



# **Way forward to Smart Grid Regulation**

by

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## **Brief Author Biography**

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# Abstract

Around the world, in developed and developing countries, the way electricity is generated and distributed is being subject to change. Either because of environment reasons (EU), ageing grids (USA), or booming development (China), this is now subject to several transformations; some of them taking place on a big scale, others taking the form of pilot projects. One point is consensual, i.e., these are transformations that span through the activities of several actors across the electricity value chain, and are transformations that involve huge investment sums. Given this, some coordination mechanisms are needed so that stakeholders (such as Distribution System Operators) don't fall in holdup situations; besides that, and going straight to the heart of our dissertation, these players shall have the incentives to make the changes in the direction of a Smart Grid (an automated electric grid that promises more intelligence on the way electricity is generated, transported, and consumed) and not to continue their operations keeping the *status quo*.

In this work, we look at the European Union (EU) and ask if current policies and regulation provide the environment needed for Smart Grid implementation; we go through the EU Energy Policy, governments support, and regulation, and gouge the initiatives taken so far. These incentives, mainly economic, shall last for long time, as the transformations foreseen take several years (if not decades) to be implemented; thus as many authors, we think these incentives shall be given in the context of regulation. We also take in account that electricity industry is a network industry, and as such, interoperability is of significant importance; as that, and because of standards' role in Global Governance, we go through the world of Smart Grid standards and evaluate the EU standards in the global arena. Standards are seen as an important tool of global regulation, so the EU is confronted in the world stage with the adoption of non-EU standards. Our work is thus centered on the question of incentives and standards strategies needed for the development of Smart Grid in EU countries.

*Keywords:* Electricity sector, Regulation, Smart Grids, European Union.

*JEL-codes:* L94, L98.

## Resumo

Um pouco por todo o mundo, nos países desenvolvidos ou em vias de desenvolvimento, assiste-se a uma mudança de paradigma na forma como a electricidade é produzida e distribuída. Seja por causas ambientais (UE), envelhecimento das redes (EUA), ou crescimento económico exponencial (China), estas mudanças começam a desenrolar-se. É consensual que estas transformações são transversais à cadeia de valor do sector eléctrico, e implicam investimentos avultados. Desta forma, são precisos mecanismos de coordenação de forma a que os interessados (por exemplo operador da rede de distribuição) não caiam em situações de *hold-up*; para além disso, e indo de encontro ao tema da nossa dissertação, a estes actores devem ser dados os incentivos para que operem mudanças no sentido da implementação de uma *Smart Grid* (uma rede eléctrica automatizada que é anunciada como trazendo mais “inteligência” à forma como a electricidade é produzida, transportada, distribuída e consumida).

Nesta dissertação, propomo-nos, no contexto da União Europeia, avaliar se as políticas e regulações em vigor são as mais adequadas para a implementação de uma *Smart Grid*, olhando para a Política Energética da UE, apoios governamentais, e regulação. Estes incentivos, maioritariamente de ordem económica, devem perdurar no tempo uma vez que é previsto estas transformações levarem anos (ou mesmo décadas) a serem realizadas. Assim como muitos autores, pensamos que estes incentivos devem acontecer num contexto de regulação. Devemos também ter em conta que o sector eléctrico se insere nas chamadas indústrias de rede, e como tal, a interoperabilidade é de grande importância; por isso, e devido ao papel das normas na *Global Governance*, fazemos uma incursão pelas normas das *Smart Grids* e avaliamos o posicionamento das normas Europeias no ambiente global. As normas são uma ferramenta importante da regulação global, e no contexto das *Smart Grids* a UE tem vindo a confrontar-se com a adopção de normas não Europeias. Desta forma, a nossa dissertação está centrada na questão dos incentivos e estratégias de normalização necessárias ao desenvolvimento de *Smart Grids* nos países Europeus.

*Palavras-chave:* Sector Eléctrico, Regulação, Smart Grids, União Europeia.

*Códigos JEL:* L94, L98.

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# List of Abbreviations

ACER	Agency for the Cooperation of Energy Regulators
AMI	Advanced Meter Infrastructure
AMR	Automated Meter Reading
BRICS	Brazil, Russia, India, China and South Africa
CAPEX	Capital Expenditure
CAES	Compressed Air Energy Storage
CBA	Cost Benefit Analysis
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CHP	Combined Heat and Power
DA	Distribution Automation
DECC	Department of Energy and Climate Change (UK)
DER	Distributed Energy Resources
DG	Distributed Generation
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EC	European Commission
ECSC	European Coal and Steel Community
EEC	European Economic Community

ENTSO-E	European Network of Transmission System Operators for Electricity
ERGEG	European Regulators' Group for Electricity and Gas
ESO	European Standards Organizations
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicle
GATT	General Agreement on Trade and Tariffs
ICT	Information and Communications Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEM	Internal Energy Market
ISO	Independent System Operator
ITU	International Telecommunications Union
NIST	National Institute of Standards and Technology
NRA	National Regulatory Authority
NSB	National Standards Body
Ofgem	Office of Gas and Electricity Markets (UK)
OPEX	Operating Expenditure
PV	Photovoltaic
R&D	Research and Development
RIIO	Revenue = Incentives + Innovation + Outputs
RES	Renewable Energy Sources

SDO	Standard Development Organization
SEA	Single European Act
SG	Smart Grid
SM	Smart Meter
SMP	Single Market Programme
TFEU	Treaty on the Functioning of the European Union
TOTEX	Total Expenditure
TSO	Transmission System Operator
UK	United Kingdom
USA	United States of America
V2G	Vehicle to Grid
VPP	Virtual Power Plant
WACC	Weighted Average Cost Of Capital
WTO	World Trade Organization

# Chapter 1

## Introduction

The word Energy comes from the Greek *ἐνέργεια* (*energeia*) which means activity, operation, while the word Electricity, which also comes from Greek, *ἤλεκτρον* (*electron*) means amber, because electrical effects were produced classically by rubbing amber. Since the antiquity, man has been attracted by the electricity phenomena, but it was in the 19th century that it turned from a scientific curiosity into an essential tool for modern life. Electricity was in fact a major driving force of the Second Industrial Revolution, that is to say, an important technology that contributed to mass production activity, operation.

Electricity was then deployed over the territory of the industrialized nations, and the grid grew to accommodate its increasing demand, turning up to become a commodity. However, this growth was based on the business model introduced by Thomas Edison, in which utilities owned the plants that generated electricity, the transmission lines that carried it to substations, and the wires that distributed it to customers. Despite of the waves of liberalization that started in the 1980s, the grids didn't improve their expanding capability, and we have seen some serious blackouts affecting millions of people, such as the 2003 Northeast Blackout in the United States of America (USA), and the 2003 Italy Blackout – both caused by lack of reliability and ageing of the grid. It is also a fact that during the first half of the 20th century, utilities had unlimited access to cheap fossil fuels, and had no incentive to upgrade their inefficient old plants. From the recent decades, we have been assisting to a rise in consumption of energy from the so-called BRICS<sup>1</sup> countries, and we can expect that consumption of electricity will further rise (BP, 2012), and with that, the concern on the fossil fuels, and their impact on the environment. With this, environmental concerns are also playing a very

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<sup>1</sup> BRICS is the title of an association of leading emerging economies, arising out of the inclusion of South Africa into the BRIC group in 2010. As of 2012, the group's five members are Brazil, Russia, India, China and South Africa. With the possible exception of Russia, the BRICS members are all developing or newly industrialized countries, but they are distinguished by their large, fast-growing economies and significant influence on regional and global affairs. (Source: <http://en.wikipedia.org/wiki/BRICS>, last visited August 8, 2013)

important part on energy planning. One key measure identified to tackle the transition to sustainable and low-carbon industry is the expansion of Renewable Energy Sources (RES), and more than that, its integration into the electricity grid. Besides the environmental effects, what is intended is to help solving the limitations of storage capacities, and at the same time, being economically efficient.

Thus, the electric grid needs to accommodate the changes to meet challenges of improved load control and increased generation from renewables. There are two views on how to achieve those goals: one is the adaptation of the current grid by means of conventional “Dumb Grid”<sup>2</sup> so that it integrates a high share of RES, and the other view is to get there by means of a more automated and integrated grid that brings intelligence using information and communication technologies, and metering from generation to all the final consumers. As for the second view, we are talking about Smart Grid (SG), an electrical grid that incorporates Information and Communications Technology (ICT) and Smart Meters (SM). The drivers for SG are several and different, depending on the geopolitical domain we consider. For example, main drivers for SG in USA are the ageing and security of the grid, while the EU seems to be more motivated by the 20-20-20 objectives<sup>3</sup>. The SG is seen as a means (not an end) of achieving the goals of a global energy challenge that countries face in the next years. Wherever these changes are going to take place, its development will be part of a major change to the way electricity is generated, transmitted, distributed and used, and like any substantial change in national infrastructures, the costs will be challenging.

However, technology alone won't fix all the concerns about the grid, as they are not mainly a technological problem – instead, it relates to a whole system, where political gridlock, inefficient markets, and shortsighted planning that have created those bottlenecks that cannot be solved solely with millions of Smart Meters and ICT

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<sup>2</sup> “Dumb grid” is a term used to refer to the traditional grid, which is seen as being based on limited information and leaving no real control for consumers. A Dumb grid demands a large amount of physical infrastructure, practically meaning more cables needed to be laid, because it will not be able to rely on smart distribution of intermittent energy through ICT and therewith compensate peaks in supply or demand (Knödler, 2012).

<sup>3</sup> The climate and energy package is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020. These targets, known as the "20-20-20" targets, set three key objectives for 2020: A 20% reduction in EU greenhouse gas emissions from 1990 levels; raising the share of EU energy consumption produced from renewable resources to 20%; A 20% improvement in the EU's energy efficiency. (Source: [http://ec.europa.eu/clima/policies/package/index\\_en.htm](http://ec.europa.eu/clima/policies/package/index_en.htm), last visited August 8, 2013 )

infrastructure. Without further policy stability, appropriate regulatory incentives, and more investment, may result in not realizing the Smart Grid, and consequently falling behind in what can be a new global growth market and a source of prosperity and jobs for years to come (Ernest & Young, 2012). Our work proposes to look at a way forward to bring the Smart Grid to the stage, and let it play the role of a new energy management paradigm.

## **1.1 EU Energy Policy**

As (Morais, 2011) refers, although the energy sector was considered a vital area from the beginning of European integration process, we observe that the European Community, in which the integration process is anchored, surprisingly didn't have (as its origins are the European Coal and Steel Community – ECSC) any preparation/reference in what concerns to energy policy. As a consequence, there were delays in the construction and consolidation of a global energy policy since the adoption of the Treaty<sup>4</sup>, until the first oil crisis during the seventies. After the second oil crisis, there was an approach to the energy supply problem, but the first legislative initiatives, for the oil and gas sector, took place only with the raise of the Single Market Programme (SMP).

The first branch of EU Energy Policy to be developed was the energy security. After the oil crisis, the EU adopted legislation that specified the emergency level of oil stocks. Since then, the European Commission (EC) has been assuming a dominant role, although the Member States (MSs) always shown reluctance in transferring their decision powers. Thus, the energy security dimension of energy policy provided limited opportunities to the strengthening of the energy policy of the EC at a supranational level. However, with the recent EU enlargement, and with the dependence of Central and Eastern European States on Russian energy, the concerns about energy security have seen more attention from Member States that are now more open to the idea of a stronger rule of the EC (Tosun and Solorio, 2011).

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<sup>4</sup> European Economic Community (EEC) and Rome Treaty.

The most important stimuli to the further development of an energy policy were the Single European Act<sup>5</sup> (SEA), and the subsequent SMP<sup>6</sup>. These stimuli gave room for the institutionalization at a supranational level of policies related with the internal market, and regulation and competition (Morais, 2011). The defense of the free-market values, by the EC, has been a drive to build the Internal Energy Market that resulted in the adoption of three packages of directives (First, Second and Third Packages started in 1996), which had as main goal the energy market liberalization.

### **EC Directives and the Internal Energy Market (IEM)**

In order to implement an Energy Policy, and an Internal Energy Market, it was fundamental to make legislation efforts, by producing a set of directives and regulations.

The institutionalization of environmental policy through the SEA opened an avenue for the promotion of Energy Policy in Europe (Morais, 2011). This green dimension provided a more effective mean to progress with energy policy. In 2005, the EC started to promote the debate about energy, with the main goal of establishing the foundations to a new Energy Policy of global scope essential to combat environmental changes. Subsequently, the EC promoted a review of the actual energetic challenges, as a guide for EU Energy Policy, in which renewable energies, energetic efficiency, and the reduction of greenhouse gases effect, were specified as a mandatory requirements to limit climate changes<sup>7</sup>.

