Loop

Extending producer responsibility (EPR) was intended to incentivise manufacturers to increase waste management efficiencies through better product design. EPR's rationale is that financial and/or physical responsibility on producers brings them to internalize waste management considerations into their product strategies [186]. Reports illustrate, however, that extended product responsibility remains a distant goal within the EU [187]. A new model is needed, and the EU Circular Economy Action Plan [168] goes in such a direction, as it tackles one of the main obstacle to a fair management of the life-cycle of EU products: the planned obsolescence.

This term dates back to the Great Depression, when Bernard London recommended the strategy as a way to foster economic recovery [188]. London perceived the economic value of stimulating repetitive consumption, and lightbulbs were the first items to be designed with planned obsolescence in mind [189]. On the contrary, the circular economy is based on the principle of planned durability, of which manufacturers have full responsibility. Improving product durability and reparability is important in reducing pressure on natural resources, reducing import costs for manufacturers, as well as saving money for consumers [189].

There is no legal definition of durability, but, so far, the European Commission has proposed the following: *"Durability is the ability of a product to perform its function at the anticipated performance level over a given period (number of cycles/uses/hours in use), under the expected conditions of use and under foreseeable actions. Performing the recommended regular servicing, maintenance, and replacement activities as specified by the manufacturer will help to ensure that a product achieves its intended lifetime"* [169].

The practicalities of delivering planned durability are numerous and challenging [190]. Manufacturers generally want to restrict access to spare parts, and limit repair and reuse of old products [191]. Key issues include not only the cost of spare parts but also access to information and skills development. The EU has produced a number of reports exploring the potential for using regulations to stimulate durability, reparability and reusability of products [192]. It has also developed rules to increase design durability for some products, such as lighting and vacuum cleaners. Several EU Member States have introduced national legal measures to reduce planned obsolescence and increase reparability [193]. France, for instance, has introduced a law to address planned obsolescence. Article L. 213-4-1 of the Consumer Code now reads: "Planned obsolescence is defined by all the techniques by which a person that places goods on the market seeks to deliberately reduce the lifespan of a product to increase the substitution rate" [194]. Although limited in scope, due to pressure from manufacturers lobbying in the negotiation of the law, interpretation by the courts could provide positive developments to reduce design obsolescence. Another example is Norway that requires companies to extend consumer guarantees on certain products, increasing the responsibility of the manufacturer [195].

To overcome excessive and unnecessary consumption, product designers need to factor durability and reparability to product design. Spare parts should be made easily available at an affordable price that, consequently, incentivises repair. Design models have to be able to incorporate old components into newer versions of a product. Also, regarding software, making new software compatible with older models can deter consumers from upgrading to new versions. The electronic equipment industry has notoriously exploited incompatibility across new models as well as fostered design obsolescence, which has driven a global e-waste disposal crisis, especially in several developing countries, such as Nigeria [196]. Apple even have the battery built into their computers and phones. Batteries are a component that is easily replaced, as well as being a high level toxic waste that requires safe disposal, using the best available technology.

The Eco-design Directive is a key instrument in order to promote durability [168]. Already used to set binding minimum energy efficiency requirements, the Directive is being used to develop new eco-design requirements to manufacturers, so that they need to provide mandatory information on proper disposal, disassembly and recycling at the end-of-life stage, especially for product groups with toxic content (e.g. mercury) [190]. Extension of lifetime is specifically listed in the Directive and for certain products is "expressed through: minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability, reparability" [197]. A different way of tackling the issue is through an indirect approach, where voluntary based agreement with manufacturers are signed. Even if those agreements are not compulsory, they imply the interest of the manufacturers to commit to these issues, making such a voluntary approach sometimes even more effective than legal or regulatory rules, leading to better and longer term results in terms of contribution to the circular economy [198].

The definition of durability does not refer to reparability. Design for reparability is difficult to measure and can lead to legal complexities, if not addressed [169]. Durability and reparability are two sides of the same coin [195]. The circular economy opens up opportunities for small and medium scale enterprises to provide reparability and recycling services. Remanufacturing and repair industries need rules that clarify that the repairer, or anyone putting the product into re-use, should not be considered to be the manufacturer/producer of the repaired/re-used product. Becoming a "producer" in the meaning of some EU Directives will be indeed avoided by the re-manufacturers, because they would be otherwise economically responsible for the collection and the recycle of the product and they would have to comply with the requirements of "new" products, such as respecting the rules on energy efficiency [195].

The complexity of smart grid systems will undoubtedly lead to demand manufacturers and service providers to offer support services to consumers. It will benefit consumers, the collaborative economy and the environment, as well as future generations, if the legal and regulatory framework were in place to ensure this occurred in a circular economy where all the loops are closed.

5.4 DIGITAL TECHNOLOGY, SMART GRIDS AND LAW

5.4.1 Background

Amongst Information and communications technologies (ICT), new digital applications for smart grids play an essential role in creating opportunities to meet the various EU energy policy goals (including efficiency, security and sustainability) by enabling new energy providers to monitor and process data. New digital technologies have made it possible to re-design the traditional analogue electricity power system infrastructure that has dominated the energy landscape in Europe since World War II. A transformation in the energy system will provide new opportunities not only to energy suppliers, but also to consumers [199]. Through advanced sensing technologies, it is now feasible to provide predictive information and bespoke recommendations based on almost real time data to all stakeholders (*e.g.* utilities, suppliers, and consumers).

Smart grids refer exactly to this new digital networked energy infrastructure [200].

Smart grids services, amongst which intelligent appliance control for energy efficiency and better integration of distributed energy resources, can reduce carbon emissions: They offer the potential of higher level capabilities to meet current and future energy demands [201]. Smart grids could deliver improved performance related to concepts such as reliability, resiliency, environmentally friendly generation, transmission, and distribution, which will help the EU to achieve strategic economic, environmental and social goals [202]. These changes, which ultimately make energy systems more complex, have led to concerns regarding potential cyber-attacks of critical infrastructure, energy and data theft, fraud, denial of service, hacktivism and design obsolescence adding to energy poverty [203]. Also, the regulation of smart grids and smart meter technologies directly impacts the way data privacy is implemented in technical systems (like smart meters and energy saving services) [204].

It is contended that the intelligent control and an adequate economic management of energy consumption require a higher degree of interoperability between consumers and service providers: "*Unprotected energy-related data will cause invasions of privacy in the smart grid*" [201]. Law and policy-makers need to consider the trade-offs to enable smart grids to deliver low-cost and green energy within locally, regionally and nationally secure networked systems. Given the dependency of smart grids on digital technology, their uptake is intricately interlinked with law and policy on ICT more generally.

This section outlines developments in ICT law that are relevant to smart grids, both internationally and in the EU. The first section provides a survey of key law and policy issues related to security and privacy, when dealing with smart grids and ICT, including the analysis of concept such as cyber-security, cyber-crime and data management. The section is followed by an outline of existing and emerging EU and international legislation that addresses the above-mentioned issues and will be divided into privacy and data protection and digital systems security.

5.4.2 Smart Grids and Security: Cyber Security and Privacy Issues

With smart grids come risks. Some risks are known old and foreseeable issues; others are new and less predictable. Cyber-security is likely to acquire increasing importance in the next few years [205]. Cyber-technologies are becoming less expensive and easier to acquire, which allows States and even non-State actors to potentially inflict considerable damage to countries [206]. Cyber-operations may not only be used for industrial espionage or intelligence collection, but also to delete, alter, or corrupt software and data resident in computers, with possible negative repercussions on the functionality of computer-operated physical infrastructures, including disabling power generators [206]. Smart grids increasingly couple information in the energy sector with digital communication systems. This has created new vulnerabilities and resulted in smart grids becoming a security domain issue beyond the traditional energy security framing and including cyber security [207].

Smart grids are integrated systems that includes technologies, information, social and organizational components, policy and political requirements, as well as legislation and regulatory compliance [202]. As a consequence, this increases the risk of compromising the ultimate objective of smart grids: reliable and secure power system operation. In 2008, the European Commission acknowledged that the electricity sector constitutes "an essential component of EU energy security" [208]. Some even argue that the current interdependence between the electricity and communication infrastructures is so profound that could be conceived within an "energy-and-information" paradigm [209]. This inter-dependence becomes even more intricate when considering the energy systems critical infrastructure status and the potentially catastrophic impact of cyber-attacks.

An effective regulatory framework manages both known and unknown risks, with the latter involving a precautionary approach. Smart grids need to ensure the security of sensitive customer information transmitted, an increasing number of internet of things (IoT) devices and communication between stakeholders reliant on the grid to deliver stable operation. There is a need to develop resilient formulations of risk related to holistic considerations [202]. An integrated multilevel governance approach is required to integrate smart grids securely within society, although it presents new legal challenges for lawyers and policy-makers.

Unlike traditional energy systems, smart grids fully integrate high-speed and two-way communication technologies to create dynamic and interactive infrastructure with new energy management capabilities [210]. Smart grid energy systems are "*a literal IoT*": networks with billions of interconnected smart objects, such as smart meters, smart appliances and other sensors [211]. As a cyber-physical system, an IoT-based smart grid present risks across different domains (i.e., generation, transmission, distribution, customer, service-provider and operations markets) [202]. The EU acknowledges that smart metering systems and smart grids foreshadow this impending IoT, and that with this come potential risks associated with the collection of detailed consumption data that are only likely to increase in the future [212]. Sander Kruese, privacy and security adviser at Alliander, a DSO in the Netherlands, noted that "Every component in the grid that has become digitized is becoming an attack-point" [213]. Providing securitization across the entire system, which is a system that continuously incorporates new software systems and hardware from a range of providers, is a demanding task to meet. The EU has adopted a strategy on cyber-security [214]. Operationalizing the goals contained in the strategy will be integral to address new potential threats posed by embedding ICT technologies into the EU's energy system [214].

Threats that were not possible in the traditional electric grid, such as energy theft and fraud, sensitive information theft, service disruption for the purpose of extortion, cyber-espionage, vandalism, hacktivism and terrorism, are now the main concern regarding the energy grid [211]. When combined with data from other multiple independent data sources (such as geo-location data, tracking and profiling on the internet, video surveillance systems, radio frequency identification systems, etc), smart meter data becomes part of a broader and more open meta-data system [215]. In different ways, all users are potential victims of attacks in such a context, and their vulnerabilities could be drown from previous experience gained in different sectors, such as IT and telecommunications [201]. As an example, automated smart meters rely on tracking, in real time, actual power usage and allow for a two-way communication between the utilities and end-users. Hackers targeting this technology may potentially induce disruptions in power flows, create erroneous signals, block information (including meter reads), cut off communication, and/or cause physical damage [216].

Digital ICT has accelerated the expansion of personal data systems – making them more extensive and more consequential in the lives of ordinary citizens [217]. The costs of using personal data in today's computerized record-systems are all but negligible. The result is that all sorts of personal data that would otherwise be "lost", are now "harvested" by different actors that do everything from allocating consumer credit to preventing cyber terrorist attacks. New technologies allow for an unprecedented level of information-integration, "*providing the possibility to combine new and existing data and technologies (interoperability) and cope with growing resources and number of users (scalability), through the adoption of distributed systems (cloud computing)*" [218].

Information gathered from energy users is integral to empowering individuals, households and organisations to change their consumption patterns, increasing efficiency, reducing energy costs and carbon emissions [219]. In 2010, the EU Commission noted that "the ICT sector should lead the way by reporting its own environmental performance by adopting a common measurement framework" [220]. There is an assumed positive relationship between data access, processing and dissemination to achieve beneficial behavioural change by citizens that underpins the EU policy.

Unlike "oil, a product that does not generate more oil (unfortunately) … the product of data (self-driving cars, drones, wearables, etc.) will generate more data" [221]. In a 2012 estimate, "90% of the world's data was created in the last two years alone. In fact, 2.5 quintillion bytes of data are created each day, which is more data than was seen by everyone since the beginning of time" [222]. However, a consequence of increased data availability, especially in the form of meta-data, is to narrow the realm of anonymity – so that fewer interactions, relationships and transactions are possible without identifying one's self [217]. This leads to questions about privacy and security [223].

In 1890, Brandeis and Warren, associated the need for privacy and solitude as a fundamental need for an individual due to the increasing intensity and complexity of life [224]. Privacy is going to be even further challenged in the digital era. Computer technologies increasingly make it possible to capture and use personal data in all sorts of settings and for all sorts of purposes that would once have been inconceivable. Leading figures amongst the on-line corporations have argued that privacy is no longer a social norm, or indeed possible: "Facebook and its CEO Mark Zuckerberg have taken the position that sharing of information and connectedness is the new social norm, and that privacy, on the contrary, is now outmoded" [225]. Key questions at stake include what personal information institutions and other non-state actors collect, how it is collected, where it is stored, who can access it and what actions can be taken on its basis [217]. It can be argued that this pressure on information privacy is not the result of a new social norm, but the consequence of a desire for profit, at the expense of pushing the privacy-protection boundaries [226]. What is evident is that governments and citizens in the EU are pushing back on these incursions on privacy. The EU has always indeed paid much attention to personal and domestic privacy, differently from many other context, such as the Asian one, for instance [227].

The perceived threat to security of personal and family life has led to a resistance to smart meters from citizens: For some householders, since their personal sphere is at stake, they consequently react with distrust, suspicion and hostility towards such new systems [228]. "Surveillance" via smart meters and IoT, therefore, results in extortion and fraud of the domestic sphere [229]. Ensuring privacy appears to be crucial in order to address social barriers and support the new energy system technologies as a result [229]. The European Commission has recognised that, in order to achieve its broader energy and climate policy goals, building consumer trust about smart grids and data management has to find a central role in its policy on smart grids. In the 2011 the European Commission advised that: *"Developing legal and regulatory regimes that respect consumer privacy in cooperation with the data protection authorities … and facilitating consumer access to and control over their energy data processed by third parties is essential for the broad acceptance of Smart Grids by consumers"* [230].

Increasing consumer and business confidence in smart grids needs good governance and effective regulatory frameworks and laws. In the following section the legal approaches adopted to deliver increased privacy, as well as reduce cyber-security risks from ICT and smart grids technologies are critically examined.

5.4.3 International and EU Privacy Laws

Dependence on smart-grids-ICT-based energy systems pose two major risks: one to privacy and data protection; the other to digital systems security. This section considers the evolving legal frameworks, especially within the EU, to provide a reasonable regulatory architecture to ensure the risks are managed effectively.

5.4.3.1 Privacy and data protection

Internationally, privacy is embedded in fundamental legal documents. Privacy is included as a normative principle in the post-war Universal Declaration of Human Rights (1948) and the legally binding International Covenant on Civil and Political Rights (1966) [231]. Developments in technology in the late 1960s and 1970s saw both the US and Europe to recognise the need to guarantee data protection alongside the right to privacy. Each jurisdiction, including EU Member States, adopted differing approaches [232].

The EU has separate legislation and guidelines on data protection that is technology neutral. Explicit recognition of the legal basis for data protection is contained in Article 16 TFEU. Article 7 of the EU Charter of Fundamental Rights protects the fundamental right to the respect for private and family life, home and communications and Article 8 provides specifically for the protection of personal data. EU data protection law has been decentralised in each Member State. The decentralisation of this governance structure has led to jurisdictional tensions amongst relevant public authorities; in respect of both the applicable domestic law to data processing operations and of the identification of the relevant enforcing national authority [233].

Additionally, the Member States of the Council of Europe have a positive obligation to act in a proactive manner in order to secure the effective enjoyment of protected under the European Convention on Human Rights: If it can be established that the State has failed to take appropriate measures to protect individuals under its jurisdiction from privacy violations, then it will be liable under the ECHR [234].

The European Commission has addressed data privacy matters and it has also specifically referred to smart grids technologies. The 1995 Data Protection Directive provides the foundational legal architecture for subsequent regulation [235]. Subsequent regulation and Directives have added in an ad-hoc manner to these initial foundations. The 2002 e-Privacy Directive [236], which was subsequently amended by Directives 2006/24/EC and 2009/136/EC, has failed to live up to the challenges that technological developments have brought along. The 2016 EU General Data Protection Regulation, however, repeals the current e-Privacy Directive. Other key legal developments included the 2008 Data Protection Framework Decision [237] and the Regulation 45/2001 [238].

The 1995 Data Protection Directive constitutes a layered system consisting of three levels. Amongst the referred three levels, the first one applies generally to every single processing of personal data. The second, which applies cumulatively to the first one, becomes relevant in respect of the processing of sensitive data. The third level applies, also cumulatively, to the transfer of personal data to third countries (i.e. in these latter cases all three levels apply [239]). All subsequent data protection legislation at the EU level needed to comply with these principles and they also had to be keep in mind by Courts, when interpreting related legislation. These principles are incorporated into the 2016 General Data Protection Regulation (GDPR) that will apply to all EU Member States in April 2018 [232]. Having said this, it is important to consider how new principles are going to be incorporated into the smart grids related law and policy.

Each principle needs to be applied according to certain conditions. Understanding the principles is essential to interpreting data protection laws to each given context, for example smart grids. The following considers key principles in greater detail:

Lawful processing – to understand this principle, it is necessary to refer to Article 52(1) of the EU Charter and Article 8 (2) of the European Convention on Human Rights (ECHR). The processing of personal data is only lawful when it is done so in accordance with the law, pursues a legitimate purpose and is necessary in a democratic society in order to achieve that legitimate purpose. However, there is no definition of what constitutes 'lawful processing' in Article 5 of the 108 Convention nor in Article 6 of the 1995 Data Protection Directive. The 2016 EU General Data Protection Regulation has not included a definition either. The obligations to meet the principle fall on the data gatherer and user. As such it is imperative in developing smart grids related regulations that lawmakers are clear what expected legitimate purposes might be for the data gatherers and users that are deemed reasonable.

Data minimisation – Data minimisation requires that the purpose of processing data be visibly defined before processing is started. This requirement, although part of EU law, is left open to Member States to interpret in domestic law. Having said this, there will be less scope for such flexibility under the GDPR 2016: Data specification requirements regulations are designed to limit the accumulation of data gathered and prevent the processing of data for undefined purposes [240]. This is a procedural requirement based upon the principle of transparency. The use of collected data for another purpose needs an additional legal basis if the new processing purpose is incompatible with the original one [240]. If data is transferred to third parties a new additional legal basis is necessary as well. The onus is placed on the data controller to comply with the obligations. A data controller must specify and make it clear to data providers the purpose for which data is being processed [241]. There is space for flexibility only if data is used for a compatible purpose. Both the Convention 108 and the Data Protection Directive resort to the concept of compatibility: the use of data for compatible purposes is allowed on the ground of the initial legal basis [242]. Neither law defines "compatibility" so this leaves open interpretation to determine if the initial legal basis for collecting the data is breached when used for a different purpose than the original one for which it was collected. The Data Protection Directive explicitly declares that the "further processing of data for historical, statistical or scientific purposes shall not be considered as incompatible provided that Member States provide appropriate safeguards" [243]. There is no requirement on the data controller, where collected data is used for a compatible purpose than the original one, to gain the consent of the data subject. This flexibility gives data controllers the freedom of using collected data further. This could result in uses that data subjects would, if they were made aware, actually object to. It is also a way to keep the data beyond the time period the original data was gathered for. Despite a lack of reference to consumer rights in even the most recent General Data Protection Regulation the European Data Protection Supervisor has stated that consumer protection law has a part to play in data protection, especially on the subject of transparency of data usage [244].

Data quality, retention and accuracy – it requires that all processed data is "adequate, relevant and not excessive in relation to the purpose for which they are collected and/or further processed" [245]. The data controller must ensure that the purpose of gathering the data is clear, that this is kept to a minimum, and that it is relevant for declared processing operations started. The data quality principle is aligned with the principle of limited data retention. Data should be deleted as soon as it is no longer needed for the purposes it was collected by the data controller. The obligation lies with the data controller to ensure that the principle on retention is met. As with the data minimization principle, exemption to the principle on data retention need to be established in law. Safeguards to ensure that their data is not used in contravention to the retention principle should protect data subjects. Data controllers are obliged to ensure that the data held is accurate as can reasonably be expected. This is essential for billing purposes, for example [246].

Fair processing – it upholds procedural transparency between data subjects and data controllers. Controllers must inform data subjects who they are processing their data on behalf of and about any intentions to process for other purposes. Fair processing prevents secret or covert processing which may be against the wishes or interests of the data subject. This principle is perhaps the most significant for developing trust between the data subject and the data controller [247]. For the principle to be effective, the terminology used to communicate with data subjects by data controllers must be understandable. Where data subjects have specific needs, these should be taken into account by the data controller, in order to meet the transparency principle obligations. Indeed, fair processing also means that controllers are prepared to go beyond the mandatory legal minimum requirements, if the legitimate interests of the data subject require so [247]. Going beyond what it is expected can be demonstrated by adopting data management standards. Data subjects should have free, easy access to their data. Data controllers should be able to demonstrate how their procedures meet the data protection requirements under EU law. This emphasis on accountability and legitimacy is integral to build secure and trustworthy relations between data generators and data controllers. According to the 2013 Organization for Economic Co-operation and Development (OECD) privacy guidelines "a data controller should be accountable for complying with [data management] principles" [181]. Also, according to the Article 29 Working Party's opinion [248], the essence of accountability is the controller's obligation to: put in place measures which would – under normal circumstances – guarantee that data protection rules are adhered to in the context of processing operations; and have documentation ready which proves to data subjects and to supervisory authorities what measures have been taken to achieve adherence to the data protection rules [249].

Data Anonymization /Pseudonymization – pseudonymization is central to significantly reduce the risks associated with data processing, while also maintaining the data's utility. The concept of pseudonymization is central to the GDPR. The GDPR defines pseudonymization as "the processing of personal data in such a manner that the personal data can no longer be attributed to a specific data subject without the use of additional information" [250]. To pseudonymize a data set, the "additional information" must be "kept separately and subject to technical and organizational measures to ensure non-attribution to an identified or identifiable person". Any "personal data," which is defined as "information relating to an identified or identifiable natural person 'data subject'," falls within the scope of the Regulation. There are limits to pseudonymization: pseudonymization is "not intended to preclude any other measures of data protection" [251].

Ongoing interpretation of principles in data protection law is important in considering their relevance for smart grids. All actors involved in supply and demand of energy via smart grids need to understand and consider how to meet the legal obligations they face. As noted above, failure to address concerns amongst regulators and customers over privacy issues in the smart grid will be a major obstacle to successfully moving forward with planned targets to establish the new systems [201].

Aware of this significant problem, in 2010, the European Commission established an institution body to examine the multiple regulatory matters relating to smart grids, the Smart Grid Task Force (SGTF). The SGTF brings together eight different Commission Director General including energy, climate, environment and justice along with 30 European organizations representing all relevant stakeholders on the smart grids arena, from both the ICT and the energy sector [252]. Given the cross-sectoral representation, the SGTF is seen as key to regulatory development on ICT and energy interconnections.

The SGTFs main purpose is to advise the Commission on policy and regulatory framework at the European level and to assist in coordinating initial steps towards the implementation of smart grids under the provision of the Third Energy Package [252]. Four expert working groups were established in April 2011 to explore the key challenges to smart grids deployment [230]. Expert group 2 (EG2) specifically focuses on privacy and security issues, including developing a data protection template, an energy-specific cyber security strategy, and identifying minimum security requirements. The mandate of EG2 was to provide a Smart Grid Data Protection Impact Assessment (DPIA) template. In 2014, the EG2 published a template for data protection impact assessment for smart grids and smart grid metering systems [253]. The purpose of the DPIA is to provide guidance on how to perform an assessment for smart grid and smart metering systems. The template will help organizations to take the "necessary measures to reduce risks, and as such, reduce the potential impact of the risks on the data subject, the risk of non-compliance, legal actions and operational risk, or to take a competitive advantage by providing trust" [253]. The DPIA is intended to help achieve holistic implementation of data protection principles and rules. It is this holistic approach that the SGTF believes will safeguard confidentiality, integrity and information assets for the smart grid system. Under the GDPR it is mandatory to conduct a DPIA.

The new regulatory landscape within the EU, dominated by the reform in data protection under the GDPR, is largely considered to provide more effective data protection and privacy arrangements for data subjects than previously. However, there remain concerns, especially with the rapid development in technology, including the up scaling of the IoT and Big Data, and it seems that legislators are perpetually fighting a losing battle on privacy [254]. The GDPR arguably restrains this slightly but only to a relatively limited degree, and arguably is easily circumvented by procedural formatting over 'consent' protocols [255]. Purtova argues that '*personal data will be appropriated in proportion to the de facto power of the data market participants to exclude others"* [256]. It may be that the boundaries within which the legal concept of privacy is interpreted are changing. Schwartz, who considers that the normative function of privacy lies in the formation of community and personal identity, argues that the individual specific privacy focus is now challenged, and that privacy should be seen as a condition of social systems instead of a feature of "inborn" autonomy or a means to control personal data [257]. The shifting nature of this debate will no doubt be evident in Court cases brought to interpret the EU GDPR in the coming years. What is certain, however, is that the principles for data protection will provide the foundations upon which the substantive law will continue to evolve.

5.4.3.2 Digital System Security

For all actors engaged in delivering a digital ICT-based energy system across Europe security is a priority. The previous section considered the security in data handling by data controllers of data subjects' information, in order to respect the fundamental right to privacy. This section surveys efforts within the EU to attend to risks posed, on a number of fronts, by the increasing dependence, by all sectors in society, on ICT. It frames this within the context of up scaling smart grid energy systems that see a rise in the number of service providers.

In 2013, the EU launched the Cyber-Security Strategy [214]. It was understood that the goal of achieving a Single Digital Market would flounder if cyber security issues were not addressed: The strategy acknowledged that “for new connected technologies to take off, including e-payments, cloud computing or machine-to-machine communication, citizens will need trust and confidence” and that this would be undermined by “threats [from] different origins — including criminal, politically motivated, terrorist or state-sponsored attacks as well as natural disasters and unintentional mistakes” [214]. The key initiative by the EU to secure critical digital ICT systems, such as banking, energy, health and transport, is the 2016 Directive on Security of Network and Information Systems (NIS) [258]. The NIS Directive strengthens and modernizes the mandate of the European Network and Information Security Agency (ENISA) that was established in 2004 [259]. The NIS Directive will apply to operators of "essential services" and to "digital service providers." EU countries have until 9 May 2018 to implement the Directive into their national law. There will be some overlaps between the obligations under the GDPR, but organizations, both large and small, will face new requirements. A significant distinction can be made with regard to the type of data protected under the NIS Directive and the GDPR. The NIS Directive covers any type of data breaches whereas the data protected under the GDPR is limited to "personal data" [260].

Unlike the GDPR that revised existing data protection law within the EU, according to the European Commission Vice-President for the Digital Single Market, Andrus Ansip, NIS is the first comprehensive piece of EU legislation on cyber security and a fundamental building block in the area [260]. As a Directive, the NIS will require Member States to adopt legislation to transpose it. This is different from the GDPR, which is a Regulation and, per its very nature, is directly applicable in all EU Member States. As a consequence there is space for differences in the approach adopted by Member States in how to meet the requirements under the NIS directive. This could impact its effectiveness in terms of securing transboundary critical energy digital ICT infrastructure however the Directive actively promotes network collaboration and cooperation [261].

The NIS Directive provides guidelines for "essential service operators" for example within the energy, transport, banking, financial market infrastructure, health, drinking water, and digital infrastructure sectors, as well as "digital service providers," including entities such as online marketplaces, online search engines, and cloud computing service providers. National government are to play a key coordinating role amongst other actors nationally and within the EU as each Member states under the NIS Directive is required to set up a Computer Security Incident Response Team Network (CSIRT), in order to promote swift and effective operational cooperation on specific cyber security incidents and sharing information about risks [262]. Critical service providers who will need to cooperate with national CSIRTs are defined under the NIS Directive as entities who ‘provide a service which is essential for the maintenance of critical societal and /or economic activities; that the provision of the service depends on network and information systems and that “an incident would have a significant disruptive effect on the provision of that service” [263].

Obligations are placed on operators of essential services to “take appropriate and proportionate technical and organizational measures to manage the risks posed to the security of network and information systems” [264]. To effectively achieve this, it is encouraged that service providers adopt internationally accepted standards and specifications in order to secure networks and information system [265]. Annex 11 of the NIS Directive lays out the entities considered to be ‘essential service operators.’ Under the energy sector electricity is a sub-sector. The NIS Directive provision applies to several entities as outlined in Article 2 of the EU Electricity Directive 2009. These include DSOs [266] and TSOs, who are engaged in an ‘electricity undertaking’ – which includes at least one of the following functions: generation, transmission, distribution, supply, or purchase of electricity [267]. The NIS clearly applies to the electricity sector. Providers of the service, whatever the size of the operation will be, need to comply with the Directive requirements by taking appropriate measures.

It is important that small scale energy providers, such as prosumers and energy cooperatives, are given the necessary support to adopt appropriate measures to reduce the risks to their technical and information networks. The focus of the observers is often on large-scale cyber-attacks across national systems, however targeted criminal activities on relatively small-scale energy providers could inflict harm on customers (as well as the service providers) in many ways, from loss of power, to fraud. The national government as well as service providers have an obligation to ensure this situation does not occur. An area that will require further security risk measures to be taken will be the financial transaction between service providers and customers. This could become more challenging with the emergence of virtual currencies and smart contracts [268].

6 CONCLUSIONS AND RECOMMENDATIONS

Electricity sectors across the EU are on the brink of experiencing a profound transition towards smart energy systems. This smart revolution entails several changes that amount to a paradigm shift in the conventional architecture of electricity markets. The advent of environmentally-friendly technologies such as smart grids, energy decentralisation, blockchain technologies, energy storage and EVs is leading to a substantial reformulation of the traditional equation of electricity industries. The pace of technology is pushing current regulatory frameworks to uncharted waters. Indeed, technological developments are such that existing legislation is grappling to keep abreast. In this rapidly evolving juncture, the objective of legal frameworks must be, first and foremost, to be sufficiently attuned not only to refrain from preventing the progress of these advancements but to promote the "smartening" of energy systems. This begs the question of how and to what extent does the present legislation (or, in certain occasions, lack thereof), affect a range of smart grid-related topics spanning from energy security and business modelling to social and ethical considerations.

Against this backdrop, the WiseGRID project strives to empower European energy consumers by offering a number of ICT services and systems geared towards contributing to a more reliable, flexible and open energy grid. This set of technological products shall lead to an enhanced utilisation of storage facilities; an increased share of RES that can be accommodated into the grid; and the integration of charging facilities to streamline the deployment of EVs. What is more, the WiseGRID tools shall promote the emergence of new actors (such as prosumers, electric cooperatives or SMEs, for example) thereby paving the way for more open and competitive electricity markets. The WiseGRID integrated solution shall be demonstrated and tested in four pilot sites. These large-scale demonstrators are located in different cities interspersed across the EU: Ghent (Belgium), Terni (Italy), Kythnos and Mesogia (Greece), and Crevillent (Spain). The objective being to assess the WiseGRID integrated solution in disparate technical, climatological, regulatory, legislative and social circumstances (a detailed analysis of each pilot site is available in ANNEX A – COUNTRY CASE STUDIES.

Even though the development of smart grids is essentially a key measure advocated by the European Commission to improve energy efficiency throughout the EU, the roll-out of this technology also shows promise as a catalyst in terms of energy security. The report has endeavoured to outline this by analysing the influence of smart grids on three aspects of energy security (sustainability, security of supply and affordability). As to sustainability, the adoption of smart grids naturally favours the proliferation of indigenous RES as opposed to resorting to fossil fuels from external suppliers. This increase in renewable energy generation should follow from certain developments such as priority dispatch mechanisms; integration of ICT technologies to the grid; the possibility for consumers to engage in self-consumption; or the creation of local energy communities through distributed generation, to name a few). The main challenges here will be to render RES a more attractive option than alternative, cheaper and more polluting, sources of energy such as gas and especially coal.

As to security of supply, using a domestic energy mix which is richer in solar, wind, hydro and other RES represents a more decisive move towards energy diversification than opting to purchase hydrocarbons from abroad. Furthermore, it reduces energy dependency from the outside world and eludes the unpredictability of global energy markets which tend to be fraught with geopolitical tension and are strongly subjected to international relations. Moreover, smart grids are the best-suited means to confront energy poverty at the root. This is so as with decentralised generation, such as in a microgrid scenario, the power generators are closer to the local consumption which prevents energy leakages and substantially facilitates the supply of electricity from a logistical perspective. This makes sure that energy is supplied where it is most needed. The major challenge in terms of energy security revolves around the task of balancing the load of the electricity network. The volatile and intermittent nature of RES calls for greater storage capacity. Furthermore, demand response schemes, now facilitated through the availability of consumption data for consumers through AMI, are other possible avenues to address this concern.

As to affordability, self-consumption, demand management and access to "near-real time" consumption information are anticipated to lead to a reduction of the energy bill for European citizens. Prosumers will have the choice to use, store or sell their own electricity emanating from production facilities installed in their private household. These active customers will be able to sell their energy surplus to aggregators, DSOs and even fellow prosumers (through peer-to-peer platforms). The main hurdle on this front arises from the neo-classical economic presupposition that prosumers are rational actors that will naturally seek to maximise their energy consumption by correctly interpreting the available information. Nevertheless, several surveys suggest that the average consumer struggles to process the wealth of information tendered. Consequently, the average consumer falls short of redressing his consumption behaviour in accordance to the most cost-beneficial pattern. Hence, for the corporate players involved in the roll-out of smart meters to engage and educate consumers will be a necessary process. Furthermore, certain consumers (such as senior citizens, for example) are more likely to require specific guidance in order to fully reap the benefits offered by smart metering systems. User-friendly smart grid applications such as the ones advanced by the WiseGRID project will be crucial to this end.

The manner in which the deployment of smart grids unfolds is contingent on the legislative framework for a number of aspects that have been analysed in this report (such as smart meters, demand response, electricity storage and electric vehicles, in particular). The report has carried out this evaluation by assessing the relevant regulations and policies both at the EU and Member State levels. Smart grid regulation transcends energy law insofar as these policies are confronted with the task of striking the correct balance between promoting the development of new technologies while safeguarding the interests of consumers. As to smart grids themselves, several regulatory questions surface such as the specificities of the future role of DSOs. A middle ground has to be found between incentivising DSOs to invest in smart grids and avoiding the imposition of high tariffs on consumers. Furthermore, questions relating to data protection such as access and ownership of data represent quandaries that have been addressed in different ways across Member States. Taking into consideration concerns associated with cyber security, government surveillance and data protection, together with public scepticism on the utility of such technology, common action has to be taken to raise sufficient awareness to surpass these apprehensions. Thus, it is imperative to provide more information to European citizens about the role that these technologies can play in maximising energy efficiency and reducing their energy bills. A greater awareness and engagement of consumers in energy markets would, in turn, encourage the development of smart grids.

As to demand response, the most common legislative stumbling blocks among Member States have been identified. Perhaps the most interesting regulatory recommendation in this sense includes the possibility to automatise these schemes. The underlying logic being to make it as easy as possible for consumers to participate in demand response. For example, legislation can frame opt-in models where consumers opt to join the services provided by an aggregator or opt-out models where consumers belong to the aggregation scheme unless they manifest their refusal to the latter. Regulatory incentives will be necessary to encourage investments in storage technologies. A review of grid fees structure is also necessary to avoid the situation where storage assets pay double grid fees. Specific schemes and tailored policies will be necessary to promote EVs (such as direct grants to support electric mobility, lower taxes for EVs, higher taxes for vehicles using gasoline, the possibility for EVs to use exclusive taxi or bus lanes, as well as support to research and development activities). Moreover, the scarcity of charging infrastructure remains another substantial deterrent towards the effective electrification of mobility trends.

The last chapter of the report explores the social and ethical issues associated with the deployment of smart grids. The present document emphasises how the collaborative economy has integrated the progressive dynamic of the most recent developments in the field of ICT technologies. The collaborative economy updates business models as well as services offered by energy utilities thereby challenging the idiosyncrasies of conventional electricity markets. In turn, increased competition generally leads to lower transaction costs and cheaper services for end customers. With the adequate regulatory framework in place, the collaborative economy could cater for the provision of essential services such as access to energy. In this context, smart grids could serve as a suitable platform to further the principles advocated by the collaborative economy. Indeed, the forward-looking outlook of smart grids empowers consumers to actively participate and influence the market; fosters the emergence of new energy suppliers in the market; and encourages the establishment of energy communities. Nonetheless, for the collaborative economy to truly deliver on this particular front, its possible benefits must be made available not only to those who can become energy suppliers but also to end customers. At any rate, the collaborative economy is likely to generate opportunities in terms of efficiency and affordability. This premise fully subscribes with the rationale behind the deployment of smart grids.

Finally, and in light of the necessary treatment of data performed by smart grids, new challenges such as cyber security and privacy issues appear. Indeed, smart grids couple information streams in the energy sector (such as consumption data) with digital communication systems. Securing an entire energy supply network which is continuously incorporating new software systems and hardware from a variety of providers is a burdensome effort. To this end, the latest regulatory frameworks established at the EU sphere such as the GDPR (where the protection is circumscribed to personal data) and the NIS directive (where the protection covers any type of data breach) have been discussed insofar as they represent tangible efforts towards these growing concerns. Small-scale energy suppliers (such as prosumers, SMEs and electricity cooperatives, for instance) must benefit from the necessary support to adopt contingency plans to mitigate any data protection risks to their technical and information networks.

7 REFERENCES AND ACRONYMS

7.1 References

[1] The International Energy Agency, "World Energy Outlook," OECD/IEA, Paris, 2016.

[2] D. Yergin, The Prize: The Epic Quest for Oil, Money & Power, New York: Simon & Schuster, 2011.

[3] Eurostat, "Main origin of primary energy imports. EU-28. 2005-2015 (% of extra EU-28 imports)," Eurostat, [Online]. Available: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Net_imports_of_primary_energy,_2005-2015_YB17.png. [Accessed 25 July 2017].

[4] F. Proedrou, EU Energy Security in the Gas Sector: Evolving Dynamics, Policy Dilemmas and Prospects, Farnham: Ashgate, 2012.

[5] M. Sidi, "The scramble for energy supplies to South Eastern Europe: the EU's Southern Gas Corridor, Russia's pipelines and Turkey's role," in *Turkey as an Energy Hub?* , Baden-Baden, Nomos, 2017, pp. 51-66.

[6] F. Proedrou, "EU Energy Security beyond Ukraine: Towards Holistic Diversification," *European Foreign Affairs Revew,* vol. 21, no. 1, pp. 57-73, 2016.

[7] A. Goldthau, "Assessing Nord Stream 2: regulation, geopolitics & energy security in the EU, Central Eastern Europe & the UK," Europeean Centre for Energy and Resource Security, London, 2016.

[8] A. Aissaoui, R. Mabro, I. Wybrew-Bond, U. Bartsch, M. Peebles and J. Stern, Gas to Europe: The Strategies of Four Major Suppliers, Oxford: Oxford University Press, 1999.

[9] T. Casier, "Great Game or Great Confusion: The Geopolitical Understanding of EU-Russia Energy Relations," *Geopolitcs,* vol. 21, no. 4, pp. 763-778, 20116.

[10] A. Florini and B. K. Sovacool, "Who governs energy? The challenges facing global energy governance," *Energy Policy,* vol. 37, no. 12, pp. 5239-5248, December 2009.

[11] T. Maltby, "European Union energy policy integration: A case of European Commission policy entrepreneurship and increasing supranationalism," *Energy Policy,* vol. 55, pp. 435-444, April 2013.

[12] European Commission, "2020 climate and energy package," European Commission, [Online]. Available: https://ec.europa.eu/clima/policies/strategies/2020_en. [Accessed 26 July 2017].

[13] Conclusions of the European Council of 23 October 2014.

[14] F. Proedrou, "Are smart grids the key to EU energy security?," in *Research Handbook on EU Energy Law and Polilcy*, R. Lear-Arcas and J. Wouters, Eds., Edward Elgar, 2017.

[15] G. P. Verbong, S. Beemsterboer and F. Sengers, "Smart grids or smart users?: involving users in developing a low carbon electricity economy," *Energy Policy,* vol. 52, pp. 117-125, 2013.

[16] C. Eid, R. Hakvoort and M. de Jong, *Global trends in the political economy of smart grids: A tailored perspective on 'smart' for grids in transition,* UNU-WIDER, 2016.

[17] A. Bressand, "The Role of Markets and Investment in Global Energy," in *The Handbook of Global Energy Policy*, A. Goldthau, Ed., West Sussex, John Wiley & Sons, 2013, pp. 15-29.

[18] Proposal for a Directive of the European Parliament and of the Council on common rules for the

internal market in electricity, at p. 68, COM(2016) 864 final/2 (23 February 2017).

[19] C. Clastres, "Smart grids: Another step towards competition, energy security and climate change objectives," *Energy Policy,* vol. 39, no. 9, pp. 5399-5408, 2011.

[20] L. Boscan and R. Poudineh, "Flexibility-Enabling Contracts in Electricity Markets," The Oxford Institute For Energy Studies, 2016.

[21] European Commission, Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, COM(2016) 767 final (23 February 2017).

[22] P. P. Varaiya, F. F. Wu and J. W. Bialek, "Smart Operation of Smart Grid: Risk-Limiting Dispatch," *Proceedings of the IEEE,* vol. 99, no. 1, pp. 40-57, 9 November 2010.

[23] D. Buchan and M. Keay, "EU energy Policy - 4th time lucky?," The Oxford Institute for Energy Studies, 2016.

[24] M. Wissner, "The Smart Grid - A saucerful of secrets?," *Applied Energy,* vol. 88, no. 7, pp. 2509-2518, 2011.

[25] D. Helm, "The European framework for energy and climate," *Energy Policy,* vol. 64, pp. 29-35, 2014.

[26] K. Szulecki, S. Fischer, A. T. Gullberg and O. Sartor, "Shaping the 'Energy Union': between national positions and governance innovation in EU energy and climate policy," *Climate Policy,* vol. 16, pp. 548-567, 2016.

[27] J. Jansen and A. van der Welle, "The Role of Regulation in Integrating Renewable Energy: The EU Electricity Sector," in *The Handbook of Global Energy Policy*, A. Goldthau, Ed., West Sussex, John Wiley & Sons, 2013, pp. 322-339.

[28] S. A. Halasah, D. Pearlmutter and D. Feuermann, "Field installation versus local integration of photovoltaic systems and their effect on energy evaluation metrics," *Energy Policy,* vol. 52, no. C, pp. 462-471, 2013.

[29] K. B. Jones and D. Zoppo, A Smarter, Greener Grid, Forging Environmental Progress through Smart Policies and Technologies, California: Praeger, 2014.

[30] G. Masson, J. I. Briano and M. J. Baez, "Review and Analysis of PV Self-Consumption Policies," International Energy Agency - Photovoltaic Power Systems Programme, 2016.

[31] M. A. Brown and B. K. Sovacool, "Climate Change and Global Energy Security: Technology and Policy Options," MIT, Cambridge, 2011.

[32] P. Lehman and E. Gawel, "Why should support schemes for renewable electricity complement the EU emissions trading scheme?," *Energy Policy,* vol. 52, pp. 597-607, 2013.

[33] S. Ruester, S. Schwenan, C. Batile and I. Perez-Arriaga, "From distribution networks to smart distribution systems: Rethinking the regulation of European electricity DSOs," *Utilities Policy,* vol. 31, pp. 229-237, 2014.

[34] International Energy Agency, "Royal Decree 900/2015 on self-consumption," International Energy Agency, 10 May 2017. [Online]. Available: https://www.iea.org/policiesandmeasures/pams/spain/name-152980-en.php. [Accessed 7 July 2017].

[35] M. Galanova, "Spain's sunshine toll: Row over proposed solar tax," BBC, 7 October 2013. [Online]. Available: http://www.bbc.co.uk/news/business-24272061. [Accessed 29 June 2017].

[36] European Environment Agency, “Country Profile-Belgium. Energy Support 2005-2012,” European Environment Agency, Copenhagen.

[37] Natural Gas World, “Siemens Rolls Out Micro-LNG in the US,” Natural Gas World, 20 January 2017. [Online]. Available: https://www.naturalgasworld.com/siemens-rolls-out-micro-lng-in-us-35447?utm_medium=email&utm_campaign=Natural%20Gas%20World%20Newsletter%20January%2019%202017&utm_content=Natural%20Gas%20World%20Newsletter%20January%2019%202017+CID_3075bf421815cdc13fa0d66.

[38] O. Renn and J. P. Marshall, “Coal, nuclear and renewable energy policies in Germany: From the 1950s to the "Energiewnde",” *Energy Policy,* vol. 99, pp. 224-232, 2016.

[39] F. Muhammad-Sukki, R. Ramirez-Iniguez, A. B. Munir, S. H. M. Yasin, S. H. Abu-Bakar, S. G. McMeekin and B. G. Stewart, “Revised feed-in-tariff for solar photovoltaic in the United Kingdom: A cloudy future ahead?,” *Energy Policy,* vol. 52, pp. 832-838, 2013.

[40] T. Raines and S. Tomlinson, “Europe's Energy Union: Foreign Policy Implications for Energy Security, Climate and Competitveness,” Chatham House Royal Institute of International Affairs, 31 March 2016. [Online]. Available: https://www.chathamhouse.org/publication/europes-energy-union-foreign-policy-implications-energy-security-climate. [Accessed 29 June 2017].

[41] Natural Gas World, “EU Approves €444MN CEF Grants,” Natural Gas World, 20 February 2017. [Online]. Available: http://www.naturalgasworld.com/eu-approves-444mn-cef-grants-36013?utm_medium=email&utm_campaign=Natural%20Gas%20World%20Newsletter%20February%2021%202017%20-%20AM&utm_content=Natural%20Gas%20World%20Newsletter%20February%2021%202017%20-%20AM+CID_d023afdd8.

[42] D. G. Victor, *The Gas Promise,* Laboratory on International Law and Regulation, ILAR, 2013.

[43] A. Boston, “Delivering a secure electricity supply on a low carbon,” *Energy Policy,* vol. 52, pp. 55-59, 2013.

[44] D. Scholten and R. Bosman, “The Geopolitics of Renewable Energy; a Mere Shift or Landslide in Energy?,” *Technological Forecasting and Social Change,* vol. 103, pp. 278-279, 2016.

[45] HEDNO, “Regulatory Framework,” [Online]. Available: http://www.deddie.gr/en/i-etaireia/ruthmistiko-plaisio.

[46] European Commission, “Commission proposes new rules for consumer centred clean energy transition,” European Commission, [Online]. Available: https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition.

[47] T. Hargreaves, M. Nye and J. Burgess, “Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term,” *Energy Policy,* vol. 52, pp. 126-134, 2013.

[48] A. Goldthau and B. K. Sovacool, “The uniqueness of the energy security, justice, and governance problem,” *Energy Policy,* vol. 41, pp. 232-240, 2012.

[49] International Energy Agency, “Renewable Energy Medium-Term Market Report 2015,” International Energy Agency, Paris, 2015.

[50] P. Bradley, M. Leach and J. Torriti, “A review of the costs and benefits of demand response for

electricity in the UK,” *Energy Policy,* vol. 52, pp. 312-327, 2013.

[51] The Editorial Board, “The Case for a Carbon Tax,” The New York Times, 6 June 2015. [Online]. Available: https://www.nytimes.com/2015/06/07/opinion/the-case-for-a-carbon-tax.html.

[52] M. Paterson, “Selling Carbon: From International Climate Regime to Global Carbon Market,” in *The Oxford Handbook of Climate Change and Society*, J. S. Dryzek, R. B. Norgaard and D. Schlosberg, Eds., Oxford, Oxford Universtity Press, 2011, pp. 611-624.

[53] T. Dolphin and D. Nash, “Complex new world: Translating new economic thinking into public policy,” Institute for Public Policy Research Paper, London, 2012.

[54] R. Wustenhagen and E. Menichetti, “The Influence of Energy Policy on Strategic Choices for Renewable Energy Investment,” in *The Handbook of Global Energy Policy*, A. Goldthau, Ed., West Sussex, John Wiley & Sons, 2013, pp. 373-388.

[55] European Regulators Group for Electricity & Gas (ERGEG), “Position Paper on Smart Grids: An ERGEG Public Consultation Paper,” ERGEG, E09-EQS-30-04, 2009.

[56] European Regulators Group for Electricity & Gas (ERGEG), “Position Paper on Smart Grids; An ERGEG Conclusion Paper,” ERGEG, E10-EQS-38-05, 2010.

[57] European Commission, Communiation from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "Smart Grids: from innovatio to deployment", COM (2011) 202 final, Brussels, 12 April 2011.

[58] Council of European Energy Regulators (CEER), “CEER Status Review on European Regulatory Approaches Enabling Smart Grids Solutions ("Smart Regulation"),” CEER, C13-EQS-57-04, Brussels, 2014.

[59] F. Xiufeng, “Smart Grids in China: Industry Regulation and Foreign Direct Investment,” *Energy Law Journal,* vol. 37, no. 1, pp. 135-176, 2016.

[60] Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electriciy and repealing Directive 2003/54/EC.

[61] VREG, “Kosten-batenanalyse slimme meters,” 18 May 2017. [Online]. Available: http://www.vreg.be/nl/nieuws/kosten-batenanalyse-slimme-meters. [Accessed 11 July 2017].

[62] GEODE, “From Theory to Reality,” in *GEODE Workshop*, Brussels, 2014.

[63] Autorita per l'energia elettrica il gas e il sistema idrico (AGEESI), “Smart metering second-generation systems for the measurement of electricity in low voltage,” 6 August 2015. [Online]. Available: http://www.autorita.energia.it/it/docs/dc/15/416-15.jsp#. [Accessed 30 June 2017].

[64] European Commission, *Cost-benefit analyses & state of play of smart metering deployment in the EU-27,* Brussels: EC SWD(2014) 189, 2014.

[65] SIA Partners, “Energy Outlook: Energy Storage in Belgium,” SIA Partners, 10 May 2013. [Online]. Available: http://energy.sia-partners.com/energy-storage-belgium. [Accessed 14 September 2017].

[66] EnerConsultoría. Derecho de la energía, “contadores inteligentes y protección de datos,” EnerConsultoría. Derecho de la energía, 8 December 2015. [Online]. Available: http://www.enerconsultoria.es/BlogLeyesEnergia.aspx?id=36002236&post=Contadoresinteligentesyprotecciondedatos. [Accessed 15 June 2017].

[67] European Regulators Group for Electricity & Gas (ERGEG), “Final Guidelines of Good Practice on

Regulatory Aspects of Smart Metering for Electricity and Gas," ERGEG, E10-RMF-29-05, Brussels, 2011.

[68] Agency for the Cooperation of Energy Regulators (ACER), "Framework Guidelines on Electricity Balancing," ACER, FG-2012-E-009, Ljubljana, 2012.

[69] M. V. Balijepalli, V. Pradhan, S. Khparde and R. M. Shereef, "Review of demand response under smart grid paradigm," in *IEEE Xplore*, India, 2011.

[70] Smart Energy Demand Coalition , "Mapping Demand Response in Europe Today," Brussels, 2015.

[71] Directive 2012/27/EU, on efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, 25 October 2012.

[72] European Commission, *Guidelines on State aid for environmental protection and energy 2014-2020,* EC, (2014/C 200/01), 2014.

[73] P. Bertoldi, P. Zancanella and B. Boza-Kiss, "Demand Response status in EU Member States," European Union, Italy, 2016.

[74] Hellenic Public Power Company SA (PPC), "Residential Night Tariff," PPC, 2013. [Online]. Available: https://www.dei.gr/en/oikiakoi-pelates/timologia/oikiako-timologio-me-xronoxrewsi-oikiako-nuxterino. [Accessed 4 July 2017].

[75] J. M. R. Fernandez, M. B. Payan, J. M. R. Santos and A. L. T. Garcia, "Renewable generation versus demand-side management. A comparison for the Spanish market," *Energy Policy,* vol. 96, pp. 458-470, 2016.

[76] AEEG, "DCO 528/2014/A, Consultation Document," 30 October 2014. [Online]. Available: http://www.autorita.energia.it/allegati/ docs/14/528-14.pdf. [Accessed 26 September 2017].

[77] X. Luo, J. Wang, M. Dooner and J. Clarke, "Overview of current development in electrical energy storage technologies and the application potential in power system operation," *Applied Energy,* vol. 137, pp. 511-536, 2015.

[78] Committee on Industry, Research and Energy (ITRE) European Parliament, "Energy Storage: Which Market Designs and Regulatory Incentives Are Needed?," European Commission , 2015.

[79] E. Stoppani, "Smart charging and energy storage: bridging the gap between electromobility and electricity systems," *International Energy Law Review,* vol. 1, pp. 10-22, 2017.

[80] Council of European Energy Regulators (CEER), "Development and Regulation of Electricity Storage Applications," CEER, Brussels , 2014.

[81] Proposal for a Directive of the European Parliament and of the Council on common rules for the internal market in electricity, at p. 82, COM(2016) 864 final/2 (23 February 2017).

[82] Roadmap to a single European Transport Area - Towards a competitive and resource-efficient transport system COM 144 Final (28 March 2011) .

[83] Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure..

[84] Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committe and the Committee of the Regions. A European Strategy for Law-Emission Mobility COM 501 Final of 20 July 2016..

[85] G. C. Gissey, P. E. Dodds and J. Radcliffe, “Regulatory barriers to energy storage deployment: the UK perspective,” RESTLESS Project, London, 2016.

[86] J. Deign, “Spain's New Self-Consumption Law Makes Batteries Impractical for Homeowners,” GreenTech Media, 16 October 2015. [Online]. Available: https://www.greentechmedia.com/articles/read/spanish-self-consumption-law-allows-batteries-at-a-cost. [Accessed 31 July 2017].

[87] European Environment Agency (EEA), “Electric Vehicles in Europe,” EEA, Copenhagen, 2016.