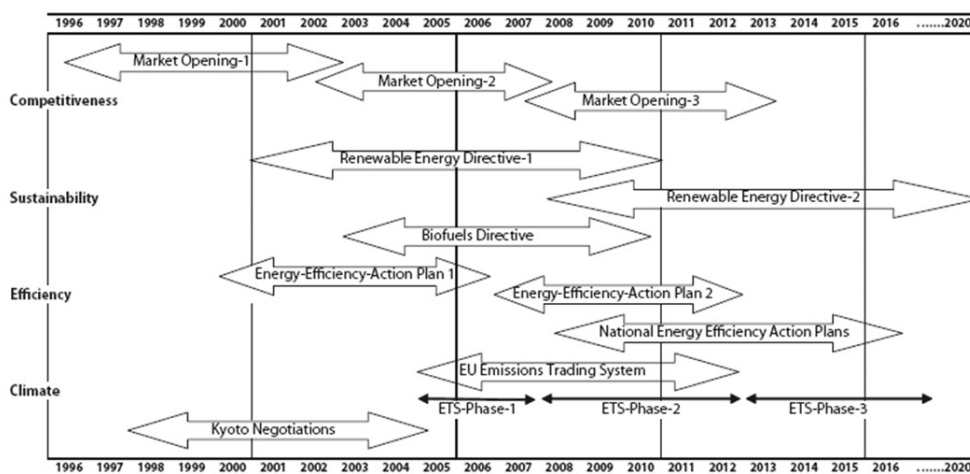
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<sup>5</sup> The Single European Act (SEA) revises the Treaties of Rome in order to add new momentum to European integration and to complete the internal market. It amends the rules governing the operation of the European institutions and expands Community powers, notably in the field of research and development, environment, and common foreign policy. (Source: [http://europa.eu/legislation\\_summaries/institutional\\_affairs/treaties/treaties\\_singleact\\_en.htm](http://europa.eu/legislation_summaries/institutional_affairs/treaties/treaties_singleact_en.htm), last visited August 8, 2013 )

<sup>6</sup> The Single Market Programme is the result of a detailed timetable and law enforcement process of the SEA. This project was based on the European Commission's 1985 White Paper '*Completing the Internal Market*', a comprehensive blueprint for welding together the fragmented national markets to create a genuinely frontier-free single market by the end of 1992. (Source: [http://fritz.breuss.wifo.ac.at/Badinger-Breuss\\_Quantitative\\_European\\_Integration\\_in\\_JOVANOVIC\\_Vol\\_3\\_2011\\_285-315.pdf](http://fritz.breuss.wifo.ac.at/Badinger-Breuss_Quantitative_European_Integration_in_JOVANOVIC_Vol_3_2011_285-315.pdf), last visited August 8, 2013 )

<sup>7</sup> The document (European Commission, 2006) known as "Green Paper" marks an important milestone in developing a common energy policy by regrouping the disparate range of energy policies into a common strategy for Europe. This Paper is the result of several summits held by Heads of State and Government in the European Union in 2005. In these summits it was recognized a need for a common response to the issues of ensuring energy security, effective action against climate change and stable economic conditions.

Regarding the competitiveness dimension of the EU Energy Policy, a series of directives for the electricity and gas were developed. These directives are composed by three packages as illustrated in Figure 1<sup>8</sup>. These efforts are based on the need to address the congestion of networks and discrimination along the electricity value chain, and are the result of several Benchmarking Reports by the European Commission<sup>9</sup>.



**Figure 1 - EU Energy Policy Development**

Source: Eurostat, *Panorama of energy, Energy statistics to support EU policies and solutions*, 10 July 2007

Without going into much detail, the First Package of Directives has thrown the basis for the construction of rules for the electricity and gas markets, and established that Transmission System Operators (TSOs) should have their accounts separated from production and commercialization activities (Account Unbundling). The Second Package of Directives established that TSOs should be independent from vertically integrated undertakings at least in legal, organizational and decision making terms (Legal Unbundling). The Second Package also included a regulation that established a committee at European level, the ERGEG<sup>10</sup>, which was constituted by the Member States National Regulators. In the Third Package of Directives, the European Commission proposed Ownership Unbundling for transmission network as a way of

<sup>8</sup> In this figure the three directive packages are identified as Market Opening-1, Market Opening-2 and Market Opening-3, although they are known as First, Second and Third Packages..

<sup>9</sup> The annual benchmarking reports on the opening of the electricity and gas markets monitor since 2000 how EU legislation is implemented across EU. Input for the reports comes from the European Regulators Group (ERGEG) and the Commission's own investigations. (Source: [http://ec.europa.eu/energy/gas\\_electricity/legislation/benchmarking\\_reports\\_en.htm](http://ec.europa.eu/energy/gas_electricity/legislation/benchmarking_reports_en.htm) , last visited August 8, 2013)

<sup>10</sup> European Regulators' Group for Electricity and Gas (ERGEG) - consultative organism establish according with a decision by European Commission in 11 November 2003.

removing competition distortions. This was not a simple process and consensus was very difficult to reach, and in reality no consensus on this strict option was found; the outcome was a political compromise that leaves three options to comply with stricter unbundling requirements (Full Ownership Unbundling, Independent Transmission Operator, and Independent System Operator, which we will describe later).

## **1.2 Regulation in the EU**

In the context of market liberalization, we can find two extremes in EU - sectors in which there are almost no signs of natural monopolies (e.g. the telecommunications), and in the other extreme, sectors where the elements that characterize monopolies are still present (e.g. water supply). The energy sector may be positioned somewhere between these two extremes and as such, liberalization and regulation are of main importance. One of the most important questions in the regulation of ex-monopolies is entry regulation - that is to say, how easy it is for new competitors to enter the market (Motta, 2004), (Viscusi et al., 2005).

Regulation is an essential (instrumental) tool when it comes to implement policy. We are going to see how Energy (in particular Electricity) Regulation gained a European dimension. This is important because there shall be a good articulation between EU Regulatory Policy and the National Regulatory Authorities (NRA). As for the EU law, regulations are transposed to MSs National law by means of directives.

### **The way to ACER (Agency for the Cooperation of Energy Regulators)**

When the liberalization of energy markets started in the EU (during the 1990s), simultaneously with the construction of the Internal Energy Market, the dominant idea was that competition should be a very important aspect of the energetic sector. However, national regulation was not in force in the first directives for the energy market (First Package). Still, there were countries (including Portugal) that started liberalization and also created national regulators before the directives were approved. We shall note that the first directives didn't contemplate EU level regulation. Instead, the EU proposed a voluntary approach to regulation which didn't result.

The Second Package directives identified some barriers to liberalization and competition, and tried to find solutions for those constraints, namely i) the need of existence of a legal and financial unbundling for the energy network operators; ii) an access system to energy networks and transparent, non-discriminatory and predictable infrastructure; iii) to ensure these points, the Directives established that the MSs should create National Regulation Authorities (NRAs) with a sufficient autonomy degree and effective market intervention powers. However, it was found out that the Directive's requirements were not enough to assure open energy markets, competitive and efficiently (besides other aspects, it was found excessive market concentration, incumbent vertical integration, and foreclosure that created entry barriers to new competitors, very little cross border integration, lack of transparency, and lack of fair competition in wholesale markets) (European Commission, 2007). Besides that, a regulatory gap existed in the cross border regulatory environment. These points directly influenced the regulatory side of the Third Package.

The Third Package has two aspects that we think very important: the first respects to a trend to reinforce the separation of commercialization and production activities from network operation activities, including transport and distribution (preference for the Ownership Unbundling); the second point concerns to a new EU Agency for the Cooperation of Energy Regulators - this is the birth of ACER<sup>11</sup>. This was an important step for regulation at European level and was welcomed by the European Parliament, but it was not received with enthusiasm by the European Council. In other words, this agreement difficulty represents one solution not very robust institutionally. The Third Package also contains legislation at national level - all Member States shall have a regulator.

In March 2007, the European Council considered that once the production and use of energy are the main sources of greenhouse gas emissions, an integrated approach to climate and energy policy should be taken, in order to avoid the global temperature raising. Such an approach means that regulation cannot focus exclusively in market questions - it shall take in account the EU objectives related with energetic efficiency

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<sup>11</sup> ACER is a EU body which has as mission to assist National Regulatory Authorities in exercising, at Community level, the regulatory tasks that they perform in the Member States and, where necessary, to coordinate their action.

and electricity generation based in RES. In order to accomplish these objectives, it is needed appropriate incentive regulation, namely in what respect to energetic efficiency, green products, EVs (Electric Vehicles) and interconnections. In such a context, the traditional regulation tools shall be reviewed and expanded.

### **1.3 Smart Grid and Unbundling**

Network unbundling is the separation of generation and retail activities from network business, and has been introduced to guarantee non-discriminatory network access for third parties and to foster fair competition.

Coming back to the Third Package, we will now summarize the EU policy on Unbundling, that is, Transmission unbundling. The three options to comply with unbundling are:

**Full Ownership Unbundling** – requires that the TSO would own both the transmission assets and operate the network. It would be independently owned, i.e. supply/generation companies could not hold a significant stake in the TSOs. It implies that: same person cannot exercise control over a production or supply company and at the same time exercise control or any right over a transmission system, and vice versa; same person cannot appoint board members of a TSO and exercise control or any right over a production or supply company; and same person cannot be a member of the board of a TSO and of a production or supply company (European Commission, 2010b). Although full ownership unbundling is expected to eliminate discrimination incentives and benefit competition, it eliminates firm internal coordination along the vertical supply chain.

**Independent System Operator (ISO)** – requires separation of system operation from ownership of the assets. Supply/generation companies could no longer hold a significant stake in the ISO. This option enables the vertically integrated undertaking to keep the transmission assets on its balance sheet. ISOs would require sufficient funds and personnel not employed at the same time by a vertically integrated group. ISO must have a strong say in investment planning, the Transmission System owner is legally and functionally unbundled. It also implies significant regulatory involvement (European Commission, 2010b). The ISO concept addresses

discrimination concerns without requiring ownership changes, but also very important is that ISO can be left freedom to coordinate system actors from a central perspective (Friedrichsen, 2011).

**Independent Transmission Operator (ITO)** – In this option the TSO remains within the integrated company and the transmission assets remain on its balance sheet. Many additional regulatory provisions should ensure that the integrated company would have no control over these assets and provide for a huge regulatory burden. In fact, the entire vertically integrated undertaking will be subject to severe regulatory scrutiny (assets, equipment, staff and identity, effective decision making rights, independence of management, and supervisory body) (European Commission, 2010b).

The result of these regulations is that European electricity systems are now a mix of regulated and competitive activities: power generation, wholesale supply and retail supply are now competitive elements of the value chain, and transmission and distribution are regulated, as they still be characterized as natural monopolies. Keeping unbundling in mind is essential to understand the implications (coordination and competition) on SG system organization.

#### **1.4 EU Energy Policy and Smart Grids: Critical Questions**

In this dissertation we propose to find a way forward that enables regulation to achieve the Energy Policy targets by means of a SG. It is consensual that SG may deliver the desirable results; however, investing on a SG is a not-so-consensual point. Currently the value chain actors (Distribution System Operators (DSOs), TSOs, and Network Operators) are not keen on investing on SG in an uncertain environment<sup>12</sup>. What we intend to research is what would be a proper environment, in terms of regulation, that may make the implementation of SG move forward having in mind the EU Energy Policy objectives.

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<sup>12</sup> We mean by uncertain the fact that current regulation doesn't give the proper incentives to invest. Besides that, it is not clear who will benefit from these investments, and which task each player will be responsible for.

**Thus, our research questions are the following:**

1. *“Will Smart Grid be able to give an answer to main today’s questions such as energy security, energy cost and environment impact?”*
2. *What is the role of economic regulation in providing the incentives to invest in Smart Grid?*

Furthermore, these can be disaggregated into two sub-questions:

**Sub-questions:**

1. *Is the European regulation designed so that it promotes the implementation of Smart Grids (directives, financial funds, support)?*
2. *What is the rule of standards on the choices of Smart Grid technologies, and how does the global governance of standards can influence those choices (taking in account that interoperability is important in network industries)?*

This dissertation is divided in five chapters. The first two chapters bring us to the roots of our subject: following this Introduction (Chapter 1), Chapter 2 reviews the main concepts of Smart Grid that we found useful to contextualize. Chapter 3 deals with regulation of Smart Grid – motivation for building a Smart Grid, and how to get there. In Chapter 4 we provide possible ways to progress with Smart Grid implementation, mainly by means of regulation and policy. Chapter 5 summarizes the main findings of this work and provides suggestions for future research.

Before proceeding, we would like to note that this dissertation exceeds the limit of the number of pages because Smart Grid is a very recent and critical topic for which background information is needed to provide a proper context.

## Chapter 2

### Smart Grids: basic concepts and context

Building a SG is very challenging because many aspects shall be taken in account, from the technical complexity of these new grids, to the institutional complexity of organizing the consensus (coordination) needed for such a shift of electricity generation, transmission and distribution paradigm. In our view, the latter needs to be handled by means of institutional action, namely at EU level, by means of a coherent Energy Policy and institutions that create the right environment to make such large scale investments.

In this chapter we will see what a SG is, and the motivations to build it (as opposed to maintain the current architecture of electricity networks). We make an introduction of the electricity market value chain and see important aspects that SG will need to take in account such as Distributed Generation (DG), Distributed Energy Resources (DER), Demand Side Management (DSM) and Smart Meters (SM). We will also make an assessment of current Cost Benefit Analysis (CBAs) on SG.

#### 2.1 Definition: is there any consensus?

The term Smart Grid has seen several definitions from author to author, and in different contexts. It may be difficult to pick a concise and clear definition, so we are going to present a few given by reference institutions.

According to the EU, (European Commission, 2011c), *"A Smart Grid is an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety"*.

As for the International Energy Agency (IEA, 2011), *"A Smart Grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart Grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all*

*parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience and stability”.*

The definition given by the United States Department of Energy, seems to give more focus on the integration and performance delivery of the following characteristics: *“self-healing from power disturbance events; enabling active participation by consumers in Demand Response; operating resiliently against physical and cyber attack; providing power quality for 21<sup>st</sup> century needs; accommodating all generation and storage options; enabling new products, services, and markets; optimizing assets and operating efficiently”*<sup>13</sup>. (U.S. Department of Energy, 2009) complements the definition with the consideration that *“The electric industry is poised to make the transformation from a centralized, producer-controlled network to one that is less centralized and more consumer-interactive. The move to a smarter grid promises to change the industry’s entire business model and its relationship with all stakeholders, involving and affecting utilities, regulators, energy service providers, technology and automation vendors and all consumers of electric power.”*

From all these views, one common thing is that SGs will result in systemic changes in the electricity systems: new business models, new service providers, new tasks for regulators, and probably new consumer behavior. Many of these ideas are already in operation. Yet it is only when they are empowered by means of the two-way digital communication and plug-and-play capabilities that exemplify a smarter grid, that genuine breakthroughs begin to multiply. We are talking about Advanced Metering Infrastructure (AMI), Distributed Generation (DG) and Demand Response (DR).

While supply and demand is a bedrock concept in virtually all other industries, it is one with which the current grid struggles mightily because electricity must be consumed at the moment it is generated. Without being able to ascertain demand precisely at a given time, having the ‘right’ supply available to deal with every contingency is problematic. This is particularly true during peak demand, those times of greatest need for electricity during a particular period (U.S. Department of Energy, 2009). During the hours of peak demand, in addition to base load generators, it is needed to dispatch peak-load generators (with relative low marginal costs). As that, the costs of production during

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<sup>13</sup> Taken from <http://energy.gov/oe/technology-development/smart-grid>, last visited August 8, 2013

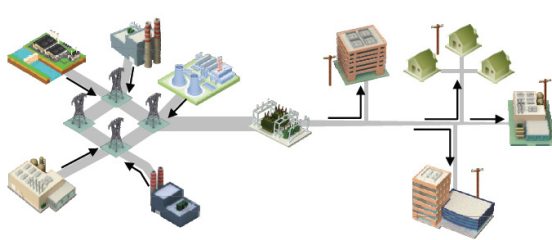
peak hours are higher than other hours of the day when demand can be met with base load generators. As consumers are not able to know the short-run changes in the costs of generation, they receive no price incentive to consume more power when costs of production are cheaper, and to reduce consumption when production is more expensive. These facts have a consequence in the reliability of the system and on future capacity investments decisions, as supply needs to meet daily, seasonal and annual variations in load.

In the last years we have assisted to a dramatic surge of RES; however these energy sources have the limitation of generating electricity in specific conditions (electricity is generated only in the presence of sun or wind), and thus they are considered as intermittent. (Knödler, 2012) suggests four ways to overcome this problem: by providing peak load capacity, by importing energy, by establishing storage systems, and/or Demand Side Management (DSM). Improvements in metering technologies, network management practices and Distributed Generation (DG) technologies are enabling Demand Side participation to become a more active component in energy market operations. The main barriers to increasing participation are i) inelasticity of demand; and ii) information asymmetry. The first category is often referred to as Demand Response (DR) and is the most recent stage in the evolution of DSM programmes, a subject we develop in section 2.5. The second aspect is treated in section 2.6.

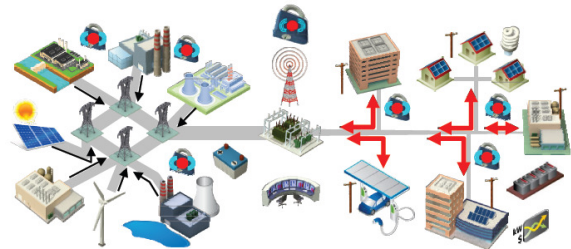
## **2.2 Smart Grid and the electricity value chain**

SGs are often seen as an effective solution to address some of the toughest challenges the electricity industry has faced so far: the integration of renewable on a very large scale, the promised rise in number of EVs, the necessity of energy efficiency, the improved security of supply and the arrival of the '*prosumer*'. Equipment manufacturers and ICT solution providers are eagerly awaiting the hundreds of billions of Euros to be invested in the next decades (Lapillonne et al, 2012). To understand how SG affects the

electricity market, we need to revise the electricity value chain and the relationship between its players<sup>14</sup>.



**Figure 2 - The grid as it is today**  
Source, (EPRI, 2011)



**Figure 3 - The Smart Grid**  
Source, (EPRI, 2011)

(European SmartGrids, 2012) considers as Smart Grid stakeholders the players described in Table 4 (see Appendix I). This is certainly a complex environment that captures not only the stakeholders of the electric value chain, but also other players and concepts such as Telecom providers, EV users, new grid technologies with renewable generation, storage, increased consumer participation, sensors, communications and computational ability (ICT). This results in a bidirectional electricity infrastructure, since the traditional consumption side now also has possibilities to produce electricity. For the sake of simplicity and without sacrificing the objectives of this work, we will consider and make a summarized characterization of the electricity value chain players (these descriptions shall have in mind what the grid looks like today, and the vision of future Smart Grid - Figure 2 and Figure 3 respectively).

Traditionally, managing the electricity supply chain consisted of producers and consumers acting on the electricity market and awaiting the real-time control of network operators and power generation companies. Distributed generation, distributed storage

<sup>14</sup> The traditional electricity value chain is mainly composed of generation, transmission, distribution and commercialization. To transport electricity, a large infrastructure has been constructed. This infrastructure can be divided into two types of grids: a transmission grid and a distribution grid. This division is related to the voltage levels at which the grids operate. The higher the voltage level, the more efficiently equivalent amounts of electricity can be transported over long distances, since transmission losses depend on current instead of voltage. Generally speaking, the installed capacity shall be able to satisfy a peak demand, and transmission lines are used to transport high voltage until the distribution points, and from there to homes or industrial customers.

The transmission grid is operated and maintained by the Transmission System Operator (TSO); the distribution grid is connected to the transmission grid and is operated by Distribution System Operators (DSOs). Where a TSO is responsible for large-scale electricity transmission, a DSO is responsible for the final part in the electricity supply chain, i.e. the delivery towards the customer. TSOs and DSOs are monopolists in their respective areas. Therefore, they are bounded by regulations set by governmental authorities (Bosman, 2012).

and demand side load management are becoming realities across the value chain, having important impact on the way the traditional supply chain is managed and balanced, leading to a growing need for decentralized intelligence (that is to say, the implementation of SG).

### *Generation*

Generators are traditionally the generating plants which are away from heavily populated areas. The generated electric power is stepped up to a higher voltage at which it connects to the transmission network. The generators that can react fast are called peak plants, since they take care of the fluctuating peak demand in the electricity consumption. While they respond fast to fluctuating demand, in general their energy efficiency is relatively low, compared to the energy efficiency of the power plants that mainly supply the electricity base load. Already this difference shows that it is beneficial to decrease peaks in the electricity demand, in order to improve the energy efficiency of generation (Bosman, 2012).

As (Wissner, 2011) puts, one crucial option that ICT offers in generation is the better integration of RES like wind and solar power and cope with the intermittent feed-in of these power plants. The main concept is that a SG is driven by a decentralized generation architecture. According to (Bosman, 2012), distributed generation emerges in two general types: sustainable Distributed Generation (e.g. wind turbines and solar panels) and energy efficiency improving generation (e.g. Combined Heat and Power (CHP)<sup>15</sup>).

### *Storage*

Because of its efficiency losses and high costs, electricity storage systems have not been applied at a large scale. Thus, in the traditional networks, the challenge is to continuously find a match between consumption and production. If efficient and less costly, storage would probably be the best tool to control balance in the electricity

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<sup>15</sup> A micro CHP produces both heat and electricity for household usage at the kW level; the electricity can be delivered back to the electricity grid or consumed locally. Combined with a heat buffer, the production of heat and electricity can be decoupled and an operator has flexibility in the times that the micro CHP is producing, which creates a certain degree of freedom in electricity production.

supply chain, as the temporary fluctuations in demand and supply could be better managed (acting as a buffer).

Recently, new techniques of storage emerged; at a domestic scale, electricity storage can be combined with a power supply system. EVs can be used as storage devices when the car is parked; this gave rise to the Vehicle to Grid (V2G) systems, which help to control voltage and frequency in the grid. At a larger scale, Compressed Air Energy Storage (CAES) can help control the fluctuation of wind, as well as pumped hydro-electric energy storage.

### *Transmission*

Transmission moves power long distances, often across nations, and sometimes across international boundaries, until it reaches its wholesale customer (usually the company that owns the local distribution network). Many components of SGs are already known from transmission networks where most equipment allows remote supervision and control.

### *Distribution*

In contrast, distribution networks are largely still operated relying on human intervention. Upon arrival at a substation, the power is stepped down in low voltage – from a transmission level voltage to a distribution level voltage. As power exits a substation, it enters the distribution wiring. Finally, upon arrival at the service location, it is stepped down again from the distribution voltage to the required service voltage(s).

The way customers use electricity networks is changing as a result of trends such as the electrification of heat and transport, or the growth of DG. The bidirectional electricity flow (as a result of the possibility of consumers becoming also producers - *prosumers*) gives both an increased attention towards load and congestion management, and may ask for technical improvements in the infrastructure (e.g. a Smart Metering infrastructure has to be clearly defined and implemented) (Bosman, 2012). Thus, with SGs, because we can expect a generation feed-in increase (due to integration of DG), the power flow in distribution networks is not anymore unidirectional top-down, but increasingly also bottom-up; this triggers a change to more actively managed

distribution networks, similar to the present management at transmission level (Friedrichsen, 2011).

### *Consumers/Prosumers*

Recent developments in domestic appliances lead to more flexibility in consumption control. Controllable washing machines, dryers, fridges and freezers are responsible for a big percentage of the total consumption/demand of a household. Heat pumps are also used to supply domestic heat demand, by transferring energy from the soil or the outside air. This development means that the total load profile of a household gives room for adjustment by a control system, as opposed to the traditional uncontrollable consumption.

The decentralized generation based on small units like Photovoltaic (PV) cells of private households or CHP units, creates the role of prosumers, which is a term that recognizes the emancipation of customers from electricity producers and feeders (Knödler, 2012).

(Clastres, 2011) has the opinion that the positive effect expected from SG is not necessarily a drop in prices but rather a reduction in the bills paid by consumers. A different opinion is expressed in (Verbong et al, 2013) stating that although SGs might lead to short term benefits, the proportion of income that users will spend on energy is bound to rise. Benefits are therefore relative to a future without SG. Besides this, an overly positive approach could be harmful to public acceptance when SGs is introduced and prices do still rise.

### *Management and control*

The introduction of DG, intelligent consumption, and storage devices needs an advanced energy monitoring and control. SM is the first step for such an intelligent control. Real-time load balancing and congestion management in distribution networks is also needed<sup>16</sup>.

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<sup>16</sup> A large system that is in use for years in the traditional electricity supply chain is SCADA (Supervisory Control And Data Acquisition), that, in combination with grid protection systems, secures the actual generation of electricity. In this system, human operated control rooms oversee and steer, in combination with the help of computer programs, the real-time generation.