[88] P. Hockenos, “With Norway in Lead, Europe Set for Surge in Electric Vehicles,” Yale Environment 360, 6 February 2017. [Online]. Available: http://e360.yale.edu/features/with-norway-in-the-lead-europe-set-for-breakout-on-electric-vehicles. [Accessed 27 April 2017].

[89] The International Council on Clean Transportation (ICCT), “European Vehicle Market Statistics,” ICCT, 25 November 2015. [Online]. Available: http://www.theicct.org/european-vehicle-market-statistics-2015-2016. [Accessed 27 April 2017].

[90] P. McAllister, “Huge New Study Compares Every UK Council's Electric Vehicle Usage,” Intelligent Car Leasing, 23 January 2015. [Online]. Available: http://www.intelligentcarleasing.com/blog/new-study-compares-every-uk-council-electric-vehicles/.. [Accessed 27 April 2017].

[91] L. Macdonald, “Bulgarian city introduces free parking for electric cars,” The urban mobility observatory, 12 November 2014. [Online]. Available: http://www.eltis.org/discover/news/bulgarian-city-introduces-free-parking-electric-cars. [Accessed 27 April 2017].

[92] E. Commission, “ Guidelines for conducting a cost-benefit analysis of Smart Grid projects,” 2012. [Online]. Available: http://ses.jrc.ec.europa.eu/smart-grid-cost-benefit-analysis. [Accessed 2017].

[93] E. Commission, “Commission Recommendation on preparations for the rollout of smart metering systems,” 2012. [Online]. Available: ttp://ec.europa.eu/energy/gas_electricity/smartgrids/smartgrids_en.htm. [Accessed 2017].

[94] E. S. HUB, “The European Commission's science and knowledge service,” [Online]. Available: https://ec.europa.eu/jrc/en/energy-efficiency/eed-support/energy-service-companies.

[95] K. L. E. Institute, “The current electricity market design in Europe,” [Online]. Available: https://set.kuleuven.be/ei/images/EI_factsheet8_eng.pdf/.

[96] D. Toke, “Community wind power in Europe and in the UK,” *Wind Engineering,* no. 3, pp. 301-308.

[97] Brooklyn Microgrid , Brooklyn Microgrid, [Online]. Available: https://www.brooklyn.energy/. [Accessed 19 September 2017].

[98] R. Wüstenhagen, M. Wolsink and M. J. Bürer, “Social Acceptance of Renewable Energy Innovation : an Introduction to the Concept,” *Energy Policy,* vol. 35, no. 5, pp. 2683-2691, 2007.

[99] V. Giordano, “Smart Grid projects in Europe: Lessons learned and current developments,” *JRC Scientific and Policy Reports,* p. 9, 2013.

[100] European Commission, “Europe 2020: Commission proposes new economic strategy in Europe,” 3 March 2010. [Online]. Available: http://europa.eu/rapid/press-release_IP-10-225_en.htm?locale=en. [Accessed 6 October 2017].

[101] A. Papandreou, “The Great Recession and the transition to a low-carbon economy,” *FESSUD Working Paper Series,* no. 88, 2015.

[102] Communication from the Commission, Entrepreneurship 2020 Action Plan, Reigniting the entrepreneurial spirit in Europe, COM(2012) 795 final.

[103] G. Lougher and S. Kalmanowizc, "EU Competition Law in the Sharing Economy," *Journal of European Competition Law & Practice,* vol. 7, no. 2, pp. 87-102, 2016.

[104] N. Ciocouiu, "Integrating Digital Economy And Green Economy: Opportunities For Sustainable Development," *Theoretical and Empirical Researches in Urban Management,* vol. 6, no. 1, pp. 33-43, 2011.

[105] G. Lougher and S. Kalmanowicz, "EU competition law in the sharing economy," *Common Market Law Review,* vol. 7, no. 2, p. 87, 2016.

[106] K. Schwab, "The Fourth Industrial Revolution: What It Means and How to Respond," Foreign Affairs , 12 December 2015. [Online]. Available: https://www.foreignaffairs.com/articles/2015-12-12/fourth-industrial-revolution. [Accessed 15 February 2017].

[107] M. Böckmann, "The Shared Economy: It is time to start caring about sharing; value creating factors in the shared economy," *University of Twente,* 2013.

[108] G. Beltra, "The consumer-policy nuts and bolts of the sharing economy," BEUC. The European Consumer Organisation, 2016 October 11. [Online]. Available: http://www.beuc.eu/blog/the-consumer-policy-nuts-and-bolts-of-the-sharing-economy/. [Accessed 15 February 2017].

[109] European Commission, "A European agenda for the collaborative economy," Press Release Database, 2 June 2016. [Online]. Available: http://europa.eu/rapid/press-release_IP-16-2001_en.htm. [Accessed 13 April 2017].

[110] D. Rauch and D. Schleicher, "Like Uber, But for Local Governmental Policy: The Future of Local Regulation of the 'Sharing Economy'," *George Mason University Law & Economics Research Paper,* no. 15-01, pp. 1-61, 2015.

[111] Commission Staff Working Document. A European agenda for the collaborative econmy - supporting analysis, SWD(2016) 184 final (2 June 2016).

[112] V. Hatzopoulos and S. Roma, "Caring for sharing? The collaborative economy under EU law," *Common Market Law Review,* vol. 54, no. 1, pp. 81-127, 2017.

[113] Communication from the Commission, "Unleashing the Potential of Cloud Computing in Europe", COM(2012)529 final.

[114] European Commission, "Establishing a Trusted Cloud Europe," European Commission, Brussels, 2014.

[115] P. Katina, "A Criticality-based Approach for the Analysis of Smart Grids," *Technology and Economics of Smart Grids and Sustainable Energy,* vol. 1, no. 1, pp. 1-20, 2016.

[116] European Commission, *"Smart grids for a smart Energy Union" Speech of Miguel Arias Cañete - Commissioner for Climate Action & Energy,* Brussels: European Commission, 2015.

[117] Communication from the Commission A Framework Strategy for a Resilient Energy Union with a Forward - Looking Climate Change Policy, at p. 2, COM(2015) 080 final (25 February 2015).

[118] K. Bickerstaff, "Decarbonisation at home : the contingent politics of experimental domestic energy technologies.," *Environment and Planning A,* vol. 48, no. 10, pp. 2006-2025, 2016.

[119] Y. Strengers, Smart Energy Technologies in Everyday Life: Smart Utopia?, London: Palgrave Macmillan,

2013.

[120] INSIGHT_E, "Energy poverty and vulnerable consumers in the energy sector across the EU: analysis of policies and measures," INSIGHT_E, 2015.

[121] S. Bouzarovski, Petrova and S, "The EU energy poverty and vulnerability agenda: An emergent domain of transactional action," in *Energy Policy Making in the EU: Building the Agenda*, Berlin, Springer, 2015, pp. 129-144.

[122] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.A Digital Single Market Strategy for Europe, at p. 15, COM(2015) 192 final (6 May 2015).

[123] A. Half, K. Sovacool and J. Rozhon, "Energy Poverty: Global Chanllenges and Local Solutions," Oxford University Press, Oxford, 2014.

[124] Joint Research Centre, "The Passions and the Interests: Unpacking the 'Sharing Economy'," Joint Research Centre, Seville, 2016.

[125] T. Dillahunt and A. Malone, "The Promise of the Sharing Economy among Disadvantaged Communities," *CHI '15 Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems ,* no. 23, pp. 2285-2294, 2015.

[126] G. Newlands, "Power in the Sharing Economy," Report from the EU H2020 Research Project Ps2Share: Participation, Privacy, and Power in the Sharing Economy , 2017.

[127] E. Nica and A. Potcoravu, "The Social Sustainability of the Sharing Economy," *Economics, Management and Financial Markets,* vol. 10, no. 4, pp. 69-75, 2015.

[128] M. Bauwens and V. Kostakis, "From the Communism of Capital to Capital for the Commons: Towards an Open Co-operativism," *Triple C - Journal for a Global Sustainable Information Society,* vol. 12, no. 1, pp. 356-361, 2014.

[129] Article 2.1(a) Paris Agreement.

[130] C.-F. Schleussner, T. K. Lissner, E. K. Fischer, J. Wohland, M. Perrette, A. Golly, J. Rogelj, K. Childers, J. Schewe, K. Frieler, M. Mengel, W. Hare and M. Schaeffer, "Differential climate impacts for policy-relevant limits to global warming: the case of 1.5 °C and 2 °C," *Earth System Dynamics,* vol. 7, no. 2, pp. 327-351, 2016.

[131] M. Burke, S. Hsiang and E. Miguel, "Global non-linear effect of temprature on economic production," *Nature,* vol. 527, pp. 235-239, 12 November 2015.

[132] J. Rogelj, "Paris Agreement climate proposals need a boost to keep warming well below 2 °C," *Nature,* pp. 631-639, 30 June 2016.

[133] Communication from the Commission on the Mid-term review of the Sixth Community Environment Action Programme, COM(2007) 225 final (30 Apri 2007).

[134] R. Leal-Arcas, "The transition towards decarbonization: A legal and policy examination of the European Union," *Queen Mary School of Law Legal Studies Research Paper No. 222/2016,* pp. 1-31, 2016.

[135] Communication from the Commission, "A strategy for smart, sustainable and inclusive growth" COM(2010) 2020 final.

[136] Conclusions on 2030 Climate and Energy Policy Framework, SN79/14 (23 October 2014).

[137] Communication from the Commission to the European Commission, Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, “Energy Roadmap 2050,” COM(2011) 885 final (15 December 2011).

[138] I. Solorio, “The European Energy Policy and its green dimension – discursive hegemony and policy variations in the greening of energy policy,” in *Sustainable Development and Governance in Europe*, P. Barnes and T. Hoerber, Eds., Routledge, 2013.

[139] E. Orlando, “The Evolution of EU Policy and Law in the Environmental Field: Achievements and Current Challenges,” in *The EU, the US and Global Climate Governance (Hardback) book cover*, C. Bakker and F. Francioni, Eds., Routledge, 2014.

[140] N. Roht-Arriaza and J. Mariezcurrena, Transitional Justice in the Twenty-First Century Beyond Truth versus Justice, Cambridge University Press, 2006.

[141] R. Teitel, Globalizing Transitional Justice: Contemporary Essays, Oxford University Press, 2014.

[142] ClientEarth, “Sustainable Development as a Key Policy of the European Union,” Briefing Series No. 1, 2011.

[143] European Commission , “"Towards Sustainability" the European Community Programme of policy and action in relation to the environment and sustainable development,” [Online]. Available: http://ec.europa.eu/environment/archives/action-programme/5th.htm. [Accessed 15 February 2017].

[144] European Commission, “Strategy for sustainable development,” [Online]. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:l28117&from=EN. [Accessed 15 February 2017].

[145] European Commission, “Environment 2010: Our Future, Our Choice. 6th EU Environment Action Programme,” European Commission, Brussels, 2001.

[146] Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 ‘Living well, within the limits of our planet’.

[147] European Commission, “Environment Action Programme to 2020,” [Online]. Available: http://ec.europa.eu/environment/action-programme/. [Accessed 15 February 2017].

[148] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, “Roadmap to a Resource Efficient Europe” COM(2011) 571 final.

[149] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, “A Roadmap for moving to a competitive low carbon economy in 2050”, COM(2011) 112 final.

[150] M. Montini and E. Orlando, “Balancing climate change mitigation and environmental protection interests in the EU Directive on carbon capture and storage,” *Climate Law,* pp. 165-180, 2012.

[151] M. D. Sánchez Galera, “The Integration of Energy Environment under the Paradigm of Sustainability threatened by the Hurdles of the Internal Energy Market,” *European Energy and Environmental Law Review,* vol. 26, no. 1, pp. 13-25, 2017.

[152] R. Hastik, “Using the "Footprint" Approach to Examine the Potentials and Impacts of Renewable Energy Sources in the European Alps,” *Mountain Research and Development,* vol. 36, no. 2, pp. 130-140, 2016.

[153] European Commission, “State of the Union 2016: Strengthening European Investments for jobs and growth,” European Commission, 14 September 2016. [Online]. Available: http://europa.eu/rapid/press-release_IP-16-3002_en.htm. [Accessed 6 October 2017].

[154] U. Collier, Energy and Environment in the European Union, Aldershot, 1994.

[155] European Commission, “Sustainable Development: EU sets out its priorities,” European Commission, 22 November 2016. [Online]. Available: http://europa.eu/rapid/press-release_IP-16-3883_en.htm. [Accessed 6 October 2017].

[156] Communication from the Commission, Next Steps for a Sustainable European Future European Action for Sustainability, COM(2016) 739 final (22 November 2016).

[157] W. Steffen, “Planetary boundaries: guiding human development on a chaning planet,” *Science,* vol. 347, no. 6223, pp. 11285-11305, 2015.

[158] K. Fang, “The Environmental Sustainability of Nations: Benchmarking the Carbon, Water and Land Footprints against Allocated Planetary Boundaries,” *Sustainability,* vol. 7, no. 8, pp. 11285-11305, 2015.

[159] Sustainable Europe Research Institute (SERI), “How to measure Europe's resource use,” 2009.

[160] European Commission, “Sustainability Now! A European Vision for Sustainability,” European Political Strategy Centre Stategic Note Issue 18, Brussels, 2016.

[161] European Environment Agency, “The European Environment State and Outlook 2015. Assessment of Global Megatrends,” European Environment Agency, Copenhagen, 2015.

[162] A. Smith and A. Stirling, “The Politics of Social-ecological Resilience and Sustainable Socio-technical Transitions,” *Ecology and Society,* vol. 15, no. 1, 2010.

[163] B. Chaffin, “A decade of adaptive governance scholarship: synthesis and future directions,” *Ecology and Society,* vol. 19, no. 3, 2014.

[164] S. Muench, “What hampers energy system transformations? The case of smart grids,” *Energy Policy,* vol. 73, pp. 80-92, 2014.

[165] Commission Staff Working Paper, Analysis associated with the Roadmap to a Resource Efficient Europe Roadmap to a Resource Efficient Europe, SEC(2011) 1067 final, Brussels (20 September 2011).

[166] E. Morgera and A. Savaresi, “A Conceptual and Legal Perspective on the Green Economy,” *Review of European Comparative and International Environmental Law,* vol. 22, no. 1, pp. 14-28, 2013.

[167] Communication from the Commission, Next Steps for a Sustainable European Future European Action for Sustainability, COM(2016) 739 final (22 November 2016).

[168] “Communication from the Commission to the European Parliament. Closing the Loop – An EU action plan for the Circular Economy, COM(2015) 614 final (2 December 2015)”.

[169] S. Boulos, The Durability of Products: Standard Assessment for the Circular Economy Under the Eco-innovation Action Plan, Publications Office , 2015.

[170] I. C. De los Ríos and F. Charnley, “Skills and capabilities for a sustainable and circular economy: The changing role of design,” *Journal of Cleaner Production,* vol. 160, pp. 109-122, 2017.

[171] Directive 2012/19/EU of the European Parliament and of the Council, 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE), L 197/38, 24.7.2012.

[172] Proposal for a Directive of the European Parliament and of the Council amending Directive 1999/31/EC on the landfill of waste, COM(2015) 594 final (2 December 2015).

[173] D. Langlet and S. Mahmoudi, EU Environmental Law and Policy, Oxford University Press, 2016.

[174] Framework Directive on Waste 75/442/EEC [1975].

[175] Article 1 Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste.

[176] R. Cherrington, "Producer responsibility: Defining the incentive for recycling composite wind turbine blades in Europe," *Energy Policy,* vol. 47, pp. 13-21, 2012.

[177] European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste.

[178] Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on of-of-life vehicles.

[179] Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE) – recast as Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012.

[180] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, L 312/3, 22.11. 2008.

[181] Organisation for Economic Co-operation and, "OECD Guidelines on the Protection of Privacy and Transborder Flows of Personal Data," OECD, 2013.

[182] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE).

[183] Royal Decree 110/2015 of 20 February.

[184] Legislative Decree No. 49, 14 March 2014, Implementing Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE).

[185] K. Ortegon, "Preparing for end of service life of wind turbine," *Journal of Cleaner Production,* vol. 39, pp. 191-199, 2013.

[186] H. Kalimo, "What Roles for Which Stakeholders under Extended Producer Responsibility?," *Review of European Community and International Environmental Law ,* vol. 24, no. 1, pp. 40-57, 2014.

[187] Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Thematic Strategy on the Prevention and Recycling of Waste, COM(2011) 13 final (19 January 2011).

[188] B. London, Ending the Depression through Planned Obsolescence, University of Wisconsin, 1932.

[189] M. Krajewski, "The Great Lightbulb Conspiracy," IEEE Spectrum, 24 September 2014. [Online]. Available: http://spectrum.ieee.org/geek-life/history/the-great-lightbulb-conspiracy. [Accessed 15 February 2017].

[190] European Environmental Bureau, "Delivering Resource-Efficient Products: How Ecodesign Can Drive a Circular Economy in Europe," European Environmental Bureau , Brussels, 2015.

[191] C. Dalhammar, "Industry attitudes towards ecodesign standards for improved resource efficiency," *Journal of Cleaner Production,* vol. 123, pp. 155-166, 2016.

[192] A. M. Bundgaard, "Ecodesign Directive 2.0. From Energy Efficiency to Resource Efficiency," Environmental project No. 1635, 2015, Aalborg, 2017.

[193] RREUSE, "Improving Product Reparability: Policy Option at the EU Level," RREUSE, 2015.

[194] Law No. 2015-992 on Energy Transition for Green Growth (Energy Transition Law).

[195] E. Maitre-Ekern and C. Dalhammar, "Regulating Planned Obsolescence: A Review of Legal Approaches to Increase Product Durability and Reparability in Europe," *Review of European Community and International Environmental Law,* vol. 25, no. 3, pp. 378-394, 2016.

[196] G. Pickern, "Making connections between global production networks for used goods and the realm of production: a case study on e-waste governance," *Global Networks,* vol. 15, no. 4, pp. 403-423, 2014.

[197] Part 1.3, point (i) of Annex I Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.

[198] Directorate General for Internal Policies, "A longer Lifetime for Products: Benefits for Consumers and Companies," 2016.

[199] The Climate Group. GeSI, "SMART 2020: Enabling the low carbon economy in the information age," The Climate Group. GeSI, 2008.

[200] European Commission. Directorate-General Information Society and Media, "ICT for a Low Carbon Economy. Smart Electricity Distribution Networks," Brussels, European Commission. Directorate-General Information Society and Media, 2009.

[201] J. Liu, "Cyber Security and Privacy Issues in Smart Grids," *IEEE Communications Surveys & Tutorials,* vol. 14, no. 4, pp. 981-987, 2012.

[202] K. Polinpapilinho, "A Criticality-based Approach for the Analysis of Smart Grids," *Technology and Economics of Smart Grids and Sustainable Energy,* vol. 1, no. 1, pp. 1-20, 2016.

[203] C. Wueest, "Attacks Against the Energy Sector," Symantec Official Blog, 13 January 2014. [Online]. Available: https://www.symantec.com/connect/blogs/attacks-against-energy-sector. [Accessed 5 May 2017].

[204] REScoop, "6.1 European Legislative Environment," REScoop, 2017.

[205] C. Cerrudo, "Why Cybersecurity Should Be The Biggest Concern Of 2017," Forbes, 17 January 2017. [Online]. Available: https://www.forbes.com/sites/forbestechcouncil/2017/01/17/why-cybersecurity-should-be-the-biggest-concern-of-2017/#dc35d95218a8. [Accessed 9 October 2017].

[206] M. Roscini, Cyber Operations and the Use of Force in International Law, Oxford University Press, 2014.

[207] M. Masera, "The Security of Information and Communication Systems and the E+I Paradigm," in *Critical Infrastructures at Risk: Securing the European Electric Power System*, V. Gheorghe, M. Masera, M. Weijnen and L. De Vries, Eds., Springer, 2016, pp. 85-116.

[208] Commission Staff Working Document. Second Strategic Energy Review an EU energy security and solidarity action plan. Europe's current and future energy position. Demand-resource-investments, SEC(2008) 2871 (13 November 2008).

[209] I. Pearson, "Smart grid cyber security for Europe," *Energy Policy,* vol. 39, pp. 5211-5218, 2011.

[210] W. Wang and Z. Lu, “Cyber security in the Smart Grid: Survey and challenges,” *Computer Networks,* vol. 57, no. 5, pp. 1344-1371, 2013.

[211] K. Weaver, “Smart Meter Deployments Result in a Cyber Attack Surface of “Unprecedented Scale”,” Smart Grid Awareness, 7 January 2017. [Online]. Available: https://smartgridawareness.org/2017/01/07/cyber-attack-surface-of-unprecedented-scale/. [Accessed 8 February 2017].

[212] Article 29 Data Protection Working Party, “Opinion 07/2013 on the Data Protection Impact Assessment Template for Smart Grid and Smart Metering Systems (‘DPIA Template’) prepared by Expert Group 2 of the Commission’s Smart Grid Task Force,” 2064/13/EN WP209, Brussels, 2013.

[213] A. Gurzu, “Hackers threaten smart power grids,” Politico, 1 April 2017. [Online]. Available: http://www.politico.eu/article/smart-grids-and-meters-raise-hacking-risks/. [Accessed 9 October 2017].

[214] Joint Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Cybersecurity Strategy of the European Union: An Open, Safe and Secure Cyberspace, JOIN(2013)1final (7 February 2013).

[215] Recommendation CM/Rec(2010)13 of 23 November 2010 of the Committee of Ministers to member states on the protection of individuals with regard to automatic processing of personal data in the context of profiling.

[216] US Department of Energy, “Transforming the Nation’s Electricity System: The Second Installment of the QER,” US Department of Energy, 2017.

[217] J. Rule and G. Greenleaf, Global Privacy Protection: The First Generation, Edward Elgar, 2010.

[218] Z. Zulkafli, “User-driven design of decision support systems for polycentric environmental resources management,” *Environmental Modelling and Software,* vol. 88, pp. 58-73, 2017.

[219] J. Cai and Z. Jiang, “Changing of energy consumption patterns from rural households to urban households in China: An example from Shaanxi Province, China,” *Renewable and Sustainable Energy Reviews,* vol. 12, no. 6, pp. 1667-1680, 2008.

[220] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A Digital Agenda for Europe, COM(2010)245 final (19 May 2010).

[221] M. Shah, “Big Data and the Internet of Things,” in *Big Data Analysis: New Algorithms for a New Society*, N. Japkowicz and J. Stefanowski, Eds., Springer, 2015, pp. 207-237.

[222] International Telecommunication Union, “ICT Facts & Figures. The world in 2015,” ITU, 2015.

[223] E. McKenna, “Smart meter data: Balancing consumer privacy concerns with legitimate applications,” *Energy Policy,* vol. 41, pp. 807-814, 2012.

[224] L. Brandeis and S. Warren, “The Right to Privacy,” *Harvard Law Review,* vol. 4, no. 5, 1890.

[225] M. Roggensack, “Face It Facebook, You Just Don’t Get It,” Huffington Post, 25 5 2010. [Online]. Available: http://www.huffingtonpost.com/human-rights-first/face-it-facebook-you-just_b_589045.html. [Accessed 3 May 2017].

[226] J. Stoddart, *Why Privacy Still Matters in the Age of Google and Facebook and How Cooperation Can Get Us There,* 2010.

[227] European Commission, “Flash Eurobarometer 443,” European Commission , Brussels, 2016.

[228] N. Balta-Ozkan, “Social barriers to the adoption of smart homes,” *Energy Policy,* vol. 63, pp. 363-374, 2013.

[229] J. Lazar, Ensuring Digital Accessibility through Process and Policy, Morgan Kaufmann, 2015.

[230] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Smart Grids: from innovation to deployment, COM(2011) 202 final (12 April 2011).

[231] Convention for the Protection of Human Rights and Fundamental Freedoms as amended by Protocols No. 11 and No. 14.

[232] O. Lynskey, “Deconstructing data protection: the 'Added-value' of a right to data protection in the EU legal order,” *International and Comparative Law Quarterly,,* vol. 63, no. 3, pp. 569-597, 2014.

[233] O. Lynkskey, The Europeanisation of data protection law, Cambridge Yearbook of European Legal Studies, 2016.

[234] E. Izyumenko, *Think before you share: Personal data on the Social Networking Sites in Europe; Article 8 ECHR as a tool of privacy protection,* Lund, 2011.

[235] Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data.

[236] Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector (Directive on privacy and electronic communications).

[237] Council Framework Decision 2008/977/JHA of 27 November 2008 on the protection of personal data processed in the framework of police and judicial cooperation in criminal matters.

[238] Regulation (EC) No 45/2001 of the European Parliament and of the Council of 18 December 2000 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data.

[239] C. Cuijpers and B.-J. Koops, “Smart metering and privacy in Europe: lessons from the Dutch case,” in *European Data Protection: Coming of Age*, S. Gutwirth, Ed., Springer, 2012, pp. 269-293.

[240] Article 5.1.(b) of Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive.

[241] Article 29 Data Protection Working Party, “Opinion 03/2013 on purpose limitation,” 00569/13/EN WP 203, Brussels, 2013.

[242] Article 6.1.(b) of Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data.

[243] Chapter II of Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data.

[244] European Data Protection Supervisor, “Preliminary Opinion of the European Data Protection Supervisor. Privacy and competitiveness in the age of big data: The interplay between data protection, competition law and onsumer protection in the Digital Economy,” European Data Protection Supervisor, Brussels, 2014.

[245] Art. 6 (1) (c) Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data.

[246] J. Shishido, “Smart Meter Data Quality Insight,” *ACEEE Summer Study on Energy Efficiency in Buildings,* 2012.

[247] European Union Agency for Fundamental Rights, “Handbook on European Data Protection Law,” European Union Agency for Fundamental Rights, 2014.

[248] Article 29 Data Protection Working Party, “Opinion 3/2010 on the principle of accountability,” 00062/10/EN, WP 173, 2010.

[249] European Union Agency for Fundamental Rights, “Handbook on European,” European Union Agency for Fundamental Rights, 2014.

[250] Article 4.(5) of the GDPR.

[251] DSB-MIT-SYSTEM, “Recital 28 EU GDPR,” [Online]. Available: https://www.privacy-regulation.eu/en/r28.htm. [Accessed 5 May 2017].

[252] Smart Grid Task Force Group 3, “Smart Grids Task Force (SGTF), Workshop on experiences and conditions for successful implementation of storage,” Smart Grid Task Force, Brussels, 2016.

[253] Expert Group 2: Regulatory Recommendations for Privacy, Data Protection and Cyber in the Smart Grid Environment, “Data Protection Impact Assessment Template for Smart Grid and Smart Metering systems,” Smart Grid Task Force 2012, 2014.

[254] V. Mayer-Schönberger and Y. Padova, “Regime Change? Enabling Big Data through Europe’s New Data Protection Regulation,” *The Columbia Science and Technology Law Review,* vol. 17, pp. 315-335, 2016.

[255] E. Kosta, Consent in European Data Protection Law, Brill , 2013.

[256] N. Purtova, “Illusion of Personal Data as No One's Property,” *Law, Innovation, and Technology,* vol. 7, no. 1, pp. 83-111, 2015.

[257] P. M. Schwartz, “Beyond Lessig's Code for Internet Privacy: Cyberspace Filters, Privacy Control and Fair Information Practices,” *Wisconsin Law Review,* pp. 743-788, 2010.

[258] Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[259] Regulation (EC) No 460/2004 of the European Parliament and of the Council of 10 March 2004 establishing the European Network and Information Security.

[260] Jones Day , “The New EU Cybersecurity Directive: What Impact on Digital Service Providers?,” Jones Day, [Online]. Available: http://www.jonesday.com/the-new-eu-cybersecurity-directive-what-impact-on-digital-service-providers-08-24-2016/. [Accessed 10 June 2017].

[261] Article 11 Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across

the Union.

[262] Articles 9 and 11, together with Annex I Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[263] Article 5 (2) Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[264] Article 14 Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[265] Article 19 (1) Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[266] Annex II Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[267] Article 2 (35) of Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.

[268] R. Caillière, “Managing energy markets in future smart grids using bilateral contracts,” *Frontiers in Artificial Intelligence and Applications,* vol. 285, pp. 133-140, 2016.

[269] Eurostat, “The EU was dependent on energy imports for,” 4 February 2016. [Online]. Available: http://ec.europa.eu/eurostat/documents/2995521/7150363/8-04022016-AP-EN.pdf/c92466d9-903e-417c-ad76-4c35678113fd. [Accessed 22 August 2017].

[270] International Energy Agency, “Energy Supply Security 2014,” International Energy Agency, Paris, 2014.

[271] Elia Group, “Making the Energy Transition Happen. Rapport annuel 2016,” Elia Group, Brussels, 2016.

[272] World Nuclear Association, “Nuclear Power in Belgium,” [Online]. Available: http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/belgium.aspx. [Accessed 22 August 2017].

[273] R. Laleman and J. Albrecht, “Belgian blackout? Estimations of the reserve margin during the nuclear phase-out,” *International Journal of Electrical Power and Energy Systems* , vol. 81, 2016.

[274] International Energy Agency, “Energy Policies of IEA Countries. Belgium. 2016 Review,” International Energy Agency, Paris, 2016.

[275] European Environment Agency, “Country profile-Belgium,” European Environment Agency, Copenhagen, 2014.

[276] Elexys, “Les compétences en matière d'énergie en Belgique,” Elexys. Think smart energy, 14 July 2016. [Online]. Available: https://www.elexys.be/fr/nouvelles/les-comp%C3%A9tences-en-mati%C3%A8re-d%C3%A9nergie-en-belgique.aspx. [Accessed 30 August 2017].

[277] The Environment, Nature and Energy Department, “About us,” The Environment, Nature and Energy Department, [Online]. Available: https://www.lne.be/about-us. [Accessed 30 August 2016].

[278] Wallonie Energie SPW, “Le Département de l'Energie et du Bâtiment durable,” 5 May 2014. [Online].

Available: https://energie.wallonie.be/fr/le-departement-de-l-energie-et-du-batiment-durable.html?IDD=11905&IDC=6267. [Accessed 31 August 2017].

[279] Be home. Be.Brussels, “Bruxelles Environnement-IBGE,” Be home. Be.Brussels, [Online]. Available: http://be.brussels/about-the-region/regional-bodies/bruxelles-environnement-ibge. [Accessed 31 August 2017].

[280] American Chamber of Commerce in Belgium, “The Sixth State Reform: Devolution à la belge,” American Chamber of Commerce in Belgium, 10 June 2014. [Online]. Available: http://www.amcham.be/blog/2014/06/sixth-state-reform-devolution-%C3%A0-la-belge. [Accessed 31 August 2017].

[281] Elia Group, “Legal Framework,” Elia Group, [Online]. Available: http://www.elia.be/en/about-elia/legal-framework. [Accessed 11 September 2017].

[282] Communication from the Commission to the European Parliament, the Council. Achieving 10% electricity interconnection target. Making Europe’s electricity grid fit for 2020, at p. 4, COM(2015) 82 final (25 February 2015).

[283] European Commission, “Electricity interconnection targets,” [Online]. Available: https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest/electricity-interconnection-targets. [Accessed 12 September 2017].

[284] Communication from the Commission to the European Parliament, the Council. European Energy Security Strategy, at p. 10, COM(2014) 330 final (28 May 2014).

[285] Elia Group , “Users Group. Sophie De Baets: Project Infrastructure Communication,” Elia Group , Brussels, 2016.

[286] Nemo Link, “Overview. Why an interconnector?,” Nemo Link, [Online]. Available: http://www.nemo-link.com/the-project/overview/. [Accessed 12 September 2017].

[287] TSCNET Services, “Interconnecting Belgium and Germany,” TSCNET Services, 30 September 2016. [Online]. Available: http://www.tscnet.eu/interconnecting-belgium-and-germany/. [Accessed 12 September 2017].

[288] Elia Group, “Interconnector Creos,” Brussels.

[289] Elia Group, “Press release. Avelgem-Avelin high-voltage connection upgrade project,” Elia Group, Brussels, 2017.

[290] European Commission, “Projects of Common Interest,” European Commission, [Online]. Available: https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest/. [Accessed 13 September 2017].

[291] European Commission, “Financing trans-European energy infrastructure – the Connecting Europe Facility,” 5 March 2015. [Online]. Available: http://europa.eu/rapid/press-release_MEMO-15-4554_en.htm. [Accessed 13 September 2017].

[292] Article 3, paragraph 11 Directive 2009/72/EC concerning common rules for the internal market in electricity.

[293] Annex I, point 2 Directive 2009/72/EC concerning common rules for the internal market in electricity.

[294] Commission staff working document country fiches for electricity smart metering. Report form the Commission benchmarking smart metering deployment in the EU-27 with a focus on electricity, at p.

108, SWD(2014) 188 final (17 July 2014).

[295] ICCS-NTUA and AF-MERCADOS-EMI, “Study on Cost Benefit Analysis of Smart Metering Systems in EU Member States,” ICCS-NTUA and AF-MERCADOS-EMI, 2015.

[296] VREG, “The future of smart metering in Flanders/Belgium,” VREG, 2013.

[297] Fédération Belge des Entreprises Electriques et Gazières asbl, “Compteurs intelligents (smart meters),” [Online]. Available: https://www.febeg.be/fr/compteurs-intelligents-smart-meters. [Accessed 18 September 2017].

[298] Federatie van de Belgische Elektriciteits- en Gas Bedrijven vzw, “Samen bouwen aan onze energietoekomst door de invoering van digitale meters,” Federatie van de Belgische Elektriciteits- en Gas Bedrijven vzw, 2017.

[299] Brugel, “Avis relatif à l'introduction des systèmes intelligents de mesure: vision de Brugel por la region de Bruxelles-Capitale,” Brugel, Brussels, 2013.

[300] USmart Consumer Project, “European Smart Metering Landscape Report. Utilities and Consumers,” USmart Consumer Project, Madrid, 2016.

[301] Vlaanderen, “De digitale energiemeter,” Vlaanderen, [Online]. Available: https://www.vlaanderen.be/nl/bouwen-wonen-en-energie/elektriciteit-aardgas-en-verwarming/de-digitale-energiemeter. [Accessed 21 September 2017].

[302] Smart Energy Demand Coalition, “Explicit Demand Response in Europe - Mapping the Market 2017,” SEDC, Brussels , 2017.

[303] S. D. Smedt, “Belgium - The New Data Protection Hub?,” *European Data Protection Law Review,* vol. 3, pp. 213 - 218, 2015.

[304] T. D'hulst, “Data Protection in Belgium: overview,” Practical Law - Thomson Reuters, 1 July 2016. [Online]. Available: https://uk.practicallaw.thomsonreuters.com/2-502-2977?__lrTS=20170610192313070&transitionType=Default&contextData=(sc.Default). [Accessed 12 September 2017].

[305] Council of European Energy Regulators (CEER), “CEER Benchmarking Report on Meter Data Management Case Studies,” CEER, Brussels , 2012.

[306] Smart Grids Task Force, “My Energy Data (Report by Expert Group on Smart Grid Deployment (EG1)),” 2016.

[307] SIA Partners, “Atrias and MIG6.0: Towards a new energy market model in Belgium,” SIA PArtners, 1 July 2016. [Online]. Available: http://energy.sia-partners.com/20160701/atrias-and-mig60-towards-new-energy-market-model-belgium. [Accessed 12 September 2017].

[308] International Energy Agency: Hybrid & Electric Vehicle Technology Collaboration Programme, “Belgium,” International Energy Agency, [Online]. Available: http://www.ieahev.org/by-country/belgium/. [Accessed 12 September 2017].

[309] National Climate Commission, “Greenhouse gas inventory for Belgium,” Brussles, 2016.

[310] K. Boussauw and T. Vanoutrive, “Transport policy in Belgium: translating sustainability discourses into unsustainable outcomes,” *Transport Policy ,* vol. 53, pp. 11-19, 2017.

[311] European Alternative Fuels Observatory (EAFO), “Belgium,” EAFO, [Online]. Available: http://www.eafo.eu/content/belgium. [Accessed 13 September 2017].

[312] I.-S. Brouhns, "CMS Guide to Energy Storage: Belgium," Global Business Media Group, 1 September 2016. [Online]. Available: https://www.lexology.com/library/detail.aspx?g=4ebed335-f539-46dc-95f2-bdf5d7bc705f. [Accessed 14 September 2017].

[313] The World Bank, "The World Bank in Greece," The World Bank Group, [Online]. Available: http://www.worldbank.org/en/country/greece. [Accessed 2 May 2017].

[314] Central Intelligence Agency (CIA), "The World Fact Book," US Central Intelligence Agency, [Online]. Available: https://www.cia.gov/library/publications/the-world-factbook/geos/gr.html. [Accessed 2 May 2017].

[315] Energypedia, "Greece Energy Situation," 26 April 2017. [Online]. Available: https://energypedia.info/wiki/Greece_Energy_Situation#Energy_Supply. [Accessed 7 June 2017].

[316] J. Anagnostopoulos and D. Papantonis, "Facilitating energy storage to allow high penetration of intermittent renewable energy," StoRe, 2013.

[317] International Energy Agency, "Greece - Energy Overview," 2016. [Online]. Available: https://www.iea.org/media/countries/Greece.pdf. [Accessed 20 September 2017].

[318] European Commission, "European Commisssion Country Reports," 2014. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/2014_countryreports_italy.pdf. [Accessed 9 June 2017].

[319] P. Andreanesis, P. Biskas and G. Liberopoulos, "An overview of Greec's wholesale electricity market with emphasis on ancillary services," *Electric Power Systems Research,* vol. 81, no. 8, pp. 1631-1642, 2011.

[320] Pöyry, "Options for Greek Compliance with Target Model. A report to RAE," Pöyry, Oxford, 2012.

[321] A. Koutantou, "Greece plans trading exchange to help reform power market," Reuters, 21 February 2017. [Online]. Available: http://www.reuters.com/article/greece-electricity-exchange-idUSL8N1G61EA. [Accessed 2 June 2017].

[322] D. Assimakis, "Electricity Regulation: Greece," Getting the Deal Through, 31 October 2016. [Online]. Available: https://gettingthedealthrough.com/area/12/jurisdiction/12/electricity-regulation-greece/. [Accessed 2 June 2017].

[323] Ministry of Environment, Energy & Climate Change, "National Renewable Energy Action Plan in the Scope of Directive 2009/28/EC," 19 July 2010. [Online]. Available: https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwjWq7vH5bPWAhWpKMAKHae5DcUQFgguMAE&url=http%3A%2F%2Fwww.ypeka.gr%2FLinkClick.aspx%3Ffileticket%3DCEYdUkQ719k%253D&usg=AFQjCNFrF6ZCjDnhKMCoiHRSfMOm1W_4fg. [Accessed 20 September 2017].

[324] European Commission, "European Commission's on Greece Transitory Electricity flexibility remuneration mechanism (State Aid Ss 38968 2015/N)," [Online]. Available: http://ec.europa.eu/competition/state_aid/cases/256426/256426_1751668_182_2.pdf. [Accessed 9 June 2017].

[325] M. Kolia and G. Mavroudis, "Public Service Obligations in the Electricity Sectors: Greece," *International Energy Law & Taxation Review,* pp. 1-, 2004.

[326] Norton Rose Fulbright, "Law 4414/2016: A new support scheme for renewable electricity in Greece," *Norton Rose Fulbright - Briefing,* October 2016.

[327] “Ministerial Decision 175067/2017 - Installation of photovoltaic plants by self-producers using net metering or virtual net metering according to Art. 14A of Law 3468/2006,” Official Gazette 1547/ B/ 2017.

[328] Regulatory Authority for Energy, “Handbbok of Power Exchange Code for Electricity as it was modified by Ministerial Decision 334/2016,” Official Gazette 3169 / B /2016.

[329] “www.admie.gr,” [Online]. Available: http://www.admie.gr/en/company/mission/duties-responsibilities/. [Accessed July 2017].

[330] “Law 4414/2016 - New governance for the support of power production units from Renewabke Energy Sources.,” Official Gazette 149/A/2016.

[331] “www.europex.org - Association of European Energy Exchanges,” [Online]. Available: http://www.europex.org/members/lagie-hellenic-electricity-market-operator-greece/. [Accessed July 2017].

[332] HEDNO S.A., “www.deddie.gr,” [Online]. Available: https://www.deddie.gr/en/i-etaireia/ruthmistiko-plaisio. [Accessed July 2017].

[333] ΛΑΓΗΕ Operator of the electricity market December 2015, “www.lagie.gr / DAS montly reports,” [Online]. Available: http://www.lagie.gr/en/market/market-analysis/das-monthly-reports/das-monthly-reports/document/129032/doccat/detail/Document/. [Accessed July 2017].

[334] ΛΑΓΗΕ Operator of the electricity market, “www.lagie.gr / DAS montly report December 2016,” [Online]. Available: http://www.lagie.gr/fileadmin/groups/EDRETH/DAS_Monthly_Reports/201612_DAS_Monthly_Report.pdf. [Accessed July 2017].

[335] ΛΑΓΗΕ Operator of the electricity market, “www.lagie.gr / DAS montlhly reports May 2017,” [Online]. Available: http://www.lagie.gr/fileadmin/groups/EDRETH/DAS_Monthly_Reports/201705_DAS_Monthly_Report.pdf. [Accessed July 2017].

[336] ΑΔΜΗΕ Independent Power Transmission Operator, “www.admie.gr,” [Online]. Available: http://www.admie.gr/en/operations-data/interruptible-load-service/information/. [Accessed July 2017].

[337] Regulatory Authority for Energy, “Hellenic Electricity Distribution Network Management Code,” Ministerial Decision 395/2016 , Official Gazette 78/ B /2017.

[338] Ministry of Environment, Energy & Climate Change, *Ministerial Decision, GG B 297/13.2.2013 "Intelligent Systems Development of Measurement to HEDNO".*

[339] “Commission Recommendation of 9 March 2012 on preparations for the roll-out of smart metering systems (2012/148/EU),” [Online]. Available: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32012H0148.

[340] European Regulators' Group for Electriciy and Gas (ERGEG), “Smart Metering with a Focus on Electricity Regulation,” ERGEG, Brussels, 2007.

[341] Karageorgiou & Associates Law Firm, “Linklaters LLP,” [Online]. Available: https://clientsites.linklaters.com/Clients/dataprotected/Pages/Greece.aspx.

[342] V. Papakonstantinou and D. Kloza, “Legal Protection of Personal Data in Smart Grid and Smart Metering Systems from the European Perspective,” in *Smart Grid Secuirty. SpringerBriefs in*

Cybersecurity, London, Springer, 2015, pp. 41-129.

[343] Joined Cases C-293/12 and 594/12, Digital Rights Ireland and Seitlinger and Others.

[344] T. Garanis-Papadatos and D. Boukis, “Research Ethics Committees in Greece,” in *Research Ethics Committees, Data Protection and Medical Research in European Countries*, D. Beyleveld, D. Townend and J. Wright, Eds., New York, Routledge, 2016.

[345] Endergiewende Team, “Greece's first battery storage system under way in the Aegean Sea,” Energy Transitioon, 2 May 2017. [Online]. Available: https://energytransition.org/2017/05/greeces-first-battery-storage-system-under-way-in-the-aegean-sea/. [Accessed 20 June 2017].

[346] European Alternative Fuels Observatory (EAFO), “Greece,” EAFO, [Online]. Available: http://www.eafo.eu/content/greece. [Accessed 20 June 2017].

[347] Ernst & Young, “EY Study on the Circular Economy in Greece,” Athens, 2016.

[348] The Econcomist Intelligence Unit (EIU), “The Economist,” The Economist Group, 2017. [Online]. Available: http://country.eiu.com/italy. [Accessed 21 August 2017].

[349] N. Rossetto, “An oversized electricity system for Italy,” Italian Institute for International Political Studies, 22 January 2015. [Online]. Available: http://www.ispionline.it/en/energy-watch/oversized-electricity-system-italy-12135. [Accessed 21 August 2017].

[350] International Energy Agency (IEA), “Energy Policies of IEA Countries; Italy 2016,” OECD/IEA, 2016.

[351] *Bersani Decree,* Legislative Decree No. 79, 1999.

[352] M. Cicchetti and G. Fabbricatore, “Electricity Regulation in Italy: Overview,” Practical Law Company, 1 May 2014. [Online]. Available: https://uk.practicallaw.thomsonreuters.com/Document/Ieb49d7bb1cb511e38578f7ccc38dcbee/View/FullText.html?originationContext=docHeader&contextData=(sc.Defadult)&transitionType=Document&needToInjectTerms=False&firstPage=true&bhcp=1. [Accessed 5 June 2017].

[353] *Law No. 239,* 2004.

[354] *(IT) (IT) Riforma organica della regolazione del servizio di dispacciamento dell’energia elettrica e conseguente attivazione del progetto interdirezionale RDE (Riforma del dispacciamento elettrico).*

[355] *(IT) Prima fase della riforma del mercato per il servizio di dispacciamento: apertura alla domanda, alle fonti rinnovabili non programmabili e alla generazione distribuita.*

[356] (IT) Decision No. 574/2014/R/eel of 20 November 2014 on Disposizioni relative all’integrazione dei sistemi di accumulo di energia elettrica nel sistema elettrico nazionale.

[357] *(IT) Dati tecnici delle unità di produzione rilevanti valevoli ai fini del mercato elettrico , allegato a60 al codice di rete.*

[358] (IT) Decision No. 642/2014/R/eel of 18 December 2014 on Ulteriori disposizioni relative all’installazione e all’utilizzo dei sistemi di accumulo. Disposizioni relative all’applicazione delle Norme CEI 0-16 e CEI 0-21.

[359] (IT) Norm No. CEI 0-21 updated in December 2014 on Regola tecnica di riferimento per la connessione di Utenti attivi e passivi alle reti BT delle imprese distributrici di energia elettrica.

[360] (IT) Norm No. CEI 0-16 updated in December 2014 on Regola tecnica di riferimento per la connessione di Utenti attivi e passivi alle reti AT ed MT delle imprese distributrici di energia elettrica.

[361] (. C. d. R. C. 4. R. p. i. dipacciamento.

[362] S. Zhou and M. A. Brown, "Smart meter deployment in Europe: A comparative case study on the impacts of national policy schemes," *Journal of Cleaner Production,* vol. 144, pp. 22-32, 2017.

[363] F. Villa, "Regulation of Smart Meters and AMM Systems in Italy," in *19th International Conference on Electricity Distribution (CIRED)* , Vienna, 2007.

[364] L. L. Schiavo, M. Delfanti, E. Fumagalli and V. Olivieri, "Changing the Regulation for REgulating the Change; Innovation-driven regulatory developments in Italy: smart grids, smart metering and e-mobility," The Center for Research on Energy and Environmental Economics and Policy at Cocconi University (IEFE), 2011.

[365] R. Panetta and A. D'Ottavio, "Data protection in Italy: overview," Thomson Reuters, 1 12 2015. [Online]. Available: https://uk.practicallaw.thomsonreuters.com/9-502-4794?transitionType=Default&contextData=(sc.Default). [Accessed 3 October 2017].

[366] European Commission, *Directive 2012/27/EU, on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC, 25 October 2012.*

[367] A. A. &. C. Scamoni, "Lexology," Globe Business Media Group, 1 September 2016. [Online]. Available: http://www.lexology.com/library/detail.aspx?g=4bf3dda1-44ba-47c3-a860-af76ca74cbe4. [Accessed 22 June 2017].

[368] E. Comelli, "ItalyEurope24," Il Sole 24 ORE, 23 February 2017. [Online]. Available: http://www.italy24.ilsole24ore.com/art/business-and-economy/2017-02-22/italy-establishing-its-presence-the-electric-vehicle-industry--104247.php?uuid=AEVHU7a. [Accessed 22 June 2017].

[369] Hybrid & Electric Vehicle Technology Collaboration Programme, "Hybrid & Electric Vehicle Technology Collaboration Programme," International Energy Agency, [Online]. Available: http://www.ieahev.org/by-country/italy-policy-and-legislation/. [Accessed 22 June 2017].

[370] D. M. Hill, A. S. Agarwal and F. Ayello, "Fleet operator risks for using fleets for V2G regulation," *Energy Policy,* vol. 41, pp. 221-231, 2012.

[371] Ministry of Environment and Protection of Land and Sea, "Ministry of Environment and Protection of Land and Sea," 29 December 2015. [Online]. Available: http://www.minambiente.it/pagina/temi-prioritari-litalia. [Accessed 23 June 2017].

[372] Spanish Institute of Strategic Studies, "Strategic Dossier 166 B Energy and Geostrategy 2014," Ministry of Defence, 2014.

[373] Eurostat, "Energy dependency in the EU. The EU was dependent on energy imports for slightly over half of its consumption in 2014," 4 February 2016. [Online]. Available: http://ec.europa.eu/eurostat/documents/2995521/7150363/8-04022016-AP-EN.pdf/c92466d9-903e-417c-ad76-4c35678113fd.

[374] International Energy Agency, "Energy Policies of IEA Countries. Spain. 2015 Review," International Energy Agency, Paris, 2015.

[375] Ministry of Industry, Energy and Tourism, "La Energía en España," Ministry of Industry, Energy and Tourism, Madrid, 2014.

[376] Ministry of Industry, Energy and Tourism, "2014-2020 National Energy Efficiency Plan," Ministry of Industry, Energy and Tourism, Madrid, 2014.

[377] King & Spalding LLP, “LNG in Europe: An Overview of European Import Terminals in 2015,” King & Spalding LLP, 2015.

[378] Gas Infrastructure Europe, “GIE LNG MAP,” [Online]. Available: http://www.gie.eu/download/maps/2016/GIE_LNG_2016_A0_1189x841_FULL.pdf. [Accessed 15 May 2017].

[379] Energía16, “In-depth analysis of the Spanish energy sector,” Energía16, 29 July 2016. [Online]. Available: http://www.energia16.com/in-depth-analysis-of-the-spanish-energy-sector/?lang=en. [Accessed 15 May 2017].

[380] Red Eléctrica de España, “Strengthening interconnections,” Red Eléctrica de España, [Online]. Available: http://www.ree.es/en/red21/strengthening-interconnections. [Accessed 19 May 2017].

[381] European Commission, “Building the Energy Union: Key electricity interconnection between France and Spain completed,” *European Commission - Press release,* 2015.

[382] Red Eléctrica de España, “European Projects of Common Interest (PCI),” Red Eléctrica de España, [Online]. Available: http://www.ree.es/en/activities/grid-manager-and-transmission-agent/european-projects-common-interest-pci. [Accessed 15 May 2017].

[383] Articles 4 and 194 of the Treaty on the Functioning of the European Union (TFEU).

[384] Instituto para la Diversificación y Ahorro de la Energía, “Quiénes Somos,” Instituto para la Diversificación y Ahorro de la Energía, [Online]. Available: http://www.idae.es/conozcanos/quienes-somos. [Accessed 16 May 2017].

[385] Corporación de Reservas Estrátegicas de Productos Petrolíferos, “About us,” Corporación de Reservas Estrátegicas de Productos Petrolíferos, [Online]. Available: http://www.cores.es/en/cores/quienes-somos. [Accessed 16 May 2017].

[386] Instituto para la Reestructuración de la Minería del Carbón y Desarollo Alternativo de las Comarcas Mineras, “El Instituto,” Instituto para la Reestructuración de la Minería del Carbón y Desarollo Alternativo de las Comarcas Mineras, [Online]. Available: https://www.irmc.es/el_instituto/index-ides-idweb.asp. [Accessed 16 May 2017].

[387] Red Eléctrica de España , “About Us,” Red Eléctrica de España , [Online]. Available: http://www.ree.es/en/about-us. [Accessed 3 October 2017].

[388] OMIE, “Introduction,” OMIE, [Online]. Available: http://www.omel.es/inicio/informacion-de-la-compania. [Accessed 3 October 2017].

[389] Comisión Nacional de los Mercados y la Competencia, “Qué es la CNMC,” Comisión Nacional de los Mercados y la Competencia, [Online]. Available: https://www.cnmc.es/sobre-la-cnmc/que-es-la-cnmc. [Accessed 16 May 2017].

[390] Consejo de Seguridad Nuclear, “CSN,” Consejo de Seguridad Nuclear, [Online]. Available: https://www.csn.es/csn/transparencia. [Accessed 16 May 2017].

[391] M. Balaguer-Coll, “Decentralisation and efficiency in Spanish local government,” *The Annals of Regional Science,* vol. 45, no. 3, pp. 571-601, 2010.

[392] European Committee of the Regions, “Division of Powers,” European Committee of the Regions, 2012. [Online]. Available: https://portal.cor.europa.eu/divisionpowers/countries/MembersLP/Spain/Pages/default.aspx. [Accessed 17 May 2017].

[393] Article 149, paragraph 1, point 22 Spanish Constitution.

[394] Article 149, paragraph 1, point 25 Spanish Constitution.

[395] Article 149, paragraph 1, point 13 Spanish Constitution.

[396] Article 149, paragraph 1, point 23 Spanish Constitution.

[397] P. Navarro Rodríguez, "Distribución de competencias en materia de Energía en España; Pluralidad de Administraciones competentes," *Actualidad Administrativa,* no. 19-20, 2012.

[398] Article 5.3 of the Treaty on European Union (TEU).

[399] R. Leal-Arcas, "The European Union and its Energy Security Challenges," *Journal of World Energy Law and Business,* vol. 8, no. 4, 2015.

[400] A. Rojas and P. Carreño, "The Reform of the Spanish electricity sector," *Spanish Economic and Financial Outlook,* vol. 3, no. 2, 2014.

[401] International Energy Agency, "Electricity sector regulation (Electricity Law 24/2013)," International Energy Agency, 2 May 2017. [Online]. Available: https://www.iea.org/policiesandmeasures/pams/spain/name-130502-en.php. [Accessed 17 May 2017].

[402] Cuatrecasas, "Legal Update I Energy. Act 24/2013, of December 26, on the electricity sector," January 2014. [Online]. Available: http://www.cuatrecasas.com/media_repository/gabinete/publicaciones/docs/1388678102en.pdf. [Accessed 18 May 2017].