Several ICT oriented methodologies are proposed to control and manage (a part of) the SG, in addition to the already existing management systems that aim at dispatching generation, load balancing and congestion management. The demand for more complex coordination and flexibility can be most economically achieved through the extensive use of ICT; as in other industries, this does not only imply the introduction of new devices, but also a fundamental rethinking of the overall system design – this may lead to some conflicts: while the incumbent powers of the electricity sector try to keep stability and their own roles by maintaining as far as possible the current system logic, the ICT industry is more used to conceive high flexible multi-layered systems with a multitude of feed-backs and distributed responsibilities, allowing different organizational configurations<sup>17</sup> (SEFEP, 2012).

### *Virtual Power Plant*

A Virtual Power Plant (VPP), is a cluster of distributed generation installations (such as micro-CHP, wind-turbines, small hydro, back-up gensets, etc.) which are collectively run by a central control entity. This VPP can be comparable to a normal power plant in production size. The wide-spread distribution of generators asks for a well-controlled generation method. These generators must be scheduled or planned to generate power at different times of the day in a way that the combined electricity production of all generators matches a given generation profile that resembles the production of a normal power plant.

## **2.3 Smart Meters**

Annex I of the Third Energy Package (2009/72/EC) states that the MSs shall ensure that customers are actively engaged in the electric supply market through “intelligent metering systems”. As of 2020, 80% of the consumers shall be equipped with SMs in case the roll-out in their country “is assessed positively”.

SMs are electronic measurement devices used by utilities to communicate information for billing customers and operating their electric systems. These meters were first applied in commercial and industrial consumers due to the need for more sophisticated

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<sup>17</sup> This fact has, as we will see later, an important impact on standardization of Smart Grid.

rates and more granular billing data requirements. Due to the decreasing cost of technology and advanced billing requirements, they became available to all consumer classes. There are two major designations in the context of SMs, one is Advanced Metering Infrastructure (AMI), and the other is Automated Meter Reading (AMR) Systems. AMR Systems use one-way communications to collect meter data. AMI was developed from AMR to today's two-way communication and data system. Thus AMI refers to the combination of meters with two-way communications technology for information, monitoring, and control (EEI, 2011).

Before SG initiatives were established, these meters and systems were referred to as – Smart Meters and Smart Meter Systems. Hence, the present state of these technologies should be more appropriately referred to as an evolution, not a revolution, because of the development and use of SM technology and communications over the last fifteen years (EEI, 2011).

A SG monitors electricity delivery and tracks power consumption with SMs that transmit energy usage information to utilities via communication networks. The two-way nature of SM Systems allows sending commands that operate grid infrastructures, such as distribution switches and reclosers<sup>18</sup>, to provide a more reliable energy delivery system<sup>19</sup>.

## **2.4 Distributed Generation**

Transmission lines connect power sources to the grid and have been technologically updated with automation and human monitoring over the last few decades. However, distribution lines never really became high-tech oriented because they have been mostly taken as user end-points of service, where power was delivered to traditional loads.

We shall note that the shift from fossil fuel and nuclear energy infrastructures to renewable energy facilities has mostly followed the “central-station” model<sup>20</sup>. The reason for this is the large extension of land needed to install wind and solar facilities

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<sup>18</sup> Reclosers are used on overhead distribution systems to detect and interrupt momentary faults.

<sup>19</sup> This is known as Distribution Automation (DA).

<sup>20</sup> A “central-station” power plant is a large-scale facility located in a single, often remote location. The electricity generated by these plants is then transmitted over long distances to the load centers (urbanized or industrial areas) where it is consumed (Hohn, 2012).

that generate the same amount of energy as the fossil fuel or nuclear – thus, these facilities have been installed away from urban areas. Besides affecting dramatically the landscape and natural resources on site, arranging a route for the transmission of energy from remote locations can be as challenging as sitting the project itself (The Economist, 2012), (Hohn, 2012).

DG has been growing in the last two decades. This type of energy generation is exactly the opposite of the “central-station” model. Renewable DGs are located near or within the developed areas likely to use the electricity they generate. Renewable DG facilities are most commonly solar projects, though wind power, geothermal plants, small hydroelectric facilities, and biomass incinerators can be developed at a smaller, more distributed scale.

There are many definitions for DG, and it is called differently in different countries. Some describe this technology in terms of voltage, whilst others based on the generation capacity, interconnection and location. Nevertheless, the main objective of DG is to get the electricity from point of generation close to the point of consumer. (Hidayatullah, 2011).

DG can provide many benefits; according to (Hohn, 2012), “central-station” renewable energy projects in the USA take too long to permit and connect to the grid, while a larger number of smaller DG projects can quickly be brought online<sup>21</sup>. Other benefits are that DG is increasingly cost effective<sup>22</sup>, provides local equitable economic benefits<sup>23</sup>, minimizes the environmental impact of renewable energy<sup>24</sup>, and increases energy security<sup>25</sup>. Although DG has benefits, there are also barriers to its implementation. These barriers are related with the interconnection (in terms of ability of the load generated on to the grid), the financial terms on which electricity is sold, and the permitting of the physical project.

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<sup>21</sup> This fact is important when governments are willing to achieve targets for renewable energy.

<sup>22</sup> Compared with “central-station” that although benefiting from economies of scale, also needs to take in account environment and transmission costs.

<sup>23</sup> As the installation of DG is not centralized, the costs of sales, installation and maintenance can be integrated in local economies.

<sup>24</sup> Solar infrastructure can be placed in already existing structures, and almost no transmission infrastructure may be required.

<sup>25</sup> As opposite to centralized generation, that when there is a failure (system or transmission line goes down), in DG results in a more resilient energy supply as it is widespread.

## **2.5 Demand Side Management**

In order to meet the demanded energy, utilities need to be designed in a way that in a peak, the supply shall meet that demand - thus, energy generation is not efficient. One way to reduce these inefficiencies is to optimize demand side. This is done by means of Demand Side Management (DSM). SMs combined with communications are the way to increase participation on the demand side by providing new pricing structures and overcoming information asymmetry. An important aspect of SG is network flexibility, and this is related with the integration of intermittent energy resources such as wind and solar, so Demand Response (DR) is important in contributing to this flexibility. Advanced communications, control methods and ICT including sophisticated metering are central to achieve this goal.

Demand Side Management involves the planning, implementation and monitoring of utility's activities with the aim of involving customers to achieve changes in the utility's load shape. According to (Gellings, 2009), these programs include load management, new uses, strategic conservation, electrification, customer generation and adjustments in market share.

Although the focus in SG discussion has been mainly on the need to integrate DG, attention is increasingly turning to the demand side, because of further energy demand and introduction of new loads such as EVs (the addition of EVs is expected to almost double the current average electricity demand per household). So, there is a pressure on the system related to the volatility and capacity of the infrastructure. SG promises to take care of these problems by making demand to follow generation. This introduces the need for more local balancing of supply and demand, including more measuring and monitoring of flows, and the use of communication tools to maintain network stability (Verbong et al., 2013). DSM shall allow consumers to make informed decisions about consumption, adjusting both the timing and quantity of their electrical use. It promises to cut costs for commercial customers, households, and to help utilities to operate more efficiently (Davito et al., 2010). To implement this vision, a two-way communication along the electricity value chain is needed. These two-way communications were not

available during the inception of the DSM concept<sup>26</sup>, so they serve to update the DSM vision.

Despite of its broad definition, DSM mainly results in the implementation of two main concepts: Demand Response (DR) and Energy Efficiency and Conservation. These activities allow consumers a greater role in shifting their own demand for electricity during peak periods, and reducing their energy consumption overall. DR programs transfer consumer load during periods of high demand to off-peak periods, and can reduce critical peak demand<sup>27</sup> or daily peak demand<sup>28</sup>. The result of shifting daily peak demand is the flattening of the load curve (meaning more electricity at less expensive base load generation). DR programs can also save the cost of building additional generation capacity to meet future peak demand. As for Energy Conservation and Efficiency, Energy Conservation is related with encouraging consumers to save money by giving up some energy (e.g. turn up thermostat a few degrees in summer), and Energy Efficiency programs allow consumers to use less energy to receive the same level of service (e.g. replacing an old home appliances with a more energy efficient models). Many pilots have shown that real-time access to information provided by the network can cut energy consumption (Davito et al., 2010). Additional gains in energy efficiency can be achieved through technologies that provide target education or real-time verification of consumer demand reduction. (Verbong et al, 2013) makes a review on the subject and the literature suggests that a reduction in energy consumption of between 5% and 15% is possible; recent trials show a mixed picture: for the US it results in a demand reduction between 4% and 15%, while similar experiments in Ireland and in the United Kingdom (UK) resulted in a reduction of only 3%. Due to a lack of long term experiences it is yet unclear to what extent these effects are temporary or lasting, and if users are returning to their old practices.

Pricing is central to DR strategies and its overall aim is to increase the elasticity of electricity demand by giving customers price signals that are more cost-reflective. More advanced forms of pricing require advanced metering solutions. Until recently, the cost of time-of-use metering was substantially less than real-time metering, making the

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<sup>26</sup> DSM is a term coined by EPRI in early 1980s.

<sup>27</sup> Critical peak demand is the 20-50 hours of greatest demand throughout the year.

<sup>28</sup> Daily peak demand is the maximum demand during a 24-hour period.

implementation of real-time pricing limited to industrial applications. Due to reduction of the cost of metering in the last decade, it became possible to combine real-time pricing with forms of automated DR technology so that responding to frequent price changes does not always require customer intervention (Haney et al., 2009). If consumers can respond to variable energy prices, their energy bill may be reduced. For energy companies and network operators, benefits result from a lower peak in energy demand, requiring fewer investments in production and transport capacity. Empirical evidence for the potential of financial stimuli, for consumers, is mixed: as for (Verbong et al., 2013), price benefits for a consumer are less than 0.5% and substantial reductions in energy use face several social and technical barriers and limitations. (FERC, 2009) estimates that DR programs can cut peak demand by 20% within the next 10 years. Consumers' active involvement in DR will encourage themselves to adapt to new and smart patterns, introducing flexibility to the way electricity is consumed. New products for customer awareness are available, such as home displays, apps, controls, etc. while new ones will be developed. The most important aspect of SG from a DSO perspective is to facilitate effective DR in order to adjust local energy usage to locally available production to avoid overload of the grid and reduce network losses. This is the key to a smart electricity market with a high degree of DER sources as is foreseen. Effective DR functions will result in lower energy costs and reduced usage of fossil fuel-based electricity production contributing to lower carbon output (GEODE, 2013).

## **2.6 Information: coordination and privacy issues**

We have just seen that the effects of improving the available information on customer energy consumption have been explored mainly to understand how better information can encourage more energy efficient behavior, i.e., reductions in total consumption. The conclusions of the work in the UK and those from the international review conducted by (Darby, 2006) suggest that there is growing evidence that more detailed information on energy consumption has a positive impact on levels of energy efficiency.

The information infrastructure is a vital component of SGs. Decentralized approaches towards control reinforce the demand on information and communication across the system. This is likely to generate extensive data flow. This data is on the one hand price information flowing to consumers and thereby informing them about system conditions.

On the other hand it is information about current status of generation, load, substations, other system components, or the system conditions such as voltage or frequency. In the simplest case diverse users could jointly use one common information structure for diverse purposes: network information, DSM, VPPs, and SMs (Friedrichsen, 2011).

Privacy is considered as an issue that can block successful introduction of SGs and DSM. Detailed data on electricity consumption gives involved actors a lot of information on consumer behavior. This raises an important question which is the ownership and control of data generated by SMs. As (Knödler, 2012) points out in her literature review, Smart Metering will entail a “data explosion”, which has to be based on data protection measures, because if consumers fear about personal data the whole SG development will fail (for example in 2008, the Dutch government debated a mandatory 100% roll-out of SM but public resistance, mainly due to data concerns, forced the government to withdraw from its initial plans and consider a voluntary roll-out).

## **2.7 The Economic Case for Smart Grid (Cost Benefit Analysis)**

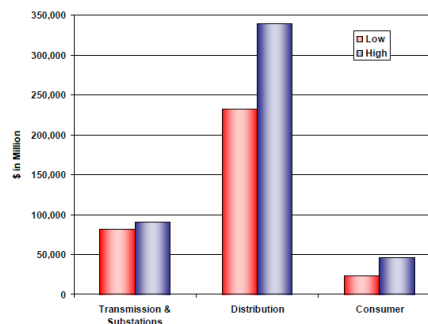
As noted by several authors, SGs are seen as an additional instrument to achieve targets to promote competition, to increase the safety of electricity systems, and to combat climate change (Clastres, 2011), (European Commission, 2012a). However, SGs involve huge investments that the electricity value chain players are reluctant to make. Without a clear definition of the scope of SG investments, costs and benefits are difficult to assess. In this section we present literature review for CBA made for UK (Ernest & Young, 2012) and USA (EPRI, 2011). There is also some work on CBA for EU (Knödler, 2012).

There is one comprehensive SG investment cost and benefit evaluation for the US, which is (EPRI, 2011). In this study, the costs cover a wide variety of enhancements to bring the power delivery system to the performance levels required for a SG. The costs include the infrastructure to integrate DER and to achieve full customer connectivity, but exclude the cost of generation, the cost of transmission expansion to add renewables and meet load growth, and a category of customer costs for SG-ready appliances and devices.

	20-Year Total (\$billion)
Net Investment Required	338 – 476
Net Benefit	1,294 – 2,028
Benefit-to-Cost Ratio	2.8 – 6.0

**Table 1 - Summary of Estimated Cost and Benefit of the SG**

Source: (EPRI, 2011)



**Figure 4 - Total Smart Grid Costs**

Source: (EPRI, 2011)

Smart Grid Cost to Consumers - Allocated by Annual kWh (a)								
Class	\$/Customer Total Cost (b)		\$/Customer-Year, 10-Yr Amortization (c)		\$/Customer-Month, 10-Yr Amortization (d)		% Increase in Monthly Bill, 10-Yr Amort (e)	
	Low	High	Low	High	Low	High	Low	High
	\$/Customer	\$/Customer	\$/Cust/yr	\$/Cust/yr	\$/Cust/Month	\$/Cust/Month		
Residential	\$1,033	\$1,455	\$103	\$145	\$9	\$12	8.4%	11.8%
Commercial	\$7,146	\$10,064	\$715	\$1,006	\$60	\$84	9.1%	12.8%
Industrial	\$107,845	\$151,877	\$10,785	\$15,188	\$899	\$1,266	0.01%	1.6%

**Table 2 - Possible Consumer Implications of the EPRI Estimate of Smart Grid Costs**

Source: (EPRI, 2011)

As we can see from Figure 4, and the analysis from (EPRI, 2011), most of the costs will be borne by DSOs (around 70%); TSOs will bear between 20 and 25% of the costs and Consumers less than 10%. We can also see from Table 2, for consumers, most of the cost will fall onto residential and commercial customers. Their bill is expected to increase by an average of 8.4% to 12.8%. Industrial users are not expected to be significantly impacted.

The only economic study we found about a possible SG at European scale was (Knödler, 2012). This study's scope is an European SG defined as 27+2 (including Norway and Switzerland) national SGs that are interconnected. The author seeks an answer for the cost effectiveness of an European SG, how are the costs distributed among market actors, and what are the opportunity benefits of a SG compared to a Dumb Grid adapted to integrate RES. The only regularity that was found across all CBAs is that in the end, consumers profit in most cases, whereas the grid operator or energy supplier has to bear the main costs and seldom profits. Knödler also considers the investment needed for an electricity grid being able to feed-in a high share of RES; here the author bases on studies that deal with the transmission investments and others that also consider distribution investments. The author finds out that annual infrastructure investment costs from different studies (ENTSO-E, EU Commission, Greenpeace, and IEA) vary

considerably, and points the different time horizons and scope (transmission, and distribution investments) as one explanation for the great differences. This emphasizes the need for more investigation on necessary investments. Other outcome from Knödler's work relates to the benefits on capacity effect and energy effect. The first takes into account the shifting of peak load demand to off-peak hours, and the latter considers possible savings of households through Smart Metering. The main result are possible benefits amounting to EUR 944 M to EUR 3.2 Bn for the capacity effect and to EUR 3.7 Bn to EUR 11 Bn for the energy effect. (Knödler, 2012) also finds out that the costs for a SG solution are higher than for a Dumb solution within a first investment period – the main reasons for this are that the bidirectional communication has to be set up once, and the Smart Metering infrastructure has to be rolled-out once, too. However, a Dumb grid would not deliver the benefits a SG will – on the contrary the investments for a Dumb grid will increase in the long run as much more transmission lines have to be installed since no intelligent distribution can be used. This leads to the conclusion that the investment decisions shall take in account a long-term perspective. However, these investments are not quantified in (Knödler, 2012), and as is noted in (Prügler and Bremberger, 2011), the question of which of the options (“Dumb” solution or SG) is more sustainable in terms of costs vs. benefits for society especially in the long-run, has not yet been completely answered.

According to (Ernest & Young, 2012), there is strong consensus in the UK and internationally about the long term need to move to SG, and a number of countries have quantified its benefits and stand ready to take advantage of the growth it might deliver. However in the UK, there is less clarity about how to make it happen, or the speed at which the transition needs to take place. (Ernest & Young, 2012) presents two major findings. The first is that the initial investment for moving ahead with SG development sooner than later appears very strong: for example, the report's figures indicate that the benefits of moving in a timely fashion far outweigh the risks and appear robust across a number of different scenarios. The second is that the timely creation of a SG can unlock significant benefits in other industries, providing a welcome boost to growth, jobs and exports.

## **Roll-out for Smart Meters and Cost Benefit Analysis (CBA)**

Europe has enjoyed notable success with SMs. In 2006, Italy became the first country in Europe to complete a national SM program after Italian utility Enel conducted a five-year €2 billion (\$2.6 billion) scheme - mainly to reduce non-technical losses - for its 30 million customers. Elsewhere, Scandinavia leads the way. Sweden also achieved full-scale penetration in 2010, while Finland, Norway and Denmark are likely to achieve their targets by 2016. Yet for many EU nations which did not take it upon themselves to be early adopters, SM programs have struggled (Energybiz, 2013).

As part of the Third Package, based on a provision in the Electricity directive (2009/72/EC), the EU has mandated that all MSs deploy SMs to 80% of customers by 2020, if economically feasible. Based on best practices and projects in MSs, by April 2012, the Commission developed guidelines and new instruments to further stimulate the rollout of SM Systems in the present decade, monitoring the progress of current Smart Metering projects in the EU and supporting promising R&D and pilot projects in SG<sup>29</sup>. All EU countries were meant to complete Smart Metering CBA<sup>30</sup> by September 2012. The coordination of this activity is with DG Energy<sup>31</sup>, and assessment criteria and required functionalities have been developed in cooperation with DG INFSO<sup>32</sup> and DG JRC<sup>33</sup>. These CBAs should give a positive or negative CBA which would result in going (or not going) ahead with a roll-out. Most nations have reported a positive Cost Benefit Analysis, although there were some exceptions. The Czech Republic's analysis was negative and has recommended its rollout to start in 2018, while Germany delayed

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<sup>29</sup> Commission recommendation on preparations for the roll-out of smart metering systems [C/2012/1342] <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32012H0148:EN:NOT>, last visited August 8, 2013

<sup>30</sup> Guidelines for conducting a cost-benefit analysis of Smart Grid projects [http://ec.europa.eu/energy/gas\\_electricity/smartgrids/doc/20120427\\_smartgrids\\_guideline.pdf](http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/20120427_smartgrids_guideline.pdf), last visited August 8, 2013

<sup>31</sup> See footnote 36 below.

<sup>32</sup> EU Directorate General Information Society and Media or "DG INFSO" is a Directorate-General of the European Commission. From 1 July 2012, the name of the DG became Directorate General for Communications Networks, Content and Technology or DG CONNECT (internally also DG CNECT).

<sup>33</sup> The Joint Research Centre is the scientific and technical arm of the European Commission. It is providing the scientific advice and technical know-how to support a wide range of EU policies. The JRC has seven scientific institutes, located at five different sites in Belgium, Germany, Italy, the Netherlands and Spain. The Smart Electricity Systems and Interoperability team (or Action, as it is officially named) is part of the Energy Security Unit at the JRC Institute for Energy and Transport, located both in Petten (NL) and Ispra (IT).

the publication of its report until February 2013 (Energybiz, 2013)<sup>34</sup>. Smart Metering market continues to be negatively affected by macroeconomic challenges, as well as delays in national regulatory frameworks. The complexity of issues pertaining to Smart Metering (financing, privacy, data security, and so on) has made the national discussions challenging, particularly as they need to result in sound national regulatory and legal frameworks guiding the rollouts.<sup>35</sup>



Before we move to the next chapter, we shall note that the distributed and decentralized nature of SG is at the same time its strength and its weakness. These characteristics ask not only for a highly coordinated operation but also a high degree of investment coherence along the value chain. Thus, regulation shall not only work as an incentive, but also as a way of ensuring that each player is contributing to a system transformation. We also think that interoperability, by means of standardization, is a way of coordinating the development of this system architecture. As we have seen, for both the USA and the EU cases, the biggest costs are being placed under the responsibility of regulated businesses (especially in DSOs). Thus, it means that regulators shall be able to design regulations that give the appropriate incentives to regulated companies to invest in SGs.

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<sup>34</sup> It was not possible to find more information about Germany CBA assessment after the publication date of (Energybiz, 2013).

<sup>35</sup> <https://idc-insights-community.com/energy/smart-grid/personalobservationsfromtherecentsmartutilitiescentralampeasterneuro>, last visited August 8, 2013

## **Chapter 3**

# **EU Energy Policy and Regulation for Smart Grid**

In the previous chapter, we have seen that in order to implement a SG, huge investments need to be done by some players of the value chain, especially by DSOs. However, with current regulation, DSOs are not willing to make such investments (EURELECTRIC, 2011). It is necessary to create a new regulation design that makes them to appropriately balance short run concerns with long run concerns, that is, a greatest focus on dynamic efficiency.

In this chapter, we revisit the EU Energy Policy relative to SG, the regulation frameworks currently enforced, and assessments of the ability of those frameworks to provide the incentives needed for SG implementation. We will make a short review of regulation tools, and look at regulation innovation examples that may work as point of departure for the demanding SG regulation. We also give attention to one of the most important aspects of network industries – interoperability. This chapter thus lays the foundations for the discussion of what is the way forward for SG implementation.

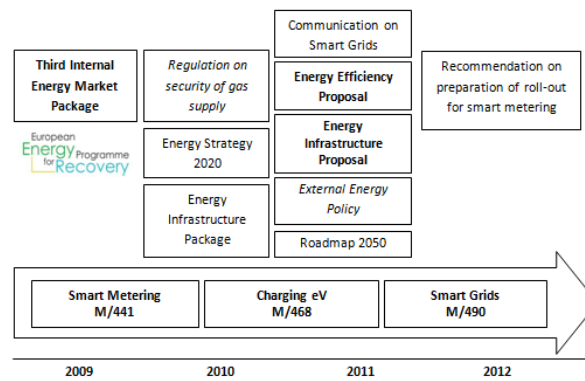
### **3.1 EU Energy Policy for Smart Grid**

The EU Energy Policy shall be considered as an important source of guidelines and regulations for the EU countries. As we will see in this section and in particular for SGs, the discussion in EU is being made by several bodies, although (apparently), sometimes, not in a well-coordinated way.

The EU Third Package has been an important step to establish the context of SG in the EU energy policy/regulation framework. In this package, European law introduced the concept of intelligent grids and intelligent metering systems. It is also important to consider the work being done at the EC level and European Regulators concerning the standardization and the new shape of regulatory policy in the implementation stage. The efforts taken by the EC to promote SGs have the involvement of several Directorate-

General (DGs)<sup>36</sup> such as DG Energy (Grid activities such as: Competitive Energy Markets, Energy Efficiency, Integration of Fluctuating Renewables), DG Enterprise & Industry (ICT, Electrical Equipment, Appliances), DG Information and Society, and DG Research and Innovation.

From the Communication "Smart Grids: from innovation to deployment" (European Commission, 2011a), five objectives are considered as key: 1. Developing technical standards, 2. Ensuring data protection for consumers, 3. Establishing a regulatory framework to provide incentives for SG deployment, 4. Guaranteeing an open and competitive retail market in the interest of consumers, and 5. providing continued support to innovation for technology and systems.



**Figure 5 - EU Energy Policy Development**  
(Adapted from (European Commission, 2012b))

In order to understand the current EU energy regulatory environment, we make a course into the initiatives and directions that the EU/EC made (beyond the important Third Package). Figure 5 gives a summary of the EU Energy Policy initiatives.

### Smart Grids Task Force (SGTF)

The Smart Grids Task Force (to implement the SG for the the European Internal Market) was set up by the European Commission (EC) at the end of 2009 (under the provision of the Third Energy Package). The SGTF reached a consensus in its first years

<sup>36</sup> The Commission is divided into several departments and services. The departments are known as Directorates-General (DGs). Each DG is classified according to the policy it deals with. The Commission services deal with more general administrative issues or have a specific mandate, for example fighting fraud or creating statistics. (Source: [http://ec.europa.eu/about/ds\\_en.htm](http://ec.europa.eu/about/ds_en.htm), last visited August 8, 2013 )

on policy and regulatory directions for the deployment of SGs. SGTF has also issued key recommendations for standardization, consumer data privacy and security<sup>37</sup>.