[403] M. Nachmany, "Climate Change Legislation in Spain. An excerpt from the 2015 Global Climate Legislation Study," The London School of Economics and Political Science - Grantham Research Institute on Climate Change and Environment, 2015.

[404] The Mediterranean Energy Regulators, "Study to evaluate net metering system in Mediterranean Countries," MedReg, Milan, 2016.

[405] Articles 19-21 Royal Decree 900/2015.

[406] Article 4 Royal Decree 900/2015.

[407] J. López Prol and K. Steininger, "Photovoltaic self-consumption regulation in Spain: Profitability analysis and alternative regulation schemes," *Energy Policy,* vol. 108, 2017.

[408] Article 5, paragraph 1, point c) Royal Decree 900/2015.

[409] Articles 17 and 18, respectively, Royal Decree 900/2015.

[410] I. Tsagas, "Spain Approves 'Sun Tax,' Discriminates Against Solar PV," Renewable Energy World, 23 October 2015. [Online]. Available: http://www.renewableenergyworld.com/articles/2015/10/spain-approves-sun-tax-discriminates-against-solar-pv.html. [Accessed 10 July 2017].

[411] Commission Staff Working Document. Best practices on Renewable Energy Self-consumption, at p. 3, COM(2015) 33 final (15 July 2015).

[412] J. Donoso, "Self-consumption regulation in Europe," *Energetica International,* no. 7, 2015.

[413] J. Roberts and S. Skillings, "The market design initiative: Towards better governance of EU energy markets," *ClientEarth and E3G - Regulatory Assistance Project publication,* 2015.

[414] European Commission, “Electricity interconnection targets,” [Online]. Available: https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest/electricity-interconnection-targets. [Accessed 22 May 2017].

[415] Booz & Company and others, “Benefits of an Integrated European Energy Market,” Booz & Company, 2013.

[416] European Network of Transmission System Operators for Electricity, “Scenario Outlook and Adequacy Forecast 2014,” 2014.

[417] Communication from the Commission to the European Parliament, the Council. Achieving 10% electricity interconnection target. Making Europe’s electricity grid fit for 2020, at p. 4, COM(2015) 82 final (25 February 2015).

[418] European Commission, “Projects of common interest,” European Commission, [Online]. Available: https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest/. [Accessed 25 May 2017].

[419] European Commission, “Financing trans-European energy infrastructure – the Connecting Europe Facility,” European Commission - Fact Sheet, 5 March 2015. [Online]. Available: http://europa.eu/rapid/press-release_MEMO-15-4554_en.htm. [Accessed 25 May 2017].

[420] Red Eléctrica de España, “Spain-France underground interconnection,” Red Eléctrica de España, [Online]. Available: http://www.ree.es/en/activities/unique-projects/new-interconnection-with-france. [Accessed 22 May 2017].

[421] *Madrid Declaration,* Madrid: Energy Interconnections Links Summit, 2015.

[422] European Commission, “Clean energy for all. New Electricity Market Design: A Fair Deal for Consumers,” 2016.

[423] [Online]. Available: http://www.datosmacro.com/demografia/poblacion/espana.

[424] “Red Electrica de Espana,” [Online]. Available: http://www.ree.es/en/red21/strengthening-interconnections.

[425] Red Eléctrica de España, [Online]. Available: https://www.youtube.com/watch?v=yLSJ_Nr3yAk.

[426] “Department of Electrical Engineering from the Polytechnic University of Valencia,” 2017. [Online]. Available: http://iie.webs.upv.es/inicio.

[427] "Nobel Grid" project, “Deliverable 2.1 "Market Analysis"”.

[428] Comisión Nacional de los Mercados y la Competencia, “Listado de Distribuidores de Energía Eléctrica: teléfonos para incidencias y dirección web para consulta de los datos de consumo”.

[429] “Holaluz,” [Online]. Available: https://www.holaluz.com/.

[430] [Online]. Available: https://www.cnmc.es/sites/default/files/1687350_8.pdf.

[431] “CNMC,” [Online]. Available: https://www.cnmc.es/en.

[432] [Online]. Available: https://uk.practicallaw.thomsonreuters.com/4-529-8116?__lrTS=20170409182335156&transitionType=Default&contextData=(sc.Default)&firstPage=true&bhcp=1.

[433] “Ministry of Energy, Tourism and Digital Agenda, Espana,” [Online]. Available:

http://www.minetad.gob.es/en-US/Paginas/index.aspx. [Accessed 2017].

[434] “Solargis,” [Online]. Available: http://solargis.com/products/maps-and-gis-data/free/overview/.

[435] Red Eléctrica de España, “The Spanish Electricity System 2016”.

[436] Red Eléctrica de España, “Las energías renovables en el sistema eléctrico español 2016”.

[437] El País, [Online]. Available: https://economia.elpais.com/economia/2015/10/09/actualidad/1444388935_118022.html.

[438] PwC, [Online]. Available: https://www.pwc.es/es/publicaciones/energia/assets/informe-autoconsumo-pwc.pdf.

[439] [Online]. Available: https://www2.deloitte.com/es/es/pages/strategy/articles/medidas-descarbonizacion-transporte.html.

[440] [Online]. Available: https://motor.elpais.com/electricos/puntos-de-recarga-coches-electricos/.

[441] [Online]. Available: http://www.recargacocheselectricos.com/aprobadas-las-ayudas-para-infraestructura-de-recarga-de-vehiculos-electricos-para-la-comunidad-valenciana-2017/.

[442] [Online]. Available: http://www.muycanal.com/2017/07/18/smart-home-espana.

[443] Article 2, point 28 of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

[444] C. De Julián Rodríguez, “Current state of Article 9 implementation,” *Executive Summary 3.8 Concerted Action Energy Efficiency Directive,* 2016.

[445] Comisión Nacional de los Mercados y la Competencia, “El 62% de los contadores analógicos ya han sido sustituidos por contadores inteligentes,” *Nota de Prensa,* 2017.

[446] USmart Consumer Project, “European Smart Metering Landscape Report. Utilities and Consumers,” USmart Consumer Project, Madrid, 2016.

[447] J. Leiva, “Smart metering trends, implications and necessities: A policy review,” *Renewable and Sustainable Energy Reviews,* vol. 55, 2016.

[448] Commission staff working document country fiches for electricity smart metering accompanying the document Report form the Commission benchmarking smart metering deployment in the EU-27 with a focus on electricity”, SWD(2014) 188 final (17 July 2015).

[449] European Commission, “Good practice in energy efficiency for a sustainable, safer and more competitive Europe,” European Commission, 2017.

[450] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

[451] Commission Recommendation 2012/148/EU of 9 March 2012 on preparations for the roll-out of smart metering systems.

[452] Report from the Commission “Benchmarking smart metering deployment in the EU-27 with a focus on electricity”, at p. 6, COM(2014) 356 final (17 June 2014).

[453] Communication from the Commission to the European Parliament, the Council, the European

Economic and Social Committee and the Committee of the Region, at p. 5, COM(2015) 339 final (15 July 2015).

[454] European Commission, "Smart grids and meters," European Commission, [Online]. Available: https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters. [Accessed 5 June 2017].

[455] Article 45, paragraph 3 Data Protection Law 15/1999.

[456] Hogan Lovells, "Data protection compliance in Spain. Mission impossible?," Hogan Lovells, 2015.

[457] R. Azim-Khan, "New Spanish Regulation Tightens Up Data Protection Requirement," *Privacy and Data Security Law Journal,* 2008.

[458] Linklaters, "Data Protected. Spain. General. Data Protection Laws," Linklaters, [Online]. Available: https://clientsites.linklaters.com/Clients/dataprotected/Pages/Spain.aspx. [Accessed 16 June 2017].

[459] Spanish Data Protection Agency, "Spanish Data Protection Agency," Spanish Data Protection Agency, Madrid.

[460] European Smart Grid Task Force, "My Energy Data," Smart Grids Task Force Ad hoc group of the Expert Group 1 - Standards and Interoperability, 2016.

[461] EnerConsultoría. Derecho de la energía, "contadores inteligentes y protección de datos," EnerConsultoría. Derecho de la energía, 8 December 2015. [Online]. Available: http://www.enerconsultoria.es/BlogLeyesEnergia.aspx?id=36002236&post=Contadoresinteligentesyprotecciondedatos. [Accessed 15 June 2017].

[462] J. Rubio, "Recommender system for privacy-preserving solutions in smart metering," *Pervasive and Mobile Computing,* 2017.

[463] The International Energy Agency. Hybrid and Electric Vehicle Technology Collaboration Programme, "Spain Policies and Legislation," The International Energy Agency. Hybrid and Electric Vehicle Technology Collaboration Programme, [Online]. Available: http://www.ieahev.org/by-country/spain-policy-and-legislation/. [Accessed 20 June 2017].

[464] J. Martínez Lao, "Electric Vehicles in Spain: An overview of charging systems," *Renewable and Sustainable Energy Reviews ,* vol. 77, 2017.

[465] C. Ávila Rodríguez, "Marco jurídico para la implantación de infraestructuras para las energías alternativas en el transporte en España," *Comunicación Proyecto (I+D) de Investigación,* 2017.

[466] Corriente Eléctrica, "Se activa el Plan MOVEA 2017 para coches y vehículos eléctricos," Corriente Eléctrica, 17 June 2017. [Online]. Available: http://corrienteelectrica.renault.es/asi-sera-el-plan-movea-2017-para-coches-y-vehiculos-electricos/. [Accessed 20 June 2017].

[467] Ministry of Industry, Energy and Tourism, "Estrategia de Impulso del vehículo con energías alternativas (VEA) en España (2014-2020)," Ministry of Industry, Energy and Tourism, 2015.

[468] Article 82, paragraph 2 Sustainable Economy Law 2/2011 of 4 March.

[469] Article 6, point h) Electricity Sector Law 24/2013 of 26 December.

[470] Article 48, paragraph 1 Electricity Sector Law 24/2013 of 26 December.

[471] Article 2, paragraph 1 Royal Decree 639/2016 of 9 December.

[472] Article 4, paragraphs 4 and 5 Royal Decree 639/2016 of 9 December.

[473] S. Bjerkan, “Incentives for promoting Battery Electric Vehicle (BEV) adoption in Norway,” *Transportation Research Part D: Transport and Environment,* vol. 43, 2016.

[474] Energías Renovables, “La escasez de puntos de recarga frena la compra de coches eléctricos más que el precio,” Energías Renovables. El periodismo de las energías limpias, 22 June 2017. [Online]. Available: https://www.energias-renovables.com/movilidad/la-escasez-de-puntos-de-recarga-frena-20170622. [Accessed 23 June 2017].

[475] Amsterdam Vehicle2Grid, “The Solution to Sustainable Urban Mobility and Energy,” Amsterdam Vehicle2Grid, [Online]. Available: http://www.amsterdamvehicle2grid.nl/. [Accessed 23 June 2017].

[476] Red Eléctrica de España, “Electric vehicle,” Red Eléctrica de España, [Online]. Available: http://www.ree.es/en/red21/electric-vehicle. [Accessed 23 June 2017].

[477] Deloitte, “¿Cuántos coches eléctricos necesita España?,” Deloitte , [Online]. Available: https://www2.deloitte.com/es/es/pages/strategy/articles/Cuantos-coches-electricos-necesita-Espana.html. [Accessed 23 June 2017].

[478] Red Eléctrica de España, “Interruptibility Service,” Red Eléctrica de España, [Online]. Available: http://www.ree.es/en/activities/operation-of-the-electricity-system/interruptibility-service. [Accessed 3 October 2017].

[479] IndustRE, ““Innovative Business Models for Market Uptake of Renewable Electricity unlocking the potential for flexibility in the Industrial Electricity Use” Business models and market barriers,” IndustRE, 2016.

[480] Universidad Pontifica Comillas, “The Impact of the Electric Vehicle and Energy Storage Technologies in Power Demand and CO2 emissions,” Universidad Pontifica Comillas, Amsterdam, 2016.

[481] E. Stoppani, “Smart Charging and Storage: bridging the gap between electromobility and electricity systems,” *International Energy Law Review,* no. 1, p. 17, 2017.

[482] Red Eléctrica de España, “Energy Storage,” Red Eléctrica de España, [Online]. Available: http://www.ree.es/en/red21/energy-storage. [Accessed 3 October 2017].

[483] [Online]. Available: http://www.irena.org/DocumentDownloads/Publications/IRENA_REthinking_Energy_2017.pdf.

[484] [Online]. Available: https://climate.nasa.gov/vital-signs/global-temperature/.

[485] [Online]. Available: https://www.agl.com.au/about-agl/media-centre/article-list/2016/august/agl-launches-world-largest-solar-virtual-power-plant.

[486] c. VPP. [Online]. Available: https://www.coned.com/en/about-con-edison/media/news/20160613/virtual-power-plant.

[487] V. I. Energy. [Online]. Available: https://www.vpp.hu/eng/2/company_profile.

[488] [Online]. Available: https://www.irgc.org/wp-content/uploads/2015/09/Stromback-Demand-Response-2015.pdf.

[489] [Online]. Available: http://www.regalgrid.com/.

[490] [Online]. Available: https://www.db.com/cr/en/docs/GRCM2015PROD033635_Web.pdf.

[491] [Online]. Available: http://www.eleconomista.es/empresas-finanzas/noticias/7846171/09/16/Ya-hay-mas-de-un-millon-de-coches-electricos-registrados-en-el-mundo.html.

[492] [Online]. Available: http://www.irena.org/DocumentDownloads/Publications/IRENA_REthinking_Energy_2017.pdf.

[493] [Online]. Available: http://www.epectec.com/batteries/cell-comparison.html.

[494] [Online]. Available: https://previa.uclm.es/actividades/2010/congresoIM/pdf/cdarticulos/226.pdf.

[495] [Online]. Available: http://celsiuscity.eu/.

[496] [Online]. Available: https://www.fenercom.com/pdf/publicaciones/Guia-de-la-Cogeneracion-fenercom-2010.pdf.

[497] [Online]. Available: http://www.cogeneurope.eu/what-is-cogeneration_19.html.

[498] “NobelGrid H2020 project website,” [Online]. Available: http://nobelgrid.eu/. [Accessed 2017].

[499] EAS, 2017. [Online]. Available: http://energystorage.org/energy-storage/energy-storage-benefits/benefit-categories/grid-operations-benefits.

[500] P. N. a. H. Johal, “Energy Storage in a Resurrecting,” ICF, 2016.

[501] Y. D. D. S. K. C. A. S.-M. J.-P. W. Bolun Xu, “Comparison of Policies on the Participation of Storage in U.S. Frequency Regulation Markets,” in *Power and Energy Society General Meeting* , 2016.

[502] G. John Jung and David Miller, “Electric light and Power: Energy Storage: Designing for Performance,” 2015. [Online]. Available: http://www.elp.com/articles/powergrid_international/print/volume-20/issue-3/features/energy-storage-designing-for-performance.html. [Accessed 2017].

[503] L. J. v. d. R. e. a. Ugarte Sergio, “Energy Storage: Which Market Designs and Regulatory Incentives Are Needed?.,” Directorate General for Internal Policies, Policy Department A: Economic and Scientific policy , 2015.

[504] R. D. B, “Electric vehicles and the electric grid: a review of modeling approaches, impacts and renewable energy integration,” *Renew. Sustain. Energy Rev 2013,* p. 247–54, 2013.

[505] R. M. A. A. Talebizadeh E, “Evaluation of plug-in electric vehicles impact on Cost-based unit commitment,” *J Power Sources 2014,* p. 545–52, 2014.

[506] M. M. J. A. L. T. Lyon TP, “ Is smart charging policy for electric vehicles worthwhile?,” *Energy Policy ,* p. 41:259–68, 2012.

[507] J. P. M. J. Weis A, “ Estimating the potential of controlled plug-in hybrid electric vehicle charging to reduce operational and capacity expansion costs for electric power systems with high wind penetration.,” *Appl Energy,* p. 115:190–204., 2014.

[508] R. A. Windecker A, “Fuel economy, cost, and greenhouse gas results for alternative fuel vehicles in 2011,” *Transp. Res Part D: Transp. Environ. ,* p. 23:34–40, 2013.

[509] S. J. S. E. Gass V, “Analysis of alternative policy instruments to promote electric vehicles in Austria,” *Renewable Energy ,* p. 61:96–101., 2014.

[510] Y. Z. G. J. S. D. Lunz B, “Influence of plug-in hybrid electric vehicle charging strategies on charging and battery degradation costs,” *Energy Policy ,* p. 46:511–9, 2012.

[511] M. J. Karabasoglu O, “Influence of driving patterns on life cycle cost and emissions of hybrid and plug-in electric vehicle powertrains,” *Energy Policy 2013,* p. 60:445–61., 2013.

[512] “SMART CHARGING:steering the charge, driving the change,” [Online]. Available:

http://www.eurelectric.org/media/169888/20032015_paper_on_smart_charging_of_electric_vehicles_finalpsf-2015-2301-0001-01-e.pdf.

[513] S. E. D. C. SEDC, "The Importance of Smart Charging," [Online]. Available: [3] http://www.smartenergydemand.eu/wp-content/uploads/2017/05/SEDC-Background-Paper-Smart-Charging-April-2017.pdf.

[514] C. M. PORTELA, "OSCP - AN OPEN PROTOCOL FOR SMART CHARGING OF ELECTRIC VEHICLES," [Online]. Available: http://cired.net/publications/cired2015/papers/CIRED2015_0106_final.pdf.

[515] GridTECH.EU. [Online]. Available: http://www.gridtech.eu/.

[516] C. a. CENELEC, "Making Standards for Europe," [Online]. Available: https://www.cencenelec.eu/standards/Sectors/Transport/ElectricVehicles/Pages/default.aspx.

[517] N. M. CORPORATION, ""Vehicle to Home" Electricity Supply System," [Online]. Available: http://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/vehicle_to_home.html.

[518] E. COMMISION, "Guidelines on financial incentives: Promoting energy efficient vehicles," [Online]. Available: http://europa.eu/rapid/press-release_IP-13-174_en.htm.

[519] F. ISI, "Electric vehicles are mainly interesting in car-sharing and commercial fleets," [Online]. Available: http://www.isi.fraunhofer.de/isi-en/service/presseinfos/2016/press-release-12-2016-now-electric-vehicles-sharing-fleets.php.

[520] U. o. Saskatchewan, "Car-sharing Co-operatives," [Online]. Available: http://usaskstudies.coop/about-us/affiliations%20and%20links/car-sharing-co-operatives.php.

[521] H. L. P. A. A. R. Aarno Airaksinen, "Statistics on small and medium-sized enterprises. Dependent and independent SMEs and large enterprises," [Online]. Available: http://ec.europa.eu/eurostat/statistics-explained/index.php/Statistics_on_small_and_medium-sized_enterprises.

[522] T. f. L. |. E. J. Matters, "Cleaner greener taxis," [Online]. Available: https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/cleaner-greener-taxis.

[523] E.-S. M. Sortomme E, "ptimal scheduling of vehicle-to-grid energy and ancillary services". *IEEE Trans Smart Grid 2012; 3(1):351–9..*

[524] G. S. M. M. Ghanbarzadeh T, "Reliability constrained unit commitment with electric vehicle to grid using hybrid particle swarm optimization and ant colony optimization," in *Proceedings of the IEEE power and energy society general meeting*, Jul 24–29 2011. p. 1–7.

[525] V. Z. C. B. M. H. Soares J, "Multi-objective parallel particle swarm optimization for day-ahead Vehicle-to-Grid scheduling," in *Proceedings of the IEEE CIASG 2013: symposium on computational intelligence applications in smart grid;* , Apr 16–19 2013. p. 138–45..

[526] W. S. Wang Z, "Grid power peak shaving and valley filling using vehicle-to-grid systems.".*IEEE Trans Power Deliv 2013;28(3):1822–9..*

[527] T. S. d. l. M. S. A. J. López MA, "Demand-side management in smart grid operation considering electric vehicles load shifting and vehicle- to-grid support".*International J Electr. Power Energy Systems 2015;64:689–98..*

[528] S. D. R. A. Silvestre C, "Reactive power compensation using on board stored energy in electric vehicles," *Proceedings of the IECON 2012: 38th annual conference on IEEE industrial electronics*

society, p. p.5227–32, 2012.

[529] M. M. K. D. G. M. B. G. Vittorias I, "A bidirectional battery charger for electric vehicles with V2G and V2H capability and active and reactive power control.," in *Proceedings of the IEEE ITEC 2014: transportation electrification conference and expo;*, Jun 15–18 2014; p. 1–6..

[530] M.-M. M. G.-M. M. R.-. C. E. Gallardo-Lozano J, "Electric vehicle battery charger for smart grids," *Electr. Power Syst. Res.,* p. 90:18–29, 2012.

[531] U. M. E. O. G. E. Boynuegri AR, "A new perspective in grid connection of electric vehicles: different operating modes for elimination of energy quality problems.," *Appl Energy 2014,* p. 132:435–51., 2014.

[532] F. J. W. R. Rauchfuss L, "Charging station as an active filter for harmonics compensation of smart grid," in *Proceedings of the IEEE ICHQP2014: 16th international conference on harmonics and quality of power;* , May 25–28 2014. p. 181–4..

[533] Y. G. T. C. L. E. O. J. B. B. e. a. Marra F, "EV charging facilities and their application in LV feeders with photovoltaics," p. 4(3):1533–40, 2013.

[534] A. P. S. F. Peas Lopes J.A., "Using vehicle-to-grid to maximize the integration of intermittent renewable energy resources in islanded electric grids," in *Proceedings international conference on clean electrical power*, June 9–11 2009.

[535] F. Lambert, "An exclusive look at Tesla's plan to build largest EV charging station in the world with 40 Superchargers," [Online]. Available: https://electrek.co/2017/07/11/tesla-supercharger-largest-ev-charging-station-world/.

[536] N. M. CORPORATION, "Nissan Europe boosts charging infrastructure as an official partner of EU-backed project, Fast-E," [Online]. Available: [16] https://newsroom.nissan-global.com/releases/release-565ecd90576057f7e8365399eb06d369-nissan-europe-boosts-charging-infrastructure-as-an-official-partner-of-eu-backed-project-fast-e.

[537] EURELECTRIC, "Charging infrastructure for electric vehicles," [Online]. Available: http://www.eurelectric.org/media/285584/ev_and_charging_infrastructure_final-2016-2310-0001-01-e.pdf.

[538] [Online]. Available: http://www.ree.es/en/red21/strengthening-interconnections.

[539] N. Consortium.

7.2 ACRONYMS

Acronyms List	
ACER	Agency for the Cooperation of Energy Regulators
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AT	Austria
BE	Belgium
BOS	Balance of Systems

BRP	Balance Responsible Party
CAES	Compressed Air Electricity Storage
CEER	Council of European Energy Regulators
CEF	Connecting Europe Facility
CEO	Chief Executive Officer
CHP	Combined Heat and Power
CNMC	Comisión Nacional de los Mercados y la Competencia (The National Commission of Markets and Competition)
CORES	Corporación de Reservas Estrátegicas de Productos Petrolíferos (The Strategic Reserves Corporation)
CRES	Centre for Renewable Energy Sources (CRES)
CSIRT	Computer Security Incident Response Team Network
CSN	The Nuclear Safety Council
CY	Cyprus
CZ	Czech Republic
DAS	Day-Ahead System
DE	Germany
DER	Distributed Energy Resources
DK	Denmark
DPIA	Data Protection Impact Assessment
DSO	Distribution System Operator
EE	Estonia
EEA	European Energy Agency
EEE	Electrical and Electronics Engineering
EG	Expert Group
ENISA	European Network and Information Security Agency
ENTSO	European Network of Transmission System Operators for Electricity
EPBT	Energy Pay-Back Time
EPR	Extending Producer Responsibility
ERGEG	European Regulators Group for Electricity and Gas
ES	Spain
ESCO	Energy Service Company
ETS	Emission Trading Systems
EU	European Union
EV	Electric Vehicle
FDW	Framework Directive on Waste
FI	Finland
FR	France
GDPR	General Data Protection Regulation

GHG	Greenhouse Gas
GR	Greece
GW	Gigawatts
HCC	Hellenic Competition Commission
HEDNO	Hellenic Electricity Distribution Network Operator
ICS	Industrial Control Systems
ICT	Information and Communication Technology
IDEA	Instituto para la Diversificación y Ahorro de la Energía (The Institute for Energy Diversification and Savings)
IE	Ireland
IEA	International Energy Agency
IMF	International Monetary Fund
IoT	Internet of Things
IRMC	Instituto para la Reestructuración de la Minería del Carbón y Desarollo Alternativo de las Comarcas Mineras (The Institute for Restructuring and Alternative Development of the Coal Mining Regions)
IS	Iceland
IT	Italy
KLIEN	Climate and Energy Fund (Klima- und Energiefonds)
LAGIE	Hellenic Electricity Market Operator
LNG	Liquefied Natural Gas
LT	Lithuania
LU	Luxembourg
MEEC	Ministry of Environment, Energy and Climate Change
MW	Megawatts
NII	Non-Integrated Island
NIS	Network and Information Systems
NL	Netherlands
NO	Norway
NRA	National Regulatory Authority
NREAP	National Renewable Energy Plan
OECD	Organisation for Economic Co-operation and Development (OECD)
PCI	Projects of Common Interest
PL	Poland
PPA	Power Purchase Agreement
PPC	Public Power Corporation
PT	Portugal
PV	Photovoltaic
RAE	Regulatory Authority for Energy
RES	Renewable Energy Sources

RES-E	Electricity from Renewable Energy Sources
RO	Romania
SCADA	Supervisory Control And Data Acquisition
SDG	Sustainable Development Goals
SE	Sweden
SEDC	Smart Energy Demand Coalition
SGTF	Smart Grids Task Force
SI	Slovenia
SMP	System Marginal Price
TFEU	Treaty on the Functioning of the European Union
TPES	Total Primary Energy Supply
TSO	Transmission System Operator
UK	United Kingdom
US	United States
V2G	Vehicle to Grid
VPP	Virtual Power Plants
WEEE	Waste Electrical and Electronic Equipment
WP	Work Package
WtE	Waste-to-energy

Table 32 – List of Acronyms

8 ANNEX A – COUNTRY CASE STUDIES

ANNEX A – COUNTRY CASE STUDIES endeavours to provide a comprehensive analysis of the WiseGRID large-scale demonstrators. To this end, it examines the regulatory framework and policies of each jurisdiction (Belgium, Italy, Greece and Spain), together with their implication for the areas depicted in the report (namely, energy security; business modelling and social considerations).

8.1 BELGIUM

8.1.1 General overview

Belgium is a sovereign state located in Western Europe which borders France, Germany, the Netherlands, Luxembourg and the North Sea. The country is a federal state comprising three regions (the Brussels-Capital region, the Flemish region and the Walloon region) as well as three linguistic communities (the Flemish-, the French- and the German-speaking communities). The two largest regions are Flanders and Wallonia which are monolingual (Flemish and French, respectively); the Brussels-Capital region is officially bilingual (Flemish and French); while the German-speaking community lies in Eastern Wallonia. Belgium has an area of 30.500 square kilometres (km^2) and a population of around 11 million. The country has an oceanic climate with substantial precipitation during all seasons. Belgium was one of the founding Member States of the European Union (EU) in 1951.

8.1.2 Energy profile

Belgium features an energy dependency that is well above the EU average. Indeed, Eurostat estimated Belgium's energy dependency at 80.1% while the average among EU Member States was 53.4%, as of 2014 [269]. A sizeable share of the country's energy consumption stems from fossil fuel imports. Oil and natural gas supplies are the largest commodities consumed. Even though Belgium has no indigenous oil or gas production, the country represents one of the backbones of the EU's supply chain of both sources. This is so because of Belgium's geographical location and excellent energy infrastructure (especially in the case of gas). In a similar vein, natural gas supplies are expected to become increasingly sought after as an alternative to ageing nuclear facilities [270].

More than half of the electricity generation of the country emanates from nuclear power. Furthermore, nuclear energy amounted to roughly 29% of the total installed capacity in Belgium (see **Figure 14**) [271]. The country has seven nuclear reactors which are distributed between two power plants: one in Doel (Flanders) and the other in Tihange (Wallonia). These nuclear facilities were manufactured in the 1970s and 1980s and are therefore reaching the end of their lifespan (2015-2025) [272]. In 2003, a law on the progressive phase-out of nuclear energy for the purpose of electricity generation was approved. This law prohibited the construction of new nuclear power plants and restricted the operation of existing ones to 40 years. In spite of this ban, the government decided to extend the activity of the oldest reactors in 2015 (when they were due to be decommissioned) for an additional 10 years. This is so as the nuclear phase-out compromises Belgium's capacity to ensure energy supply at a reasonable price. Hence, it is safe to say that the consequences of refraining to resort to nuclear energy were underestimated by previous governments [273].

Belgium boasts a gas market that is well integrated with bordering EU Member States. Its transport infrastructure has a considerable entry and exit capacity (113 and 80 bcm per year, respectively). The Zeebrugge port is of crucial strategic relevance for several reasons. Firstly, it is an important liquefied natural gas (LNG) terminal. Secondly, it is key for the Belgian and EU gas markets. Finally, it enjoys direct pipeline connections with both Norway and the United Kingdom (UK). Given the challenges posed on the nuclear front, it is expected that natural gas will become more prominent in the energy mix of the country [274].

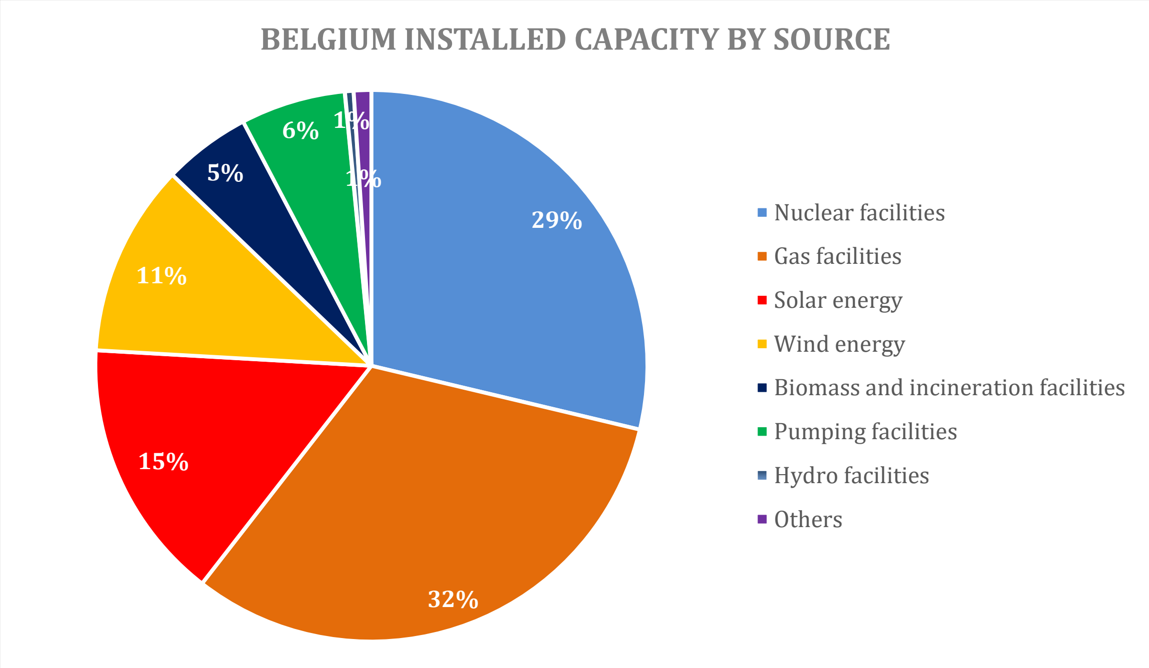


Figure 14 – Belgium installed capacity by source [271]

Belgium's total final consumption was 40.1 million tonnes of oil equivalent (Mtoe) in 2014. The largest consuming sector was industry as it represented 47.5% of the total final consumption. The transport and residential sectors followed with 21.7% and 18.4%, respectively. The commercial and public services sector (including agriculture, fishing and forestry) accounted for the remaining 12.3%. From 2004 to 2014, the industry as well as the commercial and public services sectors have experienced a slight rise in their share of the country's total final consumption; the consumption deriving from the transport sector has remained unchanged; whereas it has moderately decreased in the residential sector [274].

Generally speaking, the major challenge for Belgium is to achieve an effectively integrated national energy strategy. Competence in energy and climate change is officially shared between the central government and the three regions. However, these policies are essentially a regional prerogative in Belgium. This can lead to an unclear repartition of competences between federal and regional authorities. What is more, the current architecture can be conducive to a lack of coherence between the administrative bodies that are responsible for implementing energy and climate change policies. Consistency in energy governance will require seamless coordination between the different administrative strata of the federal state [275]. Consequently, the federal and regional governments decided in 2015 to develop an energy pact for Belgium. The rationale behind the energy pact was to endeavour to encapsulate a long-term vision for the country. The draft of this inter-federal agreement was meant to include concrete measures to reach energy and climate change objectives both at the national and the EU level [274]. Unfortunately, this initiative was eventually watered down due to political discord.

8.1.3 Governance system

8.1.3.1 Relevant institutions

Central government: Directorate-General for Energy

The competent authority in terms of energy at the federal level is the Directorate-General for Energy which is part of the Federal Public Service for Economy, Small and Medium-Sized Enterprises, Self-Employed and Energy. The Directorate-General for Energy is responsible for the production and transmission of energy. As to energy transmission, Elia and Fluxys are the TSOs for electricity and gas, respectively. In terms of energy production, the central government manages stockholding and energy production facilities. Thus, nuclear power and nuclear fuel cycles fall within its remit. In a similar vein, the federal authority is responsible for guaranteeing Belgium's security of supply. An example of such efforts are the strategic energy reserves that are accumulated by the TSOs to confront demand peaks during winter periods [276].

Flemish region: The Environment, Nature and Energy Department

The Environment, Nature and Energy Department is the environmental administration of the Ministry of the Flemish community. This entity elaborates the energy, environment and nature policies of the Flemish region. The Environment, Nature and Energy Department verifies that the Flemish region complies with its international obligations in terms of global environmental issues. The scope of the department spans a profusion of topics such as air pollution, climate policy and environmental nuisances and their impact on human health, for instance. The department is in charge of coordinating and implementing the region's environmental plan, together with the annual environmental programmes. Moreover, The Environment, Nature and Energy Department participates in large-scale projects many industries such as agriculture, economy and town planning in the Flemish region [277].

Walloon region: Operational Directorate-General for Land Management, Housing, Patrimony and Energy

The Operational Directorate-General for Land Management, Housing, Patrimony and Energy is responsible for drafting energy policy and related research and development schemes in the Walloon region. The Operational Directorate-General strives to reduce energy consumption, fosters the use of renewable energy and supervises the correct management of the regional energy market. In addition, this body guides energy research, supports the different renewable sources of energy and elicits the promotion of energy efficiency by industries and companies in the Walloon region. Finally, the Operational Directorate-General monitors the adequate implementation of EU directives in energy efficiency and services [278].

Brussels-Capital region: "Institut Bruxellois de Gestion de L'Environment/Brussels Instituut voor Milieubeheer" (IBGE/BIM)

This institute is in charge of the environment and energy strategy in the Brussels-Capital region. The IBGE/BIM performs a number of tasks. These include: elaborating plans to prevent waste; tackling noise nuisances; managing green spaces such as the Sonian Forest; granting environmental licenses; or supervising compliance with environmental law, for instance. This entity cooperates with other authorities and businesses to develop environmental plans in the Brussels-Capital region. Finally, the IBGE/BIM is involved in raising environmental awareness among the general public, schools and enterprises [279].

Energy regulators

In addition to these organs, there are four regulators – one for each of the governmental layers outlined earlier – in the Belgian energy sector. The Commission for the Regulation of Electricity and Gas (CREG) is the competent regulator at the federal sphere. The regions have their own regulators: the *"Vlaamse Regulator voor Elektriciteit en Gas"* (VREG) for the Flemish region; the "*Commission Wallone pour l'Énergie*" (CWaPE) for the Walloon region; and Brugel for the Brussels-Capital region [274].

8.1.3.2 Energy competences and regionalisation

The first revision of the Belgian Constitution in 1970 brought about to the creation of the three linguistic communities and three regions. This turn of events was precipitated by Flanders' aspiration to preserve its cultural autonomy while Wallonia sought to secure its economic independence. Subsequent state reforms further elaborated on these efforts and eventually led to Belgium's current federal architecture. The Sixth State Reform was adopted in 2014 in a bid to render the federal state more efficient and to ascribe greater self-government to its federated entities. Nonetheless, past state reforms have resulted in a myriad of actors that sometimes present overlapping competences [280].

Article 35 of the Belgian Constitution gives the regions the competence to manage certain areas pursuant to the requirements and modalities framed by national law. Belgian law distinguishes between the energy competences that are to be attributed to the central government and those that fall within the scope of the regions. The repartition of competences in the area of energy is spelled out in Article 6, paragraph 1, section

VII of the Special Law of Institutional Reform of 8 August 1980 (see Figure 15).

Central government	Regional authorities
- Nuclear energy - Major energy storage infrastructure - The transport and production of energy (for electricity grid superior to 70 kV), and prices - Security of supply - National indicative investment plans for gas and electricity (in collaboration with the CREG) - Nuclear fuel cycles and related research and development programmes - Large stockholding installations for oil - Transport tariffs and prices - Product norms - Offshore wind energy	- Local transport and distribution of electricity - The public distribution of gas - The rational use of energy - Distribution tariffs for gas and electricity (except tariffs of the TSOs) - Regulation of gas and electricity retail markets - Distribution and transmission of electricity (for electricity grid equal or inferior to 70 kV) - Distribution of natural gas - Distribution tariffs - District heating equipment and networks - Renewable sources of energy (except offshore wind energy) - Recovery of waste energy from industry or other uses - Promotion of the efficient use of energy - Energy research and development programmes (except nuclear) - Use of firedamp (coal-bed methane) and blast furnace gas

Figure 15 – Division of energy competences in Belgium

8.1.4 Electricity market

8.1.4.1 Regulatory framework

Liberalisation of the Belgian electricity market started at the turn of the millennium in accordance with EU prescriptions. This process was carried out steadily until the electricity markets of the three regions were all effectively legally opened (in 2003 for the Flemish region and 2007 for both the Brussels-Capital region and the Walloon region). Subsequently, the Law of 8 January 2012 amending the Law of 29 April 1999 on the organisation of the electricity market was introduced. The Law of 8 January 2012 reinforced the powers of the federal regulator (the CREG); increased the competences of regional authorities; and mandated unbundling requirements for the electricity industry [274].

The TSO (Elia), in conjunction with the numerous DSOs scattered across the three regions, became fully unbundled from utilities in conformity with this new regulatory framework. As to the CREG, its independence from the Directorate-General for Energy was asserted by the Law of 8 January 2012. Moreover, a decision of the Constitutional Court of 7 August 2013 confirmed the exclusive prerogative of the federal regulator in the application, determination and exemption of tariffs. Nevertheless, the Special Law of 6 January 2014 regarding the Sixth State Reform brought about a fundamental shift towards regionalisation on this question. Indeed, the Special Law of 6 January 2014 transferred the power to determine distribution tariffs from the federal sphere to the regional scope. Therefore, Brugel, the VREG and the CWaPE became the competent bodies to set distribution tariffs in the Brussels-Capital region, the Flemish region and the Walloon region, respectively [274]. In other words, transmission tariffs are now established by the central government whereas distribution tariffs are settled by the regional regulators.

Broadly speaking, the federal authority is in charge of the transmission of electricity for operating systems with a voltage superior to 70 kV. On the other hand, the regional authorities are responsible for the local distribution and transmission of electricity operated by network facilities with a voltage equal or inferior to 70 kV. Further, the regions are competent in the areas of renewable energy (with the caveat of offshore wind energy) and the rational use of energy. Each region has its own regulatory framework for the management of its electricity market: the Ordinance of 19 July 2001 regarding the organisation of the electricity market in the Brussels-Capital region; the Decree of 8 May 2009 on energy policy (also known as the Energy Decree) for the Flemish region; and the Decree of 12 April 2001 regarding the organisation of the regional electricity market for the Walloon region [281].

8.1.4.2 Energy security dimension

Belgium lies at the heart of Europe. Currently, the country's electricity network is interconnected with France, the Netherlands and Luxembourg. The Belgian electricity network has a transmission capacity of 3.500 megawatts (MW) which accounts for an interconnection rate of 17% [282]. Hence, Belgium has already met the interconnection roadmap outlined by the European Commission for the foreseeable future (namely, the official target of 10% electricity interconnection by 2020 [283] and a suggested objective of 15% by 2030) [284]. However, Belgium is further deepening on this positive outlook through the engagement of several undertakings to raise its interconnection capacity with surrounding EU Member States:

- Brabo: an interconnector with the Netherlands with a transfer capacity of 1.000 MW located in the North border. This project is structured in three phases (Phase I: end of 2016; Phase II: 2018-2019; and Phase III: end 2023). Brabo will foster the economic growth of the Port of Antwerp area; enable the connection of new generation plants; and increase the transfer capacity between Belgium and the Netherlands [285].
- Nemo: the first electricity interconnector between Belgium and the UK. Nemo is estimated to boast a nominal capacity of 1.000 MW and traverse the North Sea through sub-sea and underground cables. This venture will run for 140 km between Herdersbrug (Belgium) and Richborough (UK). Nemo is expected to supply enough energy to cater for the needs of half a million households. This interconnector is set to be in operation in 2019. Let alone the increased cross-border capacity with the UK, Nemo will also contribute to power offshore wind farms in the Belgian coast as well as other national renewable energy initiatives [286].
- ALEGrO: the first electricity interconnector between Belgium and Germany. ALEGrO is expected to be in operation in 2020. This cross-border infrastructure will have a total capacity of 1.000 MW. ALEGrO will stretch for roughly 100 km from Lixhe (Belgium) to Oberzier (Germany). ALEGrO will increase the security of supply of both Member States and the European electricity market as a whole. Furthermore, the project will ease the integration of renewable energy [287].
- Creos: an interconnector with Luxembourg commissioned with the intention to *inter alia* reinforce the security of supply of Luxembourg and to facilitate the market coupling between Belgium and Germany. This project is divided in two phases. Phase I, which started in 2015, consists in reusing existing infrastructure to create the new interconnector. The objective is to control transit flows from Germany to Belgium. As of now, Phase II in 2020 contemplates a proposal with cables of a nominal capacity of 1.000 MW between Belgium and Luxembourg [288].
- Avelin-Avelgem: This scheme plans to upgrade the eponymous overhead link between Belgium and France. This cross-border infrastructure runs for 21 km from Avelgem (Belgium) to Avelin (France). The Avelin-Avelgem overhead link is part of the larger Mercator-Avelin interconnector which stretches for 110 km and represents a lynchpin of the Belgian grid. Thus, ageing conductors, pylons and foundations are set to be replaced by 2021. These works will entail a higher transfer capacity with France thereby warranting Belgium's energy security [289].

The aforementioned cross-border ventures have been identified as Projects of Common Interest (PCI) [290]. This designation qualifies these projects to have access to an array of EU funding schemes such as the

Connecting Europe Facility (CEF) [291]. These anticipated interconnections will considerably increase external electricity exchange capacities. In turn, reinforced transfer ratios with neighbouring EU Member States will enable the domestic grid to accommodate an expanding proportion of renewable energy. This is fully in line with the latest developments with respect to renewable energy in Belgium. Electricity generation deriving from RES has experienced an impressive growth. For the sake of illustration, RES increased their share in national electricity production by more than 10% (from 7.8% to 19%) over a 5-year span (2009-2014). This remarkable upswing was achieved through a panoply of policies including munificent green certificate schemes; warranted minimum prices; and the successful implementation of offshore wind programmes [274].

This positive trend in renewable energy is only set to rise due to numerous reasons. Firstly, if Belgium persists in casting aside nuclear energy entirely by 2025, RES – together with natural gas – emerge as the most logical alternative source to generate electricity. Secondly, the completion of the above enterprises will substantially enhance Belgium's electricity interconnection, thereby streamlining the integration of RES into the grid. Finally, Belgium is bound to further promote the use of RES in agreement with objectives charted at the international plane such as the EU 2020 Climate and Energy Package or the 2030 Climate and Energy Framework, for example. Pursuing a cleaner energy mix, particularly with the assistance of a stronger electricity interconnection with bordering EU Member States, is the best manner to revitalise the country's energy security while at the same time lowering CO_2 emissions [282].

As to the WiseGRID consortium, the most glaring challenge in the Belgian electricity market is the absence of a concerted plan regarding an eventual full-scale smart meter roll-out throughout the country. As of now, smart grid initiatives remain sparse and fragmented in light of Belgium's highly decentralised energy governance. Consequently, only a limited number of small-scale pilot sites have been carried out locally. Certain regions appear to be keener than others in upgrading their electricity networks (more specifically, the Flemish region has been more active on this front by running the most ambitious pitot sites). Yet, whenever the full-scale deployment of smart grids transpires, smart grid applications should have a promising value in an electricity market where cost-efficient decisions on energy use will bear a greater significance in the wake of the presumably imminent nuclear phase-out.

8.1.5 Market characteristics and idiosyncrasies of the Belgium pilot site

In 2016 55% of the electricity generation in Belgium is provided by nuclear power plants and 14 % by renewable energy sources. At the end of 2016 about 1.500 plug-in electric vehicles (PEV) and 590 plug-in hybrid electric vehicles (PHEV) were registered in Belgium, accounting for a mere 0.5% of the national fleet. Clearly, the breakthrough of electric driving still needs to occur. Belgium has two pumped storage hydroelectric power stations, one in Coo-Trois Ponts (Liège) and one in Plate-Taille, Lacs de l'Eau d'Heure (Charleroi).

8.1.5.1 General barriers and challenges due to the special characteristics of the local market

- DSO's have a monopoly and are not motivated to reward market players (aggregators, balance responsible parties or suppliers) for aid to the grid balance on a local level.
    - The overall balance of the grid is guaranteed by the TSO on federal (Belgian) level. There is no reward for local production that helps local balance or reduce local investments in the grid.
    - The grid tariffs are in debate for a possible big change from a tariff per kWh to a capacity tariff. The tendency is to make the (possible) new tariff in such a way that it would be difficult to avoid it (e.g. with lower capacity connection with the help of a battery). This makes it difficult to create new business models.
    - The tests of the DSO's with smart meters were interesting, but the evaluation was very negative (lots of problems with communication and very expensive). The foreseen roll out is going to start in 2019, but will be slow roll out (mainly with replacement of meters).
    - In 2018 a new system of communication between suppliers and DSO's will be implemented in

Belgium. Clearing house Atrias (founded in 2011 by the five most important DSO's in Belgium) has the mission to develop a new market model and improved market processes, together with the suppliers, DSO's and regulators. Atrias provided a manual for the implementation of MIG6 (Market Implementation Guide), which is foreseen mid-2018. MIG 6 describes the exchange of information between DSO's and other market players and aims for more cost-efficient, customer friendly and less error-stove operation of the liberated energy market, taking into account the future availability of smart meters. This opens the possibility to work with flex prices and Demand Response.

- Stats on the penetration of REs, constraints, barriers etc.- In Flanders the region where the Ghent Pilot Site is located6% of the energy (gross final consumption) is renewable energy of which: 18% wind, 29% solar, 52% bio-energy of which 12,7% of the electricity is green electricity.

8.1.5.2 RES generation

The main constraints for wind energy in Belgium is that is difficulty to acquire permits. There are also insufficient measures to enhance social acceptance and lack of clarity and objectivity regarding environmental requirements. The main constraints for solar power is actual profitability. The solar installation requires high initial investment, intermittent energy source, and requirement of large installation area to setup solar farms are restraining the market from growing. The space requirement for a solar power plant is another restraint for this market. Developments in battery storage technology, growth of rooftop solar installations etc. In addition, the support for the solar installation was not sufficient enough, now additional grid prosumer tariff of around 100 euro/kVA of inverter is payable. There is no incentive to inject in the grid as there is no feed-in tariff.

8.1.5.3 Market penetration of storage technologies

Storage (e.g. batteries) is increasingly contributing to the management of the daily variability of renewables and the balancing of the system, but is not yet mature (in the short to medium-term) to manage the weekly or seasonal variability. Given the limited storage capacity and the intermittent nature of renewables, the contribution of conventional fuels to the energy mix still remains necessary for providing flexibility and keeping a role as a backup. Also, the actual cost of storage provides difficulties to install it and have profit. This conventional generation will highly likely come from gas-fired power stations that allow a quick start/stop to adapt to the variable nature of renewables, while maintaining a limited CO2 emission rate.

Number of EVs and charging stations (fleets and/or standalone owners): End of 2016, only 4368 EVs were available on a total of 5.7 mio cars. EVs consist 0,4% of the sales in 2016 (statistics from Traxio), a marginal number. With consumers waiting for new models with better specs to come out late in 2017 (Hyundai Ioniq, Opel Ampera, etc.), the current expectation is that 2017 will have same sale numbers. The stimuli of the government does not seems to resort effect. Half of the new cars are obtained by natural persons, 25% by companies, 17% by leasing companies. Most new cars (52%) are diesel fuelled. Furthermore, the battery capacity of current EV sold in Belgium is between 30 kWh and 75 kWh.

8.1.5.4 Market penetration of smart metering

After interesting but failed tests with smart meters the government and DSO's wants to start a new roll out of smart meters in 2019. They will use as standard as possible smart meters.

8.1.5.5 Market penetration of Demand Response services

Limited only on the level of TSO. Partly this can be done with injection of extra energy on DSO-level.

8.1.5.6 Market penetration of smart homes systems

New products are on the market, but they are not commonly used, because it is mostly rather high tech, expensive and not proven to be profitable.

8.1.5.7 WiseGRID products for the Belgian market

The use of WiseHOME needs to enable the consumers and prosumers to become more active energy players in the Belgian energy market. Since real time monitoring of their consumption and production will be shown in WiseHOME they will be able to participate in Demand Response programs, which otherwise they are not able to do so with the current regulatory framework in Belgium. Giving consumers and prosumers an insight in energy prices and working with flex prices should also give them the opportunity to lower their energy bill. This is what will be possible with the new communication system mid-2018 and the smart meters from 2019 on.

Moreover, with WiseCOOP SME's, consumers and prosumers (both owner and non-owner of solar panels on their roof) it will be possible to work smart with solar panels. When there are many connections on one hub, over-voltage is possible and some installations will be cut off. By using WiseCOOP they can share the reduction over every installation.

8.1.6 Smart metering systems

At the EU level, the European Commission encourages the modernisation of electricity networks through the introduction of intelligent metering systems as a means to promote energy efficiency [292]. What is more, Directive 2009/72/EC and Directive 2009/73/EC mandate Member States to carry out a cost benefit analysis (CBA) to ascertain whether the national deployment of smart metering systems would be economically sound. If so, the same directives invite Member States to outline a feasible timeframe for their roll-out. Should the CBA lead to positive results, Member States are expected to supply 80% of their consumers with smart meters by 2020 [293]. Nevertheless, Belgium's global CBA with reference to the adoption of smart metering systems led to overall negative results. The Belgian case study presents the peculiarity that each of the three regions carried out their own CBA [294].

Considering that the WiseGRID pilot site is located in Ghent, the analysis will be circumscribed to the Flemish region. The CBA for the Flemish region was performed in 2012 under the supervision of the VREG. This CBA was updated in 2014. It is worth noting that the CBA considered a joint roll-out (that is, the deployment of both electricity and gas smart meters). Interestingly, the 2012 CBA actually yielded positive results (albeit only for electricity smart meters). However, the updated 2014 CBA calculated a net cost of EUR 157 million [295]. In spite of the negative result of the CBA, discussion as to the suitability of smart meters is nonetheless on-going and is perhaps more topical than before among energy stakeholders. Belgium is currently at the experimental stage, with pilot projects being run throughout the country on a local basis. These different trials have permitted regional energy regulators and DSOs to extract specific information regarding economic, technical and logistical aspects related to this technology. These details will be useful to ensure that an eventual large-scale deployment of smart meters runs smoothly [296]. In that sense, some market segments have been identified as offering more potential for their roll-out (for example, new electricity installations; important construction works in existing electricity infrastructure; replacement of pre-paid meters; prosumers; and early adopters that directly request intelligent metering systems) [297].

The Flemish region announced that it will proceed to the segmented deployment of smart meters from 2019 onwards [298]. Prior to this, the Flemish region had already monitored a number of pilot programmes which, combined, roughly amount to a total 50.000 smart meters interspersed across its geographical breadth. The smart meters of the region were installed by Eandis and Infrax (the Flemish DSOs). The Flemish pilots have gone beyond analysing conventional parameters as they have also sought to *inter alia* involve different stakeholders such as energy suppliers; facilitate the establishment of decentralised electricity generators; and locate the most suitable sections of the grid to integrate RES, for instance. The VREG has played a crucial role in supervising these appraisals [299]. In addition to the decision by the Flemish region to roll-out smart metering systems in instalments starting from 2019, another anticipated development is worth pointing out: Belgium will establish a federal clearing house in the field of energy in 2018. This federal entity will facilitate the exchange of data and the market processes framing the national electricity and gas markets by implementing a new energy market model. This new model shall encompass emerging technologies and will therefore certainly include smart meters and decentralised energy generation [300]. It is safe to say that this institution will be pivotal to align efforts in the regional electricity markets as a means to ensure a cohesive national energy governance. This seems a well-grounded move, especially in a complex electricity market which is on the brink of undergoing a profound reshuffle due to the gradual advent of smart meters.

The fact that Belgium is presently in a speculative phase is clearly reflected by its scarce legislation regarding smart metering systems. As to the Flemish region, the Decree of 14 March 2014 transposing Directive 2012/27/EU and amending the Decree of 8 May 2009 on energy policy regulates smart meters in open-ended terms. Indeed, Article 4.1.22/2 of the Decree of 8 May 2009 is the legal basis setting the fundamental principles. Firstly, the Flemish government will determine the circumstances under which DSOs can proceed to the installation of smart meters. Secondly, should a smart meter be installed, DSOs must ensure that the consumer is thoroughly informed of his rights and obligations as well as of the full potential of the technology. Thirdly, the Flemish government will ascertain the compulsory requirements for smart meters. Fourthly, the Flemish government will decide which parties and the purpose for which they can have access to the specific data provided by smart meters. Finally, this provision asserts that the parties that will be granted access to the information supplied by smart meters must ensure effective data protection in accordance with the applicable data protection law.

As mentioned earlier, Minister Tommelein of the Flemish region announced that all conventional meters (up to 56 kV) will be progressively replaced by smart meters starting from January 2019. On 14 July 2017, the Flemish government issued a draft decree on the segmented deployment of smart grids. As of September 2017, the draft decree is being reviewed by advisory councils. The final version of the decree should be submitted to the Flemish Parliament by the end of this year [301]. Thus, the legal framework for smart metering systems in the Flemish region is still on the making at the time of writing.

8.1.7 Demand response

Belgium may be described as a paragon amongst the WiseGRID pilot jurisdictions as far as the production of flexibility through demand response is concerned. It is one of the few countries in the EU which has a commercially viable demand response system [70]. Demand response is eligible for the primary and tertiary reserves, as well as the interruptible contracts programme. In 2014, the capacity market was opened to demand response to ensure security of supply during winter, consequently demand response accounts for 10% of strategic reserve [70]. There is currently a pilot project underway which is testing the use of demand response in the secondary reserve. Should the pilot be successful, Elia hopes to open the secondary reserve to demand response in 2019 [302]. Table 33 below outlines balancing products for which demand response is accessible in Belgium.

<table>
<tr><th colspan="2">Product</th><th>Minimum size (MW)</th><th>Notification Time</th><th>Activation</th><th>Triggered</th></tr>
<tr><td colspan="2">R1-Load (Up)</td><td>1 MW</td><td>15s (50%)
30s (100%)</td><td>Automatic speed, rotation and frequency control system</td><td>No limit, but reasonable number of activations per year, about 80 min/ year</td></tr>
<tr><td colspan="2">R3-DP</td><td>1 MW</td><td>15 min</td><td>Remote control</td><td>Max 40 times/year</td></tr>
<tr><td colspan="2">R3 ICH</td><td>1 MW</td><td>3 min</td><td>Remote control</td><td>Not more than 4 times/ year</td></tr>
<tr><td rowspan="2">SDR</td><td>SDR_4</td><td>1 MW</td><td rowspan="2">6,5h (warm-up) + 1,5h (ramp-down)</td><td rowspan="2">TSO's website, day-ahead forecast + intraday correction</td><td>Max 40 times/year</td></tr>
<tr><td>SDR_12</td><td>1 MW</td><td>Max 20 times/year</td></tr>
</table>

Table 33 – Description of some main programmes requirements concerning the balancing products accessible to DR [70]

Despite the laudable advancements made in the Belgian system, it is not without its challenges. Many of these challenges revolve around expanding the reach of the current demand response to residential customers, either individually or through independent aggregators. One of the major barriers is that, aggregators need prior agreements with the customer's supplier in order to pool the customer's excess load for onward sale on the power exchange. This is because in order to sell flexible load, the selling entity must be the customers' BRP, and given that the supplier is the customer's default BRP, the said right has to be transferred to the aggregator. This problem is further exacerbated by the fact that aggregators cannot become BRPs because, in order to become a BRP, an entity must be able to provide a performance guarantee of EUR 4.000 per MWh [70]. This model does not only curtail the customer's right to choose an aggregator but also offers unfair/uncompetitive advantages to suppliers. Another challenge to demand response in the Belgium system is that, the nature of prequalification requirements operate to limit the programme to large industrial consumers. For instance, in order to provide balancing services, the customer has to be connected to high, medium and low voltage grids and subjected to an approval process by the DSO. This effectively excludes residential customers from participating in balancing markets.

It is interesting to note that, aggregators have been operating in Belgium without specialised legislation defining their identity, or operation in the electricity market. Arguably the problems regarding qualification requirements for providing ancillary services, and independent relationships with customers can be attributed to the lack of specialised laws. However, a new law passed in July of 2017, and currently awaiting ratification, would remedy these problems, as it is envisioned to define the role of independent aggregators. The new law also recognises the right of every customer in the electricity value chain to exercise the option of providing flexibility without constraints from his retailer [302].

8.1.8 Data protection

Belgium's regulatory framework for data protection and privacy is set out in the Law of 8 December 1992 on the protection of privacy in relation to the processing of personal data and subsequently implemented by the Royal Decree of 13 February 2001. The law has undergone a number of amendments and has commendably remained abreast with technological developments. The progressive approach taken by Belgian authorities have earned the country the accolade of data protection hub among some pundits [303]. The law provides for all the fundamental protections envisaged by Directive 95/46/EC on the protection of individuals with regard to the processing of personal data and the free movement of such data, such as the as the registration of data controllers; prior informed consent for the collection and processing of personal data; as well as the data subject's right to access, request rectification and object to the processing of personal data. The Privacy Commission ("*Commissie voor de bescherming van de persoonlijke levenssfeer/Commission de la protection de la vie privée*") is the national data protection authority and is responsible for ensuring compliance with the relevant laws.

In accordance with general data protection principles, the Belgian law imposes primary data protection responsibility on data controllers, which in the electricity context is the DSO. Consequently, controllers are required to notify the Privacy Commission prior to adopting any fully or partly automated systems for the processing of personal data. Article 1(3) of the law defines processing very broadly to include activities like the collection, recording, organisation, storage, adaption, alteration, retrieval, consultation, use, disclosure, alignment, and deletion of personal data. It appears that by emphasising "automation" in the law, the legislators intended to remove manual data processing activities from the remit of the law [304]. Therefore, the duty to notify the Privacy Commission only arises when the controller employs computer systems in its processing activities. Further, Article 55 of Royal Decree of 13 February 2001, exempts data controllers from the notification requirement when processing is in furtherance of the administration of its clients and suppliers. In this vein, DSOs and energy retailers appear to be exempted from the notification requirement as far as billing information is concerned. The problem however is that while *prima facie*, it is assumed that consumption data is meant for billing purposes, the reality is that, consumption data collected through smart meters, while not 'personal' in itself, can, together with other information be used to identify a customer, a scenario which the Belgian law appears not to cater for. This lacuna in the Belgian data protection regime can however be attributed to the fact that, the law was enacted prior to the advent of smart metering infrastructure. Indeed, meter reading in Belgium is done annually [305], thus it may be argued that the processing is not frequent enough to pose a significant risk to the customer's privacy. It may thus be argued that, given that AMI systems are still being tested on pilot basis, and yet to be rolled-out nationally, a case for regulatory reform is yet to be made.

In addition to the data controller's notification responsibility, it must, in a bid to ensure fair and lawful processing of data ensure that it implements appropriate technical and organisational security measures to prevent accidental or unauthorised, access or loss of personal data. The law however does not specify any requirements for these measures. Data controllers are therefore at liberty to adopt such measures as are appropriate within the context of their processing activities.

The Belgian electricity market operates a uniform nationwide communication platform, the Belgian Utility Market Information Exchange (UMIX), through which DSOs use information such as working orders and forecasts supplied by the TSO to ensure the smooth operation of the network. The portal also allows suppliers to access the meter readings taken by DSOs for billing purposes [305]. This process calls into operation, the rules on third party processing. In this regard, article 16(1) of the data protection law requires that a contract exist between the controller and the third-party who processes the data. The contract must *inter alia* make provision for the necessary technical and organisational security measures, and establish the third party's responsibility towards the controller. The controller must however have informed the customer of the fact of sharing the data, and obtained the customer's consent. The Smart Grid Task Force has however noted that there is insufficient clarity on the control and certification of third-party processors, and called for greater scrutiny over third party processing [306].

The UMIX is undergoing a complete overhaul to cater for wide-scale roll-out of smart meters and the increase of DERs in the Belgian electricity system [307]. In this new system, the streams of personal data that would be processed would increase exponentially and therefore regulatory reform would be imperative to ensure that personal privacy is not compromised. It is also expected that the institution of a Data Protection Impact Assessment (DPIA) will significantly reduce data and privacy risks [306].

8.1.9 Electric vehicles and storage

The transport sector has been one of the most important sectors in Belgium. In 2008 the sector recorded revenue of EUR 15.9 billion [308]. Owing to the importance of the sector in economic landscape, the reduction of greenhouse gas (GHG) in the sector has been a priority of the Belgian government. Indeed, Belgium has been at the forefront of GHG emission reduction in the transportation sector. Having been reported to have had a 31% increase in GHG emissions between 1990 and 2010, it succeeded in reducing its transport-related emission by 7% between 2010 and 2014 [309]. This has been achieved by several federal and regional initiatives to reduce reliance on vehicular transportation. These include high taxes on fuel; low-emission zone policies which exclude diesel and high emitting vehicles from city centres and policies on alternative means of transport; for instance, the Flemish Climate Policy Plan was adopted to amongst others increase the share of bicycles [310].

In keeping with its emission reduction strategy, Belgium has not been left behind in the electric vehicle 'revolution'. Since 2010, the number of electric vehicles (EVs) registered in the country has increased progressively, and by 2017, had obtained a market share of nearly 2% including one of the highest fleet of electric buses in the EU [311] [87]. The country is poised to increase the share of EVs in the country. To this end, at the federal level, the Belgian Platform on EVs was established. This joint-stakeholder platform was tasked with the responsibility of developing a national plan for electric mobility. It has produced a policy document – 'Roadmap 2030 for the Stimulation of Electric Mobility in Belgium.' At the regional level, the Flemish government has, since 2010, supported the setting up of demonstration sites to test real-life conditions for electric vehicle uses, by providing funding in excess of €16 million. There have also been special tax regimes established to incentivise the use of EVs. These include tax reductions for companies who purchase electric or hybrid vehicles and the construction of charging infrastructure; tax subsidies applied to the purchase of EVs by domestic users (In the Flemish region the government gives grants to individuals); and low tariffs for vehicle registration (the Flemish region applies a 0 tariff) [87].

The EV revolution in Belgium is largely being driven by research; there are several organisations which are undertaking research on electric and hybrid vehicles, spanning various aspects of the value chain. These include Flanders' DRIVE, "*Katholieke Universiteir Leuven*" (K.U. Leuven), the Limburg Catholic University College (LCUC), University of Ghent, *"Vrije Universiteit Brussel"* (VUB). Much of this research is akin to the WiseGRID project, and aimed at integrating EVs with smart grids by providing solutions for charging EVs, preferably with power from RES, as well finding workable means of employing EVs as energy storage solutions.

Charging infrastructure is crucial to a successful deployment of large-scale EV use. The challenge for most governments is the regulatory/policy approach to be taken in respect of the installation and operation of public charging stations. These include considerations about the type of charging technology (*i.e.* slow or fast charging); the siting of charging stations; the ownership of charging infrastructure; safety; standardization and cost. Belgium is not immune from these challenges, in fact, the partitioning of energy regulatory competence between the federal and regional government serves to make this even more challenging in the Belgian context. However, the Belgian platform on EVs is a step towards ensuring cross-regional efforts at ensuring the development of a workable regulatory framework. Despite the lack of concrete legal structures, there are currently about 1.500 public charging stations in Belgium. This is largely attributable to the existence of support schemes for the construction of charging infrastructure by the private sector.

An important corollary of the development of EVs the development of electricity storage systems as a whole. This is particularly important at the current stage of Belgium's energy development trajectory; given the increased integration of renewables, the closing of gas plants and the proposed phasing-out of nuclear energy. Currently, the large-scale use of storage facilities is very limited, there are only two hydro power plants located in Coo and Platte Taille, with a total capacity of about 1.3 GW. While the original purpose of these plants was to regulate generation from the nuclear plant in Tihange, they are currently being use to balance load in the grid [65].

The storage capacity needs in Belgium are expected to increase from 7 GW to 12 GW by 2020. To this end there are plans underway to construct a manmade offshore pumped-storage facility – an 'energy atoll', to support offshore wind generation [312]. There is also a proposed 600 MW extension to the pump hydro plant at COO. Despite the promise of the proposed infrastructural advancements, there are yet regulatory challenges, which if left unaddressed would impinge the development of storage technology in Belgium. In 2014, an amendment to the Federal Act of 29 April 1999 was introduced to facilitate the construction and operation of offshore pumped-hydro storage projects [312]. However, the law was very limited in scope and failed to address the pervasive challenges of the legal landscape for energy storage solutions. For instance, like many other European countries, storage facilities attract a double payment of grid fees. This is due to lack of a proper classification of storage technology in the electricity value chain. Other regulatory issues that merit consideration in the new energy landscape include special tariff and subsidy regimes for storage facilities. This would help encourage investment in storage technology, because the high capital investment operates as a disincentive.

8.2 GREECE

8.2.1 General overview

Greece is located in the Mediterranean coast of Europe, made up of large peninsulas and over 2,000 islands, it covers a total area of 132,000km^2, and has a population of 10.82 million [313]. Athens is the country's capital and largest city, followed by Thessaloniki. Given that a large part of the mainland is mountainous, majority of the population live in Athens and Thessaloniki. The country's 13,676 km coastline is said to be the

11th longest in the world [314].

The climate of Greece is characterised by mild, wet winters, particularly in the islands, and dry, hot summers. Areas west of the Pindus Mountain tend to be wetter on average due to exposure to south-westerly systems. The mountainous areas in the Northwest and the central parts of Peloponnese are alpine and characterised by heavy snowfall.

Greece operates a unitary parliamentary system, with a President of the Republic who is elected for a five-year term, as its nominal head of state, while executive powers are vested in a Prime Minister. Legislative powers are exercised by a 300-member, four-year unicameral parliament. The country is divided into thirteen administrative regions which are subdivided into 325 municipalities. Despite having a largely decentralised public administration system, energy policy formulation and regulation is largely centralised with legislation being passed by the Hellenic Parliament and other regulations being determined by the national regulatory authority. Greece has been a member of the European Union since 1981.

The country is still recovering from a financial crises and is currently under an austerity programme funded by the International Monetary Fund (IMF) and the Eurozone countries. In 2015, the country's GDP was $194.9 billion, representing a decline of 17% from 2014 figures [313].

8.2.2 Energy profile

Greek's energy security situation points clearly to a large domestic supply deficit, with 61% of its energy needs being met by imports consisting mainly of petroleum products and natural gas. The country's total primary energy supply (TPES) in 2015 was 23.6 Mtoe [315]. Domestic supply consisted of coal and renewable energy, however crude oil and natural gas, which make up 59% of the total TPES were 100% imported. Although the share of oil in the country's TPES has declined over the years, it still remains an important source of energy.

The liberalisation of the electricity market started in 2001, and was fully liberalised in July 2013. The liberalisation of the market notwithstanding, electricity production is dominated by the state owned 'Public Power Corporation' (PPC). High capital investments and the bureaucratic licensing procedure have proven to be barriers to market entry [316]. In 2016, 19% of electricity generation in the interconnected system was from hydroelectric power plants, while 28% was from natural gas. In response to concerted efforts at improving generation of electricity from RES, RES accounted for 29% of the country's energy mix in the interconnected system and 21.8% in the non-interconnected islands [315]. Figure 16 shows the energy mix of Greece as at 2015. Electricity consumption in 2016 was 50.1 TWh; a decline of about approximately 10% from the previous year's. The decline in consumption may largely be attributed to the current economic situation which has resulted in the adoption of various cost-cutting measures by both industries and households.

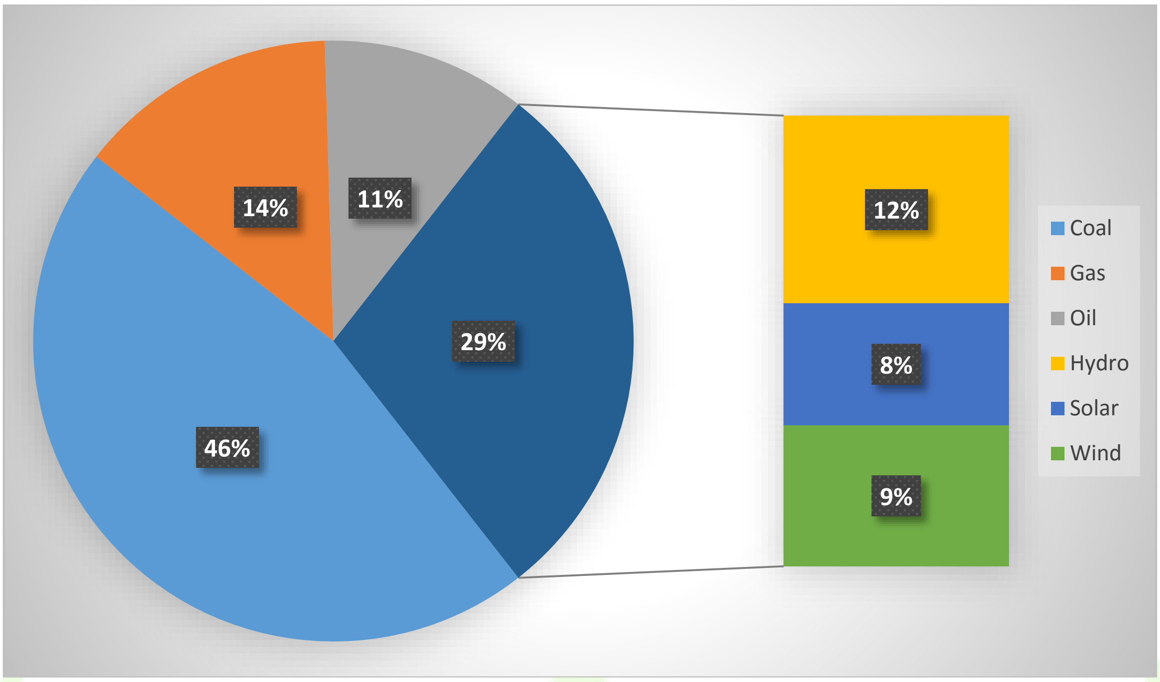


Figure 16 – Electricity Generation in Greece [317]

Greece is a member of the Union for the Coordination of the Transmission of Electricity (UCTE) and has since 2004 synchronised its transmission system with the rest of the European transmission system. Its transmission system is interconnected with all its neighbouring countries, including a submarine cable to Italy. In furtherance of the TEN-E Regulation, Greece has also established a single authority for licensing Projects of Common Interest (PCIs). In 2013, two electricity interconnections were identified as PCIs: the AC 400kV interconnection between Maritsa East 1 in Bulgaria and Nea Santa in Greece, and the DC 600kV underwater connection between Israel, Cyprus and Greece [318]. In order to enhance security of supply, to the Aegean islands, to facilitate the continued growth of RES, and to reduce cost, an underwater interconnection of the Cyclades islands has been commissioned by the TSO [318]. This is expected to be completed in 2017. In addition to this, planned interconnection of Crete has commenced and is expected to be completed by 2022.

Although Greece has immense potential for the development of gas interconnectivity due to its proximity to gas supplies from Russia, it has yet to harness its full potential. Greece is involved in several regional projects, all of which are at different stages of development including the Trans Antolian Pipeline, Trans Adriatic Pipeline and the Southern Caucasus Pipeline, which are intended to form part of Europe's Southern Gas Corridor for the supply of gas from Caspian sources. Other initiatives include the upgrade of LNG terminal Revithoussa, interconnections with Bulgaria through the reverse flow in Kula-Sidirokastron and the Interconnector Greece-Bulgaria pipeline [318]. Interconnections with Italy through the Trans-Adriatic Pipeline, potentially, with IGI Poseidon, and from Turkey with the upgrade of the compressor station in Kipi. [318] Given the country's supply deficit, the improvement of gas supply by the augmentation of infrastructure would go a long way to help improve the energy situation, particularly by helping manage the transition from a fossil fuel based system to a 'greener' system.

8.2.3 Relevant government institutions

Ministry of Environment, Energy and Climate Change (MEEC)

The ministry was created in 2009 and is responsible for climate and energy policy formulation. The General Directorate for Energy is responsible for energy policy and the publication of statistics, as well as the development of renewable energy and energy efficiency policy. There is also the Centre for Renewable Energy Sources and Saving (CRES) which advises the ministry, on the transposition of EU energy-related directives into Greek legislation. The ministry works closely with the Regulatory Authority for Energy (RAE), and exercises majority control over the Hellenic Transmission System Operator.

Ministry of Infrastructure, Transport and Networks

The ministry is responsible for transport planning and works closely with the MEEC. It is also responsible for policy formulation, for the telecommunications sector and postal services.

Ministry of Finance

The ministry is responsible for formulating fiscal policy.

Regulatory Authority for Energy (RAE)

It was set up in 2000 as the independent regulator for the energy markets. Since the 3rd Energy Package, its independence and powers have been improved and it is now responsible for licensing, secondary legislation, market control and supervision. It acts as the dispute settlement body in respect of complaints against TSOs or DSOs.

Hellenic Competition Commission (HCC)

The HCC is an independent body responsible for the proper functioning of competition in all Grecian markets. It advises the government on competition related issues and conducts investigation into anti-competitive behaviour.

Centre for Renewable Energy Sources (CRES)

CRES is an independent national entity established for the promotion of RES, energy efficiency and energy conservation, and operates under the supervision of MEEC. The Centre provides advisory services to MEEC and coordinates national policies for renewable energy and energy efficiency. It also conducts research on the country's energy systems and coordinates EU funded projects.

Public Power Corporation

The PPC is a publicly listed company, and electricity supplier in Greece. It is structured as a holding company for the separate companies which own and manage various transmission and distribution assets. It has a 100% stake in Hellenic Distribution Network Operator (HEDNO), the operator of the power distribution network in Greece. In 2016, its 7.3 million customers, consumed 91.9% of the total electricity supplied to end-customers in Greece.

Hellenic Electricity Distribution Network Operator (HEDNO)

HEDNO was established in April 2012 with the secession of the Distribution sector of PPC S.A. in accordance with Law 4001/2011 and in compliance with EU Directive 2009/72/EC. It is a 100% subsidiary of PPC S.A., however is functionally and administratively independent, in compliance with all the requirements of independence incorporated in the above legal framework. It is responsible for the operation, maintenance and development of the electricity distribution network (Medium and Low Voltage networks), the High Voltage network in Attiki and in the non-interconnected islands of in Greece. It is also responsible for the management of the production and operation of the electricity system market of these islands

Hellenic Electricity Market Operator (LAGIE)

Formerly part of the Hellenic Transmission System Operator (HTSO), LAGIE is responsible for the operation and settlement of the energy market in Greece. It is also responsible for the conclusion of power purchase agreements (PPA) with RES producers based on existing feed-in-tariffs. LAGIE also has responsibility for managing the imbalance settlement mechanism and the long term capacity market.

Hellenic Independent Transmission System Operator (ADMIE)

ADMIE is responsible for the operation, maintenance and development of the interconnected Hellenic electricity transmission system ensuring security of supply. Among its responsibilities is the real-time dispatch of the production units, the imbalance settlement, the Capacity Adequacy Mechanism, cross-border electricity trading as well as performing the auctions for the Interruptible Load Service.

8.2.4 Special conditions of the Electricity Market in the Non-Interconnected Islands

In Greece there is a significant number of Non-Interconnected Island Electrical Systems (NIIES). These are autonomous power systems that are not interconnected to the mainland power system and are characterised by the higher cost of electricity production compared to the mainland marginal price because of the significant use of diesel or fuel oil and the limitations in the penetration of renewables in the local energy mix.

More specifically the Greek NIIES comprise of 60 islands in total, forming 32 independent electrical systems, located mostly in the Aegean Sea, while only 2 NIIPS are located in the Ionian Sea. They host 15 % of the Greek population and account for almost 14 % of the total national annual electricity consumption (~42.300 GWh/year in national level).

The Kythnos NIIES is one of the smallest such electrical systems with almost 6 MW installed thermal capacity supplemented by 665 kW wind and 238 kW PV stations. The electricity demand of the island may reach up to 5 MW during summertime and drops down to an average of 600 kW during winter time.

The operation of the electricity market in the non-interconnected islands, like Kythnos, is regulated according to the provisions of the Non-Interconnected Islands Management Code (NIIMC) published by the Regulatory Authority for Energy.

Responsibility for operation and management of NIIES has been assigned to the Hellenic Electricity Distribution Network Operator (HEDNO S.A.), which effectively acts as the island generation and transmission system operator, as well as the market operator, besides its default role as the distribution network operator.

The operation of the electricity market in the NIIES is significantly affected by European regulation. More specifically in the case of medium-sized thermal power plants (rated power between 1 and 50 MW_{th}), which is the Kythnos case, the Environmental Directive 2015/2193/EU (MCPD) [13] for power stations emissions applies, according to which as of 1.1.2030, compliance with Emission Limit Values (ELV), as they will apply, is required for all the existing plants that are installed and operating in NIIES, with a production license before 19.12.2017 and operational date before 20.12.2018. Special provisions are foreseen when a NIIES gets interconnected to the mainland system.

The energy market, electricity production and supply on Greek NIIES is mainly affected by two EU directives; Directive 2003/54/EC [14] and Directive 2009/72/EC [15]. The directives include provisions for market opening and development of new conventional production stations and foresee derogation from the provisions for micro isolated systems that consumed less than 500 GWh in 1996, which is the case for Kythnos and all the other NIIES besides Crete. Following the provisions of directives, Hellenic Republic had applied for derogation expect for Crete and Rhodes. According to the EC Decision 2014/536/EU [16] the derogation is allowed only for refurbishment, expansion and upgrading of existing conventional units (derogation for new conventional capacity, RES and CHP is not approved) for micro isolated systems until 2021, and derogation for market opening until 2019, or earlier if the infrastructures described in NII Code are ready. The Greek Law 4414/2016 [17], has adjusted Greek legislation to the provisions of Decision 2014/536/EE.

8.2.4.1 Specific barriers and challenges of the NIIES

1. Geographical dispersion and isolation
   a. Lack of specialized local personnel
   b. Obstacles in equipment/personnel transportation
2. Autonomous systems powered by diesel generators
   a. High production cost, in relation to the Pool System Marginal Price in Mainland
   b. Environmental concerns from the operation of thermal power plants on the islands
3. Weak networks
   a. No HV transmission systems - MV distribution networks
   b. Exposure to adverse conditions - Quality of supply often impaired
4. Unfavourable demand characteristics

a. Extreme seasonal variations (summer/winter peak > 4, annual max/min > 8)
b. Low generating capacity utilization and operational difficulties

5. Obstacles in capacity expansion
   a. Frequent investment in new capacity needed - Installation of portable units
   b. Local community reactions (environmental concerns, tourism), lack of space, land acquisition difficulties (availability, cost), lack of infrastructure (ports, roads etc.)

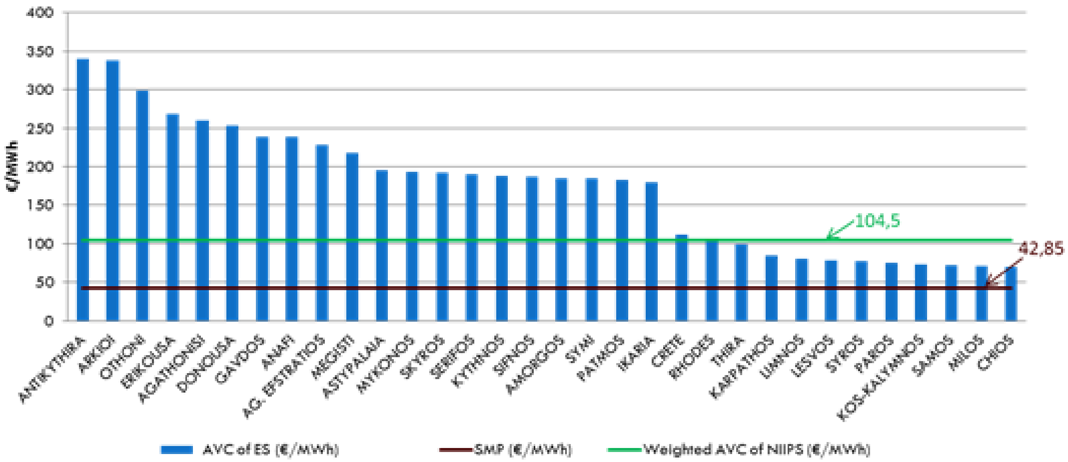


Figure 17 – Average Variable Cost (AVC) per NIIPS for the year 2016

8.2.4.2 RES penetration in the NIIES

The amount of renewable generation that can be allowed in an island grid at any given moment (instantaneously) is regulated and cannot exceed a certain technical limit which is determined by the must-run capacity of the thermal generators and the spinning reserve requirements to ensure grid stability. In the case of Kythnos, the diesel generators provide all the necessary ancillary services to the grid and maintain the frequency stable at 50 Hz by constantly balancing the demand and the load.

At the moment, the only on-grid renewable generation in Kythnos comes from 238 kWp of PV plants. The main challenge to address when allowing more renewable sources such as the planned and licensed wind turbines on Kythnos is to manage their intermittency, namely the fact that their production can fluctuate heavily and cannot provide ancillary services in an efficient way. This is even more important in Kythnos whose grid is rather weak (few power lines, old infrastructure, few generator units, one power plant) and therefore any mismatch between load and demand that may occur within a few milliseconds can cause power outages when not handled properly by the energy control center.

Lately new RES penetration margins have been approved by the Regulatory Authority of Energy (RAE) with Decision 616/2016 [12], defining the hosting capacities for the various RES technologies in each NIIES. The basic points of this Decision can be summarized in the following:

- RES technologies include wind, solar PV, solar thermal, biomass-biogas. Both intermittent and dis-patchable RES generation is foreseen.
- Contractual guarantees to be provided to dispatchable RES and storage stations against excessive levels of curtailment, to safeguard investment viability.
- Storage development foreseen under the Hybrid Power Station (HPS) framework with overall stor-age capacity beyond 300 MW for all NII systems to be feasible. No restrictions imposed on storage technology, but high energy capacity solutions are favored.
- RES energy penetration levels up to 50% of annual energy demand made feasible with the penetra-tion margins approved by the Regulator.

- Further increase of RES penetration is possible, both in small island systems through integrated solutions, as well as in medium and large islands by innovative storage applications and demand flexibility.

8.2.5 Regulatory framework for the electricity market

The regulatory framework for electricity in Greece is largely driven by the EU's energy policy towards the creation of a single energy market, the liberalisation of the electricity sector, and the promotion of RES. Consequently, Greece's electricity sector is governed by a series of laws which represent a transposition of various EU legislation. The main laws regulating the sector are:

- Law 4001/2011 (Fundamental Energy Markets Law) which sets out the role of the national Regulatory Authority for Energy (RAE); regulates the operation of the electricity and natural gas markets ; and regulates the unbundling and independence of national energy networks and their respective operators, adopted in transposition of the third EU Energy Package;
- Law 2773/1999 and Law 3426/2005 regulate the liberalisation of the electricity market;
- Law 3468/2006, Law 3734/2009, Law 3851/2010, Law 4062/2012 and Law 4414/2016 regulate power generation from RES and high-efficiency CHP in transposition of relevant EU Directives and the European Commission's Guidelines on State Aid for environmental protection and energy for the period 2014-2020;
- Law 24461/2014, which provided for the installation of RES systems by self-producers with net-metering;
- Law 4425/2016 sets out the rules for the restructuring of the Greek electricity market and describes the establishment of energy and capacity balancing markets. Operation of these markets will start as soon as the respective Market Codes are issued.

In addition to these, there are also secondary legislations which are relevant to the operation of the electricity sector. These include:

- the Electricity Supply & Trading Licences Regulation (Part A) of November 2012;
- the Regulations for the award of production licences to conventional power plants of December 2000;
- the Power Production Licences Regulation for RES and CHP power plants of October 2011;
- the Grid Code and the Market Transactions Code of January 2012;
- the Electricity Supply Code of April 2013;
- the Non-Interconnected Islands (NIIs) Network Code of February 2014;
- the Distribution Network Code of January 2017 (Government Gazette, B'/20.01.2017); and
- The Handbook of Measurements Management and Periodic Clearance of Network Suppliers, as established with RAE's decision of 13.31.2006 (O-12582, Government Gazette 'B 82/27-01-2006).

8.2.6 Market characteristics and idiosyncrasies of the Greek pilot sites

8.2.6.1 The electricity market

Owing to the geographical nature of the area that constitutes Greece, the electricity market in the country has been divided into two; the interconnected system which consists of mainland Greece and islands that are connected to the high-voltage grid, and the Non-Interconnected Islands (NIIs) which consist of the islands in the Aegean Sea, Crete and Rhodes which are not connected to the mainland grid but rather have their own independent production. In the interconnected system, generation and supply are fully liberalised, under the control of LAGIE, while transmission and distribution have remained monopolies. In Crete and Rhodes generation and supply are also fully liberalised.

A Greek Wholesale Electricity Market was set up in 2005 as a pure mandatory pool. It has since undergone a number of revisions, and the current market design is deemed a full implementation of the Grid and Market

Operation Code. The market operates a day-ahead system (DAS) which is run by LAGIE. Unlike some other European markets where energy and ancillary serves are cleared sequentially, the Greek market co-optimizes both as part of its DAS. [319] As is depicted in Figure 18 – Overview of the Greek market below, dispatchable conventional units that are available, submit offers for primary and secondary reserves (one price-quantity pair per unit per dispatch period) following specific rules stipulated by the Market Operator. The offers are submitted and can be modified until at least 12:30 of the preceding day. The result of the resolution of the DAS is the unit prices for the primary and secondary reserve (not for the tertiary reserve). The quantities for secondary reserve are determined during the real-time operation. The design of the mandatory pool for the simultaneous clearing of energy and ancillary services markets is a transitional step towards the full compliance with the EU legislation. Since the coming into operation of law No. 4425 in September 2016, a new market design for electricity is envisaged, in which clearing of the day-ahead, intra-day and balancing (energy and capacity) services market would be separate.

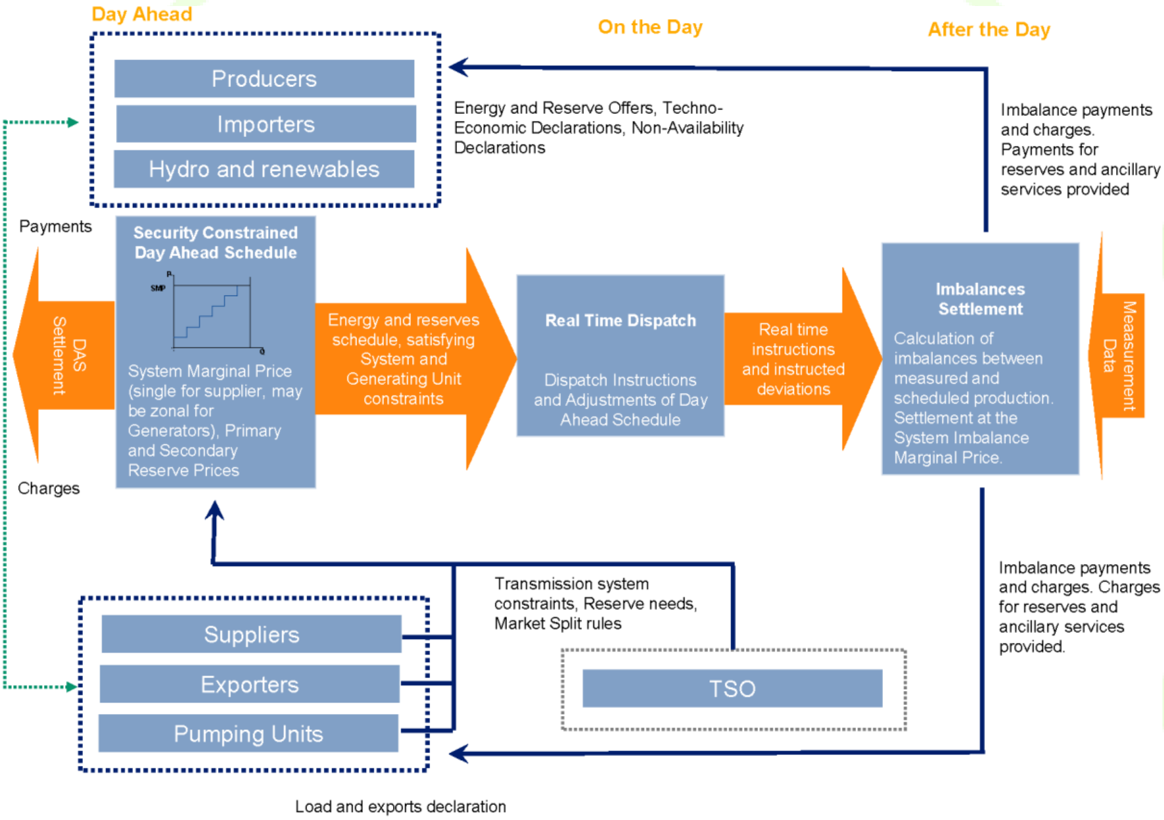


Figure 18 – Overview of the Greek market [320]

Relevant changes in the market codes are expected to take place according to recommendations made by the RAE; once the recommendations are approved by MEEC, RAE will is responsible for its publication. In a bid to further develop its wholesale market, Greece plans to launch a power trading exchange in line with EU plans for an interconnected energy grid. The exchange which will be set up through the joint efforts of LAGIE and the Athens Stock Exchange will be based on a day-ahead, an intraday, forward and balancing market. [321] It is expected that the trading exchange will help boost competition, secure transparency in power sales and lower prices for consumers.

Electricity pricing in Greece represents an attempt to balance the real-time cost of electricity with the need to ensure that electricity remains affordable for customers. In the wholesale market, price is determined by the System Marginal Price (SMP) which is calculated by LAGIE. The SMP is the hourly clearing price for the day-ahead scheduling of power pool transactions and is dependent on the economic merit order of the merchant power plants' schedules. [322] The transactions on which this calculation is based do not however include RES, as the price of this is affected by the application of feed-in-tariffs. In the retail market on the other hand, pricing is fully liberalised, allowing electricity suppliers, including the dominant PPC, to set their own prices. However, the law requires electricity bills to distinguish between regulated charges in respect of transmission and distribution; public service obligations; renewable support scheme charges and municipal duties or taxes, from the actual charges for electricity supply [322].

As part of efforts to comply with EU emission targets to cut GHG emissions by 20% compared with 1990 and at least 40% by 2030, Greek policymakers have prioritised Green House Gas (GHG) emission reduction in the energy sector. In the electricity sub-sector, the focus has been on the promotion of RES with the view to securing smooth, uninterrupted, affordable and reliable electricity supply. To this end, the MEEC, pursuant to EU Directive 2009/28/EC, developed a National Renewable Energy Action Plan [323] which came into force in 2010. The National Renewable Energy Action Plan outlines a number of measures aimed at achieving the goal of tripling RES penetration by 2020. The policies *inter alia* aim at capitalizing on the country's high levels of solar irradiation. Consequently, 4.1 million m^2 of solar thermal systems have been installed [315]. It is in this context that WiseGRID becomes even more relevant to the development of the Greek electricity market, as one of its main objectives is to improve RES integration in electricity networks.

Greek's renewable energy policy as dictated by the 'Generation of Electricity using Renewable Energy Sources and High Efficiency Cogeneration of Electricity and Heat Miscellaneous Provision' (Law 3468/2006) and the 'Accelerating the Development of Renewable Energy Sources to Deal with Climate Change and other Regulations Addressing Issues under the Authority of the Ministry of Environment, Energy and Climate Change' (Law 3851/2010) entitles power from RES to dispatch priority to the grid making it conducive to the objectives of the project. Grid operators are mandated to off-take power at regulated prices (feed-in-tariffs) and in accordance with standardised power purchase agreements (PPAs), subject to grid safety and technical limitations. The PPAs between grid operators and generators are for a term of 20 years, and in the case of solar thermal plants, 25 years. In August of 2016, the Greek parliament passed a law which introduced sliding feed-in premium (determined by the type of renewable energy technology being applied) as a top up to revenue received by new renewable energy generators who participate in the wholesale electricity market. Under the new law, large RES generators will benefit from a contract for difference (CfD) against the market value of RES energy from that particular technology. Yet another renewable support scheme which is worthy of mention is the net-metering scheme, under which consumers have the possibility to produce their own electricity from photovoltaic systems installed on rooftops or on ground-mounted systems, inject any surplus into the grid and offset this surplus electricity against future consumption. This is being managed by HEDNO. Although the net metering scheme has currently been successfully implemented for low capacity PV generators, Law 4414/2016 envisages the extension of the scheme to other RES technologies. Needless to say, the systems for gathering and management of consumption data as proposed under the WiseGRID project would contribute immensely to facilitating the further deployment of the scheme.

Further, the licensing regime for the construction and operation of generation facilities exempts small-scale and experimental generation facilities from authorisation for connection to the grid. These legislative actions reinforce the potential benefits of a successful deployment of the project, not only for the generators but invariably towards the attainment of national energy policy goals and ultimately the improvement of the energy security situation in the country.

Despite the promising outlook presented above, there are regulatory and policy uncertainties which may prove inconsistent with certain aspects of the project. The project envisages a flexibility mechanism which would enable prosumers to trade their surplus production. However the flexibility compensation scheme which has existed in Greece appears to be targeted at only supply side flexibility and even then, it only applies to large scale energy generators from specific technologies such as natural gas plants, combined heat and power plants and hydro plants, thereby excluding prosumers [324]. In addition, although the liberalisation of the market guarantees market entry, the Energy Markets Law requires entities wishing to supply electricity to customers in Greece to obtain a supply or trading licence from the RAE. Article 134 of Law 4001/2001 only envisages "supplier" as large corporate bodies with shareholding of 600,000 Euros. The law does not define "supplier", and imposes an onerous burden by requiring that suppliers either generate enough capacity or ought to provide guarantees for long-term capacity. [325] Consequently, without express room for derogation from the general terms of the law, it appears the law excludes prosumers from selling directly to the market. On the other hand, it may be argued that the net-metering system is intended as a compensations scheme for small-scale prosumers whereas the “suppliers” within the meaning of Energy Markets Law 4001/2011 is targeted as large scale producers. Be that as it may, the recently passed Law 4425/2016 aimed at restructuring the Greek Electricity Market appears to provide a glimmer of hope to prosumers. It provides for the compulsory participation of renewable energy projects in the Greek wholesale market, either directly or through aggregators. [326] The new law also envisages a replacement of the FiT scheme by a new feed-in premium (FiP). This is envisaged as additional revenue to RES generators who participate in the wholesale market. The top-up revenue is intended as a technology-specific operational aid. Again, the law is couched in very general terms, and its practical implications for prosumers is yet to be seen. This notwithstanding, the formal recognition of aggregators is definitely a welcome development which will enable further decentralisation of the electricity system.

8.2.6.2 The different market roles

The main participants and their main tasks in the electricity market in Greece are:

- Producers, Self-Producers: Producers have Production license for Production Units registered in the Registry of Power Production Units. It should be noted that there are defined categories of production units which are excluded from the obligation to hold a Production license, e.g. photovoltaic plants of installed power under 20 kW, (virtual) net-metering, etc. Self-producers produce electricity for their own use and inject the excess energy into the System or the Network. [327]Suppliers: Suppliers have Procurement license and buy energy directly through the Daily Ahead Schedule (DAS) in order to meet the requirements of their customers.
- Importers: Importers have a Procurement or Marketing license, purchase energy quantities by Producers or Suppliers outside Greece and inject these quantities into the interconnected system through the international Interconnections. Imports through the interconnections can also be scheduled by self-supplied Customers for their own use.
- Exporters: Exporters have a Procurement or Production or Marketing license and purchase energy quantities (included in the DAS as energy demand) in order to export them to other countries through the international interconnections.
- Customers (Eligible - Self-supplied): Eligible Customers are consumers of electricity who have the right to choose their Supplier. This stands for all the customers of the interconnected system, Crete and Rhodes, but not for the small islands of the Non-Interconnected system. Self-supplied customers have the right to acquire energy through the DAS for their own exclusive use. [328]
- The Transmission System Operator (TSO): The Independent Power Transmission Operator (IPTO) performs all duties stipulated in Article 94 of Law 4001/2011 and 4414/2016. Some indicative duties, mostly related with the Energy Market are:
    - Managing electricity flows on the System, taking into account exchanges with other interconnected systems;
    - Ensuring the safe, reliable and efficient operation of the System, as well as the availability of necessary ancillary services including those provided by Demand Response, insofar as such availability is independent from any other transmission system;
    - Preparing the dispatch schedule for generation plant connected to the System, determination of interconnections usage and performance of real-time dispatching of available generation plant;
    - Collection of System access charges and conduct of all relevant transactions under the inter-transmission system operator compensation mechanism, in compliance with Article 13 of Regulation (EC) No. 714/2009;

- Granting and managing third party access to the System and giving reasoned explanations when such access is denied;
- Maintaining of necessary ledger accounts pertaining to the collection of interconnection congestion charges or any other charges relevant to the operation of the Hellenic Electricity Transmission System;
- Calculating the ex-post System Marginal Price (SMP) and clearing of generation-demand imbalances and conduct of all relevant transactions for the settlement of said imbalances in cooperation with the Market Operator and the Hellenic Electricity Distribution Network Operator;
- Entering, subject to a relevant tender process, into electricity trading agreements, including agreements for demand management insofar, as this is required for the provision of ancillary services with the purpose of generation-demand imbalance settlement during real-time system operation and in compliance with the Hellenic Electricity Transmission System Operation Code;
- Cooperation with the Market Operator according to the stipulations of the Market Operation and Hellenic Electricity Transmission System Codes [329], [330].

- The Market Operator (LAGIE): According to the Greek Legislative and Regulatory Framework, the main roles, responsibilities and tasks of LAGIE are:
    - Operation of the Spot electricity market (Day Ahead Scheduling-DAS);
    - Clearing and Settlement of DAS transactions;
    - Spot electricity market monitoring and analysis;
    - National Auctioneer in the allowance auctions conducted through the common European platform;
    - Administration of the National scheme for the compensation of indirect EU ETS costs (Carbon Leakage);
    - Reporting to ACER as Organized Market Place and RRM of the Market Participants' transactions in the Spot electricity market [331]. On the 11th December 2015, following the decision of the Minister of Environment and Energy, LAGIE was designated as "Nominated electricity market Operator" (NEMO) to perform the single day-ahead and intra-day coupling in accordance with article 4 of Regulation (EC) No 2015/1222.
- The Distribution Network Operator (DNO): Hellenic Electricity Distribution Network Operator (HEDNO) is the operator of the medium and low voltage distribution network of the whole territory that was established by the separation of the PPC Distribution Division according to Law 4001/2011 and in compliance with the EU Directive 2009/72 / EC. At the non-interconnected islands though, HEDNO's role is not limited in the management and operation of the network, but covers also the management of the production and operation of the electricity systems market of these islands. [332]
- The Regulatory Authority for Energy (RAE): RAE performs all duties stipulated in Law 4001/2011 including provisions with respect to access tariffs to electricity and gas networks, the terms and conditions for the provision of balancing services in natural gas, as well as on issues related to security of electricity and natural gas supply. Furthermore, RAE monitors the operation of gas and electricity market, acts as a dispute settlement authority between the different parties of energy market and with respect to complaints against transmission or distribution system operator in both electricity and natural gas sectors, while participating also in the pre=parliamentary legislative process through recommendation to the relevant Ministry and advising on the enactment of secondary legislation.

Apart from them, there has been a provision for the role of Aggregator of energy producers from RES and CHP in law 4414/2016 and of consumers in law 4425/2016. Currently, a law draft related with the creation, definition and roles of energy cooperatives is under public consultation and it is expected that the Greek Energy Stock Market will start running in 2018, with the collaboration of Athens Stock Exchange. With the creation of energy cooperatives, the WiseGRID product WiseCOOP could be an important tool for them to manage their assets and interact with the DSO in case it is needed.

8.2.6.3 Energy mix and penetration of RES and CHP in the Greek electrical energy market and associated barriers

Regarding the electrical energy production sector, according to LAGIE's [333] and HEDNO's data, at the end of 2015, the total power generation capacity of the Mainland Interconnected System and the Non-Interconnected Islands was about 20000 MW. This capacity was distributed in thermoelectric plants with lignite with a percentage of 23% and oil 13%, natural gas 26%, hydroelectric plants with a percentage of 16%, with the rest (22%) coming from RES. More specifically, photovoltaics and wind power hold the biggest portion of the RES power capacity, with approximately 2200 MW and 1300 MW respectively. The rest of the power generation capacity in Greece consists of rooftop photovoltaic generators, biomass and combined heat and power (CHP) plants. During 2016, the use of oil for power generation was reduced, while PV net metering systems, biomass and wind power capacity increased [334]. The thermoelectric plants with oil are used at the islands autonomous electricity systems. In May 2017, RES installed capacity in the Mainland had increased by approximately 60 MW in relation to December 2016, according to LAGIE DAS data [335].

Till now renewable energy sources have been prioritized in the energy market, considered first by merit order and been offered guaranteed feed-in-tariffs. However, with the new RES law (L.4414/2016), the regulatory framework for new DER/RES participating in the Greek energy market is gradually starting to change (with photovoltaics as a first step). The new policy framework abandons the feed-in tariff (FIT) policy in favour of a feed-in premium scheme for systems over 500 kWp. In practice, this means that the new PV power plants will be participating in the energy market after participating in bidding process under NRA supervision to acquire the necessary permit and will be given a variable premium, on top of the market price for the generated green power. The amount of the premium for renewable power plants will depend on some market variables (e.g. the system's marginal price) and a tariff set via competitive tenders. The feed-in premium will be valid for 20 years. The new law does not apply to Greece's non-interconnected islands. Moreover, PV systems with a capacity of 10-500 kWp are now in theory eligible for a feed-in-tariff. However, current FITs (2016) are quite low (57 €/MWh) and do not guarantee viable investments, according to the estimation of Hellenic Association of Photovoltaic Companies.

Additionally, the Greek authorities have introduced legislation to facilitate net-metering for solar PV arrays, allowing installations up to 500 kWp, [327]. The Greek net-metering scheme (active as of mid-2015) is applicable to all solar PV systems that aim for self-consumption, thus it expands to both rooftop and ground-mounted systems. Different limits are applied among residential and commercial applications, governmental or non-governmental non-profit organizations and autonomous electricity grids. Energy compensation for net-metering owners is taking place on an annual basis. Moreover, in July 2017, HEDNO initiated the procedure for virtual net metering for MV and LV customers providing the chance to more customers to take advantage of the net metering principle (based on energy offset) without the limitation of special concentration of the photovoltaics and the consumption loads at the same place or area using the same supply point. Certain limitations in the maximum installed power of the systems exist though, as in the initial net metering scheme. Since the end-users' benefit from net-metering is based on the energy offset and the achieved self-consumption, WiseHOME and WiseCORP tools will be useful both for residential users, as also for businesses, industries, public facilities and ESCOs to take advantage of this scheme, reduce their energy bill and manage more effectively their assets, when combined with the necessary automation systems in their premises and installation of smart meters.

However, indicative barriers to new RES investments are considered the following: fiscal situation in Greece, social acceptance towards large- scale power plants or parks, technical difficulties related to network congestion, and lack of exploitation of storage technologies. Considering these aspects, the versatile and significant role of DSO as created imposes the need of an integrated tool, such as WG Cockpit enabling DSOs to control, manage and monitor the grid, improving flexibility, stability and security of the network. The offered possibilities of real-time grid monitoring, load and production forecasting, DR campaigns triggering and decentralized fast control could assist in reaching the goal of increased RES penetration with high power quality. In the complex energy market background which is created, the management of massive heterogeneous data, numerous devices and different systems will be crucial. A scalable, secure and open interoperable platform such as WG IOP could assist in ensuring an efficient and harmonized function of the interconnected systems.

CHP has been equated with RES, enjoying the same beneficial position in the electricity market. Installation procedures have been simplified, while the produced electricity can be sold to the national network according to the Feed-in-Tariff and Feed-in-Premium scheme. Those benefits have not, however, acted as an incentive to increase installed capacity, which is stable at 100 MW over the last decade, with the only exception being the period 2009-2011 when it approached 150 MW. Electricity generation is low and, even with the participation of distributed units, covers only 2.5% of national load. Most applications are related with industrial and agricultural purposes, while only 5 MW are installed in the tertiary sector.

Conditions have not been fruitful due to relatively high initial costs in combination with a highly unstable investment and economic environment. Feed-in-Tariff, for example, has been drastically decreasing since 2014. Another issue is the public's awareness related to CHP, which is very low. Nevertheless, the penetration of cogeneration into the Greek energy system and, in particular, the development of tri-generation in the tertiary sector has been foreseen in long-term national energy planning. As prices for natural gas are falling and electricity prices are rising, the economic potential for CHP is growing and if combined with new policies and incentives, can make the investment more attractive.

8.2.6.4 Market penetration of storage technologies

Regarding storage technologies, there is not a market for batteries installed in applications with grid connection, since there is not the necessary regulatory framework. Storage units, like batteries, can be found in some systems which are not connected to the Hellenic Distribution Grid (for which HEDNO is responsible) (e.g. isolated cottage houses) and in several pilot projects. In some of the pilot projects, desalination units are used as alternative storage reinforcement. The existing storage systems involve some Pump Hydro stations (one of them included in a hybrid power plant at Ikaria non interconnected island) providing energy to the system. Of course, this is on energy production level and not on the end-user level.