The SGTF is organized as a Steering Committee composed by representatives from Commission Services, Regulators, Industries (such as DSOs and TSOs), and Consumers. It is supported by four Ad-hoc expert working groups (1. Standardisation, 2. Data Protection and Security, 3. Regulation: market model and options, 4. Infrastructure) which have delivered reports in 2011. In 2012, the EC updated the Mission and the Framework Programme for the SGTF and decided to extend its activities for two more years. As a result, a new Steering Committee was appointed (with a stronger participation of the telecom industry). The updated mandate emphasizes that the key challenges for SG deployment are, first, largely of regulatory nature; second, to develop appropriate standards; and third, to support and launch appropriate infrastructures and co-ordination/dissemination of lessons learned (European Commission, 2012c).

During 2011 the EC adopted a Communication on Smart Grids (European Commission, 2011a), issued a Mandate for SG standards<sup>38 39 40</sup> to the European Standardization Organizations (CEN-CENELEC-ETSI) and created an Inventory of SG projects and lessons learned in the EU. The EC also adopted a Recommendation for the roll-out of SM Systems<sup>41</sup> and issued Guidelines for conducting CBAs of SG projects<sup>42</sup> in 2012.

### **European Energy Programme for Recovery (EEPR)**

The European Energy Programme for Recovery is a 4 billion Euro programme that was set up in 2009 to co-finance projects designed to make energy supplies more reliable

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<sup>37</sup> [http://ec.europa.eu/energy/gas\\_electricity/smartgrids/taskforce\\_en.htm](http://ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm), last visited August 8, 2013

<sup>38</sup> Mandate M/490 for Smart Grids (March 2011)  
[http://ec.europa.eu/energy/gas\\_electricity/smartgrids/doc/2011\\_03\\_01\\_mandate\\_m490\\_en.pdf](http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/2011_03_01_mandate_m490_en.pdf), last visited August 8, 2013

<sup>39</sup> Mandate M/468 for electric vehicles (June 2010)  
[http://ec.europa.eu/energy/gas\\_electricity/smartgrids/doc/2010\\_06\\_04\\_mandate\\_m468\\_en.pdf](http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/2010_06_04_mandate_m468_en.pdf), last visited August 8, 2013

<sup>40</sup> Mandate M441 for smart meters (March 2009)  
[http://ec.europa.eu/energy/gas\\_electricity/smartgrids/doc/2009\\_03\\_12\\_mandate\\_m441\\_en.pdf](http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/2009_03_12_mandate_m441_en.pdf), last visited August 8, 2013

<sup>41</sup> Commission recommendation on preparations for the roll-out of smart metering systems [C/2012/1342]  
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32012H0148:EN:NOT>, last visited August 8, 2013

<sup>42</sup> Guidelines for conducting a cost-benefit analysis of Smart Grid projects  
[http://ec.europa.eu/energy/gas\\_electricity/smartgrids/doc/20120427\\_smartgrids\\_guideline.pdf](http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/20120427_smartgrids_guideline.pdf), last visited August 8, 2013

and help reduce greenhouse emissions, while simultaneously boosting Europe's economic recovery. The projects cover 3 broad fields: 44 gas and electricity infrastructure projects, 9 offshore wind projects and 6 carbon capture and storage projects<sup>43</sup>. The EEPR was set up in the wider context of the global effort undertaken at EU level to face the financial crisis that erupted in 2008, and to stimulate economic recovery.

### **Energy Infrastructure Package/Proposal**

On 17 November 2010, the EC presented its energy infrastructure priorities for the next two decades. In the Communication<sup>44</sup>, the EC defines EU priority corridors for the transport of electricity, gas and oil. This map of priorities will serve as a basis for future permit granting and financing decisions on concrete EU projects.

In 2011, EC adopted the proposal for a Regulation on "Guidelines for trans-European energy infrastructure"<sup>45</sup>, which aims at ensuring that strategic energy networks and storage facilities are completed by 2020. To this end, the EC has identified 12 priority corridors and areas covering electricity, gas, oil and carbon dioxide transport networks. It proposes a regime of "Common Interest" for projects contributing to implementing these priorities and having this label (Projects of Common Interest (PCI)). The EC also adopted the proposal for a Regulation on "Guidelines for trans European telecommunications networks"<sup>46</sup>, which aims to establish a series of guidelines covering the objectives and priorities envisaged for broadband networks and digital service infrastructures in the field of telecommunications. It identifies PCIs for the deployment of broadband and digital service infrastructures.

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<sup>43</sup> <http://ec.europa.eu/energy/eepr/>, last visited August 8, 2013

<sup>44</sup> Communication "Energy infrastructure priorities for 2020 and beyond - A Blueprint for an integrated European energy network" [COM/2010/0677]  
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52010DC0677:EN:HTML:NOT>, last visited August 8, 2013

<sup>45</sup> Proposal for a Regulation on "Guidelines for trans-European energy infrastructure" [COM/2011/658]  
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011PC0658:EN:NOT>, last visited August 8, 2013

<sup>46</sup> Proposal for a Regulation on "Guidelines for trans European telecommunications networks and repealing Decision" [COM/2011/657]  
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0657:FIN:EN:PDF>, last visited August 8, 2013

These regulations have identified SGs deployment across the EU as a priority thematic area for infrastructure investment up to 2020. This legislation is vital as it determines fundamental parameters for future SGs in EU, their interoperability, flexibility and capacity to handle an increasing share of renewable energy sources and an even more decentralized production of energy as well as access to ICT. On 12 March 2013, the European Parliament adopted in first reading in plenary session, which opens for final adoption of the text after approval by the Council. The text needs now to be backed by the Council before final adoption. After approval, it should enter into force by the beginning of 2014<sup>47</sup>.

### **Energy Efficiency Directive**

The EU is aiming for a 20% cut in Europe's annual primary energy consumption by 2020. The Commission has proposed several measures to increase efficiency at all stages of the energy value chain. The measures focus on the public transport and building sectors, where the potential for savings is greatest. Other measures include the introduction of SMs (which encourage consumers to manage better their energy use), and clearer product labeling<sup>48</sup>. On 22 June 2011, the Commission proposed a new Directive to increase Member States' efforts to use energy more efficiently at all stages of the energy value chain. On 4 October 2012, the Council endorsed the political agreement on the Energy Efficiency Directive. The European Parliament casted its favorable vote on 11 September 2012.

The directive includes provisions on DG and DR, which will help the market to evolve in this direction. Regarding DR, the directive has two key provisions in which MSs have to ensure that: 1) DR be allowed to participate alongside supply in electricity markets, and 2) grid operators treat DR providers in a non-discriminatory manner when providing balancing and reserve services. The Directive also encourages MSs to remove disincentives in transmission and distribution tariffs that might hamper the participation of DR in balancing markets and ancillary services procurement. These provisions are crucial requirements for creating the conditions necessary for an open and fair market where demand side resources can compete freely alongside supply.

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<sup>47</sup> <http://sustainableenergylaw.blogspot.pt/2013/03/european-parliament-approves-eu-energy.html>, last visited August 8, 2013

<sup>48</sup> [http://ec.europa.eu/energy/efficiency/index\\_en.htm](http://ec.europa.eu/energy/efficiency/index_en.htm), last visited August 8, 2013

## **Renewables Directive**

The Directive establishes a common framework for the use of Renewable Energy within the EU in order to limit greenhouse gas emissions and to promote cleaner transport. Each MS has a target for the use of energy from renewable sources, which is calculated according to its gross final energy consumption for the year 2020. The MSs shall establish national action plans which set the share of energy from renewable sources consumed in transport, as well as in the production of electricity and heating, for 2020. Each MS must be able to guarantee the origin of electricity, heating and cooling produced from RES. Decentralized energy systems are supported as well as the use of agricultural material such as manure, slurry and other animal and organic waste for biogas production. MSs should aim to diversify the mix of energy from renewable sources in all transport sectors. The Commission should present a report to the European Parliament and the Council by 1 June 2015 outlining the potential for increasing the use of energy from renewable sources in each transport sector. MSs should build the necessary infrastructures for energy from renewable sources in the transport sector.

Renewables Directive (2009/28/EC, Art.16) views SGs as an enabler for integration of increasing renewable energy into the grid and obliges the MSs to develop transmission and grid infrastructure towards this aim.

## **Network Codes**

A set of common EU-level rules (termed ‘Network Codes’) was included in the Third Package and Regulation 714/2009/EC<sup>49</sup>, with the aim of covering the technical and market issues for cross-border electricity exchange.

National systems are linked together through interconnectors. These are transmission networks operated jointly by the TSOs at each end: the respective TSOs at each side of the border coordinate this interconnection between them. Internally, the individual national networks are relatively well-connected, whereas the degree of connection between national markets is substantially lower. This represents a physical barrier to

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<sup>49</sup> [http://ec.europa.eu/energy/infrastructure/infrastructure/infrastructure\\_en.htm](http://ec.europa.eu/energy/infrastructure/infrastructure/infrastructure_en.htm), last visited August 8, 2013

cross-border electricity flows. Some of the network codes regard the coordination of TSO on interconnectors, because the purpose and goal of the procedure is to establish a common set of rules for cross-border electricity exchange. While not affecting the amount of physical capacity on interconnectors per se, they might affect the use of this capacity. Thus, these codes could influence cross-border network operation as well as cross-border trade (Jevnaker, 2012).

Beyond the procedure for developing common cross-border network codes for electricity ('the NC procedure'), two pan-European associations, European Network of Transmission System Operators for Electricity (ENTSO-E) and ACER, were established with the Third Package. ENTSO-E is a single, comprehensive EU-level association for TSO cooperation, whereas ACER is a European regulatory agency (as described in section 1.2).

Based on Framework Guidelines written by ACER, ENTSO-E, in close cooperation with stakeholders, has to draft a network code on a particular subject. Those network codes are assessed by ACER to ensure they are in line with the Guidelines and, once this is the case, they are submitted to the EC. Finally the network codes go through the Comitology procedure<sup>50</sup>, in which they are scrutinized and agreed by MSs, before becoming directly applicable pieces of legislation. (ENTSO-E, 2013)

## **3.2 Regulation revisited**

In order to fully understand current regulation methods and having SG in mind, we make a short revision of the regulatory tools available.

(Vanhanen et al, 2010) provide a literature review on recent scientific papers and other relevant publications, emphasizing the incentives of alternative regulation models. In this paper the authors look at the classical regulation mechanisms, cost-based and incentive regulation, and provide an insight of their advantages and limitations.

### **Cost-based regulation**

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<sup>50</sup> Comitology in the European Union refers to a process by which EU law is modified or adjusted and takes place within "comitology committees" chaired by the European Commission. The official term for the process is committee procedure. Comitology committees are part of the EU's broader system of committees that assist in the making, adoption, and implementation of EU laws.

As for the cost-based regimes, we know that this approach results in poor performance with distorted investment incentives<sup>51</sup> (no investment risk, yet fixed return on investment), perverse efficiency incentives (loss of revenue when reducing costs) and lack of managerial effort (distorted market signals and limited managerial rewards). Cost-based regulation was developed in the USA as a form of regulation of private monopolies (Hertog, 2010).

### **Incentive regulation (Cap regulation)**

As opposite to the USA, in Europe, monopolies were regulated as public enterprises. During the privatization of public enterprises in Europe, it was consensual that one of the more important objectives of those privatizations was that those companies would become more efficient. In response to the limitations of cost-based regimes applied in USA, Stephen Littlechild designed a high powered<sup>52</sup> regime that allows the regulated firm to retain any realized efficiency gains. In Cap regimes, the regulator caps the price or revenue for the regulated company for a pre-determined period. The key to the incentive is the performance independent payment; to maximize profits, the companies minimize costs and optimize their efforts, achieving cost efficiency. Thus there is a saving in OPEX. As a drawback, companies may increase costs towards the end of the regulatory period in anticipation of future caps reviews, consequently limiting the efficiency incentives<sup>53</sup>.

### **Incentive regulation (Yardstick competition)**

Yardstick regimes try to mimic the market by making observations in order to estimate the production costs in a given period. Putting it simple, the allowed revenue for a company in a given period would be set *ex post* and determined by the costs in the same period of other companies operating in similar conditions. Thus, the revenue of the company isn't determined by its own costs but by the performance of the market.

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<sup>51</sup> Averch-Johnson-effect.

<sup>52</sup> In the context of regulation, we have two basic regimes: Low-powered regimes (cost-plus, cost recovery) and High-powered regimes (revenue caps, price caps). High-powered regimes promote efficient operation when the task is well specified, the risk is contained and the result is observable. Low-powered regimes promote efficient operation when the task or the results are poorly specified but the means are observable.

<sup>53</sup> This is known as the Ratchet effect.

## **Menu of contracts and quality regulation**

Instead of choosing a single regulation scheme, the regulator can propose a menu of multiple regulations. The idea of using a menu of contracts is to abandon a notion of one-size-fits-all. Besides that, a menu can be one way to reduce any information rent. That is, we can use a menu to “solve” adverse selection problems.

Besides price, quality is an important parameter in the relationship between companies and customers. However, there are some aspects we need to take in account: one is the cost of ensuring a higher quality level that may exceed the benefits of the present quality level, and the other is that any change in the regulatory approach will change the behavior of the agents (in particular, a movement towards a higher powered incentive regulation will induce the firms to focus more on cost minimization with a possible adverse effect on quality). So, the basic underlying problem is to determine the optimal trade-off between the costs of producing higher quality and the benefits derived from it.

## **Investment incentives in a cost efficiency regulation scheme**

(Müller, 2012) picks the fundamental question regarding regulation of SGs, i.e., does current incentive regulation provides the right investment incentives to enable technological progress and dynamic efficiency in the network infrastructure? The author observes that *“reviewing the academic literature leads to the conclusion that incentive regulation puts a strong focus on productive efficiency. In contrast, long-term incentives for investments into a technological upgrade of the network infrastructure, which require a dynamically efficient resource allocation of CAPEX, are not sufficiently promoted. A regulatory dilemma emerges vis-à-vis the on-going transformation of the energy system”*.

This problem is central in our dissertation and we will come back to it in Chapter 4, and in section 3.3 to review how this is being handled by some regulators.

## **3.3 Beyond Standard Incentive Regulation**

(Viscusi et al., 2005) point several problems to the traditional regulation regimes (cost-recovery), namely the weak incentives provided to reduce costs, or adopt efficient practices, and the lack of price flexibility between rate cases that prevents the regulated

firm from efficiently responding to cost and demand shocks. Thus, as we have seen, these deficiencies led to a series of innovations in the regulatory policy (Incentive Regulation), which were designed to create incentives for the regulated firm to lower cost, innovate, adopt efficient pricing practices, and improve quality. In section 3.2 we briefly revisited several forms of incentive regulation. The common properties of these regulatory policies give the firm a certain degree of discretion in pricing and allow them to share in profit increases. As we know, one of the main objectives of market liberalization was to lower cost for users; the first regulatory phase that followed unbundling was geared towards a cost-efficient management of grids through the minimization of OPEX and rationalization of investments. The economic objective was to be achieved without endangering the quality of power and the security of supply. If SG is chosen as solution for a transforming sector, the cost efficiency objective may not be enough in face of the investment requirements; regulators may need to introduce new objectives such as integration of RES, enabling DSM and energy efficiency, as a means of achieving the EU Energy Policy targets.

Some authors, e.g. (Lapillonne et al., 2012), believe that regulations to enable SG investments will be adapted from the current situation – some new players will emerge, but overall, the business models of TSOs and DSOs are likely to remain broadly similar to what they are today. An opposite view, that we are aligned with, is expressed in (Bauknecht, 2010) which argues that incentive regulation mechanism may not be sufficient to promote network integration of DG. For that, he gives three reasons: the first is that regulatory mechanisms to promote innovations need to be coordinated with innovation instruments outside regulation; second, the author questions if network regulation should be limited to economic incentives, or whether additional instruments should be applied by the regulator; and third, DG and network transformation as a new objective require not only adaptations on the level of regulatory instruments, but make it necessary to rethink the overall role and objectives of regulation. (Bauknecht, 2010) looks at the governance mechanisms of the standard model<sup>54</sup> in the light of network transformation<sup>55</sup> to depict what adjustment the standard model needs in order to cope

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<sup>54</sup> Incentive regulation (as price-based instruments to correct market failures).

<sup>55</sup> Network Transformation stresses the need for additional governance mechanisms. Proponents of the standard model reject the argument that system transformation represents a specific challenge.

with system transformation. Bauknecht uses integration of DG as a case of system transformation. We believe that SG also configures a situation of system transformation, as it involves several changes (besides DG, load such as EVs need to be integrated), and new roles in the electricity value chain. To follow Bauknecht's steps, the standard model was designed to improve efficiency, rather than to provide a governance mechanism for structural transformation, and thus it can encounter problems when the focus shifts from short-term efficiency to more long-term issues like investment and innovation. The electricity system and the network in particular, represent an example of an interlinked system that is prone to lock in and path dependency, which means that it is difficult to change one element without changing others. This is important from the point of view of coordination as this infrastructure system includes the network companies, the organizational setup, and strategy and planning procedures. Given this, as Bauknecht says, network companies cannot easily adapt to new objectives and requirements, even if economic signals are changed via incentive formula.

We shall now see how some EU regulators are handling change. UK and Italy regulation models have been pointed as examples in what concerns to providing the bases for the new regulation models that incentivize R&D and investment (Meeus and Saguan, 2011), (Müller, 2012). In the case of UK, RPI-X<sup>56</sup> regulation was implemented in 1990 and it proved to make distribution companies succeed in achieving significant efficiency improvements and delivering gains to customers. The incentive regulation model of distribution networks in UK has been featuring a hybrid approach since 1990. Under the current arrangements, OPEX, CAPEX and quality of service are incentivized separately within the so-called "Building Blocks" approach. That is, the different cost components receive diverse regulatory treatment. Given this, the Ofgem (Office of Gas and Electricity Markets) framework allows for a flexible regulatory treatment of CAPEX. In order to provide for a reasonable level of CAPEX, Ofgem introduced the "Menu of Sliding Scales" to individually assess the required level of CAPEX: according

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<sup>56</sup> RPI-X regulation denominates the approach of price-cap regulation employed in the United Kingdom. The allowed tariffs (price-cap) are determined *ex-ante* by the regulator and are corrected for the rate of inflation, measured by the Consumer Price Index (UK Retail Prices Index, RPI) and for expected efficiency savings  $x$  (x-factor). The x-factor is determined by benchmarking the network operators cost vis-à-vis its peers. The individual x-factor of a network operator reflects the efficiency potential to catch up with the best in class. The network operator receives a reward when he outperforms its efficiency target and a penalty in case of underperformance. This constitutes the heart of incentive regulation. The inherent logic of this regulatory approach has been adopted in many other countries worldwide.

to their investment strategy, network operators may choose between a regulatory menu of a rather cost-based driven regulation of their CAPEX or a rather incentive-based approach. Ofgem also implemented regulatory provision for innovation: this includes the introduction of an Innovation Fund Initiative (IFI) to recover R&D expenditures via regulated tariffs; moreover, the instrument Registered Power Zones (RPZ) involves the option to create tariff space for demonstration projects aiming at the connection of DG. The new regulatory framework, which became into effect this year (2013) is an outcome from Ofgem's RPI-X@20 initiative<sup>57</sup>. It is known as RIIO (Revenues set to deliver strong Incentives, Innovation and Outputs), which can be synthesized as Revenues = Incentives + Innovation + Outputs, and it is based on the RPI-X framework. The main key features of RIIO model can be summarized as follows (Ofgem, 2010), (Ofgem, 2013):

**Revenues and outputs:** revenues are set upfront during the price control review process, and are the revenues a network operator is allowed to recover. There are six output categories: "Customer satisfaction", "Reliability and availability", "Safe network services", "Connection terms", "Environmental impact", and "Social obligations". In each category, a subset of "Primary outputs" is defined reflecting customer expectations with respect to the operational business of the network operator. Output delivery is encouraged by incentives directly linked to primary outputs and the allowed revenues.

**Innovation stimulus package:** the regulatory framework includes a flexible instrument called "secondary deliverables" to provide for dynamic efficiency. This instrument gives network operators the opportunity to include expenses in their business plans related with innovative projects of which costs occur immediately but benefits only materialize within a longer time frame. To capture the horizon of dynamic efficiency, milestones in project delivery are defined. With regard to the price control, this implies that network operators will merely be allowed to raise revenues from consumers if a specific milestone is reached. This approach was chosen to provide certainty to network operators to engage in long term investments, and also that customers do not overpay

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<sup>57</sup> RPI-X@20 is Ofgem's detailed review of energy network regulation. Ofgem looked at how best to regulate energy network companies to enable them to meet the challenges and opportunities of delivering the networks required for a sustainable, low carbon energy sector (Ofgem, 2010).

and their money is only raised when there is a certainty that network operators will deliver benefits in the long run.

**Incentives – eight year regulatory period:** the extension of the regulatory period to eight years intends to provide network operators with new flexibility to efficiently optimize their delivery of outputs in a longer perspective and to reduce regulatory risks.

**Business plan review as core instrument of the price control review process:** under the RIIO model the onus would be on the network companies to determine how best to deliver outputs over time, reflecting on the results of their stakeholder engagement and subsequently developing well-justified business plans.

In the case of Italy, tariff regulation is implemented through a price cap mechanism with efficiency goals for transmission, distribution, and metering services set by regulator over a 4-year regulatory period. The efficiency targets only apply to operating costs. The regulator updates the price cap on an annual basis that provides for two costs categories: first takes in account the reduction of operating costs, and second a review of depreciation and return on invested capital to adapt for new infrastructure investments to improve security of supply, competition, and quality of service. The regulator also discriminates between different categories for transmission and distribution investment which are associated with an extra rate of return for 12 years (in the case of transmission) and 8 or 12 years (in the case of distribution). The Italian regulator also introduced efficiency indicators to measure the extra benefit an individual investment brings to the system. In what concerns to SMs, Italy has the largest SM base in the world. This is due to Enel<sup>58</sup> initiative to massively roll-out SMs. The SMs activities fall under network operator's responsibility, and related tariffs are determined by the regulator and included OPEX and CAPEX with a SM specific WACC amounting to 7.2%. In parallel, the regulator also created instruments to promote innovation consisting of a general R&D component in the network tariffs. Demonstration projects are incentivized within a competitive procedure. Selected projects will be awarded with an increased WACC of 2% points for 12 years.

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<sup>58</sup> Enel S.p.A. (Ente Nazionale per l'energia ELettrica) is an Italian electric utility company, that was formerly a state-owned monopoly, and it is now partially privatised with Italian government control.

(Müller, 2012) analyses the two regulatory environments in respect to factors related to dynamic innovation and concludes that UK example features the new regulatory awareness to undertake a long-term perspective with respect to regulatory incentives instead of focusing solely on short-term efficiency targets. The downside is a very intense regulatory scheme and a high level of regulatory scrutiny. Italy's approach implies a less holistic but rather straightforward solution to promote technological progress where the regulator may increase the rate of return for specific investments and investigates their efficiency. This may involve demarcation problems and technology preferences given by the regulator.

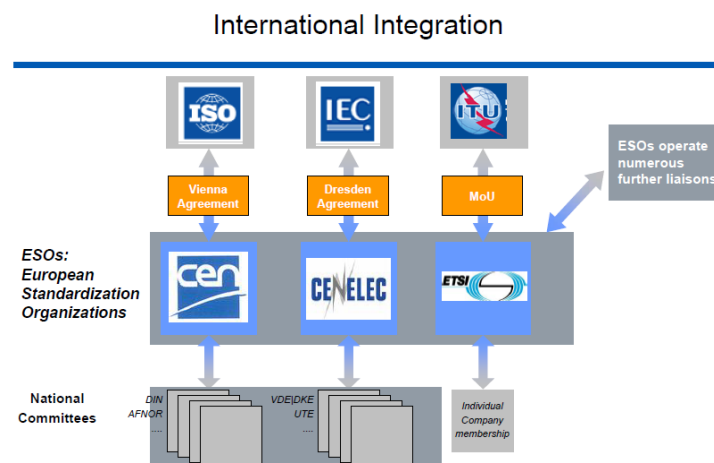
It is clear that European predominant regulatory model of revenue- or price-caps, is challenged in its fundamental assumptions. However, we have just observed that some countries are trying a new path beyond the Standard Incentive Regulation.

### **3.4 Interoperability**

We have mentioned in section 3.1, that one important outcome of the first mandate of the SGTF was the standards framed by the three Standardization Mandates (M/441 Smart Meters, M/468 Electrical Vehicles, and M/490 Smart Grids) (see Figure 5). As we have seen, standards are considered key to progress with SG because they are a guarantee of interoperability. However, the question remains: In a liberalized economy, shall we impose standards, or on the other hand, let the market decide on the standards (*de facto* standards)? Other important question is what the role of standards is in the global SG governance.