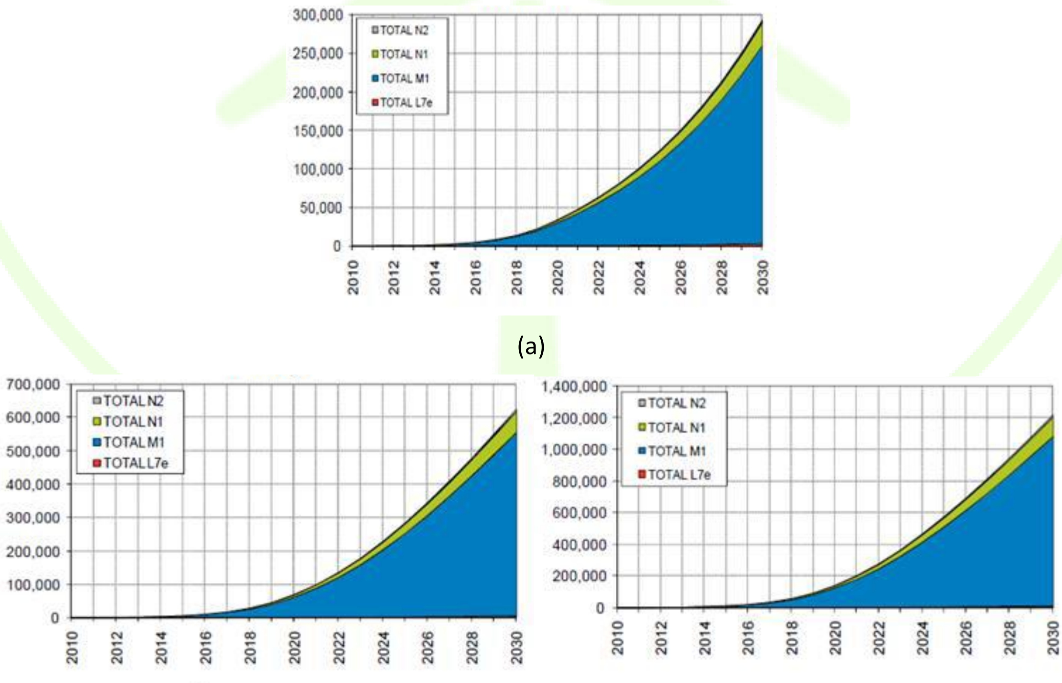
8.2.6.5 Market penetration of smart metering

Smart metering is a technology that could act as a driver for further market liberalization in Greece and for the participation of the end-user in DR schemes. Currently, smart meters have already been installed for all MV customers and are being installed for big LV customers (between 55kVA and 250kVA). At the same time, the necessary AMI infrastructure has been installed for the support of their function. HEDNO has initiated pilot projects to test the new technologies and evaluate their advantages, in order to further expand the installation of smart meters in customer premises as defined by EU planning. Meanwhile, a 200.000 LV customer pilot rollout has been planned. However, there are delays due to legal issues related to tendering procedures.

8.2.6.6 Market penetration of electric vehicles

As far as the EVs market is concerned, it seems to be in a very preliminary stage yet, in spite of several steps gradually being taken towards this direction. An accurate overview of this specific market including total number of EVs and mainly charging stations in Greece is difficult to be given, because of the lack of concentrated data by reliable sources. According to the Hellenic Association of Motor Vehicle Importers Representatives, issuing monthly reports of vehicles registration in Greece, 5 new EVs (cars) were registered in May 2016 out of a total number of 10,660 new cars (among which there were 209 hybrid cars too). In addition, it is reported that in 2016, out of 78,873 new cars that were sold, 32 were EVs, while 1,556 were hybrid cars. The sales of EVs stay on a rather low level, due to their high cost, limited autonomy and the lack of the appropriate spread of charging infrastructure being reported as the main inhibitory reasons by the end-users. However, several initiatives have been taken by the companies to boost the EV sector, even since 2011, when an oil and fuel trading company and an electrical energy production and trading company cooperated to install EV charging stations in three of the gas stations of the first. Moreover, another business plan implemented twice till now includes the cooperation of an EV producer and an electrical energy supplier to promote one of their EVs providing to the customers a substantial discount in the vehicle price, reduced electricity price for residential charging purposes. Apart from that, several public and private initiatives have been taken to expand the charging infrastructure in addition to several related pilot projects and EVSE operator business plans have started emerging. During the works of the European Research Project MERGE8, there had been developed 3 different scenarios of EV penetration in the Greek market till 2030: the realistic (predicting around 300,000 EVs), the optimistic (predicting around 600,000 EVs) and the very optimistic (predicting around 1,200,000 EVs). The results of this study are presented in the following picture and were based in predictions and market data in 2010, so they may need to be reconsidered based on the financial status of Greece at the present time. Finally, e-mobility in public transport is also gaining attention, since, apart from the existing trolleys and the tram, Athens municipality is planning the pilot usage of an E-bus covering a densely populated area of the city centre in cooperation with Athens Urban Transport Organisation (OASA).

Solutions like WiseEVP and WG FastV2G could improve the EV management, strengthen these initiatives and support them towards their success and boost of their market share. WiseEVP application could assist operators and EV Fleet managers in the optimization of the activities related to smart charging and discharging of the EVs and reduction of their energy consumption as well as their energy bill, taking into consideration the renewable generation profile, the tariffs and the EV users' requirements. WG FastV2G application could allow the usage of EVs as dynamic distributed storage devices and feeding electricity stored in their batteries back into the system, if the regulatory framework regarding energy storage gets shaped. Then, WG FastV2G could reduce electricity system costs by providing cost-effective means of operating reserve and peak-shaving capacity.



(b) (c)

Figure 19 – (a) Realistic, (b) optimistic and (c) very optimistic scenarios for EV penetration in the Greek market till 2015, as developed in MERGE project.

8.2.6.7 Market penetration of Demand Response services

As far as market services and Demand Response schemes are concerned, there is a preliminary framework, with special contracts in use, as the market currently is not mature enough.

More specifically, TSO has established a bidding process for Interruptible Load contracts for customers connected on HV and MV network, with 29 companies registered in the Interruptible Load Archive in 2017 (with total offered interruptible load of 2191 MW). The final list of participants and price per MW are determined at auction taking place every 3 months [336].

Furthermore, there are contracts for residential customers offering lower tariff during the night and Interruptible Load contracts for "agricultural customers". 2.7 % of all LV customers and 4.4 % of all MV customers participated in these special contracts in 2017 (as measured in March).

Recently, the legislative framework has included a provision, so that the DSO can make Demand Control Contracts (interruptible load) with any customer on LV network (upon agreement of NRA), as long as the customer's facilities are equipped with telemetered load technology and satisfy the necessary technical requirements set by the DSO, but no contract like that has been in place yet (Art. 28 of [337]). If such contracts start being activated, then WiseGRID tools enabling the participation of residential and business end-users to DR campaigns will facilitate their participation in the energy market.

8.2.6.8 Market penetration of smart homes systems

Automation systems and smart home devices have started to be gradually installed in houses in Greece, in order to improve the energy efficiency of the building and upgrade the quality of life of their residents. The main automation and smart systems involve control of heating and HVAC systems, safety systems (and alarms), monitoring indoor environment quality systems, houses' jalousies, control of lighting systems, smart entertainment devices and smart household electrical appliances. According to the applied Code of Energy Efficiency in Buildings, for houses to be highly rated, they need to have some kind of automation system regarding heating and HVAC systems operation. Nonetheless, the installation and use of smart devices has to do with the willingness, the preferences and the life style of the end-users, spreading from smart thermostats, to air-conditions controlled through apps using wifi, smart coffee-makers, etc. and sometimes smart houses using advanced protocols with field buses, twisted pair, powerline, radio frequency, ethernet or wifi for the creation and execution of combinational scenarios inside home, for remote monitoring of its performance in different rooms though appropriate platforms and remote control of home devices. Moreover, in the Greek market, there are certified engineers working on the implementation and integration of these systems. However, depending on the application, smart devices penetration in the Greek households could be characterized as being in a very preliminary stage; nevertheless, there could be some reservation towards the last argument, since there is lack of concentrated data about this specific market by a reliable source.

In combination with the existence of smart devices and systems, WiseHOME application would allow the residential customers (consumers and prosumers) to become active players able to monitor and control their energy consumption, participate in the market, thus also affecting their energy costs. WiseHOME could be used as an incentive for the residents to actively manage their consumption, so as to reduce their energy bill, supporting self-consumption by means of real time data, DR and load optimization schemes, providing that Demand Control Contracts will be activated on LV level. On this basis, the RES forecast provided to the prosumer would assist in a more efficient plan of the energy usage during the next day.

8.2.6.8.1 Non-Interconnected Island Electrical Systems and the Kythnos pilot site

In Greece there is a significant number of Non-Interconnected Island Electrical Systems (NIIES). These are autonomous power systems that are not interconnected to the mainland power system and are characterised by the higher cost of electricity production compared to the mainland marginal price because of the significant use of diesel or fuel oil and the limitations in the penetration of renewables in the local energy mix.

More specifically, the Greek NIIES comprise of 60 islands in total, forming 32 independent electrical systems, located mostly in the Aegean Sea, while only 2 NIIPS are located in the Ionian Sea. They host 15 % of the Greek population and account for almost 14 % of the total national annual electricity consumption (~42.300 GWh/year in national level).

The Kythnos NIIES is one of the smallest such electrical systems with almost 6 MW installed thermal capacity supplemented by 665 kW wind and 238 kW PV stations. The electricity demand of the island may reach up to 5 MW during summertime and drops down to an average of 600 kW during winter time.

8.2.6.8.1.1 Special conditions of the electricity market in the Non-Interconnected Islands

The operation of the electricity market in the non-interconnected islands, like Kythnos, is regulated according to the provisions of the Non-Interconnected Islands Management Code (NIIMC) published by the Regulatory Authority for Energy.

Responsibility for operation and management of NIIES has been assigned to the Hellenic Electricity Distribution Network Operator (HEDNO S.A.), which effectively acts as the island generation and transmission system operator, as well as the market operator, besides its default role as the distribution network operator.

The operation of the electricity market in the NIIES is significantly affected by European regulation. More specifically in the case of medium-sized thermal power plants (rated power between 1 and 50 MW_{th}), which is the Kythnos case, the Environmental Directive 2015/2193/EU (MCPD) [13] for power stations emissions applies, according to which as of 1.1.2030, compliance with Emission Limit Values (ELV), as they will apply, is required for all the existing plants that are installed and operating in NIIES, with a production license before 19.12.2017 and operational date before 20.12.2018. Special provisions are foreseen when a NIIES gets interconnected to the mainland system.

The energy market, electricity production and supply on Greek NIIES is mainly affected by two EU directives; Directive 2003/54/EC [14] and Directive 2009/72/EC [15]. The directives include provisions for market opening and development of new conventional production stations and foresee derogation from the provisions for micro isolated systems that consumed less than 500 GWh in 1996, which is the case for Kythnos and all the other NIIES besides Crete. Following the provisions of directives, Hellenic Republic had applied for derogation expect for Crete and Rhodes. According to the EC Decision 2014/536/EU [16] the derogation is allowed only for refurbishment, expansion and upgrading of existing conventional units (derogation for new conventional capacity, RES and CHP is not approved) for micro isolated systems until 2021, and derogation for market opening until 2019, or earlier if the infrastructures described in NII Code are ready. The Greek Law 4414/2016, [17], has adjusted Greek legislation to the provisions of Decision 2014/536/EE.

8.2.6.8.1.2 Specific barriers and challenges of the NIIES

The following barriers should be considered, in particular for the Kythnos pilot:

6. Geographical dispersion and isolation
    a. Lack of specialized local personnel
    b. Obstacles in equipment/personnel transportation
7. Autonomous systems powered by diesel generators
    a. High production cost, in relation to the Pool System Marginal Price in Mainland
    b. Environmental concerns from the operation of thermal power plants on the islands
8. Weak networks
    a. No HV transmission systems - MV distribution networks
    b. Exposure to adverse conditions - Quality of supply often impaired
9. Unfavourable demand characteristics
    a. Extreme seasonal variations (summer/winter peak > 4, annual max/min > 8)
    b. Low generating capacity utilization and operational difficulties
10. Obstacles in capacity expansion
    a. Frequent investment in new capacity needed - Installation of portable units

b. Local community reactions (environmental concerns, tourism), lack of space, land acquisition difficulties (availability, cost), lack of infrastructure (ports, roads etc.)

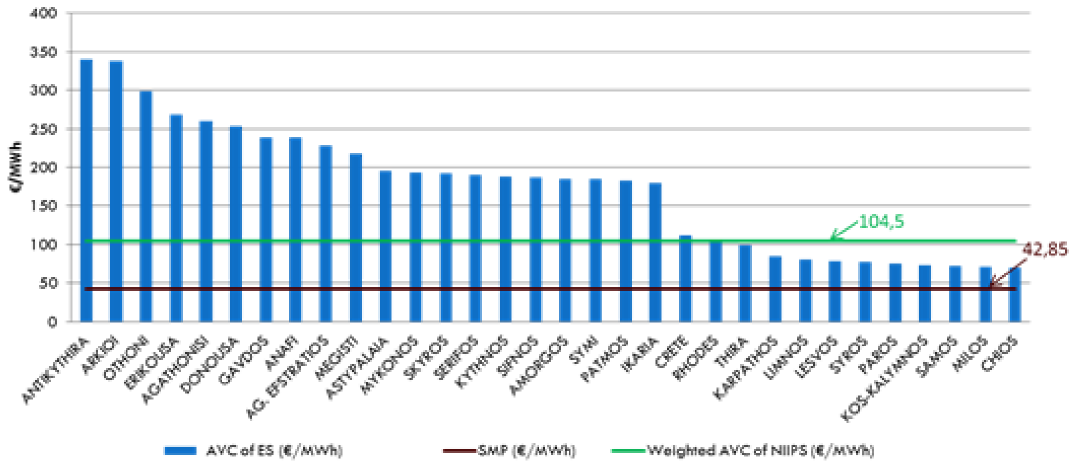


Figure 20 – Average Variable Cost (AVC) per NIIPS for the year 2016

8.2.6.8.1.3 RES penetration in the NIIES

The amount of renewable generation that can be allowed in an island grid at any given moment (instantaneously) is regulated and cannot exceed a certain technical limit which is determined by the must-run capacity of the thermal generators and the spinning reserve requirements to ensure grid stability. In the case of Kythnos, the diesel generators provide all the necessary ancillary services to the grid and maintain the frequency stable at 50 Hz by constantly balancing the demand and the load.

At the moment, the only on-grid renewable generation in Kythnos comes from 238 kWp of PV plants. The main challenge to address when allowing more renewable sources such as the planned and licensed wind turbines on Kythnos is to manage their intermittency, namely the fact that their production can fluctuate heavily and cannot provide ancillary services in an efficient way. This is even more important in Kythnos whose grid is rather weak (few power lines, old infrastructure, few generator units, one power plant) and therefore any mismatch between load and demand that may occur within a few milliseconds can cause power outages when not handled properly by the energy control centre.

Lately, new RES penetration margins have been approved by the Regulatory Authority of Energy (RAE) with Decision 616/2016 [12], defining the hosting capacities for the various RES technologies in each NIIES. The basic points of this Decision can be summarized in the following:

- RES technologies include wind, solar PV, solar thermal, biomass-biogas. Both intermittent and dispatchable RES generation is foreseen.
- Contractual guarantees to be provided to dispatchable RES and storage stations against excessive levels of curtailment, to safeguard investment viability.
- Storage development foreseen under the Hybrid Power Station (HPS) framework with overall storage capacity beyond 300 MW for all NII systems to be feasible. No restrictions imposed on storage technology, but high energy capacity solutions are favoured.
- RES energy penetration levels up to 50% of annual energy demand made feasible with the penetration margins approved by the Regulator.
- Further increase of RES penetration is possible, both in small island systems through integrated solutions, as well as in medium and large islands by innovative storage applications and demand flexibility.

8.2.6.8.1.4 Battery storage and electric vehicles

Batteries for residential or commercial buildings as well as electric vehicles are highly flexible distributed resources that can help increase renewable energy use as well as, if aggregated, provide grid services such as frequency regulation. To reap the benefits of such flexibility however, the local network control centre on Kythnos will need to get upgraded so that HEDNO can take advantage of the characteristics of these technologies.

Another challenge that will need to be addressed is the market and regulatory gap in Greece regarding batteries. Energy storage is a versatile resource that can be used in various applications such as to shave peaks of energy users or to stabilize the grid frequency by charging or discharging power. Because of this versatility however, its place in the electricity market is frequently unclear: is it a generator or is it a load, can it be owned by the DSO, what are the revenue streams and who is eligible for them? For behind the meter battery storage, like the one planned on the public buildings in Kythnos, optimization is based on tariff structure but this often does not go hand-in-hand with the needs of the grid. Sometimes the battery works without benefit for the grid but with financial benefits for the end user. In other times, the battery might even work against the grid and still receive financial benefits.

Furthermore Kythnos, and Greece in general, face the issue of unclear regulation regarding energy storage. Currently, batteries could be deployed as part of large hybrid stations in the medium voltage level but there is no provision regarding batteries in residential or public buildings or electric vehicles and vehicle-to-grid (V2G) technology on how to communicate with the power grid and how to sell DR services. Additionally, the current operating procedures for NIIES dominated by conventional generation work under the assumption that only conventional generation units can provide the ancillary services necessary for grid stability which immediately eliminates the possibility to aggregate a battery or EV fleet to provide the same service.

8.2.6.8.1.5 WiseGRID products for Kythnos

WG Cockpit tool will be the main backbone tool which may allow HEDNO to manage the Kythnos electrical system with more flexibility which will potentially lead to a more efficient and economic operation of the system with minimised RES curtailment and integration of new flexible loads (e.g. EVs, desalination plant). Upon that WG FastV2G will potentially demonstrate how electricity from the EVs batteries may be supplied to the grid upon demand of the DSO in a controllable and efficient way. This will contribute in the adoption of a consistent regulatory framework for the V2G technology.

WG STaaS and RESCO tools will be used to support the integration and management of decentralised small-scale battery storage in public buildings but also as an auxiliary tool for decentralised grid control automation assisting the possible penetration of additional renewables in the Kythnos NIIES all while promoting the collaboration of the public and private sector to deliver the more efficient management of the local infrastructures.

8.2.6.8.2 Towards the liberalization of the Greek electrical energy and natural gas markets

According to the Regulatory Authority for Energy (RAE), as of July 2004, consumers in the interconnected system of Greece have the right to choose their energy supplier, except for residential consumers whose right to choose a supplier was established later in July 2007. Since 2016 the customers of Crete and Rhodes also have the right to choose their supplier too. Consumers at the smaller non-interconnected islands are excluded from this option, since there are no other suppliers beyond PPC at these isolated microsystems. Thus, 2007 can be considered a milestone for Greek energy markets as a starting point for its liberalization. In 2011, retail market was characterized by the rising number of supplier switching. Although the PPC still remained the main energy provider, there was a lot of activity of consumers moving to other energy providers, indicating that the development of competition in the retail market is indeed possible.

According to LAGIE’s DAS report in May 2017, apart from PPC there are 20 companies that are currently enlisted as energy suppliers and 25 as energy traders. Most of the suppliers are more active as energy traders than energy suppliers though. Moreover, there are 7 companies that are licensed as producers and registered in LAGIE's archive with the exception of RES [335], while some of the producers are also active as suppliers and traders. WiseCOOP application could be used by energy retailers and local communities and cooperatives to manage their customers and assets, as well as to help domestic and small businesses, consumers and prosumers to achieve better energy deals. WiseCOOP would enable them to provide their member or customers with better services and prices, especially if DR campaigns were applied.

The liberalization of the Greek Natural Gas Market is following the electricity market with a slower pace. In 2011, Law 4001 was established providing for the separation of networks from supply and production activities and has been subject to several modifications since.

In 2015, according to Law 4336, the liberalization of the gas market is being launched in order to create healthy competition and reduce energy costs. New provisions are introduced, mainly concerning the reform of the natural gas distribution framework in Greece, with the obligation to legally separate distribution and supply activities, and the widening of the Eligible Customer (Supplier-selectable).The restrictions on DEPA's supply and monopoly are abolished, and now the PSCs and large industrial consumers and generators will be able to purchase gas directly from international suppliers.

The opening of retail market was implemented immediately for the industrial sector, continued in 2017 for professional customers, and will be completed in 2018 with the integration of domestic customers as well. The interest is strong and by the end of 2016, more than 40 companies had applied for a gas supply license in order to reach the first eligible customers. This category includes electricity customers and several industrial customers. The liberalization of the natural gas market can create more profitable conditions for the use of CHP. The combination of WG STaaS/VPP and WiseCORP applications could be beneficial for the adoption of CHP systems in the tertiary sector and in the industries to have an advantage participating in the energy market, providing more services and reducing their overall energy expenses.

8.2.6.8.3 Smart metering systems

In furtherance of a 5 year national strategic plan for the "smartening" of Greece's grid network, HEDNO is responsible for the roll-out of smart meters. Smart meters have been installed at major LV customer sites and MV customer sites. HEDNO has also set up two telemetering centres, one to collect remote meter readings from all MV customers and RES producers, and the other to collect remote meter readings from all major LV customers (>55kVA) including photovoltaics (PV). Following the success of initial rollout projects, HEDNO is evaluating bids for the pilot installation of about 200,000 smart meters in residential and small commercial customers across selected areas of Greece. HEDNO is obliged by legislation to have 80% of consumers in a telemetering system by the end of 2020. However, current implementation timelines indicate that this would not be possible. Consequently, a new timeline is being considered for a new legislation. [338] It's worth mentioning that telemetering meters that have already been rolled out in Greece cover the 45% of the installed power, at all voltage levels.

For pilot rollouts and smart meter procurement, there are legislatively specified technical requirements for smart meters according to the minimum functional requirements as defined in Commission Recommendation 2012/148/EU and Ministerial Decision, GG B 297/13.2.2013. The rollouts envisage that the meters installed are able to communicate with a central system using GPRS. The pilot rollout for the 200,000 residential and small commercial customers requires that the communication between the central system and the meters use a mixture of GPRS/3G and powerline (PLC). HEDNO's rollouts are based on slightly different technical specifications following International IEC standards, EU Directive 2004/22/EC (MID) as well as available meter technologies at tender time and substantially different customer types. Note that for major LV customers power consumption is required to be measured using current transformers (CT), for small LV customers power consumption is required to be measured using direct connection (DC) and for MV customers power consumption is required to be measured using current transformers (CT) and voltage transformers (VT).

Implemented, on-going and planned HEDNO rollouts are as follows:

- MV rollout - ~13,500 CT/VT electronic telemetering meters, communications GSM/GPRS (implemented);
- Major LV customers rollout (>55kVA) - ~74,000 of which 59,000 are CT, 5,000 are DC and 10,000 are PV electronic telemetering meters, communications GSM/GPRS (implemented);
- Smart meter procurement - ~220,000 LV DC single and three-phase smart meters with load switch, communications GSM/GPRS/3G (contract signing with the lowest bidder);
- Pilot rollout - ~200,000 smart meters single and three-phase meters LV DC and 4,300 three-phase LV CT substation meters, GSM/GPRS/3G or PLC through substation concentrators (delays in tendering procedure due to some legal issues at the Council of State).

Pursuant to Commission Recommendation 2012/148/EU [339] the smart meters that have been rolled out in Greece are designed with functionalities intended to facilitate interoperability and optimize benefits to consumers. These include pulse outputs for real-time consumption monitoring; remote reading via AMR/AMI; two-way communication; interval metering at 15-minute intervals; and remote metering amongst others. Future plans, within the pilot rollout, include alarm capability, as well In Home display, to alert consumers of exceptional energy use.

It is also worthy of note that although the smart meter roll-out in Greece is largely under the control of HEDNO, the program in few circumstances allows for private participation. For instance, customers with PV installations may, in order to participate in net metering scheme, purchase and install PV meters from a HEDNO approved meters and modem models list – the suppliers of these equipment are prior approved by HEDNO based on its technical specifications. Similarly, PPC Technical Guideline 5/1974 allows property managers are to purchase and install sub-meters for individual tenants. While the PPC rule came into force prior to the smart meter rollout, it is worth extending to cover smart meter rollout. This approach would not only share the burden of the roll-out with the public, but would represent a liberalisation of the smart meter market.

The standardisation approach taken by HEDNO, although commendable, does not appear to cater for further growth in the sector. For instance, the minimum technical standards set out above appear to be targeted merely at the pilot stages of the rollout. Consequently, they only seem to require that the equipment meet a certain standard. However, as recommended by ERGEG, [340] the standardisation of metering should be at the system level and not at the equipment level. While ERGEG's recommendation is premised on the liberalisation of the market, and envisages freedom of applying different technologies, while ensuring interoperability, it may be argued that at the pilot stages, HEDNO aims at determining ideal and workable systems, and therefore system level standardisation is not feasible. Also, as HEDNO is the sole meter operator, equipment level requirements are essential to ensure compatibility between the current and future AMR/AMI systems and smart meters. In any case, as far as the WiseGRID project is concerned, the absence of a system level standard enables the developers of the smart grid architecture ample flexibility of design regarding applicable telecommunication systems, hardware and software. However, care must be taken to ensure that the design choices made by the project promote the objectives of HEDNO and Greece's national smart grid implementation policy.

Conspicuously missing from HEDNO's technical requirements are consumer-centric minimum functionality requirements. Be that as it may, certain elements of HEDNO's technical requirements incidentally guarantee data protection, security and promote competition in the retail markets. The lessons from these pilots would present valuable stepping stones for developing the desired level of consumer-centric standards including requirements that would facilitate the wide-scale deployment of demand response mechanisms in the future smart grid of Greece. Given that Greece's market is still undergoing evolution at different levels, a unique opportunity is presented to the project to influence the development of the Greek market by providing demonstrable models for the determination of relevant functionality requirements.

8.2.6.8.4 Data protection

There is no specific national legislation, exclusively designed for data access and security for smart grids in Greece. However, data protection is subsumable under the country's general data protection laws. This law follows EU Directive 95/46/EC of the European Parliament and Council and protects individuals against the unlawful processing of personal data. There have also been various modifications of general data protection law to deal with situations arising from the collection and processing of data through ICT systems.

Greek data protection laws provide for the basic tenets of data protection, specifically, the registration of data controllers with the Hellenic Data Protection Authority (HDPA); prior informed consent for the collection and processing of personal data; and security obligations on data controllers to ensure data security; the obligation to inform the data subject of breaches which compromise their personal data; as well as the data subject's right to access, request rectification and object to the processing of personal data. These general laws apply by extension to the electricity sector and ipso facto to all the players in a smart grid scenario. Whether these laws sufficiently deal with the challenges posed by smart grids is yet to be seen. However, it is worth considering further legislation to deal with possible challenges that are likely to arise from existing lacunae.

Within the context of smart grids, it is worth considering the definition of "personal data" under the Greek Data Protection law. The law defines personal data as information relating to the data subject, excluding data of a statistical nature from which the data subject can no longer be identified [341]. The Data Protection Authority has not issued guidelines for the definition of personal data however it appears from decisions of the DPA that information which could, in combination with other information on a data subject lead to the identification of the data subject would be considered personal data. In this vein, the possibility that information collected through smart meters could be classified as personal data is high and might operate as an inhibition to the rapid deployment of smart grids.

It is also worth noting that Greek data protection law distinguishes between "personal data" and "sensitive data". While the former may give rise to obligations in the smart grids, the latter, which is defined as information relating to the racial or ethnic origin, political opinions, religious or philosophical beliefs, trade union membership, health, social welfare and sexual life, criminal charges or convictions, are unlikely to give rise to data protection obligation in a smart grid context as the data likely to be collected and processed by these systems are unlikely to lead to access to, or processing of such categories.

Another uncertainty which arises within the context of smart grids is the designation of "Data Controller" for the purposes of the imposition of data protection responsibilities. Law 2472/1997 defines Controller as a *"person who determines the scope and means of the processing of personal data"*. This definition leads primarily to the conclusion that DSOs should be fixed with the obligations of Controller given that customer consumption data which is collected by smart meters is primarily aimed at assisting in the performance of balancing functions. However, within the complex system of wholesale markets, and ancillary services for which additional customer consumption data is required, is the DSO not merely acting as a 'data processor' for LAGIE? This can only be resolved, as envisioned by Directive 95/46/EC [235], by a clear delineation of 'Controllers' and 'Processors' and their respective roles and responsibilities within the smart grid context. [342]

Data retention remains an issue in Greece. Despite the invalidation of the Data Retention Directive by the European Court of Justice in Digital Rights Ireland [343], Greece has not amended Law 3918/2011, which transposed the Data Retention Directive. Consequently, the power to determine data retention periods is vested in HDPA. Given that the HDPA has not issued any guidelines on the retention of personal data collected through smart meters, it can be assumed that data collectors within a smart grid network have no specific obligation regarding the retention of such data. This notwithstanding, it can be argued that the general caveat of retaining such data beyond periods for which its processing is necessary would be deemed a violation of the rights of the data subject.

As far as data anonymization is concerned, Greek law does not define what categories of personal data must be anonymized. Indeed, the law does not define anonymization. However, it may be argued that given that the law states that "personal data in order to be lawfully processed must be…(d) kept in a form which permits identification of data subjects for no longer than the period required, according to the Authority, for the purposes for which data was collected or processed.", the concept is adequately provided for. However, questions regarding what would be deemed sufficient anonymization remains uncertain. The general practice is to render data in coded formats, however there is insufficient guidance in Greece concerning the levels of codification which are regarded as acceptable [344].

Following from the above, the proposed EU General Data Protection Regulations (GDPR) are set to come into force in May 2018. As part of these Regulations, persons whose operations pose high risk of data intrusion are required to undertake data protection impact assessments. Although this has yet to come into operation, some data protection authorities around the continent have started taking measures towards ensuring compliance. While no specific actions towards implementation have been taken, Greece is poised for the coming into force of the new Regulations.

An important corollary of data protection which cannot be ignored, is data security. While Greek data protection laws require data controllers to instate institutional and technical measures aimed at ensuring security and confidentiality in the data processing process. It is important that given the high risk of data intrusion, risks to electricity infrastructure and perhaps to risks national security, posed by smart grid systems, data protection laws must be coupled with standard setting for the various technological components which apply to smart grids, including smart meters. As has been alluded to earlier, the smart meter roll-out undertaken in Greece did not appear to adhere to any technological requirements aimed at ensuring data protection and security.

8.2.6.8.5 Demand response

Greece's Fundamental Energy Markets law, recognises the adoption of Demand Response mechanisms as one of the aspects of the internal market to which the country aspires. However, since the transposition of the EU Directive, very little, by way of legislative action has been taken in respect of the development of Demand Response in Greece. HEDNO has been instrumental in trying to develop a framework for Demand Response and has participated in various projects in this regard. Some measures have also been taken for the participation of consumers in the Energy Market, aiming at facilitating the transition of the Market to a new structure, according to the so-called "Target model".

Since January 2016, the Interruptible Load Service was instituted and can be offered by consumers connected to the electricity transmission and MV network of the interconnected system through their participation in auctions. The Interruptible Load Service was introduced under Law 4203/2013 and allows the Greek TSO (Independent Power Transmission Operator - IPTO) to sign specific types of contracts with electricity consumers, based on which the latter are obliged to provide interruptibility services when the TSO gives the relevant command to them. The TSO can proceed to the temporary decrease of the active power of interruptible counterparties up to an agreed value and against a financial compensation. The categories of consumers that can sign an interruptibility contract, the requirements and preconditions, the reasons that lead to the activation of the Service, as well as the way, time and preconditions of the compensation of those who provide it are determined in the relevant Ministerial Decision (ΑΠΕΗΛ/Γ/Φ1/οικ. 184898, Official Gazette B' 2861/28.12.2015). Moreover, demand control contracts have also been instituted for customers connected to the MV and LV network of the interconnected system and the non-interconnected islands, as long as they have the necessary telemetering equipment. Law 4342/2015 also provides that the Greek Regulatory Authority of Energy (RAE) has to ensure that, the relevant Market Codes contain provisions that require the TSO and Distribution Network Operator to treat persons who provide demand response services in an equal and objective way, based also on their technical infrastructure and potential. The law also contains the first definition of "Aggregator".

As part of efforts aimed at facilitating the integration of the Greek wholesale market to the European electricity market, Law 4425/2015 envisages the integration of demand response into the Balancing Market.

The precise details of the demand response mechanism will be provided for by the Market Codes which are currently being drafted by the RAE.

It is perhaps axiomatic to say that the slow pace of the development of Demand Response mechanism is as a result of the lack of supporting infrastructure. For instance smart meters which are necessary for adequate recording of consumption and with it development mechanisms to assist consumers control consumption are still in the roll-out stage. Hopefully, the many research projects will ensure that demand response can take off immediately, when all the necessary infrastructure is rolled out on a large scale.

8.2.6.8.6 Electricity storage and electric vehicles

In 2010, the Greek government developed the National Renewable Energy Plan (NREAP) aimed at reducing the country's dependence on energy imports as well as improving RES penetration and reduction in carbon dioxide emissions. Subsequent to the NREAP, National Energy Strategy Committee issued an energy roadmap for 2050 in 2012. In deference to the intermittent nature of electricity from RES, Greece recognizes the importance of storage technology to support RES development. The 2050 Roadmap identifies that the improvement of pump hydro energy storage (PHES) units would be essential to achieving large RES electricity production, given that it is the most advanced and reliable technology for large-scale electricity storage, and is suitable to the topology of Greece [316].

Several initiatives are underway to try to improve storage systems in both the interconnected system and the NIIs. One of such initiatives is the installation of a battery storage system on the island of Tilos in the Aegean Sea; the battery project is expected to provide power for the entire island [345].

While a regulatory framework for energy storage is absent for the mainland interconnected system, Laws 3468/2006, 3851/2010 and 4414/2016 contain detailed provisions concerning the operation of hybrid stations in the NIIs and the interconnected system. The most recent activity regarding the operation and the building of storage facilities is a public consultation launched by RAE four years ago. RAE proposed a set of rules regarding the participation of storage in the Greek Power System. The proposal considers all types of storage technology and the aim is to support the integration of RES in the Electricity Grid, namely to minimize RES curtailment and increase RES hosting capacity. Additionally, it is also hoped that storage would provide ancillary services when RES penetration is high. Under the proposal, the TSO would be responsible for the scheduling of storage units equally. The storage units would participate in the market through bidding in the day-ahead and intraday energy market. Finally, the proposal of RAE allows the existence of bilateral contracts between the storage owner and RES stations.

RAE also proposes a pricing mechanism that will motivate the storage owners to store energy from the RES and not from thermal units. The additional cost that derives from the participation of storage in the market will be charged to the RES station, taking into account that RES station will have increased production due to reduction of curtailment.

Finally, it is assumed that the final legal framework regarding storage will take into account the Winter Package as well other EU Directives.

Unfortunately, the development of storage capacity in Greece is challenged by the grid fees regime which is operated in the country. Greece is one of 3 Member States who charge grid fees for charging and discharging storage units as a result of treating them as generation assets. Consequently, owners of storage units have to pay grid fees as generators when charging units and subsequently as consumers when discharging them [85] [78]. Needless to say the regulatory treatment of storage units in this manner is consistent with true nature of these assets and therefore regulatory reform is required to redress this problem as it operates as a disincentive for investing in storage technology.

Regarding electric vehicles, one of the key options outlined in the Roadmap for the attainment of its objectives includes the electrification of transport. Despite this aspiration, electric vehicle penetration in Greece remains relatively low, with a market share of 0.03% in the passenger car market [346].

The government has however instated a number of measures to improve electric vehicle penetration. These include an exemption from registration, annual circulation and luxury taxes for both electric and hybrid vehicles; [346] and access to certain restricted areas of city centres. These measures notwithstanding, there are yet only a paltry number of 33 charging positions in Greece [346]. Consequently, a lot remains to be done to improve on the current situation.

Currently there is no provision in the regulatory framework regarding the e-mobility V2G service provision. Existing legislation covers only the installation of charging infrastructure in filling stations and car lots and the energy pricing performed by the operators of such stations.

8.2.7 Circular economy and energy related waste

The Circular Economy Package of 2015, outlines implementation deadlines for the various Directives aimed at achieving the objective of the circular economy. While Greece has attempted to ensure that these Directives are adequately implemented, its implementation has been characterised by significant delays typified by the time taken to transpose the relevant Directives into national law [347]. Be that as it may, Greece has successfully transposed Directives on waste management including waste of electric and electronic equipment (WEEEs). However, it appears that despite legislative action, very little is being done by way of enforcement. This is evident from the number of cases brought against Greece before the European Court of Justice. The country is in need of a national strategic plan towards attaining a circular economy.

While there appears to be a lack of adequate political will to pursue the objectives of transitioning to a circular economy, there is no doubt that economic actors, such as businesses and consumers are key in driving the process [347]. It is within this context that the WiseGRID project must be seen as conducive. The project typifies an opportunity to demonstrate the cardinal principles of circular economy. Firstly, it demonstrates reliance on renewable resources for the delivery of electricity and electricity-related services. Secondly, it provides the means of optimising electricity supply and demand while allowing for the promotion of RES thereby preserving and enhancing natural capacity and balancing renewable resource flows. Lastly, the project design and implementation plan significantly eliminates the possibility of adverse environmental effects. This model of business planning is ultimately the goal of the circular economy and despite the lack of a regulatory framework, it is hoped that the successful deployment of the project would serve as useful and practical model that can be emulated in the Greek economy.

8.3 ITALY

8.3.1 General overview

Italy is a predominantly mountainous area located in the centre of the Mediterrean Sea. It includes the large islands of Sardinia and Sicily, and shares boarders with France, Switzerland, Austria, Slovenia, San Marino and Vatican City. Its total land area is approximately 301,338 km^2. With a population of approximately 81 million, it is considered the fourth most populous country within the EU (after Germany, France and the UK). Rome is the capital of Italy and its largest city.

The climate of Italy is largely diverse. In the inland and central parts, it ranges from humid subtropical to humid continental and oceanic. The coastal areas however, generally have Mediterranean climate characterised by mild winters and warm dry summers.

Since the abolishment of the monarchy in 1946, Italy has operated a unitary parliamentary system of governance. The head of state is the President who is elected for a single seven year term by the joint session of its bicameral Parliament – the Chamber of Deputies and the Senate. The President appoints the Prime Minister who acts as the head of government, and the cabinet.

The country is divided in 20 Regions, including two autonomous Provinces and four autonomous Regions. In recent years, the country has experienced a decentralization of legislative and regulatory powers to the Regions, this was pursuant to a 2001 constitutional amendments. The amendment has resulted in the sharing of regulatory jurisdiction in various sectors including energy, between the State and the Regions, and in some cases a total devolution of regulatory authority exclusively to the Regions. For instance under Legislative

Decree No 112/1998 as amended by Legislative Decree No 433/1999, local authorities have the sole prerogative in respect of the issuing of licences for the construction of generation plants and have powers to adopt their own laws.

The country is the third-largest economy in the EU and is a member of the G7, G8 and the OECD. It is a highly developed country, and is renowned for its manufacturing industry, large competitive agricultural sector, food, design and fashion industry. In 2016, the CIA fact book recorded it as the world's seventh largest exporter. Despite a strong national economic outlook, the country is undergoing fiscal austerity following the last global recession [348], which has resulted in lower electricity generation and consumption. [349] There is also a large disparity in socio-economic development between the Northern and Southern regions of the country.

8.3.2 Energy profile

Italy produced 35.5 Mtoe of energy in 2015. Notable about the country's energy production is the large share of renewable energy, which accounted for 68.4% of the total energy production in 2015. The past decade has seen a tremendous development in solar, wind, biofuels and waste production. Owing to the institution of a generous subsidy regime, solar energy production increased by 259% between 2010 and 2011. 15.9% of energy production was from crude oil and natural gas, while coal accounted for a mere 0.1%. Italy's total energy supply (TPES) in 2015 was 150.7 Mtoe, this represented a decline of 19.1% from 2005 figures. [350]

Electricity generation in Italy was 681.6 TWh in 2015. As illustrated in Figure 1 below, in 2015 natural gas and renewable energy sources were the main sources of electricity generation with 40% and 39% of the energy mix respectively.

Italy's grid is interconnected to the European transmission via France Switzerland, Austria, Slovenia, Corsica, Greece and Malta. Over the years TERNA has upgraded the transmission network with the view to improving congestion, particularly by improving connectivity between Sicily and Sardinia. The said improvements helped standardise historically disparate electricity prices between the north and south.

Despite the improvement of the market, largely arising from the growth in RES, and the improvement of network infrastructure in recent years which have occasioned an excess of supply, the energy security situation is typified by comparatively higher prices than in other EU Member States. [318] In the gas sector, the unbundling of the TSO has helped improve competition however supply at peak periods is low due to low flexibility.

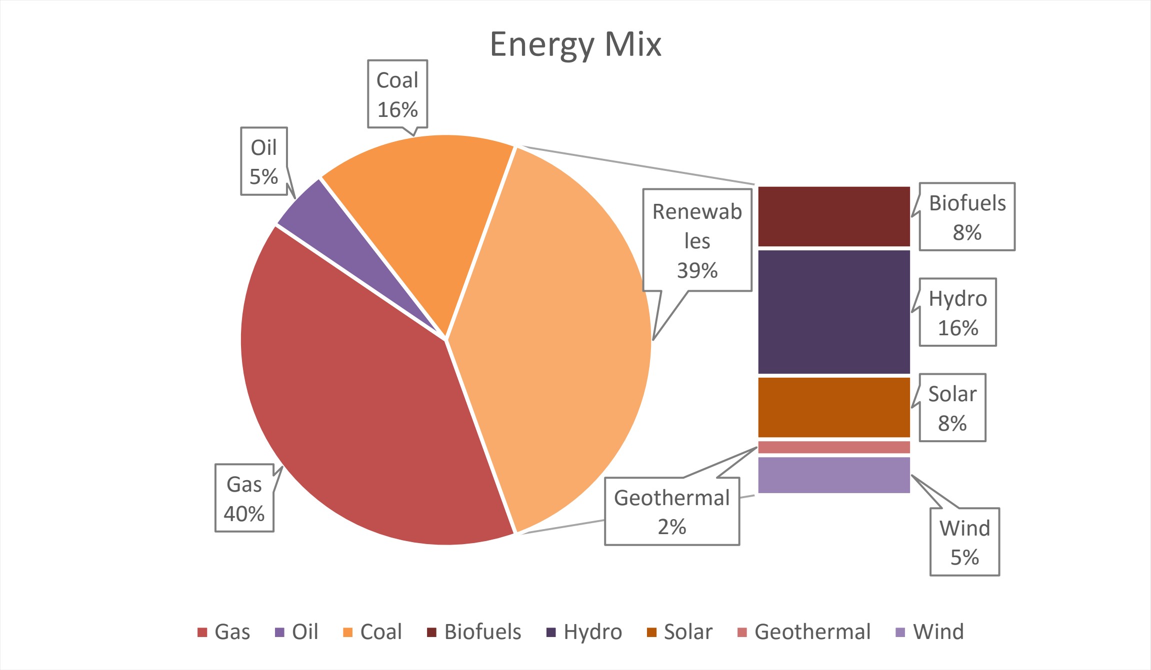


Figure 21 – Electricity generation in Italy [350]

8.3.3 Relevant government institutions

Ministry of Economic Development (MSE, "*Ministero dello Sviluppo Economico*")

This ministry is responsible for formulating and implementing the country's energy policy.

Ministry of Environment, Land and Sea (MATTM, "Ministero dell'Ambiente e della Tutela del Territorio e del Mare")

This ministry is responsible for coordinating climate policy. It works closely with the MSE in formulating policies for the promotion of renewable energy and energy efficiency.

The Inter-Ministerial Committee for Economic Planning (CIPE, "*Comitato Interministeriale per la Programmazione Economica*")

This is a collective governmental body established in 1967. It is chaired by the Prime Minister, and constituted by the Ministers for Economy and Finance, Foreign Affairs, Economic Development, Food and Forestry, Infrastructure and Transport, and Labour and Social Policies. It is responsible for the coordination and integration of a range of national policies, including climate change. As part of its functions, it approves national action for the reduction of GHG emissions.

The Inter-Ministerial Technical Committee for Emissions of GHGs (CTE)

In 2002, the CIPE passed a resolution to establish the CTE to support the CIPE's climate-change related duties. The CTE is chaired by the MATTM and includes members of the Prime Minister's office, representatives of the ministries of Economy and Finance, Economic Development, Agricultural, Food and Forestry Policies, Infrastructure, Transport, University and Research, Foreign Affairs and of Regions. CTE is tasked with monitoring GHG emissions, evaluating the implementation of policies and measures set out in the national strategy for GHG emissions.

The Institute for Environmental Protection and Research (ISPRA, "*Istituto Superiore per la Protezione e la Ricerca Ambientale*") and the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)

These two national agencies were established in 2008 and 2009 respectively. They provide data, and technical/scientific support to the CTE. ISPRA is also responsible for reporting national action on GHG emission to the European Union and the United Nations Framework Convention on Climate Change (UNFCCC).

The Regulatory Authority for Electricty, Gas and Water (AEEGSI, "*Autorità per l'Energia Elettrica, il Gas e il Sistema Idrico"*)

AEEGSI is the independent regulatory body established under the Rules for Competition and the Regulation of Public Utilities (Law 481 of November 1995) to regulate and oversee the electricity, natural gas and water sectors. It is responsible for setting tariffs, defining service quality standards, and the technical and economic conditions governing access and interconnections to the networks. The AEEGSI performs its functions by issuing regulations to market operators, as well as orders and decisions that affect a single market operator.

The Competition Authority (AGCM, "Autorità Garante della Concorrenza e del Mercato")

AGCM is the independent competition body in Italy. It was established under the Competition and Fair Trading Act (Law No. 287 of 1990), and is responsible for the enforcement rules against anticompetitive agreements, abuse of dominance, and merger control, as well as other anticompetitive commercial practices such as misleading advertising, amongst others. The AGCM has investigated several actions in the electricity and natural gas markets in the last five years.

***"Gestore dei Sistemi Energetici"* (GSE)**

This is a state-owned company tasked with promoting and supporting the development of renewable energy sources (RES) in Italy. It works to promote sustainable development by providing support for electricity generation from RES and by promoting awareness on energy efficiency and its impact on the environment. It is also the parent company for *Acquirente Unico* (AU), *Gestore deiMercati Energetici* (GME), and *Ricerca sul Sistema Energetico* (RSE).

TERNA

It was established as the national transmission system operator in 2005 following the unbundling of services from Enel. [350] It is responsible for transmission system, while the distribution system remains under the control of Enel and approximately 163 other market participants.

8.3.4 Regulatory framework for the electricity market

Italy's electricity market is regulated by a series of laws made up of Legislative Decrees, Ministerial Decisions and directives of the AEEGSI. Together, these laws among others, transpose relevant EU Directives, as well as implement various state actions in respect of the electricity market. These include:

- Law No. 481 of 14 November 1995, which creates the AEEGSI and sets out its jurisdiction and competence;
- Legislative Decree No. 79/99 of 16 March 1999, which implemented Directive 96/92/EC concerning the common rules for the internal market for electricity, and vested GME with the management and organisation of the Italian Electricity Market guided by the principles of neutrality, transparency, objectivity and competition among producers;
- The Integrated Text of the Electricity Market rules, which govern the operation of the wholesale electricity market;
- Law No. 239/2004, which reorganised the energy sector with the view to streamlining and regulating the liberalisation of the sector;
- AEEGSI Decision 111/06, which established a procedure for registering forward electricity purchases/sale contracts on the OTC Registration Platform of the Italian Power Exchange;
- Legislative Decree No. 93/2011, which implemented the Third Energy Package and aimed at enhancing security of supply and protecting consumers, particularly those with low incomes.

Owing to the decentralisation of energy regulation, AEEGSI only sets legal, technical and financial requirements. However the granting of licenses for the construction and operation of generating plants, for instance, as well as direct regulatory oversight is provided at the regional/state level. Although under

Legislative Decree No. 112/1998 (as amended by Legislative Decree No. 443/1999) local authorities have the power to make their own specific laws in respect of their spheres of operation, they must act within the rules set by AEEGSI.

Italy's electricity market has witnessed a progressive liberalisation since the first EU Electricity Directive (96/92/EC). This directive was implemented pursuant to the Bersani Decree [351] which set out the steps for the liberalisation of the market and laid down fundamental principles for further liberalisation. The liberalisation of both the wholesale and retail markets have since been significantly successful. The next frontier in the country's liberalisation agenda would arguably be the decentralisation of generation and distribution particularly through micro-grids.

Italy's wholesale electricity market consists of a day ahead market and an intraday market, both of which are managed by GME. There is also an ancillary services market (MSD) where the transmission system operator, TERNA, acts as the central counterpart. The MSD is sub-divided into two segments; the ex-ante MSD for trades in energy and balancing of services in order to release congestion and to create reserves; and the Balancing market for trades in real-time balancing services to restore reserves and to maintain grid equilibrium. GME also operates a forward electricity market (MTE) where forward electricity contracts for delivery and withdrawal obligations are negotiations. The above-mentioned markets are operated through the Italian Power Exchange (IPEX). Market participants are however not restricted to trading through the IPEX; purchasers and eligible customers may enter bi-lateral purchase and sale contracts outside of the exchange. However, bilateral contracts are required to be registered in the Energy Accounts Platform (*Piattaforma conti energia (PCE).* In 2013, Italy's wholesale electricity market accounted for 42% of the total national supply.

There are 3 retail markets in Italy; the safeguarded market, the enhanced protection market, and the open or free market. The safeguarded market is the default market, it is aimed at final consumers who do not qualify for the enhanced protection market, consequently would find themselves without an electricity supplier. The enhanced protection market is legally mandated to provide electricity to consumers who have not chosen to switch to an alternative supplier. This market is served by AU S.p.A, a state-owned company. It purchases electricity on the wholesale market and sells it retailers who then sell it customers at a regulated price. The retail market is the open, or free market. There are over 336 retailers with Enel being the largest in the free market. [350] The free market offers customers a wide range of options for selecting competitive suppliers.

Electricity pricing in the wholesale market is not regulated. The uniform prices on the wholesale market are very volatile as they are dictated by demand and supply, dispatching conditions, amongst others. On the retail market on the other hand, AEEGSI sets transmission tariffs to cover three-year periods using the cost cap mechanism. The mechanism determines tariff based on capital invested and operational costs. However the price consumers pay is determined by a combination of the network charges and the consumption at suppliers' freely determined rates.

Like many of its European counterparts, Italy has demonstrated growing commitment to reducing reliance on fossil fuel for its electricity generation. A number of initiatives have therefore been taken which have resulted in the growth of the renewable energy sector in Italy. Notable amongst these is the dispatching priority granted to RES generated electricity. However given the intermittent nature of RES, the large share of power from RES threatened the integrity of the electricity network. Therefore in a bid to tackle the problem of inconsistent supply of RES generated electricity, particularly from weather-dependent generation sources, the AEEGSI introduced penalties for shortfalls in injection. [352] A feed-in-tariff for solar energy was also introduced in 2008, and in 2012, a feed-in-tariff was introduced for all RESs. Further, since 2008, the GSE introduced the *ritiro dedicato* – the simplified purchase and resale arrangements. This allows small producers to sell electricity generated to GSE, instead of having to sell through bilateral contracts or directly on the Italian Power Exchange. In order to qualify, a producer must produce power of less than 10 MVA through RES or hybrid plants. [351] RES generators other than photovoltaic may, subject to meeting the requisite criteria, also qualify for “green certificates”. Green certificates are issued by the GSE and can be sold over the counter or on the IPEX. However the green certificate regime is being phased out to be replaced by the feed-in-tariff regime consequently no new projects can qualify for green certificates.

Despite a clear vision for the smartening of the Italian Grid, and an attendant integration of DERs, both with the view to the development of RES, there is no specific policy or legislation for the development of micro-grids. This notwithstanding, several micro-grid projects are underway in various parts of the country. If the country is to realise the objective of greater electricity decentralisation, a copious framework would have to be created to balance-out a market which has historically favoured the conventional grid, by dealing with issues such as grid connection fees, particularly for small-scale generation; transmission planning and the creation of incentives for micro-grids.

As far as market participation and the WiseGRID Project are concerned, no licence or registration is required in Italy for generation, purchase, or supply of electricity from RES. [353] Thereby making Italy a conducive jurisdiction for ‘piloting’ of the Project. Further, the country’s RES priority regime guarantees that energy produced from RES sources is injected in the national grid. Arguably, the most prosumer-friendly policy is the *ritiro dedicato*; while the participation of prosumers in electricity markets is desirable, in practice, the definition of supplier and other market entry requirements may constitute a hurdle that would operate as a disincentive for small scale prosumers like households and businesses. In this vein, what the *ritiro dedicato* does is to reel-in the section of electricity generators who do not fit the general mould of “producers” and provides them with access to the market. A question that remains unanswered however, is the eligibility of “pooled loads” from various DERs to participate in the wholesale markets. *Prima facie*, it can be said that given that the wholesale market is open (subject to meeting participation requirements), legal persons acting as VPPs should be eligible to participate in the markets. However, the existing technical requirements might operate to disqualify VPPs. For instance, in the MSD, which is, in practical terms the market in which VPPs may participate, bid offers are only admitted in respect of offer points pertaining to generating units and pumped-storage units. Needless to say, VPPs are not, by themselves either generating or hydro-pumped storage units. While it may be argued that the rule may be extended to apply to VPPs if the DERs aggregated by the VPP include the above mentioned sources, the fact remains that the limitation of energy source operates to defeat the entire purpose of VPPs.

8.3.5 Market characteristics and idiosyncrasies of the Italian pilot site

8.3.5.1 The different market roles and liberization

The electricity market was created in Italy following the approval of the Legislative Decree. N79/99 that initiated the structural reform of the electricity sector, addressing the need to:

- promote competition in the production and wholesale, through the creation of a "marketplace";
- favourable transparency and efficiency of ancillary services conducted in natural monopoly

In a context of free electricity market, the various activities that characterise the sector are quite distinct from each other and are carried out under a concession or the free market system, by different parties. The production of electricity is a liberalized activity that in recent years is characterized by a remarkable development, partly due to recently enacted legislation at European and national level for promoting the use of renewable sources and energy conservation.

Services		Who regulates the service	Who provides the service
Access to system services	Authorization	Regions or State (only for installa-tions with a input greater than 300 MWt and offshore wind farms)	Regions or State (only for installa-tions with a input greater than 300 MWt and offshore wind farms)
	Connections	Authority	Grid manager (distribution compa-nies or Terna)
	Transportation and Dis-patching	Authority	Transport: distribution companies and Terna Dispatching in input: Terna
	Measure	Authority	Grid manager (distribution compa-nies or Terna)
Sale or exchange of energy	Transfer of energy	Authority	Free market or GSE for the dedicated withdrawal
	Net metering (*Scambio sul posto*)	Authority	Distribution companies up to 31 De-cember 2008, GSE from January 1, 2009
Incentives	Incentives (where applicable)	MSE, MATTM and Authority	GSE

Table 34 – Actors governing services in the Italian electricity system

The previous organizational model to the liberalization of the electricity market was based on a Vertically Integrated Monopoly; Enel S.p.A. exercised, in this case, the role of leader or dominant operator. With the Bersani decree, the public service principle is established in order to protect final customers, leading to conditions favourable to the emergence of a competitive price. With the aim of creating a competitive market, a vertical separation between companies is set so as to isolate the free activities from competitive activities. During the process of liberalising the opening of the market, the demand side, is done partially and gradually identifying two types of customers: suitable and eligible customers. Eligible customers are all those people who recognized the opportunity to enter into supply contracts with any producer or distributor. All other customers are bound to enter into contracts only with producers or distributors engaged in community service where the user is situated.

The process ends with the Directive 2003/54/EC with the total opening of the market:

- Starting from 1 July 2004 for all non-residential customers;
- From 1 July 2007 for all other customers.

In summary, in Italy the liberalisation of the generation and sale was imposed by law, following the European directives structured in three cycles (1996, 2003, 2009) and two general stages; opening of markets on a national level and integration of national markets (see Figure 22 – Italy regulatory provisions for the internal electricity market).

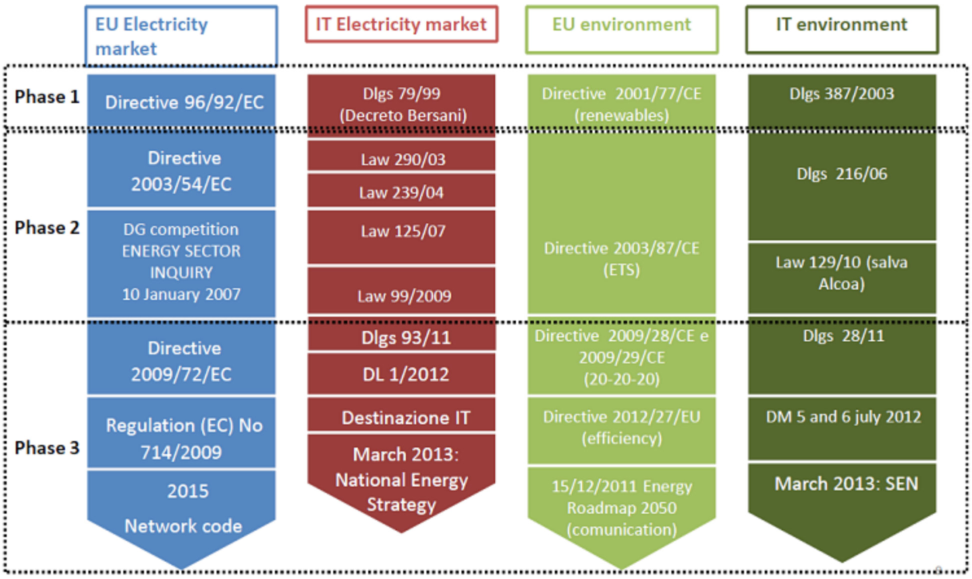


Figure 22 – Italy regulatory provisions for the internal electricity market

The Bersani decree established the Manager of the National Transmission Grid, or Grid Operator, as a limited company, whose shares have been granted by Enel S.p.A., free of charge, to the Ministry of Treasury, Budget and Economic Planning. GRTN is responsible to ensure a public utility service through the transmission and dispatching of electricity, including the unified management of the high and very high voltage grid.

Respecting the principles of safeguarding the public interest it has been considered that the unification of ownership and management of the network was necessary for the objective proposed to ensure greater efficiency and safety. For this purpose the law No 290/2003 of 27 October 2003 defined the principles of unification of management and ownership of the network through the Decree of the President of the Ministers' Council on 11 May 2004.

Ownership of the national grid is assigned to a single entity Terna SpA, which holds around 90% of the property of the national electricity system, of all the activities, functions, assets and liabilities owned by GRTN SpA. Terna became Manager and Owner of the national power grid. The share capital of Terna S.p.A. is held by Enel. With the Prime Minister's Decree of May 11, 2004 Terna was quoted in the stock market. Moreover, the obligation was introduced by the Manager to issue the Grid Code containing procedures related to the connection, management, planning, development and maintenance of the national transmission network as well as dispatching and metering.

In November 1, 2005 the GTRN becomes Manager of Energy Services S.p.A. (GSE). GSE is tasked with:

- Purchase from producers and sold on the energy market CIP/6: produced by installations that use renewable energy sources, it became operational after 30 January 1991;
- Issue of Green Certificates: titles that attest the production of energy from renewable sources;
- Qualification of renewable energy installations in operation after 1 April 1999 (IAFR).

The Authority, with Resolution 393/2015/R/eel [354], has initiated a process aimed at the creation of measures for the comprehensive reform of the regulation of the dispatching service, in line with the guidelines already expressed by the Authority in 2015- Strategic Framework 2018 (resolution 3/2015/a) and the European legislation being drawn up; in this proceedings they are also merged all the activities and the measures to implement the provisions of the Legislative Decree 102/14, for the part related to the dispatch.

The Authority intends to tackle all the aspects that characterize the reform project, and from June 2016 it is responsible for the assets identification [355],

- the supply of flexible resources;
- the definition of the products subject to negotiation of MSD, preserving, where possible, setting Central Dispatch System;
- The concept of "authorization" based on technological neutrality in order to allow the widest possible participation of the units of production and/or consumption; it also involves accumulations or synchronous compensators, even if only in relation to some products in full compliance with the future EU Regulation (balancing guidelines) to foster the competition;
- the possibility to introduce levels of aggregations "variable geometry" depending on the resource provided;
- the new role of distributors who will participate in the review of the dispatching control;
- the aggregator role and in particular the feasibility of possible market models in which this actor can also not coincide with the dispatching user;
- the interface between Terna and the aggregator, between the aggregator and the operators of production and consumption units (customers, producers or prosumer), and between the aforementioned parties and the distribution companies.

8.3.5.2 Market penetration of storage technologies

In Italy, energy storage assets are defined in the decision 574/2014/R/eel of November 20th 2014 [356]. More specifically, the article 1 specifies:

> *"An energy storage asset is a set of devices, equipment and control systems that can absorb and release electrical energy; it is designed to operate on a continuous basis"*

The article 4 of the same decree [356] specifies the status of an energy storage asset depending on its connection, which can be summed up as follows:

- The energy storage asset is considered as a generation unit if it is coupled to a generation unit.
- The energy storage asset is considered as a pumped hydro if not connected to consumption or generation units. This extends the annex A60 of the grid code [357] categorizing pumped hydro as "generation assets that can produce negative power".
- The energy storage asset is considered as a consumption asset if it shares the same connection point as a consumer and its electricity consumption will be billed to the end user with the appropriate meters in place.

The article 6 of decree [356] specifies that installation of energy storage assets coupled to solar plants is compatible with all subsidies, excepted for installations smaller than 20kW. Prior to this law, a solar plant installing energy storage would lose the subsidies associated with its energy production.

Finally, the decree [356] allows the TSO to register and manage energy storage assets through the existing GAUDI online platform: this point shows how automated the procedure is for the installation of new energy storage assets.

The decision 642/2014/R/eel [358] provides additional rules regarding the application of norms for energy storage systems. Furthermore, the standards CEI 0-21 [359] and CEI 0-16 [360] updated in December 2014 introduce provisions to ensure that energy storage systems contribute to the security of the national electricity system. Amongst others, it specifies that energy storage assets have to provide control of active power, insensitivity to voltage variations and voltage support during short-circuits.

Chapter IV paragraph 4.3.2.3 of the grid code [361] defines virtual production units as aggregation of small generation units of less than 10 MW. It also specifies the conditions to be defined as such, for instance the definition of electricity import and export points and regional boundaries for the location of the assets. Hence, it is possible to aggregate stand-alone energy storage assets smaller than 10 MW to create a virtual production unit recognized legally.

8.3.5.3 Market penetration of smart metering

The metering activity in Italy is regulated by the DSO who is the owner and the responsible party for smart metering implementations and granting third-party access to metering data.

Smart metering implementation has been already completed, covering 99% of electronic metering points. The regulation was approved in December 2006 by the NRA (AEEG) provided for a mandatory installation program of electronic meters with minimum functional requirements for all DSOs and LV consumers, starting from 2008 and reaching 95% of its completion in 2011.

8.3.5.4 Market penetration of electric vehicles

Different types of initiatives support the introduction of EVs and HEVs in Italy: legislation, regulations, standards, promotions, and demonstrations. Most of these initiatives are the result of a growing interest by electric utilities in analysing market prospects and the potential impact of EVs on the electricity grid.

Two proposed laws to support the uptake of HEVs and EVs were prepared in 2009 and 2010 and are currently being examined. The first proposed law (n. 2844: Measures to favour the development of mobility by using vehicles without CO2 emissions) was aimed at subsidizing purchase of these vehicles through installing vehicle battery charging infrastructure and other specific incentives. These incentives included zero property tax on the HEVs and EVs, lower taxes on electricity, free circulation in restricted urban areas, and free parking in reserved parking lots. A small tax on plastic bottles is proposed to cover the financial needs for all the initiatives. The second proposed law (n. 3553: Measure for the realization of infrastructure aimed at assisting the broad introduction of EVs) is a policy and strategy document stating general rules for integrating charging infrastructure for EVs into any governmental and regional strategy addressing the health impact of noxious emissions and diversification of energy sources. This approach would also support pursuing European Union targets for atmospheric emissions and clean vehicle introductions. Furthermore, the possible introduction of EV charging infrastructure must be considered in various types of initiatives: renewal of roads, research and innovation, promotion of industrial sectors, and innovation in buildings. The law proposal also includes the governmental preparation of a National EV Infrastructure Plan that would create the conditions and possible funding schemes for various installations of charging points.

On July 20, 2011 Italian Regulatory Authority for Electricity and Gas (AEEG) announced that over 1,000 charging points for electric vehicles will be installed in nine regions between North, Central and South Italy due to the incentives provided by AEEG to support the test of public charging systems and sharing the results obtained from these pilot projects. The projects will consist in providing charging stations to some large cities such as Rome, Milan, Naples, Bari, Catania, Genoa, Bologna, Perugia, in various municipalities of Emilia Romagna and Lombardy, and in various supermarkets.

8.3.5.5 Market penetration of Demand Response services

There are main barriers to the mass penetration of Automated Demand Response Programmes in Italy:

- **Consumers Access on Energy Markets:** As of today, consumers have no realistic means of accessing the wholesale, retail, balancing, reserves and other system services markets as few Demand Response service providers exist in Europe. Therefore, only the very largest industrial consumers, with their own bilateral power purchasing agreements can participate in Demand Response and only on a limited level. To this end, there is a high need to facilitate the creation of aggregation service providers towards the active participation of consumers on DR programmes.
- **Available Demand Response Products:** In order for consumers to participate in DR programs with their flexibility assets (demand side resources), there must be products/programs with participation rules that fit their capabilities and also deliver a real service to the markets. With special focus on the implementation of Auto DR programmes, there is a high need on structuring different types of products/programmes (e.g. minimum bid limit, symmetric bid, maximum number of activations, duration, etc.), to further support the viability of the proposed framework.

- **Appropriate and fair measurement and communication protocols:** Performance measurement, which is typically termed Measurement and Verification (M&V), is the process of quantifying and validating the provision of the service according to the specifications of a product. Critical elements required to measure and verify DR activation are: baseline methodology metering configuration, product delivery, communication requirements, frequency of interval readings, accuracy standards, timeliness of measurement data and communication protocols. It is important that, in the case of aggregation (by 3rd party aggregators or retailers), the communication protocols imposed are between the system operator and the aggregator. These protocols should not be mandated down to the individual customers.
- **Payment and Risk:** As of today, the European energy markets are designed to pay for energy (kWh) not capacity or flexibility (kW), and the full value of flexible resources is not reflected in market prices. This suppresses both flexible generation and demand to the active participation on energy markets. Therefore there is a high need to ensure a concrete and fair mechanism to reward consumers towards their active participation on DR programmes.

8.3.5.6 Market penetration of smart homes systems

The rapid increase of the share of decentralized fluctuating renewable energy generation, raising of the energy prices and developing technology of smart grid calls for activation of flexibility at the Demand Response side. Smart home environment devices could be keys to provide such flexibility.

The main goals for HEMS (Home Energy Management System) with regards to Demand Response are:

- Shifting energy consumption or generation in time to balance generation (e.g. PV, micro-CHP unit) and consumption (e.g. lighting, home appliances). The balancing may apply to either local generation or consumption (e.g. to increase the self-consumption from renewable energy) or generation and consumption on distribution grid level. Load balancing may be achieved by means of energy storage, but with the drawback of high cost for the storage (especially when considering electric energy). Also, storage losses cannot be avoided. Hence, the use of existing storage (electric vehicles, heat capacity of buildings) is of high interest. An alternative for energy storage would be to utilize flexible loads. However again, electric loads with the highest potential for balancing are usually equipped with a kind of storage (e.g. heat pumps).
- Reducing energy consumption via adaption of device operation such, e.g. temperature adaptions of rooms in times when they are not used in order to reduce energy losses to the outside and switching off components of the heating/cooling system when possible in order to reduce stand-by losses.

An important aspect for HEMS as compared to commercial and industrial sector energy management is user acceptance. Users of HEMS will typically be the residents, who may not at all be technical experts. Hence, HEMS solutions not only need to be very cost efficient, highly reliable and standardized as mass products, but also very robust with regards to use by non-experts. At the same time user requirements and preferences have to be taken into account when performing energy management influencing device operation

The market drivers for HEMS are:

- Policy and regulatory incentives at national and European level which drive energy efficiency and sustainability increase, hence favouring Energy Management Systems used for that.
- Active integration of residential loads (Demand Side Management) and generators, which may reduce the need for network expansion and improve network tolerance of renewables.
- Improving the quality of life by contributing to environment protection and reducing carbon dioxide emission.
- Improving the home's energy self-sufficiency and enhancing transparency.

- Energy cost reduction due to reduction of energy consumption.
- The emergence of closely interrelated fields, namely next generation media and Smart Grids.

Some of the most important market barriers for HEMS are:

- Cost of HEMS solutions (investment and running expenses).
- Lack of a smart metering infrastructure to communicate with the grid operator.
- Lack of mass-scale roll-out of "Home area automation controllers."
- Lack of interoperable smart appliances on the market with open control interface.
- Lack of interoperability between smart home and Smart Grid actors such as distributed system operator, virtual power plant and market aggregators, e.g. for enabling automatic energy procurement by the end customer.
- Lack of interoperability between solutions from different manufactures to be controlled by the HEMS.
- Lack of commonly accepted and robust solutions for data security providing guaranteed confidentiality, integrity and availability for information transfer between end user and all market actors (threat to privacy of customers).
- Lack of understanding of smart home technical aspects by end users, general disinterest.
- Loss of end-user control and freedom of decision when he gives access to grid operator to control his load.
- Threat to privacy of customers in case the HEMS is hacked.

8.3.5.7 Towards the liberization of the Italian market

In conclusion, the analysis of the Italian regulation has shown that the liberalization of the market started with the Bersani decree; it has meant that many new players in distribution and supply have become available.

Over the last few years the focus was to further improve the ability of competition beginning a process of the electricity market reform, which allows the participation of non-programmable renewable sources and the introduction of the aggregator.

At this stage, it is equally important to continue to work on the reform of the dispatching market started from AEEGSI the past years, in order to enable the greatest number of solutions, including those based on electrochemical storage, to provide services flexibility aimed at increasing safety and efficiency of the national electricity system, minimizing the system balancing costs incurred by our TSO (Terna).

The reform is now widely invoked with increasing urgency to solve the known problems of overcapacity and integration of renewables into the power grid, both with regard to energy markets (market of the day ahead, intraday markets) that with regard to the markets for ancillary services.

Finally, under the perspective of utility scale, the reform of the electricity market could greatly benefit from the contribution of innovative technologies such as battery energy storage, both in combination with other generators (especially fuelled by non-programmable renewable energy, but not only); both the technologies should operate autonomously, according to the independent operator's model of flexibility of services, able to deliver effectively strategic services for our electrical system such as for example the primary, secondary and tertiary frequency or the voltage adjustment.

8.3.5.8 Smart metering systems

In 2006, the National Regulator – AEEGSI, approved regulation which set out minimum functionality requirements for electric meters. The regulation followed the completion of the country's liberalization of the electricity sector and a subsequent consultation with electricity stakeholders aimed at improving service delivery in the sector. This regulation instituted a mandatory installation of new meters by all DSOs and LV consumers from 2008. Consequently, by 2011 Italy had achieved a 95% smart meter roll out, and by 2016 smart meter coverage was 99%. [362] Although the NRA oversees the implementation of smart meter rollout, primary responsibility for metering activity is on the DSOs who own and manage metering infrastructure. The DSO is also responsible for maintenance, meter reading and data management activities.

Italy's smart meter rollout was in furtherance of strategic objectives of improving competition in the electricity market; promoting remote meter access; and improving information gathering for cost/benefit analysis. [363] In furtherance of these objectives, AEEGSI set out minimum functional requirements for the meters that were to be installed. The meters were amongst others required to:

- Record active energy consumption;
- Be equipped with alarms to alert customers when they exceed contractual limits prior to the activation of circuit breakers;
- Be equipped with technology to protect against the loss of data collected by meters;
- Be capable of synchronizing with clocks and calendars, preferably through GPS technology;
- Be capable of performing remote transactions such as periodic reading of consumption data, upgrading of software and remote management of customers' contractual details;
- Have a display screen which provides information such as consumption, and pricing information.

The minimum functionality requirements allowed the AEEGSI to achieve, through regulatory intervention, an unprecedented degree of service quality and effective customer service. For instance, the smart meters allowed consumers to continue to use minimal amounts electricity, even in the event of non-payment (0.5kW for households) before services were terminated to the customer. Once payment is subsequently made, the smart meter allowed the supplier to remotely reconnect the customer, usually within a day of payment. If the reconnection is not successful within a day, an automatic compensation is made to the customer. [364] Another notable development in the Italian system, occasioned by the introduction of smart meters, is the enablement of Time-of-Use (ToU) pricing for LV customers. Under the ToU pricing mechanism, household consumption is categorised into three bands: peak, mid-level and off-peak, each with a different price. Consequently, consumers' bills are determined by how much electricity is used at different times of the day. It is worthy of note that this pricing mechanism only affects the energy component of the bill, and not network charges. In any case this allows customers to have a greater degree of responsibility for reducing their bills, especially when viewed against the backdrop that the energy component of bills constitutes ¾ of the total bill for a large number of customers. [364]

Italy's progress on smart meter rollout is nothing short of remarkable and can largely be attributed to the successful buy-in of the DSOs to the NRA's plans, through series of consultations held prior to the coming into force of the regulations. Indeed Enel D, one of the DSO's had already instituted its own smart meter rollout plan before the NRA's. The NRA also instituted a penalty for non-compliance which arguably propelled the DSOs to act. The setting of minimum functional requirements is laudable as it not only ensures that consumers receive uniform service levels, but it also facilitates interoperability and standardization. Evidently, the NRA in Italy recognised the role of smart meters in the further development of smart grids and sought to ensure that technological obsolescence did not become a hindrance to the development of smart grids.

8.3.6 Data protection

Italy's data protection framework is set out in the Italian Personal Data Protection Code (Legislative Decree No. 196/2003). This comprehensive piece of legislation is of general application and therefore applies by extension to smart grids. It defines personal data very broadly, to include not just data relating to a natural person by which such person may be identified, but also data by which a person may be identified indirectly by reference to some other kind of information. It provides for all the basic requirements for a robust data protection regime, as required by the 1995 Data Protection Directive, such as the registration of data controllers; prior informed consent for the collection and processing of personal data; and security obligations on data controllers to ensure data security; the obligation to inform the data subject of breaches which compromise their personal data; as well as the data subject's right to access, request rectification and object to the processing of personal data.

The Italian Data Protection Authority (IDPA) ("*Garante per la protezione dei dati personali*") is the national data protection authority and is responsible for ensuring compliance with the Data Protection Code. The Code seeks to protect natural persons from unlawful processing of information relating to them, that is, information by which they can be identified. Either directly or by reference to any other information.

Like other EU Member States, the Italian Code imposes the duty of ensuring legal data processing on the data controller. The controller is therefore required to notify the IDPA when its processing activity involves (subject to stated exemptions) the processing of genetic and biometric data; geo-localisation; and behavioural advertising. Notification must be made prior to the commencement of processing activities. [365] The data controller is also required to possess information systems and software which minimise the use of personal data, and when such data is to be processed, it must be done for the purpose and in the manner for which the written consent of the data subject has been obtained. There are no specific data retention periods. However, data must not be stored longer than it is necessary for processing.

With respect to maintaining security for data processing systems, the Italian Code is unique as it spells out minimum security measures that must be adopted by the data controller depending on whether the data processing is done electronically or manually. In the case of electronic processing, these security measures include: computerised authentication credentials management procedures for persons who have access to the processing system; regular update of specifications of the scope of processing; and procedures for safekeeping backup copies and restoring data and system availability. For manual processing, the Code requires, amongst others, procedures to keep certain records in restricted-access filing systems and mechanisms for regulating access; and the appointment of specific persons to be in charge of processing.

The notification to the IDPA for data breaches is only mandatory for providers of electronic communication services and controllers who process biometric data. However, where the data breach poses a threat to the data subject's privacy, the data subject must be notified of the breach. The law however provides an exception to the requirement of notification if the data that has been compromised had been anonymized or encrypted.

Enforcement of the Code is achieved through a system of administrative fines of up to EUR 2,448,000. In instances where individuals are found culpable in breaches of the Code, they may face criminal sanctions of up to three years imprisonment.

Within the Italian context, it can be said that primary data protection responsibility would fall on DSO's as they are responsible for metering and therefore the collection of personal data. The supply contracts between retailers and the customers serves, amongst others to obtain consent for the collection and processing of personal data. However, the electricity data management model adopted in Italy is centralised; the data from smart meters is sent to the Integrated Information System (IIS), a central database operated by Acquirente Unico Spa. [306] DSOs then access customers' data from the IIS for the purpose of billing and the TSO also access the metering information available on the IIS purpose of undertaking its balancing responsibilities. [306] However given that consent is granted for the processing of data by the DSOs, it may be argued that the sharing of data with the TSO and perhaps Acquirente Unico Spa., to the extent that it cannot be described as a data processor acting on behalf of the DSO, is a violation of the customer's privacy rights. However, given the definition of personal data in the Italian Data Protection Code, it appears that the aggregated meter information shared with the TSO is not personal data and therefore does not fall within the remit of the law.

8.3.7 Demand response

Following the successful smart meter roll-out and Italy's compliance with the European Commission's electricity market liberalisation objectives, the next frontier is perhaps Demand Response. Currently, Demand Response in Italy consists only of the interruptible contracts program. This is open to customers who qualify as Balance Response Parties (BRPs) and have available capacity of at least 1MW. This program is available both on the mainland network and the networks in Sicily and Sardinia however it is seldom ever called upon by the TSO for its balancing needs. In any case, the TSO has contracted out all existing capacity until the year 2018 therefore there is no opportunity for new entrants unless a participant withdraws [70]. Although aggregation is technically not allowed to participate in interruptible contracts, it appears consortiums or cooperatives may be allowed, this is evident from the fact that two consortiums are amongst the existing participants [70].

As far as Demand Response and participation in the wholesale market is concerned, there is no existing framework. Although wholesale market operators may act as demand aggregators, there are no independent "aggregators" within the Italian market.

There is significant room for reform in order to improve demand response in Italy, particularly in the area of enabling aggregators within the market. Although aggregators are considered third party service providers, and perhaps secondary to the provision on electricity, they are increasingly becoming important players in the market, and jurisdictions with mature demand response markets have active participation of aggregators. The Energy Efficiency Directive enjoins Member States to include the participation of aggregators in demand response and other ancillary markets [366]. The experience of other countries has shown that the participation of aggregators goes a long way to facilitate the improvement of infrastructure in the market, this is because in order to provide their services, the aggregators have to bear the responsibility of providing customers with the necessary communication infrastructure [70]. This goes a long way to expand the reach of smarter technology within the market. In addition, the inclusion of aggregated pools of electricity in the wholesale market would help improve competition within the market.

8.3.8 Electricity storage and electric vehicles

Italy's storage capacity is mostly constituted of pump hydro storage units. These units were previously owned mostly by state-owned electricity companies such as Enel. However following the unbundling of services and liberalisation of the market, storage units are owned by the TSOs and the law also permits DSOs to own such storage units [367]. The regulatory framework for electricity storage is fragmented and does not cover all aspects of electricity storage. Legislative Decree no 28/2011 is the main piece of legislation, but it merely grants the liberty of development and management of storage units to the TSO and DSOs. In addition to this piece of legislation, the AEEGSI's Decision on Provisions related to the Integration of Energy Storage Systems for Electricity in the National electricity System (Decision 574/2014/eel of 10 November 2014) has rules for the connection of storage systems to the grid by non-regulated entities such as prosumers. This decision defines energy storage as power generation and makes energy storage subject to connection, dispatching and metering obligations. Storage facilities are therefore required to pay a connection fee [78].

The TSO, Terna S.p.A., is involved in several projects aimed at improving the storage capacity of the country particularly improving battery systems in the Islands of Sicily and Sardinia. In the Puglia region, a project based on hydrogen storage is expected to match supply and demand and ensure a more stable supply in the network.

Despite an apparent interest in improving storage capacity in the country, there appears to be no support mechanisms or incentives for DSOs or other entities that are investing in storage technology research and development. In fact, the high cost of batteries and other storage related technologies coupled with the uncertainty of appropriate revenue streams for distributed generation, have been cited as some of the challenges that impinge the development of the storage sub-sector in Italy. The available mechanisms to overcome these challenges have been limited to research and development funds, facilitated by AEEGSI.

[367] There is however a lot to be gained from encouraging private sector, particularly DSOs, to invest in research and development of storage technology. However, given the high costs, and revenue uncertainties, largely attributable to the insufficient regulatory recognition of storage and its place in the electricity value chain prompt legislative intervention is required. Consequently, regulatory reform, and with it, the introduction of an appropriate incentive scheme would be of critical significance to fostering further development of the sector.

The electric vehicle market in Italy is a large market, which continues to grow with the development of a complete production chain, ranging from research to completed vehicles. [368] There is no legal framework regulating the market. However, proposals are at several stages of development. On the legislative front, there is currently no specific legislation for the market however two proposed laws aimed at supporting the development and deployment of electric vehicles were considered by the Italian parliament. The first was "law no. 2844 of 2009: Measures to favour the development of mobility by using vehicles without CO2 emissions". This law proposes measures such as the subsidization of purchases; installation of public battery charging infrastructure; property tax exemptions; access to restricted public areas and free parking in reserved parking areas. The proposal goes further to propose that the incentives be funded by imposing a levy on plastic bottles. The second proposed law was "law no. 3553 of 2010: Measures for the realization of infrastructure aimed at assisting the broad introduction of electric vehicles". The main objective of this law is to integrate charging infrastructure for electric vehicles into governmental and regional strategy for energy and greenhouse gas emission. It also calls for the adoption of a national plan for the establishment of conditions and possible funding schemes to support the development of electric vehicles. Unfortunately, neither of these laws was passed. Consequently, in 2010 AEEGSI took measures to facilitate the development of electric vehicles. These included the liberalisation of the supply of electric meters for electric vehicle charging systems [369].

The desire to develop electric vehicle infrastructure have led the Italian Government to work on a National Plan for electric vehicle infrastructures in 2012. The plan is compliant with 2014/94/EU Directive, and since 2013, 50 G€ of incentives have been established in order to incentivise the development of proper infrastructure. The exploitation of financial resources has not been already carried out, because the plan was only approved in December 2014, of which an upgrade has been published on April 2016. At the end of 2016, 19 projects in 19 Italian regions have been approved, involving a total amount of 5 G€. The plan also prescribes more compliant traffic law, as well as rules and incentives for the people who buy EVs.

The deployment of EV charging infrastructure, particularly public charging stations, cannot occur without due consideration for its possible implication for competition. Questions which should inform a regulatory design should include considerations for the ownership of public charging infrastructure. For instance, should electricity suppliers be allowed to operate their individual charging stations? Needless to say, this would have implications for accessibility of charging stations for customers, as it would become burdensome to find a charging station operated by one's supplier. It would also raise problems of urban planning and the designation of charging stations, especially if all 365 suppliers are to be afforded equal access to the EV charging market. Alternatively, public stations could be made neutral, allowing open access for all energy suppliers. In which case, technology and rules have to be developed to monitor the consumption by customers of the various suppliers; as well as mechanisms to determine volumes and payments in V2G scenarios. The Italian approach has been that the AEEGSI has approved different demonstration projects, each testing different charging infrastructure ownership models, with the view to adopting a best regulatory approach. [364]

Given that electric vehicles are still a niche technology with varying levels of penetration around the world, there have been calls for standardisation of the various technological components such as batteries and charging technology. While international standards are still being developed, Italy like many other countries around the world, has taken steps to institute temporary measures for standardisation. For instance, the Italian EV Association, a committee of Italy's Electrotechnical standardization body CEI adopted 'Safety requirements for charging stations for electric road vehicles (CEI 312 -1)' in 2010.

Like many countries around the continent, Italy is looking to develop V2G capability. To this end, several research demonstration projects are underwear, including the WiseGRID project. The aim is to employ bidirectional charge management to enable EVs store unused power and discharge it to the grid. Beyond the re-definition of 'storage' within the electricity network in order to properly cater for distributed generation through battery technology, it is imperative that proper consideration is given to the compensation scheme for such sources. In the case of EVs, the compensation scheme would have to consider amongst other issues the impact of wear and tear on the EV owner's battery as a result of grid supply. [370] The development of compensation schemes is by no means an easy task, and may even require the delineation of an EV-specific compensation mechanism outside of any compensation mechanism that is developed for DERs. It is hoped that the various demonstration projects would provide the necessary tools for further regulatory action.

8.3.9 Circular economy and energy related waste

The Italian government has been actively involved in international efforts at improving efficiency and sustainability of resources, since the inception of the concept of improving global social, economic and ecological resilience through sustainable development. The Ministry of Environment has participated actively in these efforts within the United Nations, the G7 and through other bilateral engagements with Mediterranean countries and China.

On the local arena, Italy has adopted a number of cross-sectorial measures with the view to attaining the circular economy. The transition is backed by several legislative instruments, including the Financial Stability Law contained and Environmental Annex (*Collegato Ambiente)* which came into force in February 2016; it sets out various measures aimed at improving the sustainable use of resources. Italy has also adopted Green Public Procurement measures which require amongst others the use of a "minimum environment criteria" for procurements such as, electronic devices, lighting, construction materials, amongst others. Other policy and legislative instruments that have been adopted include: the Ecodesign Decree (law no. 140/2016); a sustainable production and consumption action plan; and national sustainable development strategy.

Given the obvious synergies between climate change mitigation and energy efficiency, the WiseGRID Project presents a unique opportunity to demonstrate the viability of several of the government's measures. In order to ensure this, the Project ought to be deployed with significant consideration for the priorities of the government as far as achieving a circular economy is concerned. It is worth highlighting that one priority of the Italian government is to improving the sharing of public and private resources towards ensuring sustainability. [371] This is demonstrated within the context of smart grids by the sharing of public and privately owned assets towards meeting the energy security needs of the country. The sustainability potential presented by smart grids, as typified by the WiseGRID Project is not limited to the promotion of renewable energy, and with it, the reduction of greenhouse gas emission, but also the potential to improve economic development through the development of small-scale power generation through micro-grids and demand response mechanisms. While the value of these gains is not in doubt, the smart grid technology could be taken further to enhance resource sharing. For instance, in the area of electricity storage, in contradistinction to the status quo where a DSO or the TSO own storage units for their own use, with the integration of appropriate recording technology and the improvement of storage devices, it should be possible for two or more entities to store power within one unit to reduce the proliferation of storage units. Finally, the consumption management products envisaged under by Project are designed to provide electricity consumers with information which is intended, not only to influence their energy consumption decisions, but empower them to become active participants in the generation and distribution of electricity in a more sustainable way.

Another area in which Italy has been commendably active, is the area of waste management. Following the Directives on waste management including waste of electric and electronic equipment (WEEEs), which has been transposed into Italian law by the Waste Electrical and Electronic Equipment (WEEE) Legislative Decree No. 49/2014 suppliers of electrical equipment are required to provide arrangements for the collection, treatment, recycling and recovery of the electronic equipment. Given that smart grids rely predominantly on the supply of electronic components such as smart meters; IT and telecommunication equipment; consumer equipment and solar panels; lighting equipment; and monitoring and control and equipment all of which are covered under Legislative Decree No. 49/2014, the longevity and measures for management of retrieval and disposal of these components must be considered at the design stage of a smart grid network. It is important to note that under the law, the obligation is on the producer of the equipment and not the user. It therefore behoves on the Project to ensure that all of its suppliers have adopted the appropriate management policies prior to undertaking a contract of supplier. This will not only ensure compliance with the law and further the EU's waste reduction goals, but would ensure that the Project is not saddled with the responsibility of disposal of such waste at its end-of-life.

8.4 SPAIN

8.4.1 General overview

Spain is a sovereign state located in the Iberian Peninsula, in South-West Europe. The country is divided into 17 autonomous regions or "*Comunidades Autónomas*" (Andalusia, Aragon, Asturias, Balearic Islands, Basque Country, Canary Islands, Cantabria, Castile and León, Castilla-La Mancha, Catalonia, Community of Madrid, Extremadura, Galicia, La Rioja, Navarre, Region of Murcia and Valencian Community) as well as 2 autonomous cities in the North African mainland (Ceuta and Melilla). Spain has an area of 505.990 square kilometres (km^2) and a population of over 46 million. Due to its size and geography, the climate can vary substantially between its regions. Spain entered the European Union (EU) in 1986.

8.4.2 Energy profile

Generally speaking, Spain shares the same fundamental energy security conundrum as the rest of the EU. That is, Spain relies on energy imports (mostly oil and gas) deriving from a sparse albeit changing number of energy suppliers in order to meet its energy needs [372]. Indeed, hydrocarbons are limited within the Iberian Peninsula. Even though Spain has managed to reduce its energy dependency, the country still hinges on foreign energy supplies to power its economy. The bulk of these energy supplies from abroad are fossil fuels. Eurostat estimates Spain's energy dependence at 72.9%, as of 2014 [373].

Conversely, energy production in Spain emanates from predominantly two sources: renewable energy (50.1%) and nuclear power (43.7%) while fossil fuel production is negligible (4.7% coal; 0.9% oil; and 0.1% gas. See Figure 23). From 2004 to 2014, Spain's energy production has experienced an abatement in fossil fuels, coupled with a striking growth in renewables. Renewable energy production has increased by 93.8% over this 10-year span. This development was chiefly driven by an incentive-induced rise in solar and wind power [374].

Spain's total final consumption was 83.5 million tonnes of oil equivalent (Mtoe) in 2014 [375]. The largest consuming sectors are transport and industry as they represent 34.6% and 30.9% of total final consumption, respectively. The residential sector amounts to 18.4% while the commercial and other services sector (including agriculture) are responsible for the remaining 16.2%. From 2004 to 2014, demand in transport and industry has declined whereas the consumption for households and the commercial sector has swelled [374]. The government predicts that the consumption of electricity and renewable energy will soar and that of oil will lessen over the course of the 2014-2020 time frame. Forecasts also anticipate a slight reduction in the final energy consumption as it is expected to amount to 80.1 Mtoe (931.5 TWh) in 2020 [376].

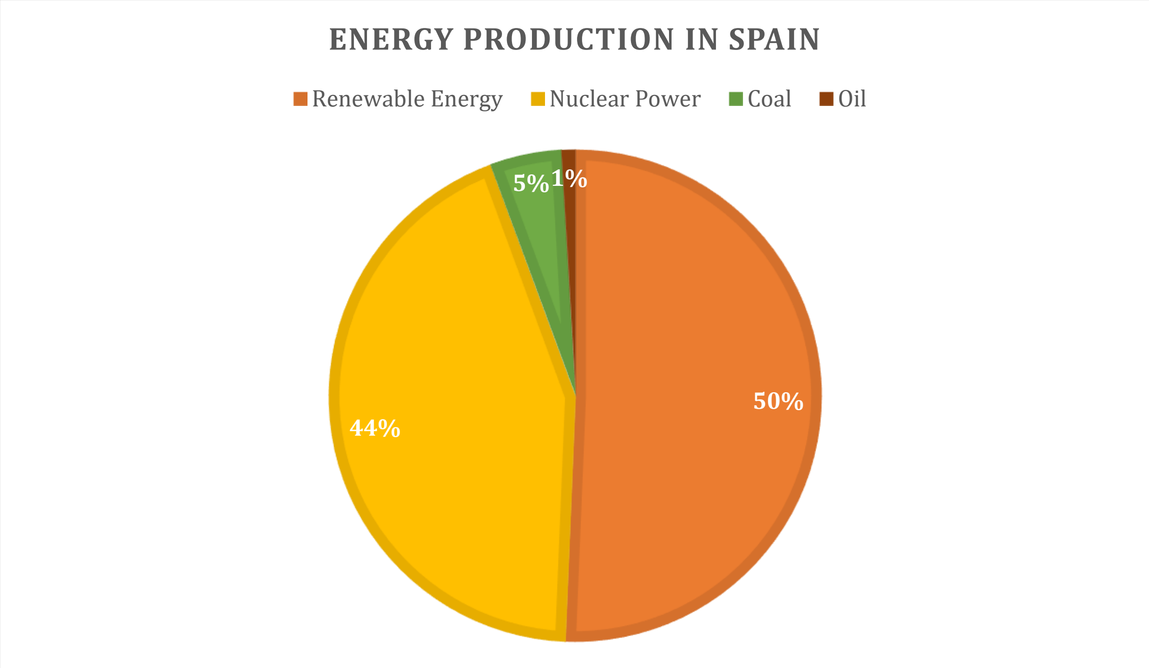


Figure 23 – Spain Energy production [374]

In terms of gas, in spite of being one of the countries that consumes the highest volumes of this commodity in Europe, Spain produces less than 0.5% of the gas it consumes. Spain imports gas from an assortment of providers such as Algeria, Nigeria, Norway or Qatar. Roughly 60% of these gas supplies come in form of LNG shipments while the remaining 40% are being delivered through pipelines [377]. A remarkable feature in terms of energy security lies in Spain's prominent regasification capacity of its liquefied natural gas (LNG) terminals. The country ranks first in Europe on this particular front due to the 7 LNG import terminals scattered all over the territory that are operational as of July 2017 (Barcelona, Bilbao, Cartagena, Gijón, Huelva, Mugardos and Sagunto) [378]. Indeed, Spain alone boasts a third of the total regasification capacity of LNG in the EU [379].

As to electricity, Spain has manufactured an extensive, well-diversified power generation fleet though limited to a few companies such as Endesa, Iberdrola and Gas Natural Fenosa. What is more, it has managed to integrate new sources of generation such as wind and solar energy. This being said, one of the country's main concerns is its status of "energy island" due to the insufficient connections between the Iberian Peninsula and the rest of the EU. Indeed, Spain's interconnection capacity with bordering Member States is currently under 5% [380]. Nevertheless, promising developments are soothing Spain's fears of being an energy-secluded nook. In February 2015, the Santa Llogaia – Baixàs power line was inaugurated. This project, completed under the auspices of the Energy Union, doubled the existing electricity interconnection between France and Spain [381]. The anticipated Biscay Bay submarine electric connection along with other interconnections through the Pyrenees (alternatives contemplate power line routes from Aragon, Basque Country and Navarre) are further avenues which are geared towards increasing the electricity exchange capacity between France and Spain [382].

8.4.3 Governance system

8.4.3.1 Relevant institutions

Ministry of Industry, Energy and Tourism – State Secretariat for Energy

Energy is a shared competence between the EU and its Member States [383]. As to Spain, national competence in energy lies with the Ministry of Industry, Energy and Tourism by virtue of the Royal Decree

1823/2011 of 21 December. The State Secretariat for Energy is the responsible body within the Ministry. Its competences include:

- Elaborating rules related to the energy and mining sectors.
- Elaborating proposals in order to legislate on tariff structure, prices of energy products as well as levies and tolls.
- Issuing proposals to save energy, promote renewable energy and on general planning in the energy sector.
- Elaborating and, if necessary, applying measures taken in order to ensure security of supply [375].

The Ministry is supported by a profusion of specialised entities in the energy sector that, in turn, operate under the aegis of the government. The most important organisations are briefly outlined hereunder.

The Institute for Energy Diversification and Savings (IDAE)

The IDAE promotes energy efficiency and renewable energy. To that end, it organises activities to raise public awareness and knowledge; provides technical advice; and finances projects to encourage technology innovation that offers replication potential. The institute conducts an intense international cooperation activity in the framework of various EU and third country programmes [384]. Furthermore, the IDAE was among the leading instigators behind the 2004-2012 Energy Saving and Efficiency Strategy (E4) as well as several subsequent National Energy Efficiency Action Plans [374].

The Strategic Reserves Corporation (CORES)

The CORES is the oil stockholding agency in Spain. Moreover, the CORES is a benchmark information resource concerning hydrocarbons. The general aim of this corporation is to safeguard security of hydrocarbon supply to the country. To that end, the CORES holds a specific number of stocks regarding petroleum products and monitors the stocks held by the industry as to petroleum products, liquefied petroleum gas as well as natural gas. In addition, the CORES also controls the diversity levels in terms of the origin of natural gas. The corporation does so by ensuring that these natural gas supplies do not exceed the legal percentage allocated to any one country [385].

The Institute for Restructuring and Alternative Development of the Coal Mining Regions (IRMC)

The IRMC is the managing body of the aid schemes for the coal mining industry and the alternative development of mining areas. The activity of the IRMC revolves around a two-fold objective: to implement the restructuration of the coal mining policy; and to issue and implement measures in order to foster the economic development of the regions identified as coal mining municipalities [386].

Red Eléctrica de España

Law 17/2007 of 4 July confirmed the condition of REE as operator of the transport network and assigned it the role of unique TSO, in an exclusive regime. In compliance with Law 17/2007, Red Eléctrica de España acquired in 2010 the assets of the Balearic and Canary Islands and the rest of the peninsular assets pending transfer from the electricity companies. As operator of the transport network, Red Eléctrica de España is responsible for the development and expansion of the network, for maintenance, for managing the transit of electricity between external systems and the peninsula and for guaranteeing third party access to the transport network in equality conditions [387].

Iberian Market Operator – Spanish Division (OMIE)

OMIE is a company regulated by the International Agreement of Santiago concerning the constitution of an Iberian market for electrical energy (MIBEL) between Spain and Portugal and subject to the sectoral electricity regulation in Spain. OMIE manages the wholesale electricity market, where buying and selling agents contract the amounts of energy they need at public and transparent prices. OMIE manages markets (daily and intraday) in an integrated manner for the whole Iberian Peninsula and its operating model is the same as that of many other European markets. OMIE also performs the billing and settlement of energy purchased and sold in these markets, as well as the preparation of the corresponding economic settlements [388].

In addition to these bodies, there are two main regulators in the Spanish energy sector.

The National Commission of Markets and Competition (CNMC)

The CNMC is the national regulatory authority (NRA) for the gas and electricity sectors. The CNMC is an institution, independent from the government, in charge of promoting the appropriate functioning, transparency and effective competition in all productive sectors and markets for the sake of both consumers and industry. The CNMC is subjected to parliamentary control thereby arguably warranting its independence and increasing legal certainty [389]. This entity harmonises the work of the competition authorities in the autonomous regions. The CNMC is the authority that sets the methodology to calculate the network access tariffs as well as the methodology to determine the charges of the electricity system. These tariffs are then established by the government in the light of the methodology provided by the CNMC [374].

The Nuclear Safety Council (CSN)

The CSN is the competent body in Spain in matters of nuclear safety and radiation protection. This entity is supposed to be independent from the government but is subjected to parliamentary control in an analogous way to the CNMC. The mission of the CSN is to safeguard workers, citizens and the environment against the dangerous effects of ionising radiations stemming from nuclear installations. The council does so by ensuring that nuclear and radioactive facilities are operated by duly qualified incumbents in a safe manner. The council is also responsible for adopting preventive and corrective measures in the event of a radiation emergency, regardless of its origin [390].

8.4.3.2 Political decentralisation and energy competences

Decentralisation has been continuous in Spain ever since the establishment of the 1978 Constitution which formally culminated the transition to democracy in the aftermath of military dictator Francisco Franco's death in 1975. The 1978 Constitution framed a decentralised organisation of the state by creating the autonomous regions or "*Comunidades Autónomas*" as a first political and administrative layer in an effort to ensure limited autonomy of the different regions of Spain. Thenceforth, the autonomous regions have been allotted an increasing number of competences to the detriment of the central government as illustrated by the sustained growth of their share in total public spending [391]. The Constitution sets out the division of powers by placing some competences in the exclusive remit of the state whereas the autonomous regions enjoy residual competences in their statutes of autonomy or "*Estatutos de Autonomía.*" Even though there were some differences between the different autonomous regions until the mid-1990s, currently, all of these regional administrations virtually enjoy the same degree of political autonomy [392].

In terms of energy competences, the central government enjoys exclusive competence to authorise electricity networks when their exploitation affects another autonomous region or when the electricity transmission lines go beyond its territorial scope [393]. Furthermore, the state enjoys exclusive competence to approve and lay down the foundations of the framework for the mining and energy sectors [394]. These questions are complemented with the prerogative of the government to lay down and ensure the foundations and coordination of the general planning of the economic activity [395] from which it is safe to say that energy policy is an essential component. Finally, the state is entitled to establish the basic legislation in terms of environmental protection without prejudice to the faculty by the autonomous regions to implement additional regulations to enhance this protection [396].

The statutes of autonomy of the autonomous regions have consequently claimed competences in the remaining areas of energy by ensuring that there is no encroachment on the sphere of action of the central government. That is, the autonomous regions see to it that their energy policy is circumscribed to their geographical breadth without affecting other autonomous regions. Moreover, the statutes of autonomy assign exclusive competence in industry to their respective autonomous regions with due regard to the framework of the general economic activity delineated by the state. The competences of the autonomous regions are further confined to the respect of the regulations adopted by the central government for reasons of security, health or military interest as well as those sectors bound by legislation on mining, hydrocarbons and nuclear energy [397].

In conclusion, autonomous regions play a crucial role in Spanish energy policy. These first administrative and political strata enjoy the legal competence to determine a range of fields in the national energy blueprint. For instance, autonomous regions are entitled to authorise power plants insofar as their capacity remains less than 50 megawatts (MW), which is the case of most solar and wind farms. What is more, autonomous regions may also approve electricity and gas distribution networks within their territory. Finally, they are active participants in the design and implementation of climate change, energy efficiency and renewable energy policies at a regional level [374]. The strong political decentralisation pervading Spanish democracy lays fertile ground for the full exploitation of the EU law principle of subsidiarity [398].

8.4.4 Electricity market

8.4.4.1 Regulatory framework

Since 2001, Spain had been accumulating a huge tariff deficit as the electricity system costs were outstripping the revenues generated by the system. In 2012, with the accumulated debt reaching unprecedented proportions, the central government adopted emergency policies to tackle the issue. These measures included temporarily ending subsidies for new renewable energy installations; reducing the remuneration for transmission and distribution network services; increasing access tariffs; and introducing a 7% tax on electricity generation [374]. Subsequently, the electricity market underwent a structural reform through the adoption of a new regulatory framework in 2013. This configuration was established with the objective of guaranteeing the sustainability of the electricity industry by addressing the endemic scourge of tariff deficits. National legislation in Spain reflects the measures adopted by the Commission in 2009 through the Third Energy Package. Generally speaking, this EU legislative package deals with an array of questions such as ownership unbundling; regulatory oversight and cooperation; network cooperation; transparency; record keeping and access to storage facilities and LNG terminals by regulating transmission network ownership; ensuring more effective regulatory oversight; reinforcing consumer protection; regulating third party access to gas storage; and promoting regional solidarity among EU Member States [399].

The Electricity Sector Law 24/2013 of 26 December was adopted bearing in mind these principles whilst taking stock of national circumstances. That is, the integration of renewable energy sources and Spain's condition of "energy island" *vis-à-vis* other EU Member States [374]. The Electricity Sector Law 24/2013 marks the shift to a more flexible framework in the remuneration of regulated activities (especially renewable energy) in order to adjust to alterations in the electricity industry. This is so as the current model will offer the chance for review every 3 years. Budgetary balance is the premise that underlies this new architecture. In other words, electricity system revenues need to be sufficient to offset the totality of the costs of the system [400].

Remuneration of renewable energy, combined heat and power (CHP) and waste-to-energy (WtE) facilities is based on the market participation of these power plants who will have to compete with traditional sources. The Electricity Sector Law 24/2013 establishes a support scheme for power plants producing electricity from renewable energy sources (RES), cogeneration and waste in order to ensure that they enter market competition on an equal footing. This subsidy permits these power plants to recover the investment as well as operating costs (that cannot be recovered in the market) and may enable them to obtain a suitable return [401]. The law approves additional support schemes for electricity produced from RES, cogeneration and waste insofar as they are required to meet goals set at the EU level. Further, autonomous regions are entitled to authorise renewable power plants if their output remains below 50 MW [402]. As to grid access and use, electricity produced from RES, cogeneration and waste enjoys priority both in terms of connection and dispatch provided that these actions can be carried out without jeopardising the grid itself [403].

Another remarkable feature of the Electricity Sector Law 24/2013 is the introduction of a toll on self-consumption. At this point, it is important to differentiate self-consumption from net metering. Net metering is defined as the procedure in which the generation facility is connected inside the network of a consumer and produces electricity for both contemporaneous and future consumptions. That is, where electricity generation surpasses consumption, the surplus is discharged into the electric system. Conversely, this electricity excess can be recuperated in periods where consumption outstrips generation. In a similar vein, self-consumption transpires when the generation facility is connected inside the consumer's network. However, this practice must be differentiated from net metering. From a regulatory point of view, only net metering allows consumers to send their energy surplus to the national grid [404].

Customers that are connected to the grid and engage in self-consumption will have to contribute financially to the related system costs of the grid in the same manner as other customers that consume electricity directly from the grid [400]. The law assimilates the concept of self-consumption with "any electricity consumption originating from generation facilities connected in a consumer's household" inasmuch as this network is fully or partially connected to the grid [402]. This fee constitutes perhaps the most controversial aspect of the Electricity Sector Law 24/2013. Several renewable energy associations campaign against self-consumption tolls as they understand that such levies are likely to deter consumers from installing their own renewable energy generating system [403] (*e.g.* Photovoltaic (PV) panels on the rooftop of private households). For the central government, the rationale behind self-consumption tolls lies in that market generation costs only account for 40% of the cost of electricity. Therefore, the burden of annual tariff deficits as well as the support schemes for electricity produced from RES, cogeneration and waste must be borne by all consumers connected to the grid, regardless of whether they engage in self-consumption or not [400].

The Royal Decree 900/2015 of 9 October regulates self-consumption in greater detail. All self-consumers have to register with the Registry for Electrical Energy Self-Consumption (only some isolated facilities are exempted) [405]. The Royal Decree 900/2015 establishes two modalities of self-consumption [406].

- <u>Type 1. Supply with self-consumption</u>
  This category refers to consumers with an installed capacity below 100 kW which are not registered as a production facility. The energy is only generated for self-consumption. No reward is granted if this type of self-consumer exports electricity surplus to the grid.

- <u>Type 2. Generation with self-consumption</u>
  This category refers to a consumer in a single supply point or facility which is associated to one or several production facilities, duly registered as a production facility, connected within its network, or which share connection infrastructure with it. As opposed to type 1, electricity surplus exported to the grid will be remunerated with an economic compensation [34].

Type 1 self-consumer is legally treated as a mere consumer while type 2 self-consumer is legally categorised as both consumer and producer. In essence, mainly commercial and industrial actors are entitled to sell their power surplus under the same conditions as any other producer. This is so as these stakeholders are the more likely to meet the requirements to register as a type 2 self-consumer. Thus, the regulatory framework in Spain fails to facilitate the advent of private households as prosumers. By raising economic and formal barriers for residential households, the Royal Decree 900/2015 makes it unlikely for regular citizens to sell their electricity surplus to the grid. Indeed, under the current legal architecture, private households are in principle only able to export their energy surplus to the grid for free [407]. Moreover, the Royal Decree 900/2015 prohibits a single installation to provide power to several different end-users [408]. This restrains the diffusion of PV technologies in urban areas as it prevents a single installation from supplying electricity to a community of neighbours, for instance.

A supplementary controversial aspect of this regulation are the back-up tolls that constitute the so-called “sun tax.” These levies stem from “charges related to the electricity system costs” and “charges for other services of the system” [409]. The Spanish Photovoltaic Union, “*Unión Española Fotovoltaica*” (UNEF), denounces that PV self-consumers pay a “sun tax” for the whole power capacity installed (the power supplied by their energy provider, plus the power produced by their PV installation). In addition, PV users with installations larger than 10 kW will have to pay for the electricity they generate and self-consume from their own PV installation [410]. Some facilities are exempted from this second “sun tax” (off-grid installations; installations smaller than 10 kW; all installations in the Canary Islands, Ceuta and Melilla). Installations with cogeneration are temporarily exempted until 2020 whereas the Balearic Islands of Mallorca and Minorca will pay a reduced rate [410]. The preface of the Royal Decree 900/2015 rallies with the philosophy of the Electricity Sector Law 24/2013 as it propounds the necessity to ensure the economic sustainability of the electricity industry as a whole. Consequently, the containment of costs has been prioritised to the detriment of a forward-looking approach to self-consumption.

The above logic is in line with the overarching premise of the new electricity industry configuration, namely budgetary balance. However, it is safe to say that conservative self-consumption policies impinge on energy decentralisation by precluding consumers from effectively evolving into prosumers. Regulation on self-consumption is undoubtedly a grey area. Surprisingly enough, given the government’s apparent enthusiasm to foster electricity from RES, cogeneration and waste, self-consumption regulation in Spain appears to be less progressive. Restrictive measures such as the administrative and financial hurdles set out above can prevent the optimal market penetration of smart grid applications in Spain. The motivation underpinning economic and regulatory barriers to self-consumption seems to remain oblivious to the numerous benefits that energy decentralisation entails. These advantages spread to both the consumer and the market spectra. Self-consumption enables consumers to actively benefit as well as to engage in energy markets, thereby turning them into prosumers; it can lower the costs associated to energy systems; it is conducive to the reduction of system losses; and it can make a significant contribution to finance energy transition [411]. Self-consumption pushes for increased technological development and energy security.

Regrettably, it appears that the majority of power companies regard energy decentralisation as a threat. This is so as the emergence of new industry players (prosumers) elicits a fiercer competition for a reduced market [412]. Surpassing these negative presuppositions regarding self-consumption is essential. The conflict of interests between entrenched energy juggernauts and up-and-coming stakeholders, together with the traditionalist policies of the government are curtailing the advent of prosumers. In terms of regulation, a more dynamic outlook is in order. Lifting tolls, bans and any similar burden to energy decentralisation would enable electricity markets to leapfrog to an energy revolution that seems imminent. To that end, future regulations should explore net-metering schemes as a means to foster decentralised RES.

Another of the main changes brought about by the Electricity Sector Law 24/2013 is the empowerment of the NRA, that is, the CNMC. More specifically, this regulatory body is now in charge of defining the methodologies to calculate transmission and distribution tariffs; providing access to cross-border infrastructure; providing balancing services; imposing penalties; and formulating binding measures for the relevant companies [374]. The reinforcement of the CNMC’s prerogatives was a direct response to the increased regulatory oversight advocated by the European Commission in the Third Energy Package. At the EU level, the NRA is called upon to cooperate with other regulators. The CNMC does so via the Council of European Energy Regulators (CEER) as well as the Agency for Cooperation of Energy Regulators (ACER). The CEER and the ACER serve as fora for these regulatory authorities to complete the internal energy market and formulate network codes [374].

Even though the reinforcement of the NRA's mandate is a positive development, there continues to be room for improvement. Whereas the CNMC is responsible for defining the methodology to calculate the network tariffs for transmission and distribution, the final decision to set these tariffs still lies with the Ministry of Industry, Energy and Tourism. Conceding the NRA full independence from the government is a vital requisite to achieve market confidence [413]. Indeed, the Spanish electricity system is prone to suffer from market and investment distortions resulting from the existing gap between the current architecture and optimum transparency levels. As it is, the government has *carte blanche* to influence prices for political reasons such as to limit inflation, for instance. Further bolstering the role of the NRA by bestowing it effective independence would constitute the best move to ensure market certainty. This could be done by granting this regulatory body exclusive powers in terms of network tariffs determination as well as regulated costs and revenues monitoring [374]. It is safe to say that the promotion of self-consumption, an arguably novel trend in energy markets, is more likely to be successful in a regulatory stable and transparent electricity system.

8.4.4.2 Energy security dimension

The Spanish electricity system is interconnected with the Portuguese system (thus forming the Iberian electricity system); with the North African system, through Morocco; and with the Central European system, through France. In turn, the Central European system is connected with the Nordic countries, with the countries of Eastern Europe as well as the British Isles thereby conforming the largest electricity network in the world [380]. At the EU sphere, completing the European internal energy market is a long-lasting aspiration. To this end, overcoming the lingering fragmentation between the energy markets of the EU Member States is imperative. Indeed, there are missing interconnection links between numerous Member States. Consequently, the European Commission set the objective to attain 10% of electricity interconnection by 2020 [414]. Thereafter, it was suggested to extend this interconnection target to 15% by 2030 [284], thereby manifesting the urgency that the Commission attributes to this task. An effectively interconnected European energy grid would entail sizeable market benefits for European citizens. This is so as consumers could save up to EUR 12-40 billion annually by 2030 [415].

Spain is in a rather delicate stance in terms of cross-border interconnections. Studies by the European Network of Transmission System Operators for Electricity (ENTSO-E) rank Spain among the Member States with the lowest interconnection capacity, with the likes of the Baltic States, Cyprus and Poland, well below the advocated 10% threshold [416]. Spain's interconnection capacity is currently under 5% [380]. Therefore, new cross-border links will have to be financed if the country is to hit EU electricity interconnection standards. The advantages ensuing from this enhanced interconnection capacity outweighs the economic forecasts set out above. Indeed, a well interconnected grid is pivotal to achieve sustainable development and to accommodate a higher share of RES, thereby decarbonising the energy mix. Resorting to RES for a greater fraction of the energy mix has the two-fold advantage of increasing energy security while at the same time lowering CO_2 emissions. Furthermore, the resulting boost to the dynamic renewable energy industry can lead to the creation of employment for a substantial number of individuals. In other words, more interconnectors bring about more affordable electricity prices due to the increased market efficiency, higher electricity supply security, reliability and quality while guaranteeing an adequate level of environmental protection [417].

Spain is relatively well connected with Portugal and constitutes one of the scarce gateways between Europe and the African continent through its undersea interconnector with Morocco. Conversely, the bottleneck in electricity exchanges with the French border has always represented a deadlock preventing the Iberian Peninsula from being effectively connected with the rest of the European internal energy market. This is all the more unfortunate considering that Spain enjoys a robust energy infrastructure albeit constrained to a few companies such as Endesa, Iberdrola and Gas Natural Fenosa. Thus, the country is unable to fully reap the benefits from being connected to the rest of the European grid. Nevertheless, recent developments have sparked cautious optimism as to Spain's energy seclusion quandary.

In February 2015, the Santa Llogaia – Baixàs power line was inaugurated. This project, undertaken under the auspices of the Energy Union, doubled the existing electricity interconnection between France and Spain [381]. Indeed, the scheme has increased the transfer capacity between these two countries from 1.400 to 2.800 MW (see Figure 24). This power line was identified as a Project of Common Interest (PCI) [418]. This label entitles such projects to benefit from several funding instruments such as the Connecting Europe Facility (CEF) [419], for instance. The interconnection link, which runs completely underground, will secure the necessary electricity supply to power the high-speed train on the Spanish side. Furthermore, it allows the grid to accommodate a higher share of renewable energy, especially wind energy from the Iberian Peninsula. This PCI represents the first interconnector between France in Spain that is brought into service in almost 30 years [420].

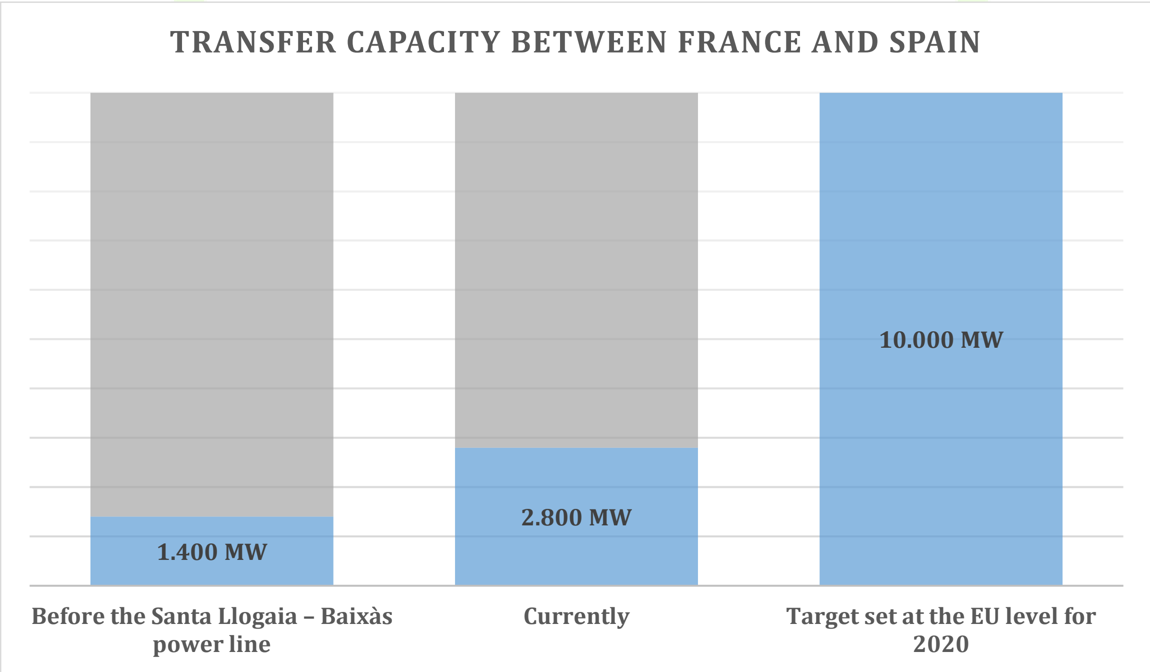


Figure 24 – Electricity interconnection capacity between France and Spain [420]

The Santa Llogaia – Baixàs power line is prototypical of the new wave of EU energy projects that is on its way. Strategic cross-border interconnectors will enjoy priority in terms of political and economic support. The role of the Energy Union and the sponsorship of such ventures via the EU financial instruments will be critical to raise the interconnection levels of Spain which surely call for particular attention. The Madrid Declaration signed in March 2015 by the European Commission, the European Investment Bank (EIB), France, Portugal and Spain as a result of the energy connection links summit further delineates upcoming projects.

The Biscay Bay project is the next in line. This undertaking sets to connect the Biscay Bay (Spain) to Aquitaine (France) through a sub-sea cable. The project is under technical studies and, as a PCI, will benefit from prominent CEF funding (estimated at EUR 3.25 million). Additional EU subsidies are expected given the promise of this initiative. The Biscay Bay project has the potential to rebalance electricity flows between East and West of the border. More importantly, the Biscay Bay project could significantly increase the transfer capacity between France and Spain. Indeed, the electricity exchange capacity would soar to up to 5.000 MW [421]. Two supplementary projects through the Pyrenees have been sketched. A first one would run from either the Basque country or Navarra (Spain) to Cantegrit (France) whereas the second one should connect Aragón (Spain) to Marsillon (France). These ventures, in conjunction with the Biscay Bay project, are expected to raise the transfer capacity between France and Spain to 8.000 MW in 2020 [421]. Hence, the anticipated operations in the wake of the Santa Llogaia – Baixàs power line could almost triplicate the current transfer capacity.

The supra-national considerations depicted above seem to constitute the ideal juncture for the market penetration of the set of solutions and technologies brought by the WiseGRID project in the Spanish electricity industry. An effective interconnection of 10% between the Spanish electricity system and the rest of the European grid should hopefully materialise by around 2020. As a result, the Spanish electricity market would become substantially more resilient. Moreover, stronger external electricity exchange capacities are conducive to the integration of a swelling proportion of renewables into the national grid. Smart grid applications will presumably be sought after as a means for consumers to make the most cost-efficient energy choices. This anticipated turn of events is also beneficial to promote self-consumption and net metering. Regulatory considerations aside, prosumers are more likely to be able to sell their energy surplus if the domestic grid is physically prepared to accommodate greater shares of renewables as a result of stronger transfer ratios with bordering countries.

8.4.4.3 Social and ethical dimension

The emergence and empowerment of civil society members in the electricity market, a reduced market with few actors currently, can entail several benefits. Increasing the number of stakeholders prompts greater competition leading to more affordable energy prices. What is more, having new active players contributing electricity to the grid inherently reinforces local electricity security. There is a case to be made for distributed resources and self-generation as they ensure that electricity flows where it is more needed. Citizens, electric cooperatives, small and medium-sized enterprises (SMEs) can play an active role by engaging in the transition to energy democracy. This revolution aligns with the consumer-centric, bottom-up approach advocated by the European Commission by allowing the active participation, protection and empowerment of European citizens, both in their capacities as consumers and prosumers. Finally, demand response will enable consumers to do their part in safeguarding the environment by helping the grid to be powered by clean energy such as wind or solar instead of fossil fuel plants that switch on when electricity prices are higher [422].

8.4.5 Market characteristics and idiosyncrasies of the Spanish pilot site

8.4.5.1 Geographical connections

Spain is a country located in south-western Europe with over 46 million inhabitants [423] and forms together with Portugal the so-called Iberian Peninsula. The geographical proximity between these two countries allows the integration of a single common Iberian electricity market (MIBEL). The Spanish hub of this market is managed by the OMIE (Operator of the Iberian Energy Market).

At the same time the Spanish electricity system is interconnected with the North African system (through Morocco) and with the Central European electricity system (through France).

Figure 25 shows the evolution of the international energy exchanges.

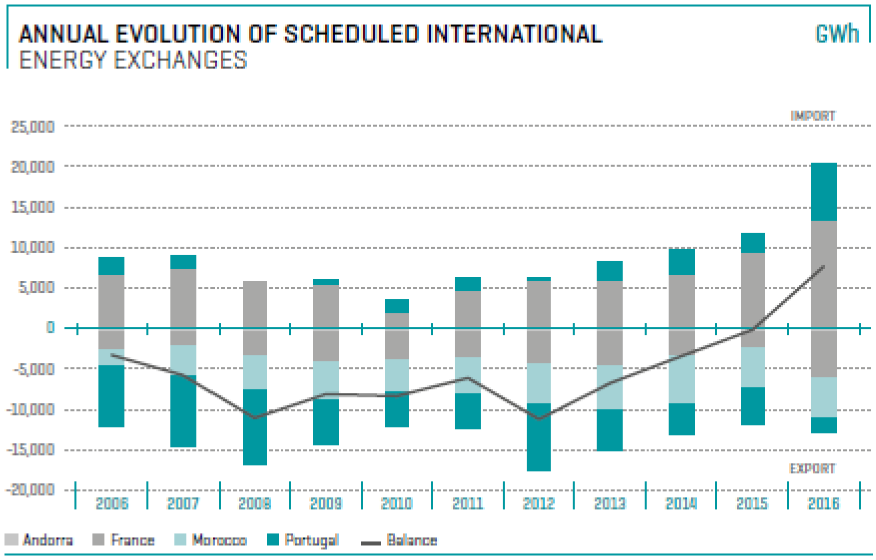


Figure 25 – Evolution of energy exchanges in Spain [424]

The European Union recommended in 2002 that all Member States should reach in 2020 a minimum of a 10% interconnection ratio (import capacity vs installed generation capacity) in 2020. This target was re-set in 2014 to 15% by 2030. Spain's interconnection ratio is currently under 5%, which is still far below the specified objectives. The interconnection ratio of the Iberian Peninsula is only 2.8% and the current support to the Iberian Peninsula comes only through the French border (through the Pyrenees). Therefore, Spain can be considered an "electrical island" [424].

This situation will try to be reversed thanks to new projects such as the submarine interconnection across the Bay of Biscay and two new interconnections across the Western Pyrenees (which will allow an 8% of interconnection ratio) [425].

8.4.5.2 The different market roles

In the following picture is showed how the Spanish Market is organized.

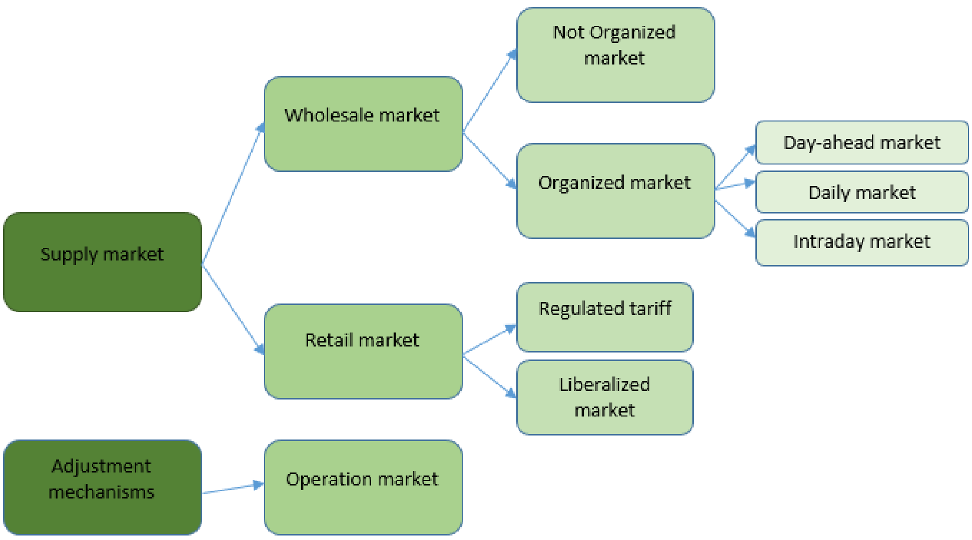


Figure 26 – Spanish electricity market [426]

Wholesale market: It trades with large amounts of energy. The deviations between purchased and consumed energy are penalized.

- **Not Organized market:** Bilateral agreements freely agreed between producers and buyers of large amounts of energy. They do not respond to any previous established market rule.
- **Organized market:** Depending on the date of agreement and execution of the contract, this market is divided into:
    - **Day-ahead market:** From 3 years to 2 days before the exchange.
    - **Daily market:** The day before the exchange.
    - **Intraday market:** Temporary ranges lower than 24 hours.

Retail market: It trades with small amounts of energy. This market establishes the relationships between the suppliers and the medium and small consumers.

- **Regulated tariff:** Only consumers with a contracted power of 10kW or less can access this tariff. The prices are fixed by the Government.
- **Liberalized market:** The contractual conditions are freely established between the final consumer and the supplier. No matter the size of the consumer, anyone can use this mechanism.

Operation market: The market operation involves 3 main tasks: Technical constraints solution, assignment of ancillary services and deviation management.

The Spanish market is managed by three main figures:

1. **System Operator:** Represented by *Red Eléctrica de España (REE)*.
2. **Market Operator:** Represented, as previously said, by *Operador del Mercado Ibérico de España (OMIE)*.
3. **Market regulator:** Represented by *Comisión Nacional de los Mercados y la Competencia (CNMC).*

8.4.5.3 Structure

The electricity system is organized into four separate activities since the Law 24/2013 of 26 December 2013 (Electricity Act). These four activities are generation, transmission, distribution and retail. Generation and retail are partially liberalized but distribution and transmission are mainly regulated [427].

8.4.5.3.1 Transmission

Red Eléctrica de España (REE) is the unique TSO and owner of the whole transmission network since 2010. REE is regulated by the Electricity Act and the Royal Decree 1955/2000 of 1 December 2000 [427].

8.4.5.3.2 Distribution

This activity in Spain is regulated in Articles 36 to 42 of the Royal Decree 1995/2000 [427]. Currently there is an amount of 365 DSOs operating in Spain [428] but 5 of them cover more than 95% of the grid [427].

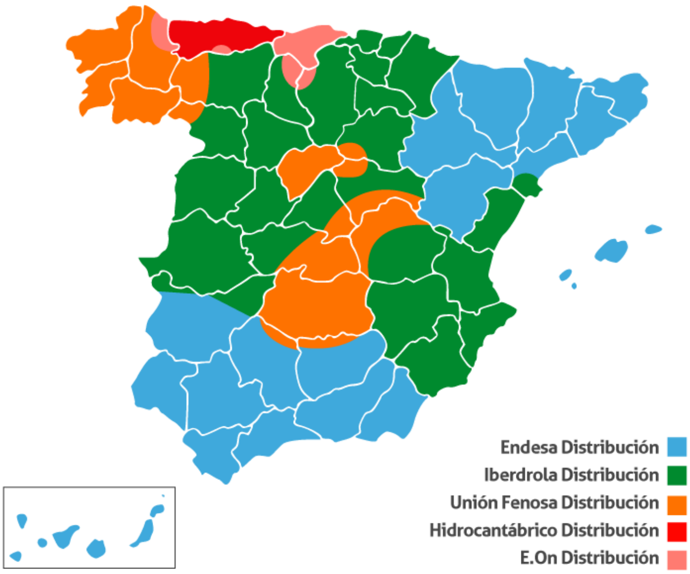


Figure 27 – Main DSOs per zone [429]

8.4.5.3.3 Retailing

This activity in Spain is regulated in Articles 46 and 47 of the Law 24/2013 of 26 December 2013 and in articles 70 to 74 of the Royal Decree 1995/2000.

There are 321 retailers in Spain [430]. In the following table are showed the most important ones:

Supplier	Number of supplies	%
Iberdrola Clientes, S.A.U.	6.448.425	38,2
Endesa Energía S.A.	5.184.265	30,7
Grupo GAS NATURAL FENOSA	2.272.860	13,5
Grupo EDP	840.193	5,0
Viesgo Energía, S.L.	409.571	2,4
Subtotal main energetic groups	**15.155.314**	**89,8**
CHC Energía, S.A.	427.186	2,5
Fenie Energía, S.A.	249.329	1,5
Clidom Energía, S.A.	72.688	0,4
Comercializadora Eléctrica de Cádiz, S.A.	61.579	0,4
Estabanell y Pahisa Mercator, S.A.	51.978	0,3
Audax Energía, S.A.	48.809	0,3
Rest	813.504	4,8
Subtotal others	**1.725.0734**	**10,2**
Total amount of supplies	**16.880.387**	**100**

Table 35 – Retailing market share (31/12/2016) [431]

8.4.5.3.4 Generation

This activity in Spain is regulated in Title 4 of the Law 24/2013 of 26 December 2013. Electricity generation is controlled by the same companies as in the Distribution field [432].

Producers whose installed capacity is higher than 1MW, may participate in the market. If their power is lower, they must act through a selling agent.

8.4.5.4 RES generation

The scarcity of deposits of fossil fuels in the Spanish territory has made Spain an importing country of energy resources. In the following picture is showed the evolution of energy dependency in Spain from the year 2000 to 2014. It shows that this dependence has always been higher than 70%.

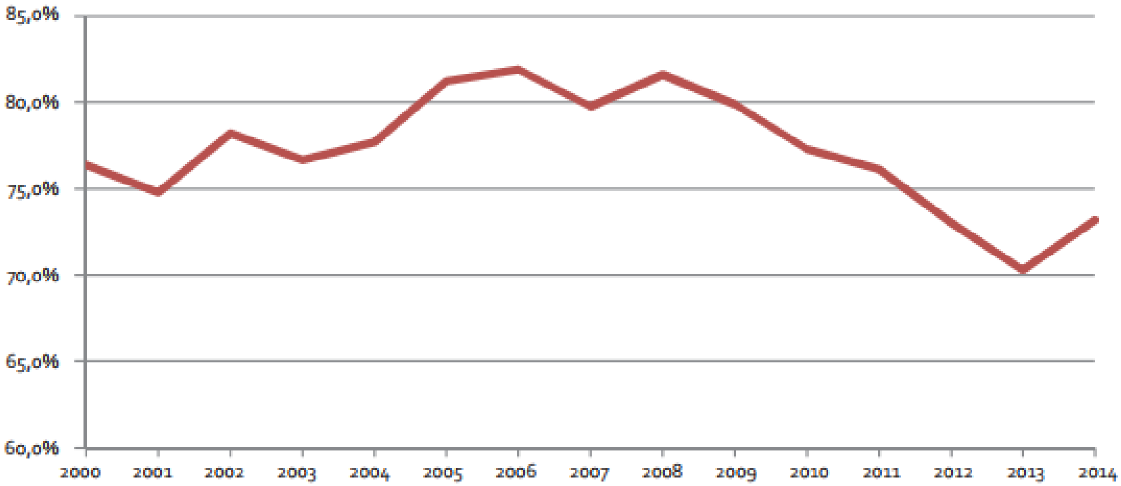


Figure 28 – Evolution of the energy dependency [433]

This situation can and must be reversed thanks to renewable energies, especially considering that Spain is the European country with the highest solar irradiance per square meter.

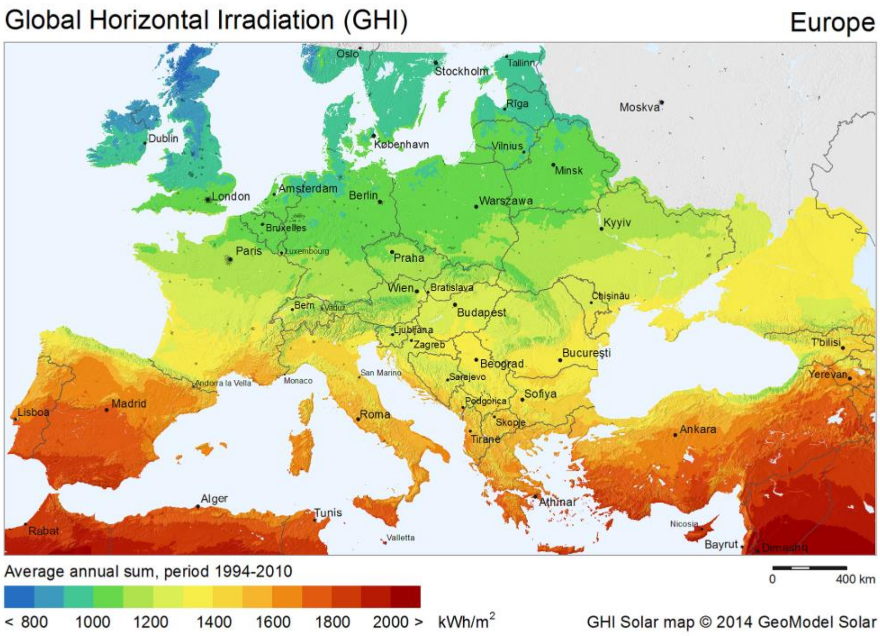


Figure 29 – Global Horizontal Irradiation in Europe [434]

The Renewable Energies had a considerable development until 2008, favoured by the production incentives set by the Government, with the objective of meeting the 2020 horizon requirements. These incentives have now disappeared.

The production of renewable energy is regulated by Royal Decree 413/2014. Renewable energy represented in 2016 more than 45% of installed capacity (100,059 MW) and almost 39% of the energy produced (258,787 GWh) [435].

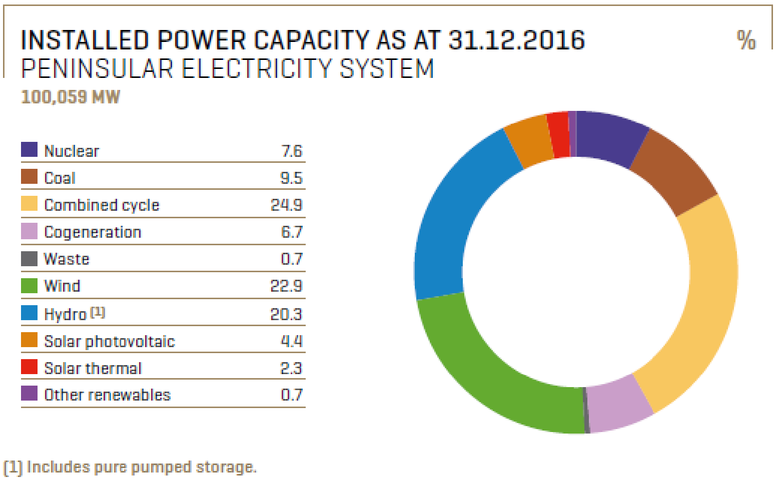


Figure 30 – Installed power capacity [435]

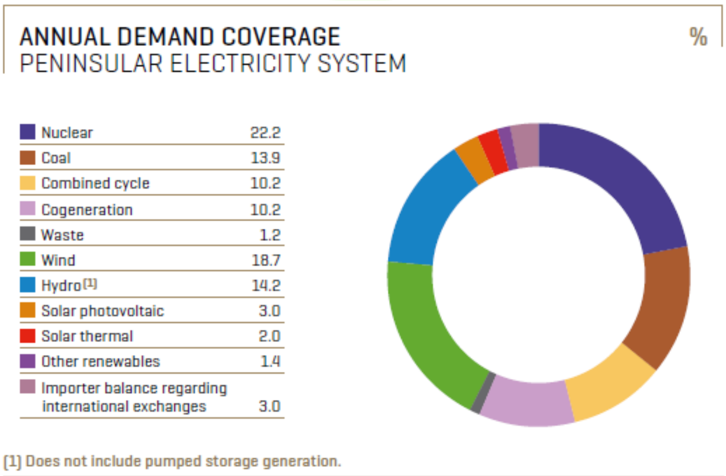


Figure 31 – Annual demand coverage in 2016 [435]

As can be seen in the previous images, the most important renewable energies in Spain are wind, hydro and solar.

8.4.5.4.1 Wind

Spain is in the second place of European countries with more installed wind power (behind Germany) and in fifth place if we talk about generation. Wind energy is already the second most used type of energy in Spain. However, the installed capacity has remained practically unchanged since 2012. In this technology, stands out the region of Castilla y León, which provides almost 23% of wind energy generated in Spain [436].

8.4.5.4.2 Hydro

Hydro had traditionally been the main source of renewable energy, but in 2009 wind power surpassed it. Spain is the fourth country with more hydraulic power and the fifth if we speak in terms of generation. However installed power has remained practically unchanged since the beginning of the century. In this technology, stands out again the region of Castilla y León, which provides more than 30% of the hydro energy generated in Spain [436].

8.4.5.4.3 Solar

According to the rest of European countries, Spain is in fourth place in both installed solar power and produced solar energy. However, the installed solar power (both thermal and photovoltaic) has remained practically unchanged since 2013. In photovoltaic solar, stands out the region of Castilla la Mancha, that supposes more than 20% of the photovoltaic energy produced. According to solar thermal, only six regions have facilities of this type. The region of Andalucía stands out providing 43.4% of the solar thermal energy produced [436].

8.4.5.4.4 Self-consumption

No one can speak about self-consumption in Spain without mentioning the Royal Decree 900/2015 that regulates this activity. This Royal Decree imposes a series of obstacles to self-consumption that slow down its development. The most important ones are: [437]

- The well-known among Spaniards as "Tax sun." A tax levied on consumers with a contracted power greater than 10 kW and connected in turn to the electricity grid. This decree contemplates two types of taxes.
  - By installed power (€/kW): It is applied in cases where the installation has batteries that allow to reduce the power contracted with the retailer.
  - By self-consumed energy (€/kWh).

  The exception of payment to consumers of less than 10kW could be revised retroactively, so even small consumers have a great risk when installing a photovoltaic panel, due to a photovoltaic installation takes several years to be amortized.
- The decree does not contemplate the net balance.
- The associations of self-consumers are forbidden.

It is counterproductive that a country with this solar potential slows down the advance of self-consumption, so a change of legislation, as in the case of Portugal and Germany, is urgently required. In fact, a report of the company PwC [438] explains that with a legislation without hindrances, the self-consumption would increase 4 times its current production (4GW to 16.8 GW). In addition, if the energy surplus were also rewarded, the self-consumption would be multiplied by 10 (4GW to 39 GW).

8.4.5.5 Market penetration of smart metering

Order ITC / 3860/2007 of December 28, 2007 (and the modifications made by Order ITC / 3860/2007 of February 16, 2012) establishes that measuring equipment in supplies with a contracted power of less than 15 kW, must be replaced by new equipment allowing remote management before 1 January 2019.

This replacement is being carried out with the deadlines established by the regulation, so everything indicates that by the end of 2018, the target will have been met. The following image shows the evolution of the implementation of Smart meters between December 2015 and June 2016.

8.4.5.6 Market penetration of electric vehicles

In Spain, 4,750 electric vehicles were sold in 2016 (51.5% more than in 2015), increasing its number to 11,000. This is an extremely low figure if we consider that the car park in Spain is about 22 million cars [439]. The number of electric charge stations hardly exceeds 2000 and most of them are in the cities. So, the electric mobility between different points of the Spanish geography is not yet widespread [440].

The Spanish government is promoting some measures to increase the implementation of the electric vehicle as the MOVEA plan. This plan provides financial incentives for the purchase of electric cars and recharging points. At the regional level, we also find measures to favour the electric vehicle. For example, in the Valencian Community (region where the pilot site of Enercoop is located), some aids have been promoted for the purchase of recharging stations [441].

The transport sector is the activity that emits more greenhouse gases in Spain. In the last 15 years the sector has reduced its emissions by 8%, while the sectors of industry and electricity production have reduced their emissions by around 31%. Therefore, it is urgent to establish more ambitious policies to support the electric car, and most of all if we want to achieve the goals set by the European Union [439] (only 50% of vehicles powered by conventional fuels in 2030 and 0% by 2050).

8.4.5.7 Market penetration of Demand Response services

Active Demand Management is a tool that can contribute to a more efficient use of the grid, but it is necessary that the regulatory agencies and governments develop the mechanisms for their implementation. In Spain, this regulation does not exist, so there is no Aggregator figure (the one that coordinates and manages consumer demand and offers this management service to the system). In Spain, the role of aggregation of demand is only found in the normative framework of the electric vehicle through the role of the Charge Manager.

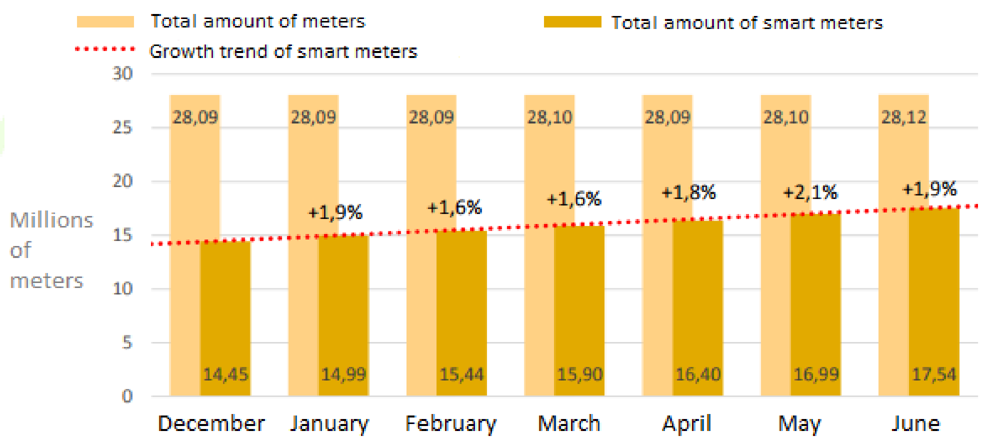


Figure 32 – Smart metering deployment [431]

8.4.5.8 Market penetration of smart homes systems

According to a study made by *Context*, only 27% of Spanish homes can be considered Smart Homes, understanding Smart Home as a home that includes appliances and smart devices that can be accessed or can be controlled using smart devices or systems. However, the level of knowledge has improved. While in 2016 only 34% of people recognized the term Smart Home in our territory, this year this figure will reach 48% [442]

8.4.6 Smart metering systems

At the EU level, smart metering systems or intelligent metering systems are understood as an electronic system that can measure energy consumption, providing more information than a conventional meter, and can transmit and receive data using a form of electronic communication [443]. Spain's legislative portfolio related to smart metering systems is fairly extensive. Firstly, the Royal Decree 809/2006 of 1 July established that, starting from 1 July 2007, new electricity meters shall enable differentiation of consumption in different time frames as well as remote management for consumers with a contracted power below 15 kW. The Royal Decree 1110/2007 of 24 August indicated that all household electricity meters shall be smart meters. Furthermore, this Royal Decree also defined the functionalities of the smart metering systems [444].

The Royal Decree 1634/2006 of 29 December and the Ministerial Order ITC/3860/2007 of 28 December chart the smart metering replacement plan in Spain (2011-2018). These legal instruments frame the modalities under which the effective roll-out of smart meters for roughly 28 million points of supply will be performed. The smart metering replacement is carried out by the DSOs (Endesa, Iberdrola, Gas Natural Fenosa, EDP and Viesgo being the most important operators). These measures will affect electricity consumers with a contracted power inferior to 15 kW. The replacement of conventional meters by smart meters is expected to be completed by end of 2018. As of June 2016, up to 17.54 million smart meters had already been installed according to the estimations of the NRA [445]. This means that smart meters currently account for more than 62% of existing meters in Spain.

Another regulation worth noting is the Royal Decree 216/2014 of 28 March setting final prices for electricity consumers according to real metering in hourly basis. The Royal Decree 216/2014 makes it mandatory for distributors to provide hourly energy consumption data. This regulation foresees two scenarios: 1) where the household already counts with a smart meter and 2) where the household still relies on a traditional meter. If there is a smart meter, consumers can choose an energy billing based on their real hourly consumption data. If there is a conventional meter, the energy invoice will be based on the average national hourly cost, with variable prices. The Royal Decree 216/2014 envisages an alternative for both situations, insofar as the household has a contracted power below 10 kW: a fixed price for one year of energy consumption [446]. As to households endowed with a smart meter, some pundits suggest that pricing based on hourly real consumption data is too progressive for the present functionalities of smart meters in Spain. Indeed, this type of billing presupposes the capacity to handle a substantial amount of data as well as to manage frequencies of submitting and processing of information much higher than those framed by the applicable law until now [447].

Metering activity	Regulated
Deployment strategy	Mandatory
Responsible party for implementation and ownership	DSO
Responsible party for third party access to metering data	DSO
Financing of the roll out	Network tariffs and smart metering rental fees

Figure 33 – Smart metering regulation in Spain [448]

Insofar as energy security considerations in Spain are running in parallel with policies issued by the European Commission, it is advisable to grasp the rationale behind the advocated deployment of smart meters across the EU. Generally speaking, the anticipated roll-out of roughly 200 million smart meters by 2020 in the Member States' electricity industries falls under the objective to promote energy efficiency. The EU has set itself the challenge to hit a 20% and 27% energy savings target by 2020 and 2030, respectively. The premise is that more efficient energy use can generate multiple positive outcomes. Energy efficiency can cut energy bills for European citizens, reduce CO_2 emissions, and foster energy security by alleviating energy dependency on external suppliers [449].

The Spanish regulations set out above are in accordance with the approach adopted by the European Commission in smart metering. The Third Energy Package calls for Member States to engage in the long-term welfare of consumers by implementing smart metering systems in their jurisdiction. More specifically, the Energy Efficiency Directive [450] advocates the evolution of energy services through data from smart meters, demand response and dynamic prices. In order to guide Member States in this smart-metering transition, the Commission Recommendation 2012/148/EU [451] outlines a series of functionalities to ensure technical and commercial interoperability, or at least ensure the possibility to add such functionalities at a later stage [452].

Remarkably enough, Spain has managed to comply with all the minimum functionalities outlined in said recommendation except with recommended functionality (b) [448]. This functionality calls for a sufficient frequency at which consumption data can be updated and made available for the consumer (and third party designated by the consumer) to achieve energy savings. The recommendation claims that an update rate of every 15 minutes is needed to this end. The European Commission itself recognises that this suggested feature is the most challenging one. However, the European Commission also deems this functionality as the most effective as it would allow consumers to make informed decisions on their consumption patterns [452]. This bottom-up approach places consumers at the helm as they will be contributing to the efforts to promote energy efficiency and security.

Smart metering and billing are critical to maximise demand response. Demand response is even more important in the light of the expected increase in the share variable renewable energy integrated in the national grid. Energy efficiency and demand response are better-suited avenues to balance demand and supply rather than keeping in operation or manufacturing new power plans and network lines [453]. In that vein, real-time energy consumption data is key to maximise energy efficiency and consumer savings. By rendering them more aware of their consumption trends, consumers are able to adjust their behaviour in order to save electricity. It is estimated that household energy consumption could be reduced to up to 9% as a result of the roll-out of smart meters [454]. Smart meters are streamlining the paradigm shift in the electricity market by making the sector more consumer-centric. In other words, smart metering systems allow consumers to reduce their electricity bills through demand response.

8.4.7 Data protection

The Data Protection Law 15/1999 of 13 December protects individuals with regard to the processing and the free movement of data. The Royal Decree 1720/2007 of 21 December develops the Data Protection Law 15/1999. Spain's data protection regime is one of the most severe in the whole of the EU. This is so as penalty fines are among the heftiest (up to EUR 600.000 per infringement) [455]. Furthermore, the national data protection authority, the Spanish Data Protection Agency, is well known for its strict enforcement of data protection rules [456].

The Data Protection Law 15/1999 requires data controllers to draft an internal security policy clarifying the technical and organisational measures to be implemented by its staff. The nature of these measures will be based on the security level (low, medium and high). In turn, the security level is ascertained pursuant to the sensitivity of the data being processed or the nature of the entity in question. By data controller, the Data Protection Law 15/1999 understands any individual or legal person who controls and is responsible for the storage and use of personal data on a computer or in structured manual files. The data processor is the entity that processes the data on behalf of the data controller as a result of their relationship. Were the processing of personal data to be outsourced, so that the processing is exclusively carried out by the data processor, the data controller may be entitled to delegate the obligation to outline an internal security policy to the data processor. The Data Protection Law 15/1999 charts the measures that must be implemented under each security level [457].

Any individual wishing to create or amend personal data files must register with the Spanish Data Protection Agency. This registration is free of charge. The applicant will have to fill in a form available on the website of the Spanish Data Protection Agency before engaging in the processing of personal data. The notification of data files entails no costs either. The Data Protection General Registry will approve notifications provided that they meet the necessary requirements. Additionally, a data protection officer must be appointed if the security level is medium or high according to the Data Protection Law 15/1999 [458]. The Spanish Data Protection Agency congratulates itself for the compliance with the prescriptions of the Data Protection Law 15/1999 in terms of registration. Indeed, the Data Protection Agency has observed an upswing in the number of registrations, especially from medium-sized companies as well as independent professionals [459].

The Royal Decree 216/2014 of 28 March is the relevant legal source that frames the obligations in terms of consumption information to be submitted by DSOs to consumers. For end users that already have a smart meter installed, the Royal Decree 216/2014 requires DSOs to publish hourly consumption data. Moreover, DSOs provide a website that permits their customers to consult and download their hourly consumption data (after billing). Interestingly, DSOs also offer the possibility for consumers to download their consumption profile made available to the energy supplier for billing purposes in comma separated values (CSV) and Excel flat-files. Data stemming from smart meters are stored in the DSOs' metering managing system. DSOs submit data to energy suppliers through secure File Transfer Protocol (FTP). Energy suppliers can only access the data pertaining to their customers. Energy suppliers may solely access the consumption profiles of other customers than their own if they have been granted consent [460]. In conclusion, smart metering data is the property of the DSOs but distributors are required to submit these data to end users for consultation and to energy suppliers for billing purposes [447].

Another legal basis worth noting is the Royal Decree 1074/2015 of 27 November. The Royal Decree 1074/2015 amends some aspects related to the data to be stored in the Supply Points Information System or "*Sistema de Información de Puntos de Suministro*" (SIPS) which is regulated by Article 7 of the Royal Decree 1435/2002 setting the basic conditions for acquisition of energy contracts and access to low voltage networks. The SIPS is a database managed by the DSOs. Only the NRA, the CNMC, and energy suppliers are entitled to access this database. The SIPS includes information, which is complete and regularly updated, related to the supply points connected to the networks and transport networks of the areas that each particular DSO is responsible for. The purpose of the SIPS is to trigger greater competence in the reduced market of electricity supply. The SIPS does so by facilitating the necessary consumption data to prompt the emergence of new energy suppliers whilst safeguarding consumer privacy [461]. The amendment introduced by the Royal Decree 1074/2015 excludes from the SIPS data corresponding to consumer hourly load curves. This is so as consumption data, collected by DSOs through smart meters, are treated as personal data which calls for the necessary protection. In that vein, energy suppliers are precluded from having access to any information, other than that of their own customers, which can lead to the direct identification of the supply point incumbent (such as supply point location, household address, forename and surname, for instance) [461].

The safeguard of consumer privacy is a question of the utmost importance, especially in the context of the European internal energy market. The effective deployment of smart metering systems must be subject to the adequate management of consumption data streams. Data protection and consumer privacy are imperative as they constitute basic requirements for the success of the large-scale deployment of smart meters. In turn, smart meters represent one of the most promising tactics to encourage energy efficiency as a means to tackle energy security challenges.

The pace of innovation has enabled smart grids to integrate information and communication technologies capable of monitoring energy consumption almost in real time. Smart meters are the Advanced Metering Infrastructure (AMI) that allow this insight. Considering the volume and sensitivity of the data they process, smart meters need to feature secure storage systems as well as backup and contingency policies. Analysing the smart metering data of end user enables to derive surprisingly precise observations about their private lives: time spent at home, working schedule, holidays, use of particular appliances, their habits, and so on. Such information is valuable for third parties for a number of reasons. The practice of consumer profiling puts the privacy of consumers at stake [462].

8.4.8 Electric vehicles

Road transport largely outweighs the consumption of alternative transport modes (air transport, railways and marine transport) as it represents 80% of the final energy consumption in Spain. The transport industry in Spain is characterised by prominent vehicle use, an ageing fleet and a low fraction of freight transport carried out by railways. The transport sector relies on oil for over 90% of its energy needs. Thus, the sector impinges on environmental protection and offers significant margin for improvement in terms of energy efficiency [374]. In light of the above, the emergence of Electric Vehicles (EVs) appears as the salient path to evolve traditional transport patterns which, at present, squarely rest on hydrocarbons. The central government has been issuing regulations and policies geared towards advancing a “smarter” and more sustainable transport industry since 2003 [463].

A number of strategies to support the purchase and deployment of EVs in Spain must be acknowledged. For instance, two programmes implemented by the Ministry of Industry, Energy and Tourism, together with the IDAE, seem to have been instrumental to that aim over the last years. These policies are the Efficient Vehicle Incentive Program or “*Programa de Incentivos al Vehículo Eficiente*” (PIVE) and the MOVELE program, that encourages electric mobility. The PIVE program was elaborated within the framework of the 2008-2012 Action Plan of the 2004-2012 Energy Savings and Efficiency Strategy (E4). The objective of the PIVE program is the replacement of ageing vehicles with new, less contaminating, and more efficient units. Grants under the PIVE are ineligible for incumbents who already benefit from another subsidy awarded by the Spanish government for purchasing vehicles [464]. As to the MOVELE program, it was established with the ambition to demonstrate the technical and energy feasibility of electric mobility in urban environments. To do so, the MOVELE program set itself a two-fold objective to attain over the 2009-2010 time frame. Firstly, the MOVELE program advocated to introduce up to 2.000 EVs in the Spanish fleet. Secondly, over 500 charging points for EVs were set to be manufactured in different cities in Spain [465].

In addition to the above blueprints, the central government launched in April 2010 the “Integral Plan for the Promotion of Electric Vehicles” which comprised an “Integrated Strategy for EVs 2010-2014” promotion in order to have one million Hybrid and Electric Vehicles (H&EVs) on Spanish roads by the end of 2014 [463]. More recently, the “Impulse to the Alternative Energy Vehicle Plan" or “*Estrategia de Impulso del Vehículo con Energías Alternativas*” (VEA) was adopted in June 2015. At the time of writing, the 2017 MOVEA plan is the latest development under the VEA strategy with a total budget of EUR 16.6 million managed by the Ministry of Economy, Industry and Competition. [466] The VEA strategy endeavours to harmonise the profusion of domestic policies framed with the intention to support the acquisition of more efficient vehicles [465]. The final objective is to maximise these different national schemes in order for Spain to meet its 2020 climate and energy goals at the EU level [467].

The Sustainable Economy Law 2/2011 of 4 March endorses research, development and innovation in a number of fields such as renewable energy, energy saving and efficiency in the transport and sustainable mobility areas [464]. The Sustainable Economy Law 2/2011 enjoins the central government, the autonomous communities as well as local municipalities to adopt the necessary measures to further the implementation of plug-in H&EVs [468]. Therefore, all public administrations are mandated by law to contribute to the advent of H&EVs by *inter alia* endowing them with the necessary renewable energy applications and facilities associated to this type of vehicles. In that sense, the Royal Decree 647/2011 of 9 May defines the role of the load system manager in terms of charging services for EVs. Moreover, the rights and obligations attached to energy charging services for EVs are also depicted in the Royal Decree 647/2011. The Electricity Sector Law 24/2013 further regulates the figure of the load system manager. A load system manager is defined as a commercial society that, while being a consumer itself, is entitled to resale electricity for charging services [469].

The Royal Decree 1053/2014 approved the Complementary Technical Instruction (ITC) BT-52 “Facilities for special purposes. Infrastructure for recharging EVs.” The Royal Decree 1053/2014 states that public areas must be endowed with the necessary facilities to supply charging points for the number of parking spaces foreseen in both municipal and supra-municipal sustainable mobility plans. The Royal Decree 1053/2014 goes on to assert that newly-constructed buildings and car parks must be equipped with specific electric facilities in order to ensure the charging of EVs. The basic requirements for these charging facilities vary depending on the type of parking space. For collective parking spaces of private use, minimum pre-installations are required so that parking-space owners are able to charge their EVs without incurring in additional costs. As to public cark parks or private fleet car parks, they must feature the necessary facilities to supply one charging point for every 40 parking spaces [465]. The Electricity Sector Law 24/2013 also refers to electricity charging services. The main purpose of electricity charging services is to supply power through the vehicle charging services and storage batteries under the adequate conditions to enable charging to be completed in an efficient manner and at the minimum cost for the user as well as the electricity system [470].

The most recent legislative development in terms of charging infrastructure has been the adoption of the Royal Decree 639/2016 of 9 December establishing a framework of measures for the implementation of alternative fuel facilities. The Royal Decree 639/2016 interprets alternative fuels as energy fuels or sources which replace, at least partly, conventional fossil fuels as sources to power transport and which have the potential to improve the environmental performance of the transport industry. This includes electricity, hydrogen, biofuels, synthetic and paraffinic fuels as well as natural gas among others [471]. As to charging points, the Royal Decree 639/2016 addresses two questions. Firstly, all charging points which are publicly accessible must offer the possibility for users to sporadically charge their EVs without being contractually bound to the electricity supplier or the load system manager. Secondly, the power supply for charging points must be able to be contracted with other energy suppliers than the one providing the electricity to the building or premises where the charging point is located [472].

It transpires from the above that regulatory measures to promote EVs in Spain are focused to a great extent on developing charging infrastructure. This seems to be a sensible course of action as empirical evidence suggests that the number of charging stations is a solid predictor of EV adoption [473]. Financial incentives such as direct grants undoubtedly represent a welcome nudge to the EV industry as well. Nevertheless, EV-specific factors represent more reliable predictors of EV adoption rates than broader socio-demographic variables such as income, education level or environmentalism [464]. Therefore, manufacturing the necessary charging infrastructure under the adequate legal architecture is crucial to facilitate the market penetration of EVs.

In terms of financial incentives, Spain has mobilised several initiatives, such as the PIVE or MOVELE programs for instance, to support the industry in the form of direct grants to individuals wishing to purchase H&EVs. In that sense, the substantial assortment of grant schemes to favour EVs seems to overlap in time as well as, arguably, thematically (*e.g.* the PIVE aims to replace ageing vehicles with more efficient units while the MOVELE program seeks to encourage the introduction of EVs in the Spanish fleet). This overlap distorts the regulatory framework as it results in a relative dearth of clarity which wanes the reach of these strategies. Furthermore, these supporting schemes are carried out by several different actors (*e.g.* assistance under the PIVE and MOVELE programs are managed by the IDAE while the 2016 MOVEA plan was organised by the Directorate General of Industry). In this sense, coordinating the array of national EV-supporting policies in order to maximise their impact emerges as the top priority [465].

A comparison with the regulatory incentives offered in other nations reveals that there are alternative policies worth exploring to democratise EVs. Being an arguably novel product in citizens' transport schemes, the EV industry largely relies on governmental inducements to break through consumer markets. For example, countries such as Korea, the Netherlands, Portugal, or the United States (US) have adopted EV-specific entry rules to urban access areas. In France, Sweden and the United Kingdom (UK), EVs enjoy preferential parking areas. Other states such as Denmark or Germany encourage the use of batteries [464]. Conversely, the regulatory framework in Spain is primarily concerned with direct economic incentives and reinforcing the charging infrastructure. Having said this, Spain's current policies seem well-judged considering that the scarcity of charging points in the country has been discerned by some studies as the first and foremost hurdle to surpass [474]. Moving forward, resorting to other regulatory advantages for EVs, such as granting these vehicles preferential parking areas for instance, could constitute further ways to enhance EV adoption rates in Spain.

EVs will play a crucial role in the electricity architecture of the future, particularly in terms of distributed energy storage systems as EVs can integrate storage capacity in smart grids. Indeed, vehicle-to-grid (V2G) systems allows EVs to power and to be powered by the grid. Further, V2G permits the storage of electricity so that it can be used in hours of low production [475]. The promotion of EVs can bring about several benefits.

Smart charging during valley hours contributes to flatten the demand curve; EVs will help optimise electricity grid surpluses and will enable a greater share of RES to be integrated in the domestic grid. In addition, the deployment of EVs will assist in reducing CO_2 emissions, mitigating dependency from foreign energy supplies as well as improving air quality and curtailing noise pollution in cities. [476] The Spanish Transmission System Operator (TSO), Red Eléctrica de España, estimates that, in the coming years, if smart charging is effectively carried out during valley hours, the national electricity system will be able to power an EV fleet equal to one quarter of the total number of vehicles in Spain without additional costs in the transmission grid [476]. Therefore, EVs and their smart charging treasure a phenomenal potential to reinforce the national grid. In this sense, certain technological products catered by the WiseGRID project could play their part by rendering EV-specific challenges more user-friendly. For example, Wise EVP (Electrical Vehicle Platform) is an application which will be used by vehicle-sharing companies and e-vehicles fleet managers (*e.g.* taxi companies) to optimise activities related to smart charging and discharging of the EVs and reduce energy billing. More importantly in this context, the application WG Fast V2G makes it possible to use EVs as dynamic distributed storage devices, feeding electricity stored in batteries back into the energy system when needed.

The need to foster sustainable transport patterns for urban mobility is all the more urgent considering the towering proportion of hydrocarbons that currently fuels the transport industry in Spain. The modal shift to EVs is essential to decarbonise the Spanish transport sector which is the largest in terms of final energy consumption. If Spain is to meet its 2020 and 2030 EU goals in terms of CO_2 emissions, ambitious thresholds will have to be attained. Indeed, it is estimated that Spain should have 300.000 EVs by 2020 and up to 6 million in 2030 in order to reduce its CO_2 emissions in accordance with Brussels prescriptions [477]. This will be a lengthy and progressive transition requiring prominent investment. To put things in perspective, in 2015 there were 6.500 EVs in Spain which represented a market share of 0.2%, well below the EV penetration rates displayed by Norway (23%) and the Netherlands (10%) which are the front runners on this particular aspect [477].

8.4.9 Demand response

The concept of aggregator for demand response does not exist in Spanish regulation. Currently, there is only one scheme allowing explicit demand response: the interruptible service. This boils down to the possibility for the TSO to curtail energy consumption by issuing a power reduction order to major industrial consumers that provide this service. The interruptible service is thus a demand-side scheme managed by Red Eléctrica de España. The plan represents an emergency mechanism for contingencies where there is an imbalance between generation and demand. This procedure seeks to offer flexibility and a swift response to the needs of the TSO in such an eventuality [478]. Although aggregators are not formally recognised by the Spanish regulatory framework, the role of “representatives” exists. These “representatives” sell energy in the name of their “representees” and build balancing perimeters thereby reducing deviations from programme and the ensuing penalties [302]. Having said this, Red Eléctrica de España and other industry stakeholders have presumably started conversations for the future implementation of these services to flexible demand [479].

Figure 34 – List of balancing market products in Spain presents the electricity market products or sub-products, and underlines where demand response and aggregation are available.

ENTSO-E's terminology	TSO's terminology		Tot. Capacity Contracted[308]	Demand Response Access & Participation	Aggregated Demand Response Accepted
FCR	Primary Control		Not applicable	✗	✗
FRR	Secondary Control		2.559 GWh	✗	✗
RR	Tertiary Control		4.753 GWh	✓	✓
RR	Deviation Management		2.763 GWh	✗	✗
	Technical Constraints (PDBF)		≈6.500 GWh	✓	✗
	Real-Time Constraints		≈1.800 GWh	✓	✗
RR	Power Reserve		2.109 GWh	✗	✗
	Secondary Regulation Band		1.197 GWh	✗	✗
	Interruptible Mainland[309,310]	5 MW blocks	1.430-1.970 MW	1.430-1.970 MW	✗
		90 MW blocks	630-1.170 MW	630-1.170 MW	✗
	Interruptible Islands		≈50 MW	≈50 MW	✗
	Capacity Mechanism		≈2.500 MW	✓	✗

Figure 34 – List of balancing market products in Spain [302]

Aggregated demand response does not have access to balancing markets. Only consumers with contracted power higher than 5 MW have access to the interruptible demand service managed by Red Eléctrica de España. It is limited to large industrial consumers, connected to the high voltage grid. Industrial energy consumers involved in this scheme come from the construction industries (such as steel, concrete and glass, for instance), other material factories (paper, chemicals and so on) and desalinisation plants (in the Canary Islands). The participants must have an ICT system, which links them directly to the TSO and not to the DSO where they may be connected. If, however, they are connected to the DSO's grid, the DSO does not participate in these strategies [302].

8.4.10 Electricity storage

Electricity storage in Spain is still negligible in comparison with the current installed power capacity. Reversible hydraulic reservoirs concentrate more than 90% of electricity storage today in Spain [70] so it is the main source of electricity storage in the country. The total hydro pump storage capacity in Spain is 4.749 MW which represented 4% of installed capacity in 2016 [480]. The central government aims to reach 8.100 MW of storage capacity in 2020 [481].

In order to develop other sources of electricity storage in the national territory, Red Eléctrica de España has launched the "*Almacena*" project, consisting of an electrochemical energy storage solution connected to the grid, as well as the installation of a prototype flywheel in the Canary Islands [482]. In addition, Endesa has developed a pioneer project introducing three different types of energy storage plants (superconductor, flywheel and electrochemical) in three different Canary Islands as well. These types of storage have been reported to offer several benefits to the grid [481].

9 ANNEX B - BUSINESS MODELLING STATE-OF-THE-ART

9.1 OVERVIEW

The Smart Grid sector is a continuously evolving field that does not advance in one direction and can grow on many fronts. Smart Grid implementation has been developed for many years, but it is now, faced with the threat of the lack of oil and the danger of the global warming, when we are working harder to perfect these technologies and make a more efficient management of our resources.

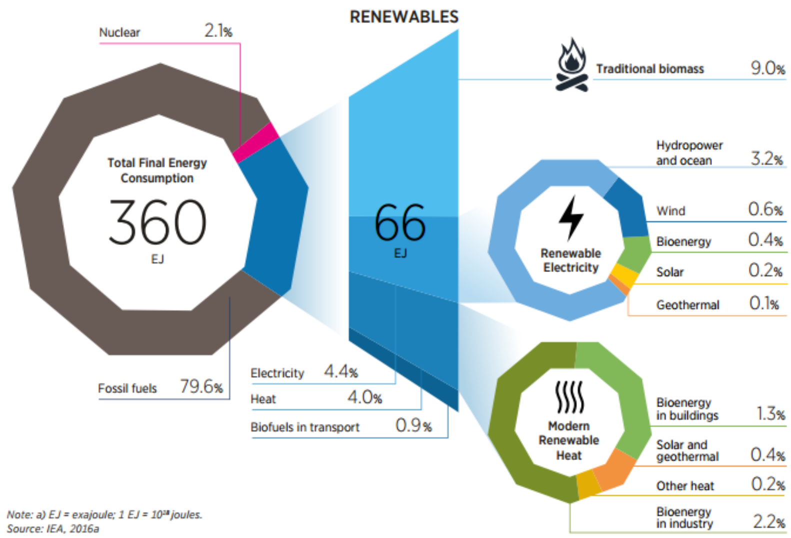


Figure 35 – Energy mix 2016 *[483]*

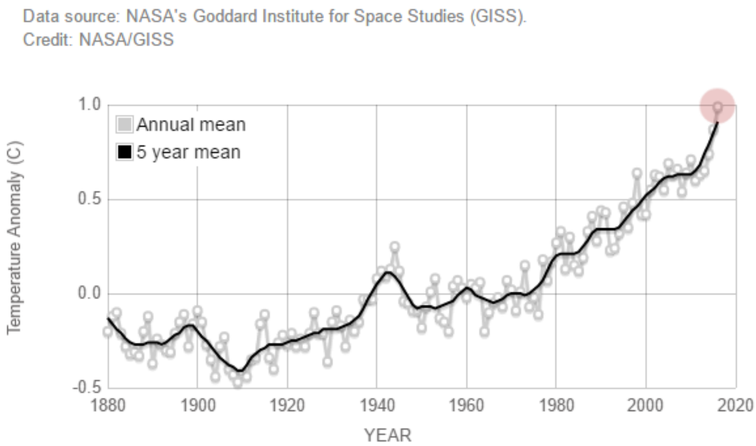


Figure 36 – Climate change *[484]*

In this new paradigm, the figure of the prosumer stands out as a key piece to achieve the goals set. Until now, the prosumer had no significant involvement in the operation of the electricity system (for example, the current Spanish legislation does not contemplate the possibility of the net balance). However, many business models are beginning to be developed to favor the prosumer's empowerment.

One of the ways in which the prosumer is going to increase his power in the electricity grid is by integrating Virtual Power Plants (VPPs) into the electricity grid. As well as to get profit from the sale of electricity surplus, VPPs can help network stability by providing ancillary services to DSOs. Currently, VPPs are not widespread and the most important one is being implemented in Adelaide-Australia, by the AGL company [485]. The company has installed batteries in 1000 households which are expected to jointly provide 5MW of peak capacity. It is estimated that each participating household may achieve a $500 reduction of its electricity bill per year. Additionally, the storage equipment is orchestrated by the Sunverge's (partner in the project) cloud-based platform and may provide grid support services. Furthermore, the Con Edison and SunPower VPP in New York [486], is the largest distributed energy storage system in USA, including 300 participating households with 1.8 MW of solar power and 1.8MW of storage capacity. The company offers the installation of a solar plus storage system at the prosumer's premises with no up-front cost, with the objective at the local level to reduce the electricity bill and provide backup energy in the case of a grid outage. Additionally, the VPP offers aggregated services to the grid, by injecting the generation in the system during the peak hours. Finally, the "VPP Intelligent Energy" company [487] composed a VPP by orchestrating the synergies between existing energy market segments. The company provides "Sales and Production Management" (SPM) services, in the sense that it trades the producers' generation simultaneously in multiple markets, including the Hungarian Power Exchange (HUPX), the balancing energy market and directly to end-users. Additionally, it provides Demand Side Management to residential prosumers for the reduction of their electricity bill, either by the more profitable utilization of their self-production or by scheduling their grid-consumption schedules.

The other main way for the prosumer to be an active part of the management of the electrical system, is through the implementation of Demand Response policies. These policies would also serve to promote the figure of the aggregator. In the following images we can see the state of implementation of these policies (both at industrial level and at the domestic level in 2015) [488].

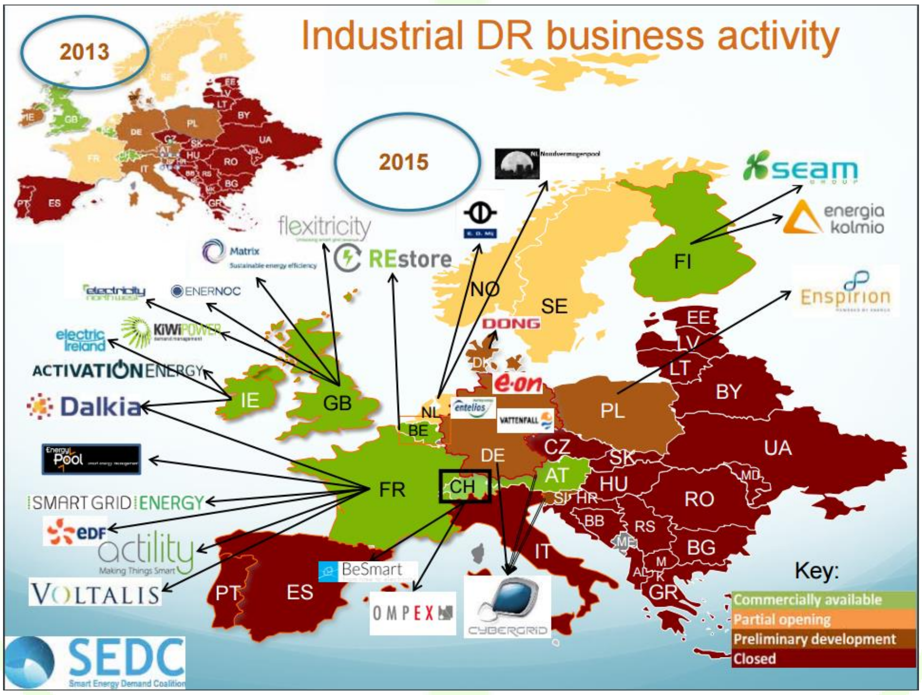


Figure 37 – Industrial DR business activity (2015) [488]

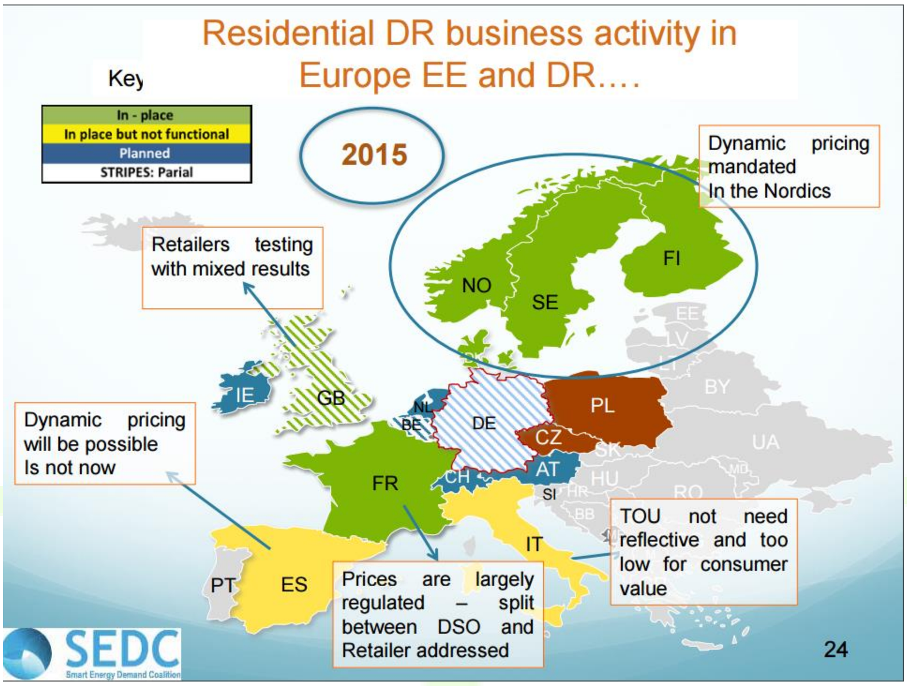


Figure 38 – Residential DR business activity in Europe EE and DR (2015) ***[488]***

These types of policies make a new unit of measure such as the *negawatt*, which is the measure that is used to quantify energy savings.

The *negawatt* makes important the concepts of sufficiency, energy efficiency and renewable production, which favors the development of ESCOs, since they can provide the user with a large number of services (such as energy audits, DER rent, energy rehabilitation, LED lighting…).

Although the business models above-mentioned are the most important in terms of prosumer involvement, there are other interesting ways to do so. One of them is the exchange of energy between a network of prosumers, which favors the increase of the collaborative economy (as has already been extended in other sectors such as lodging and transport). The European Commission is promoting projects in this direction (such as *Plug-N-Harvest*) and recently Start-ups like *Regalgrid* have developed their own energy exchange system [489].

The reflection that can be obtained from these new business models based on the small user is that the association of prosumers, produces positive synergies for the rest of the actors of the electrical system and favors the creation of Start-ups.

However, the figure of the prosumer is not the only important one in order to develop a Smart Grid. It should be remembered that the main reason why there are so many problems of operation in the electrical system and by which a greater use of renewable energy is delayed is due to the impossibility of storing the alternating current generated in power plants. For this reason, energy storage is an essential development field for Smart Grids.

The forms of energy storage (and their percentage of use) are arranged in the following tables [490].

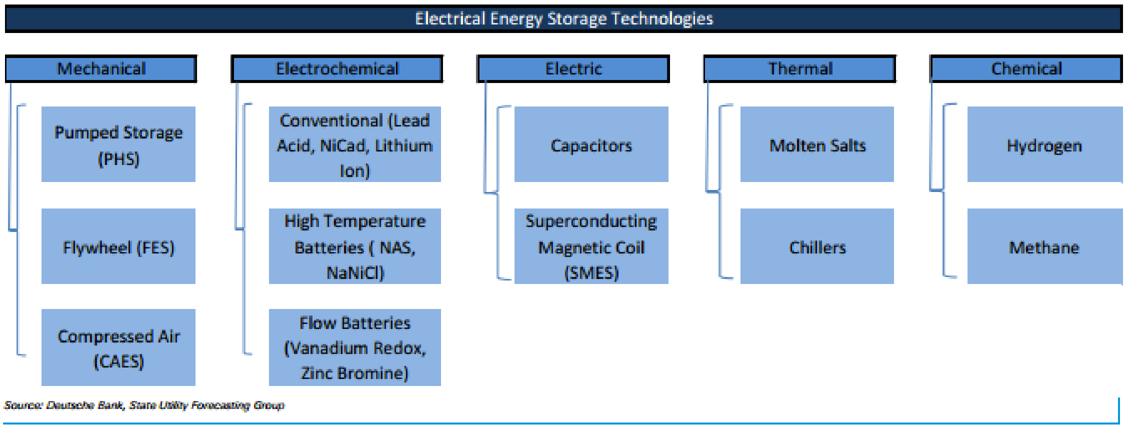


Figure 39 – Electrical energy storage technologies

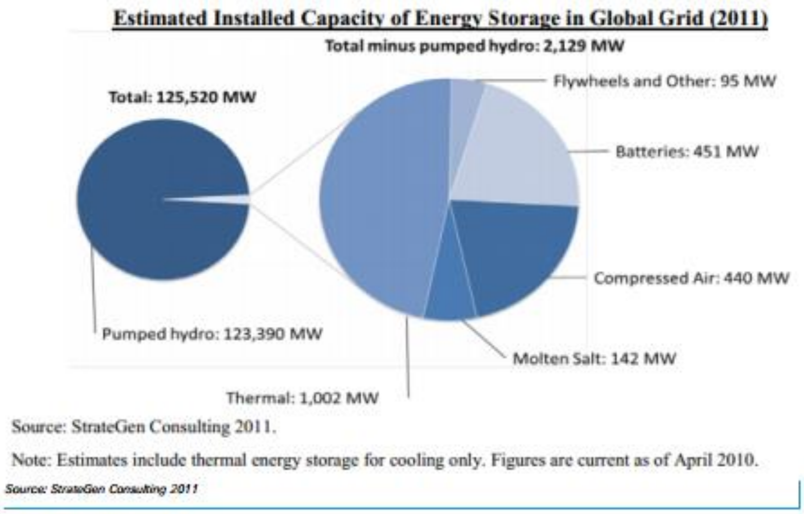


Figure 40 – Distribution of global energy storage solutions

As shown above, the percentage of energy stored relative to the one produced, is still negligible so there is a long way to go in this direction.

In this sense, the main objective of the Smart Grids is trying to increase the energy storage by means of batteries. In addition, the development of batteries inevitably entails the implementation of the electric vehicle, since the battery is the most important element of these cars. By 2015, there were 1.26 million EVs (0.1% of the total) and 1.45 million charging points [491]. It is expected that these numbers will increase substantially thanks to the initiatives of companies such as the well-known *Tesla* or the support of government agencies.

Currently, the most used batteries are those based on lithium because they have a higher energy density and a higher energy volume (which allows them to be smaller and lighter) and have no memory effect. This is leading the industry to improve the production costs of these types of batteries to make prices more attractive to customers. In 2015 lithium-ion battery prices reached 350 USD / kWh, 65% less than in 2010. They are expected to fall below 100 USD / kWh within the next ten years [492].

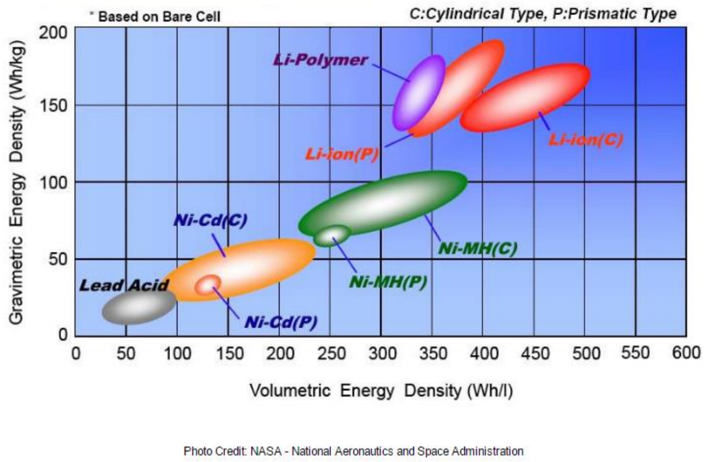


Figure 41 – Batteries comparison [493]

Nevertheless, batteries are not the only point to develop in a Smart Grid regarding energy storage. Thermal storage also has a high degree of importance. Thanks to electric accumulators or HVAC devices, the surplus of electricity can be transformed into thermal energy both domestically and industrially (which at the same time promotes the implementation of DR activities).

Although this is a good solution for energy excess, it is not the most efficient option when it comes to obtain hot water or thermal comfort. For this purpose, there are solutions at the domestic level such as the use of solar energy to get sanitary hot water or neighborhood-level solutions such as urban heating/cooling.

The latter is very important within the scope of the Smart Cities. This is because large heat generators have a 10% higher efficiency than centralized building systems and a 35% higher than domestic systems (in addition, their emissions are cleaner) [494]. It also allows renewable heat sources such as solar or geothermal. These systems have already been implemented in large cities such as New York or Moscow and new projects such as *Celsius* are also being developed in Europe [495].

Therefore, electric energy and thermal energy must go hand in hand in order to increase overall energy efficiency. Cogeneration (which is also used for district heating) is a clear example of this point. With the combined generation of electrical and thermal energy, up to 80% of the heating value of the fuel is achieved [496].

The following images show the degree of implementation of cogeneration in 2013 in Europe [497]:

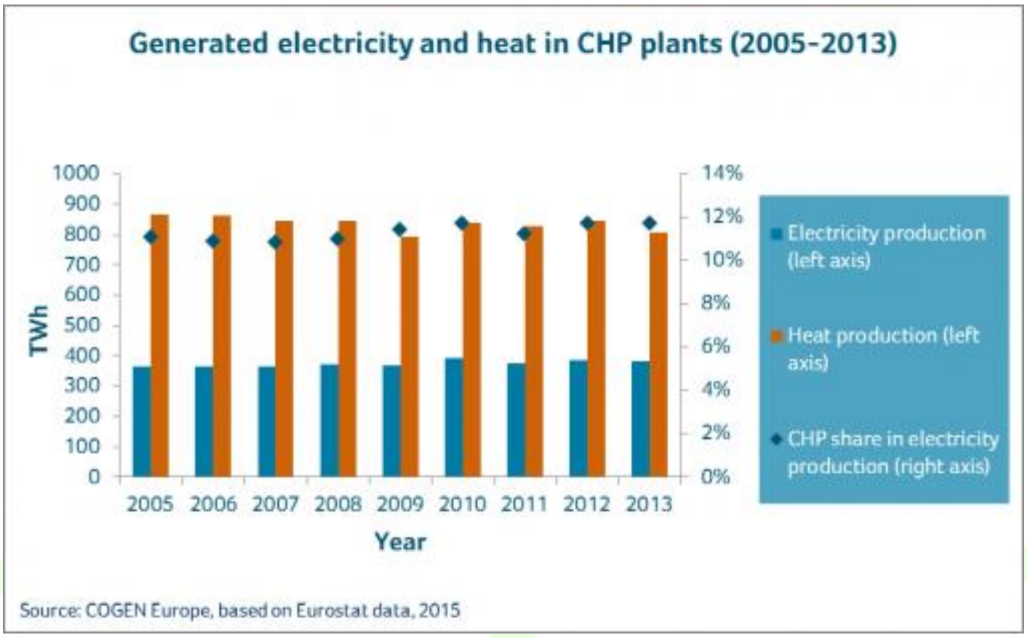


Figure 42 – Generated electricity and heat in CHP plants (2005-2013)

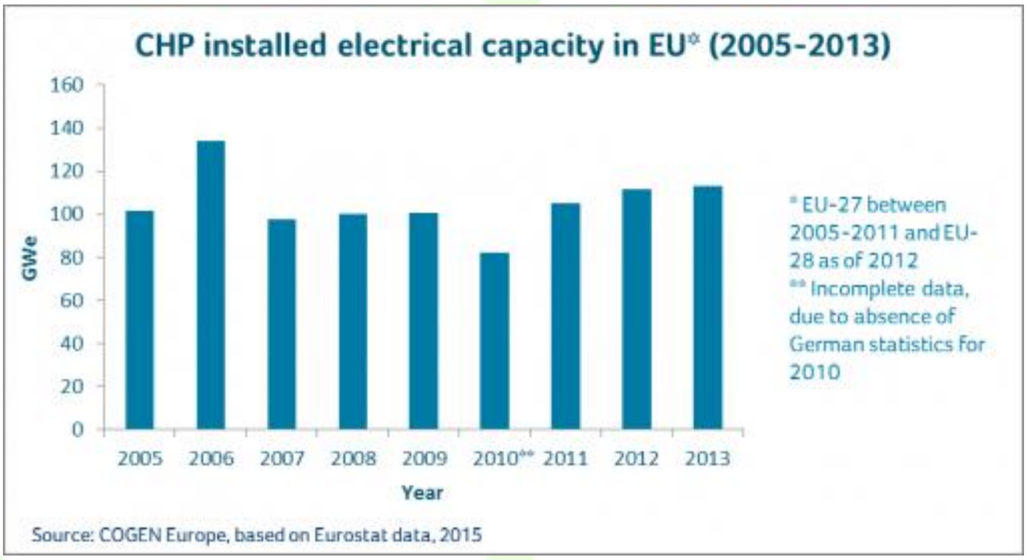


Figure 43 – CHP installed electrical capacity in EU (2005-2013)

In addition, cogeneration can also be used for domestic purposes (micro CHP), which can favor energy efficiency and the empowerment of the prosumer.

In order to achieve the objectives of a Smart Grid, all the above-mentioned technologies have to be monitored by Smart Meters. In this way, one of the most revolutionary assets is the Smart Low cost Advanced Meter (SLAM) developed under the NobelGrid project [498].

A key factor in the new Smart Meter design is the fact that a single equipment, placed at the between the distribution network and the prosumer, is serving at the same time and with the same requested quality, all possible actors in the energy field. SLAM acts as a complex smart meter serving a multitude of areas and bringing real-time support for [498]:

- Smart grid – by delivering RTU-similar real-time data in a traditional or Synchro-SCADA mode,
- Power quality – by allowing essential PQ assessment on continuity of supply and on voltage level;

- Energy services – by supporting energy records load profiles down to one minute resolution combined with appropriate recorded events, in order to properly record services such as demand response;
- Dynamic energy markets – by allowing real-time interaction between the market and the prosumer;
- Local production and storage control – by allowing to host specialized software agents which can control and optimize use of these local resources;
- Security and privacy – through means already mentioned.

It brings even support for yet-unknown functionalities at the time of a smart meter rollout, as new software modules can be developed and deployed during the lifespan.

Figure 44 – SLAM NobelGrid [498]

WiseGRID will use this kind of new Smart Meter in order to reach the established objectives showing that we are on the cutting edge of the technology.

9.2 SELECTED SOTA TOPICS OF PARTICULAR INTEREST FOR THE ARCHETYPE BMS

9.2.1 Fast-responding energy storage and the ancillary services market (related to Archetype BM4)

Related references: [499], [500], [501], [502], [503]

With more intermittent generation, fast-responding energy storage systems (ESS) are becoming essential to maintaining grid reliability. Such systems have better ramping characteristics than traditional generators to facilitate the balancing of load and generation, and hence have an advantage in competing in frequency regulation markets as these are currently developing.

However, they cannot sustain their output indefinitely. System operators have therefore implemented new frequency regulation policies to take advantage of the fast ramps that energy storage systems can deliver while alleviating the problems associated with their limited energy capacity. For example, PJM Interconnection was the first system operator in the U.S. to take advantage of FERC Order 755, which recognizes the value provided by resources that deliver fast-responding and accurate frequency regulation service. Batteries can ramp to full power virtually instantaneously, so they respond faster to grid operator signals than coal or gas plants, but they cannot last as long. The new signals and corresponding tariffs for frequency regulation are designed not only to pay for the regulation capacity that is set aside by the storage provider for the usually ancillary service, but also provide an additional payment for the “millage”, i.e., the total variation over time, of the power provided back and forth from the storage device in the fast time scales when this follows the fast regulation signal provided by the operator. There is also a performance factor used in these tariffs that compensates better regulation resources that follow closer the fast regulation signal.

But storage can provide for more ancillary services besides frequency control. Let’s review this capability by enumerating the corresponding services.

9.2.1.1 Storage and ancillary services

Load Following is required during the so-called “shoulder hours” during the daily electric demand cycle (usually while electric demand increases in the morning as people start their activities and as electric demand diminishes in the evening as such activities diminish). Storage provides load following up by a) increasing discharge and/or b) reducing charging. Both of those modes of operation are shown graphically below. Conversely, load following down is provided by a) reducing discharge and/or b) increasing charging.

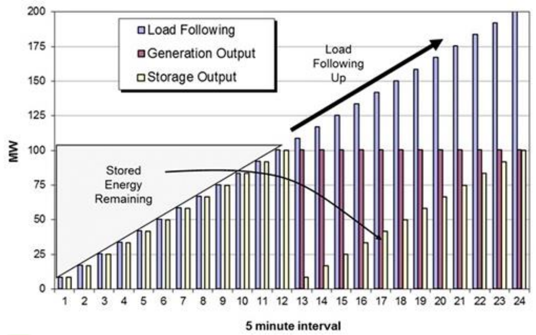


Figure 45 – Two hours of load following up by discharging one hour of storage [499]

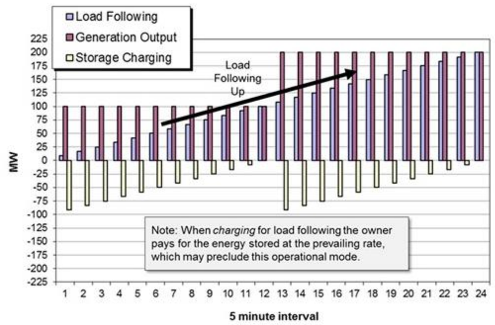


Figure 46 – Two hours of load following up by charging one hour of storage [499]

Observe that:

- Using a 100MW battery we provide load following up from 0 to 200MW over time by combining with a fixed power generating source which is switched on for a time period of 12’, (time scale of RT market). In this case the battery is always discharged. This operation might be constrained by the battery’s total capacity (the integral of the power provided over time).
- One could provide this load following up by having the battery operate in a “energy neutral fashion” (see discussion later). Just combine the ideas in Figure 45 and Figure 46. In the latter we discharge the battery and need the fixed power source to switch between 100MW and 200MW after 12’.

9.2.1.2 Frequency Regulation

Frequency regulation – sometimes referred to as area regulation – is an ancillary service that entails moment-to-moment reconciliation of the difference between electric supply (power) and electric demand. The primary purpose of frequency regulation is to maintain the stability and accuracy of the system-wide alternating current (AC) frequency within a given “control area.”

As shown in Figure 47 and Figure 48, when supply momentarily exceeds demand (i.e., excess supply) frequency regulation down is needed to offset the discrepancy. Conversely, when supply is momentarily below demand (i.e., supply shortfall) frequency regulation up is needed to offset the discrepancy. As more variable generation resources are added to the electric supply mix, especially wind and solar energy fuelled generation, the electric supply will vary along with demand. This phenomenon along with the corresponding need for frequency regulation is shown graphically in Figure 48.

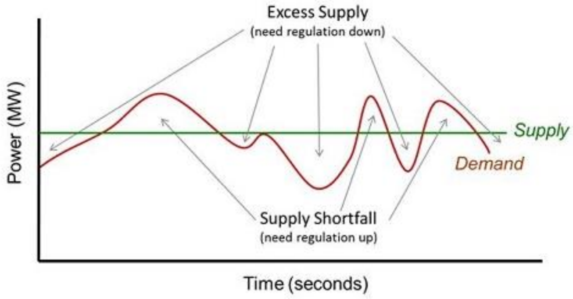


Figure 47 – Frequency regulation needs due to momentary differences between demand and a nearly constant supply [499]

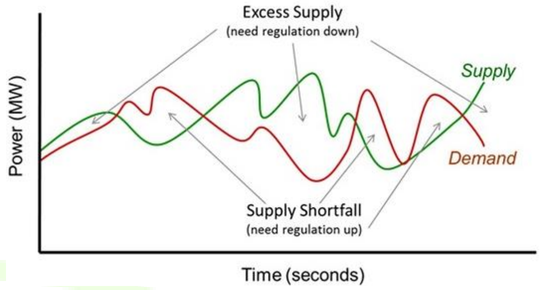


Figure 48 – Frequency regulation needs due to momentary differences between demand and a variable supply [499]

Historically, generation has provided most of the area regulation service. Generation provides up or down regulation exclusively, or it can be used to provide some of each. Similar to load following, storage provides area regulation up with increased discharge and/or reduced charging while it provides area regulation down via reduced discharging and/or increased charging. When storage charging is used to provide area regulation, storage related energy losses result in a real-time purchase of make-up energy. So storage used that way must have high efficiency (i.e., >90%) to make this service profitable for the storage operator.

9.2.1.3 Ramping

Ramping is a significant change of generation power output over time frames ranging from a few seconds to a few minutes. Of particular interest are: a) wind generation ramping that is caused by rapid wind-speed variations and b) solar generation ramping which occurs as large clouds pass over the generator. Indeed, ramping may increase as variable resources are added to the grid. If ramping does become significant, then system operators will have to respond, or the grid could become unstable.

Similar to load following and area regulation, the ramping ancillary service involves resources that offset output ramping. So resources used for the ramping service provide output variability that is the reverse of other generations' output variability due to ramping. Perhaps the best example is wind generation whose output ramps up or down quickly as wind speed changes quickly. In that case output from resources providing ramping service must increase or decrease commensurate with wind generation output changes.

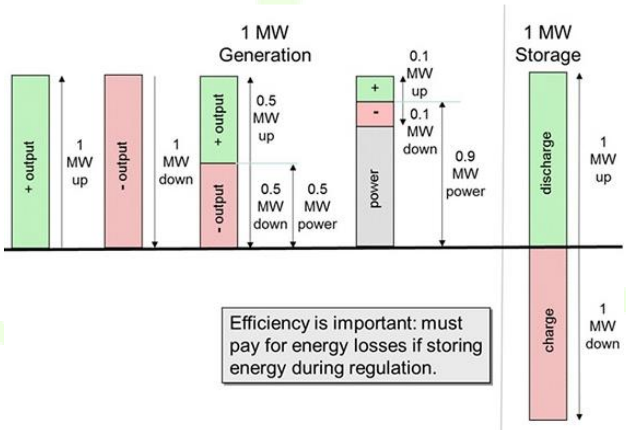


Figure 49 – Generation and storage for area regulation [499]

Storage has important advantages over generation. If the storage used is very efficient (let's neglect losses) then it can provide area regulation equal to two times its power rating, as depicted graphically, by the rightmost bar in Figure 49. That is because storage can provide both regulation up and regulation down by discharging and by charging, like load following, but faster. A 1MW battery can offer total regulation capacity of 2MW (in the range ± 1MW), compared to a 1MW generator, which by operating normally at 0.5MW, can provide regulation capacity in the range of ± 0.5MW. Of course, storage suffers from inefficiency and must be recharged from the Grid at regular intervals, adding to its cost.

9.2.1.4 Fast frequency regulation

The most common mean for a unit to provide frequency regulation is following a system operator's automatic generation control (AGC) signal, which computes the area control error (ACE) from frequency deviations and interchange power imbalances. To further utilize the fast-responsive capability of energy storage systems (ESS) beyond the traditional AGC framework, some system operators, such as PJM in the US, have introduced fast regulation. Units participating in fast regulation follow a regulation signal that changes much faster than the traditional AGC signal, and receive extra payments for doing so. The system operator also benefits from the improved regulation accuracy. A review by the California Energy Storage Alliance (CESA) shows that the combination of pay-for-performance tariffs and fast regulation mechanisms has reduced the procurement requirement in the PJM regulation market by 30%.

The fast regulation signal is obtained by applying a high-pass filter to the AGC signal. Such signals have a fast ramping rate and are designed to have a zero-mean[2]. They are therefore ideal for ESS interested in providing frequency regulation. The case of PJM is indicative of this approach. PJM provides two regulation signals in its day-ahead regulation market:

- RegA, is a low-pass filtered ACE signal designed for traditional regulation units.
- RegD, is a high-pass filtered ACE signal designed for fast regulation units. The RegD signal is generated in a way to have zero-mean within 15' (30' in the future).

9.2.1.5 Energy neutrality

The energy lost during charging and discharging and/or the energy imbalance in the regulation signal make it difficult for ESS operators to provide regulation services seamlessly over a relatively long time period (e.g. several hours, whole day). Both these factors force the ESS operator to abstain from the regulation market for a fraction of the day in order to recharge (or discharge) the batteries and bring their charging state in its nominal value. In order to mitigate this storage technology constraint that hurts storage operators and reduces their revenues, the ISOs proposed that regulation signals be "energy neutral", i.e., balanced in terms of total energy drawn from the storage device over periods of 15' (or 30'). Since the area control signal is not balanced in general (what is missing to match supply with demand might be strictly positive or negative), the solution is to separate the regulation signal[3] into two signals: one that is not balanced and fluctuates slowly (the RegA signal in the case of PJM) and one that is balanced and fluctuates very fast (provides *fast frequency regulation*, the RegD signal in the case of PJM). Clearly the second type of signal is perfectly fit to attract bids from ESS operators in the corresponding fast regulation market. Of course, storage losses imply always some extra time where storage must be taken off the regulation market, creating an additional barrier to entry to the ESS operators (reduces its revenues). Some system operators have elected to lower this barrier by co-optimizing energy storage when dispatching regulation, i.e. taking into account the state of charge (SoC) and the cycling efficiency of ESS (do concurrently the regulation operation with storage charging for efficiency loss).

Motivated by the energy neutral fast regulation signal, can we use similar concepts in slower times scales required for load following? Is it possible to operate storage in an energy neutral fashion in the case of load following or ramping? The answer seems positive. By combining storage with some fixed generation, which stays constant in the time scales of the RT market, one can perform load following up by first discharging and

[2] This "energy neutrality" is essential for a storage device to be able to operate over long periods without need to abstain from regulation services in order to recharge (if we omit the battery losses). Hence by designing the fast regulation signal to be energy neutral, the operator incentivizes more participation of storage providers to the regulation market.

[3] i.e., the automatic generation control (AGC) signal, which computes the area control error (ACE) from frequency deviations and interchange power imbalance.

then charging the battery using the fixed generation at value 200MW at time 13, and at that time start charging the battery in a decreasing fashion starting from 100MW. This suggests that storage can be used very efficiently in the ancillary services market and provide regulation services over long contiguous time intervals.

9.2.1.6 Non-energy neutral storage operation

We mentioned above the new trend where the ISO's regulation signal is designed in an energy neutral fashion to help batteries recover every 15' or 30' their desired state of charge (SoC) and hence operate continuously. But in general, a traditional regulation signal will not have zero mean.

Due to their less than perfect efficiency and the fact that the AGC signal has a non-zero mean, the SoC of an ESS is not maintained in the traditional regulation framework. While the fast frequency regulation mentioned above alleviates the effect of the signal energy imbalance, some ISOs have decided to directly compensate the energy offset of storage units in their regulation market through dispatching. Such mechanisms include the Regulation Energy Management (REM) of CAISO, and the Real-Time Dispatching (RTD) of NYSIO. For completeness we describe the case of CAISO.

CAISO compensates the energy offset of storage units that participate in REM. By participating in REM, a storage unit submits a preferred SoC set-point. CAISO will maintain this set-point by dispatching energy from the Real Time Market (RTM) for the next real-time dispatch interval. This balancing energy is dispatched to each REM units together with the AGC signal by the Energy Management System (EMS). The EMS also takes into account a unit's efficiency in the dispatch. The REM energy compensation is guaranteed during normal operations, while in emergency cases the SoC is restored later.

In the CAISO regulation market settlement, the regulation energy charged and discharged from the storage and the dispatched REM energy are settled at the RTM locational marginal price (LMP), in addition to the capacity settlement and mileage settlement. Since REM guarantees to maintain the SoC of participating storage units, the consequence of the energy settlement is that such units must pay for their energy losses at their LMP.

9.2.1.7 Summary

Regulation markets are becoming more suitable and profitable for ESS because the new pay-for-performance policy makes energy storage more competitive. New zero-mean regulation policies have lowered the barrier for ESS to provide regulation for longer periods. In the case PJM, ESS make more than a quarter of the regulation resources for fast regulation (see Figure 50). From the perspective of the ISO, the participation of energy storage facilitated by appropriate market design makes regulation provisioning more efficient. However, providing a zero-mean regulation signal can be challenging, and must be well coordinated with other ancillary service products that work on slower time scales.

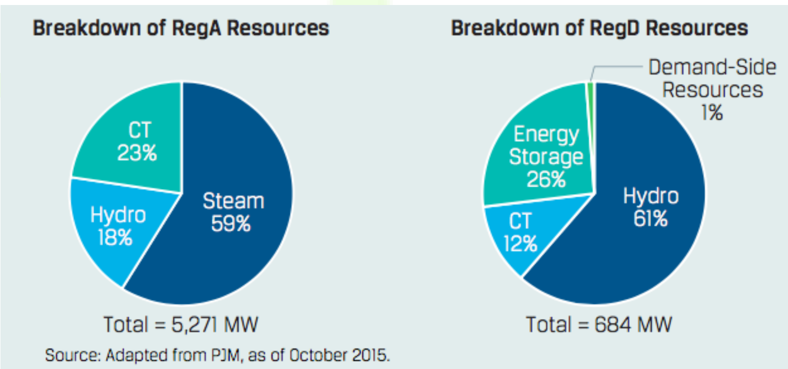


Figure 50 – Regulation resources for fast regulation

9.2.2 The economic impact of EVs and exploiting the V2G technology (related to Archetype BM3 and BM4)

The economic impact of EV deployment can be evaluated from two perspectives, the power grid and the EV owners [504]. From the power grid perspective, EVs are additional loads that need to be plugged-into power grid to receive charging. In order to cope with this massive additional EV loads, system cost will increase due to increased fuel used for more power generation [505]. There are also more power losses during the power transfer across the power grid to supply these EV loads. However, this situation can be completely changed by efficiently managing the EV charging [506]. Controlled EV charging can significantly reduce the system cost with savings up [504] to 60% [507]. The cost reduction is even better with integration of renewable energy resources in power grid, particularly wind energy.

From the EV owners' perspective, EVs have low operating costs because of the use of efficient electric motors and inexpensive electricity. However, EVs have higher initial purchase cost due to the expensive battery component. A term called "EV payback period" is introduced to estimate the length of time required to recover the investment cost of an EV [508]. Many actions can be implemented to ease the high initial purchase cost of EVs, such as mass-producing EVs [509], implementing energy trading policy [510] and adopting appropriate charging strategies [511].

Moreover, the interconnection of large EV fleets to the power grid to receive charging can introduce negative impacts to the power grid, such as harmonics, system losses, voltage drop, phase unbalance, increase of power demand, equipment overloading and stability issues. Various possible charging rates and dynamic behaviour of EVs even complicate the potential impacts. Therefore, the number of related literature has been increased recently. This section reveals various studies on the grid impact due to EV charging.

To summarize, the power grid needs to have more generation capacity for the additional EV load demand while EV owners have to pay the high initial purchase cost of EV at the present time. However, with the implementation of coordinated charging, energy trading and various electricity rates policy, EV deployment can be profitable for the operation of power grid and EV owners.

It becomes apparent that their smooth integration in the smart grid strongly depends on their respond to network stress, by shifting their flexible loads during the valleys of low demand. Such "smart charging" schedules would prevent or minimize the particularly costly grid reinforcements in terms of capacity expansion and would allow for the optimal utilization of the fluctuating RES production avoiding its curtailment. To this end, the retailers must introduce suitable economic incentives in the form of non-flat pricing schemes (e.g., ToU pricing) which should expose the EV users to the real time cost of the production.

Still, such price signals may not reflect the possible congestion conditions in the grid. This situation may occur during periods of high RES generation when the wholesale prices are low, while the peak demand may appear at a specific part of the grid. Thus, the DSO also (apart from the retailer) should be able to communicate the appropriate price signal for the congestion exposure or alternatively control signals to market players for the provision of flexibility, based on the bilateral agreements between the two parties (such control signals we consider in the BM3). According to the study in [512], the lack of smart charging business models is considered one of the basic barriers for the EVs penetration along with the high cost of the battery (which accounts for the 25%-30% of the total cost). A finding of significant importance is the fact that the current grid infrastructure can cope with the hypothetical 100% electrification of the European fleet without requiring any additional investment on capacity expansion. But, this capability strongly depends on the efficient scheduling of the EV charging, such that it does not coincide with the current peak demand. In this way, the grid reinforcements can be avoided, both for grid lines and transformers and additionally for the home connectivity, resulting to noteworthy potential cost savings for the DSO (in France the DSO subsidizes the ~50% of the households' connection cost). Figure 51 (from [513]) summarizes the potential savings that may be achieved depending on the type of the EVSE infrastructure, as estimated by the European Regional Developments Fund (the numbers are assessed per one million EV cars driving globally).

Total LV grid reinforcement cost per million EV for:	Cost without smart charging	Cost reduction due to smart charging
EV charging in single houses	200 M€	200 M€ (almost total cost avoided)
Multiple EV charging in multi-dwelling or business buildings	650 M€	450 M€
Public charging spots in the streets and parking lots	240 M€	120 M€

Figure 51 – Reinforcement costs (Million €) for low-voltage grids and cost reduction with smart charging [513]

An illustrative examples of efficient EV's charging scheduling which is based on control signals is the case of the Dutch DSO, namely "Enexis" [514]. Enexis developed the Open Smart Charging Protocol (OSCP), which provides the capability of bidirectional communication between the DSO and the Charging Station Operators (CSO) who aggregate the charging loads of multiple EVs. The DSO firstly utilizes the Electricity Load Management Optimizer algorithm, which is based on historical and environmental data, targeting to forecast both the available and the backup capacity of the cable which supplies the premises of the CSO. Then the DSO announces its forecasts to the CSO, who determines the charging pattern of each vehicle, according to e.g., the individual preferences of its user or a priority scheme based on the contracts with its clients. The CSO may inform the DSO about the possible capacity leftover (that is not necessary) or inversely ask to reserve a portion of the backup capacity in the case when the available capacity is not enough to cover the charging needs. The developers of the protocol suggest that such actions should be encourages by financial incentives in the future (reward or penalty respectively). Concerning the additional fields for the protocol's applicability, its developers foresee its utilization in the domestic sector by Home Energy Management Systems, targeting to schedule the controllable loads (private EVSE, heat pumps, air conditions) such that to economically meet the occupant's needs. In the same contexts, the "GridTech" EU-funded project [515] investigates a "plug-in while parking" business model, which incentivizes the EV owners to abandon their "charge on demand" behavior and always connect their vehicles to the grid while standing. This behavior would provide higher flexibility capabilities to the DSO for balancing the load over its grid, especially if it is combined with V2G infrastructure which enables the EVs to inject their stored energy back in the grid.

The aforementioned core directions of the arising business models, reveal the importance of the WG Cockpit and the Wise EVP tool for the smooth integration of the EVs in the grid and the potential savings both for the DSO and the CSO (and consequently for the prosumers, e.g. the fleet Operator or individual EV owners). Furthermore, according to CEN-CENELEC e-Mobility Coordination Group (eM-CG) [516], smart charging should respect customer's needs and requirements regarding vehicle availability, justifying the approach of the WiseGRID project to explicitly consider such constraints in the functionalities of the WiseEVP tool.

From the prosumer's perspective, the smart charging schedules can result to a reduction of 23% in an EV's total cost of ownership (TCO) and outweigh their 14% (on average) higher purchase price compared to their conventional counterparts. An innovative business model of V2H services is held by Nissan [517]. The installed system, gives the opportunity to the prosumer to take advantage of the fluctuating retail prices and automatically charge his EV during the periods of low prices, while it also provides the inverse functionality, meaning that the EV's battery may supply the household devices in the case of a grid outage and relief the consumer's inconvenience. Such sophisticated functionalities are also provided by the WiseHOME tool which manages the prosumer's consumption patterns at the local level and may utilize the flexibility capabilities and the V2H services, targeting to provide savings in terms of a lower electricity bill.

Concerning the penetration of EVs in the market, the biggest business model today is sales to natural persons, a model that has been promoted indirectly by many government (financial and fiscal) support mechanisms [518]. But still, although a lot of people like the experience of driving electric, the high cost as compared to ICE cars lowers the intention to purchase severely. To this end, many car manufactures and also leasing companies, rental companies, and citizens cooperative enterprises, are looking into "car sharing" models in which the customer takes a subscription of access to a fleet of vehicles, rather than bearing the cost of their ownership. Doing so offers a couple of advantages for the customer, such as removing many of the unknown investment risks of buying an EV (e.g. doubts about the battery life time, doubts of the resale value of the EV) and providing the necessary additional services (e.g. access to public charging infrastructure, access to a parking spot with charging infrastructure, road assistance) [519]. Car sharing however is an inherently slow growing market, due to the many lock out that the customers face for making use of car sharing [520]. The biggest lock-out to the car sharing service for customer is owning a car, or having access to a car as a benefit offered by the employer. Therefore, many car sharing companies target also companies and other organizations, to speed up the growth of car sharing services. Especially small companies – still 99% of all the companies in the EU have 50 or less employees [521] – are a fruitful segment for selling subscriptions to car services.

It is emphasized that the satisfaction of the customer's convenience constraints is commonly considered as a competitive advantage in the car sharing sector. As a result, a fraction of the car sharing fleet is always left unused, targeting to achieve the charging levels that meet the customer's needs. Similar issues -with respect to the efficient vehicle utilization- arise from the electrification of big fleets counting multiple vehicles, such as the taxis. The taxi sector has already large experience especially in big cities with plugin hybrid electric vehicles (PHEV), usually due to clean air directives of the local authorities (example London [522]), while this implementation is considered as the first step to a fully electric fleet. But, the complete electrification of taxi or bus fleets requires an estimated 30% increase of the fleet with current technology, due to the charging times that remain long, especially in the light of still fast-growing battery capacities.

It becomes apparent that a lucrative business model requires from the EV fleet manager to valorized this extra capacity and extend its business model besides the basic transportation services. For instance, EV car sharing companies are in a good position to benefit from the bulk intake of electrical energy needed to charge the batteries and should schedule their cost-effective consumption patterns based on the fluctuating energy prices. Furthermore, they should utilize the EVs' inherent storage capabilities and provide V2G services by e.g., purchasing electricity from the grid and injecting it back later on. In this context, the WiseEVP can be utilized as a powerful tool for achieving the efficient realization of such services.

V2G technology can bring various benefits to the power grid via proper control and management. However, the large fleet of grid-connected EVs will result in many uncertain constraints to the power grid, such as different state of charge levels of EV batteries and the dynamic probability of EV connection. In order to manage the large fleet of EVs, unit commitment optimization technique is used for planning and controlling the energy flow between EVs and power grid. With the optimization of the V2G algorithms, various power grid benefits can be accomplished based on the predefined objective functions. Some of the benefits accomplished by the V2G technology are listed, as follows:

Ancillary service – spinning reserve
V2G technology can provide ancillary services to the power grid via spinning reserve services, where the energy stored in the grid-connected EVs is used as the additional generation capacity to compensate the generation outage [523]. With the spinning reserve service provided by V2G technology, it can provide failure recovery, as well as reduce the backup generation capacity [524] [525].

Active power support/load levelling and peak load shaving
V2G technology is able to utilize the excessive EVs energy to provide active power support to the power grid during peak hour and charge the EVs during off-peak hour. These techniques are denominated as the "peak load shaving" and "load levelling", respectively [526] [527].

Reactive power support/power factor correction/voltage regulation
Large scale deployment of EV charging is a massive challenge to the power grid. With the implementation of V2G technology, the reactive power compensation service for grid voltage regulation and power factor correction can be accomplished with the grid-connected bi-directional EV chargers. The DC-link capacitor connected in a bidirectional EV charger is able to provide reactive power support to the power grid with an appropriate switching control for the EV converter [528] [529].

Harmonic filtering

The modern power grid consists of many high power non-linear loads, which generates significant amount of current harmonics into the power grid. EV chargers are one of the harmonic sources due to the use of converter switching. Therefore, the implementation of V2G technology will affect the power quality of the smart grid if no corrective measure is taken. Other than the inclusion of additional filter device to solve the harmonic problem, EV chargers with appropriate control can be used as the active filter to filter out the harmonics generated by EV chargers and other non-linear loads. The converter of the EV charger can operate as variable impedance for each individual harmonic frequency and solve the harmonic problem with proper filtering strategy [530] [531] [532].

Support for the deployment of renewable energy resources

With the implementation of proper V2G control strategy, EVs can be used as the solution for dealing with renewable energy intermittency issues. EVs will charge from the power grid when renewable distributed generation generates excessive power and discharge to power grid when renewable distributed generation does not generate enough power. In addition, an EV battery can be used as the energy storage system to regulate the voltage of a power grid with renewable energy integration [533]. This way, more renewable energy sources can be integrated into the power grid to achieve a more sustainable electrical power system [534].

Concerning the installation and operation of the EVSE infrastructure, many EV manufacturers provide also a home charging installation together with the EV, which offers a reduction on of the total cost for the owner. However, not all owners of an EV can benefit from this, especially those who live in cities not owning a parking space themselves and consequently they typically depend on publicly available charging points for their needs. Some manufacturers roll out themselves (e.g. Tesla [535]), or are partners in rolling out (e.g. Nissan [536]) a charger network to which owner have access, while customers are provided with a subscription to that charger network. In this way, the EV manufacturer complements its activities of merely selling an EV with live long EV services to the customer.

Additionally, the position paper of the EURELECTRIC [537] reports that some Members States have assigned to the DSO the responsibility for installing and operating the public charging infrastructure. The rationale behind this strategy is the low penetration of EVs in the market that causes the private vendors to be hesitant in proceeding with the investment. Still, the report emphasizes that there must be a clear exit strategy of the DSO (e.g., through auctions with the market parties), such that a competitive framework can be established once the market reaches the necessary level of maturity.