(Brunsson et al, 2012) provide a literature review on standards dynamics that includes its definition and classification. One distinction has been made between technical and non-technical standards. Technical standards, also known as “compatibility” or “interface” standards are defined as “codified specifications about components and their relational attributes”. Non-technical standards are encountered in a variety of different domains, such as quality control, social and environmental management, financial and non-financial reporting and securities regulation. The authors also elaborate on the distinction between *de jure* and *de facto* standards. *De jure* standards are the product of a deliberately steered process of decision-making. Committees are often regarded as the

organizational entities responsible for deciding on *de jure* standards (e.g. as in the case of ISO standards<sup>59</sup>). While some authors argue that standardization that is committee-based rather than market-based is more likely to achieve coordination, largely because it avoids incompatibility, other studies have shown that the internal politics of the committees, which are often closely linked to vested interests, can undercut the legitimacy of standards and slow down their development. By contrast, the concept of *de facto* standards refers to processes that lead to uniformity, in the sense that all or near all potential adopters eventually come to adopt the same solution and turn it into a model that is difficult to deviate from.



**Figure 6 - Relationship between international and European standard bodies**  
 Source: CEN/CENELEC/ETSI Smart Grid Coordination Group (SGCG)

It is important to note that ICT standards have an important difference from the traditional industrial economy product standards and Standard Development Organizations (SDOs), which is the magnitude of the externalities, or network effects, created by the need for interoperability of different ICT systems and products, and the problem of high switching costs, or “lock-in” (this is particularly important for example in the case of SGs and SMs, where massive rollouts need to be done); actually, some authors refer the non-existence of standards as a risk factor for the non-deployment of SMs (e.g.: (GEODE, 2013)). (Brunsson et al, 2012) show that beyond institutional reasons, functionalist arguments support the idea that standards are adopted for economic reasons or to improve efficiency: adopters often comply with a standard

<sup>59</sup> In the context of standardization, ISO stands for International Organization for Standardization, which is an international standard-setting body composed of representatives from various national standards organizations.

because it is linked with positive network externalities; other scholars have argued that the adoption of standards is positively associated with higher levels of operational performance. Moreover, standards are an important means of organizing markets. Standards contribute to the organization of markets by promoting compatibility and harmonization among the otherwise incongruous components of a system: they align the interests of, and enhance communication among, a variety of market actors.

Being the EU and the USA main competitors to set global standards, each one has different local regulatory cultures: while the US is seen as a LME (Liberal Market Economy) where informal standard development processes are perceived as legitimate, the EU is perceived as a CME (Coordinated Market Economy) where formal standard developing processes take place (Winn, 2009). The author presents informal private SDOs known as “consortia” or “fora” which have emerged in recent decades. The author sees such organizations as a reaction to the rapid pace of innovation in ICT markets and the large economic stakes created when strong network effects are present<sup>60</sup>. (Baisheng, 2012), on the other hand, sees the appearance of such SDOs as a reaction to the fact that in some formal SDOs, the outcome of standards competition is decided as the vote of each country; given this, in the formal Standards Organizations, the EU is in big advantage relative to the US. SDOs in the United States operate largely outside any form of government oversight and focus intensively on market conditions, while SDOs in more highly regulated countries (such as France, Germany and Japan) operate within a framework of government oversight and focus on regulatory as well as market variables. If now we want to think of standards as widely implemented (by different countries), although it seems to be an impractical idea, it is important to note that the basic outlines of a framework to achieve such goal may already exist in the Code of Good Practice for the Preparation, Adoption and Application of Standards contained in Annex 3 of the World Trade Organization (WTO) Agreement on Technical Barriers to Trade (TBT Agreement)<sup>61</sup>.

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<sup>60</sup> While traditional product standards may be soft law if voluntary, or hard law if made mandatory by incorporation into or reference from legislation, when the adoption of ICT standards is driven by strong network effects, the regulatory effect of those standards may exceed that of even hard law.

<sup>61</sup> During the decades after the World War II, of big economic growth and increased trade, the role of technical standards in cross-border trade has increased. The General Agreement on Trade and Tariffs (GATT), established in 1947, and the WTO, established in 1995, has contributed to an enormous

In the non-US developed countries with a tradition of developing their own national standards, a single dominant National Standards Body (NSB) normally handles the work of standards developing. NSBs may be organized as private sector organizations or government agencies. At the international level, the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunications Union (ITU), an agency of the United Nations, are recognized as *de jure* international standard organizations. Countries designate the standard developing body that will represent them in these international bodies. NSBs established as government agencies generally work closely with other government agencies in charge of developing and executing national economic development strategies. In Europe, the work of NSBs is subject to EU law, and is coordinated with the work of European Standards Organizations (ESO) including the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI). The ESOs have made a formal commitment to cooperate with ISO and IEC; this commitment forms part of a framework of coordination of standard setting that integrates the work of European NSBs, ESOs and international SDOs. This relationship is depicted in Figure 6.

The challenge currently facing ICT SDOs based in Europe is that, under conditions of trade liberalization, products can be sold directly to European producers and consumers that incorporate consortia-based standards, resulting in *ad hoc* recognition of *de facto* standards before *de jure* standards can be completed. Under conditions of trade liberalization it would be difficult as a practical matter and politically controversial for EU regulators to block access in local markets to products based on consortia standards.

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reduction to explicit barriers to international trade in the form of quotas and tariffs. As explicit barriers have dropped, however, the significance of implicit barriers in the form of incompatible national standards has grown enormously. Under the GATT issues related to standards and trade have been addressed by voluntary GATT Standards Code. By the time WTO was established, obligations governing technical standards changed from voluntary to mandatory under the Agreement on Technical Barriers to Trade (TBT Agreement). As for (Brunsson et al, 2012), standards are particularly important in the context of international regulation; because most state legislation remains bound to a national territory, standards are often the only type of rule that can be applied internationally. Standards have emerged particularly in those areas where intergovernmental regulation is weak or non-existent but there are significant global governance challenges. The high demand for international standards is a response to the view that divergent national standards are often seen as counterproductive and as an obstacle to global economic integration.

(Brunsson et al, 2012) note that there is a tension that arises from the conflict between the freedom to set standards and their potential regulatory impact: because standards are voluntary, in principle, everybody is free to set new standards; however, the existence of multiple equivalent or very closely related standards often undermines their regulatory effect. This is the most obvious in the case of compatibility standards, which aim to improve coordination between different parties. This is an important aspect for SG as SG will bring a global market either for electric and ICT hardware and software.

## Chapter 4

### Way Forward: are Smart Grids really feasible?

In this chapter, we take the previous sections and will think of which factors are most important to provide the development of the Smart Grid, and will point possible directions to timely achieve the EU energy policy goals.

In order to make the SG feasible, there are some barriers that shall be overcome, namely the consumer's acceptance, providing R&D incentives, incentives for investment, a proper market design, standardized interfaces promoting interoperability, and proper grid tariffs. We also make an approach based on Institutional Economics, in particular in the role of EU institutions and regulators (either at MS and EU level). Of course we don't neglect the importance of the market mechanisms, but we believe institutions will play a central role in SG implementation.

The dominant idea around the SG is that it will bring many benefits, both for consumers and utilities, and it is going to revolutionize the electric industry in the next coming years. As noted by (Ernest & Young, 2012), there are many challenges to make the SG. There are concerns amongst the key stakeholders about the ability of current or proposed mechanisms to deal with these complexities and expectations. For example, according to that report, the adoption of SG is likely to be slow, with little investment before 2023. We think that having an opposite opinion would enrich the discussion, and that is the case of (Makovich, 2011) who advises that SG is not the disruptive technology that will bring us all the advantages claimed by its advocates. Instead, in his view, changes in the power sector will continue but will be incremental because the technology is still evolving and because consumers do not want the more flexible and uncertain pricing schemes that would replace the predictable and stable pricing of today's system.

Whatever the time frame is, the huge investments required by SG, in the European context, may have to be raised through regulated tariffs, subsidies from national or regional taxes or by government-backed bank financing. These investments will not pass unseen by final consumers. Thus, it is of major importance to find regulatory

models enabling these large and urgent investments while credibly assuring tariff-payers that the cost increases do not represent higher rent-taking from the firms and operators in the supply chain.

## **4.1 Consumers**

In order to promote consumer acceptance of SG and SM technology, users should be better informed of the advantages those technologies bring to them so that they become involved. It may be benefic that MSs retain the right to choose the market model that brings the most benefits to their region and the customers, based on historical traditions, technical development and current market structure, keeping costs of changes as low as possible (GEODE, 2013).

Although users have not been actively involved in other grid innovations, they will likely play a pivotal role in the future of SGs. DSM, SMs, and appliances intervene directly in the daily routines and practices of consumers. There are many pilots for SG ongoing in Europe and in other parts of the world, although the focus of many pilots has been predominantly on technical learning. Increasingly the various SG concepts are being confronted with social reality. A pivotal part of user involvement is the way they interact with the systems. The assumption that households are willing to change their behavior in order to enable an efficient and effective grid management has not been proved yet. Besides the limited flexibility in demand, the openness of consumers to changes in behavior is also not clear because of issues such as privacy. Pilots on SG should be able to allow actors to learn at an early stage from the experience and attitudes of consumers.

(Verbong et al, 2013) tries to understand which visions on user perspectives in current and future SG experiments do stakeholders propagate, taking ongoing SG projects in Netherlands as study analysis. In this study the author interviews several stakeholders (curiously consumers are not interviewed because representatives didn't want to participate). The main conclusions from this work are that although consumers became more central in SG projects, the focus is still mainly on technical issues and economic incentives, and from this perspective consumers are often regarded as a potential barrier to SGs deployment, and financial incentives are still seen as the best instrument to

persuade or seduce them. Barriers include the domain of privacy, the degree of control, lack of interest or time, and the difficulty to change routine behavior. The proposed solutions to better understand how to involve consumers, suggest looking at the services the energy system delivers, and not at technological options to improve this system. The pilots and demonstration projects offer an excellent opportunity for such exploration. As threats for this understanding, the author points the possibility that the focus remains too much on technology and on the protection of vested interests. Given this, further reflection on the question of to what extent users should act as solution to a low carbon economy, stands up.

## **4.2 System organization/Market design**

The roles of the current actors in the electricity value chain will change as the vertical interfaces between regulated and unregulated tasks become blurred. However, not having vertical separation could distort competition by not only distorting access to information and infrastructure, but potentially also cross-subsidizing competitive business of monopoly operations. Moreover, the vertical separation of the energy sector in Europe is instrumental to the implementation of modern incentive-based regulation (Agrell et al, 2013).

As we have seen, the Third Package contains measures to ensure a more effective unbundling of transmission networks. However, distribution networks are still only subject to legal unbundling; this includes unbundling of accounts, operations and information. For unbundling in Distribution networks, a trade-off between competition and coordination may also be needed. (Friedrichsen, 2011) proposes an independent system operator (ISO) as a compromise solution for this coordination. The author raises the discussion to strengthen the rules for distribution networks, as recent developments with respect to SGs and the immense development of DG make the unbundling question increasingly interesting because of discrimination concerns and coordination needs. In this paper, the author analyses possible organizations for Distribution, which are Full Ownership Unbundling, Independent Distribution Operation and Independent System Operation. The conclusion is that the best solution for the Distribution case is to have an Independent System Operation (ISO). The arguments are that the ISO is not “suspect” to discrimination incentives but would still enable wide coordination. In SG the most

relevant point where coordination is indispensable is system operation because it requires certain central control to satisfy the need for real time coordinated actions in balancing. Furthermore, even with advanced market coordination, a system operator is needed to realize dispatch decisions that come out of the market mechanisms. However, such central controller is naturally endowed with enormous power that is linked to the ability to discriminate; therefore the central system operator needs to be neutral. In contrast to system operation, coordination of system development doesn't need to happen in real time. The considerations made for Full Ownership Unbundling are that the price mechanism is not sufficient to address all coordination needs in SG. Notwithstanding the potential for decentralized coordination and self-organization, increases in SGs with advanced information, communication and automation technology. Legal Unbundling in SG may not guarantee the neutrality of the network operator if it still has affiliated retail and/or generation activities – the high number and small size of the actors and transactions make it extremely difficult to prove neutrality in the choice of control actions. Thus, an ISO allows centralized coordination while ensuring non-discrimination for all actors. The ISO model allows network owners to engage in the generation business. Furthermore, system operation can be combined with the information function in SGs. However, the author leaves the governance of the ISO for future research. Another suggestion is that the information structure component of SG is operated independently with regulated, non-discriminatory access to information to prevent competitive distortions. Since the neutrality of the information is a key requirement for system operation, the idea is to combine both functions and give the information function to an independent DSO.

### **4.3 Incentives for investments**

We have been noticing that the European predominant regulatory model for revenue or price-caps is challenged in its fundamental assumptions, as current regulation is inadequate in the sense that (i) absolute cost containment is infeasible (since costs will increase), (ii) the standard revenue-drivers (e.g. energy transported) will generate lower income to the operators (intrinsic in the energy efficiency component of the SG), and (iii) that explicit incentives are weak or ineffective for activities such as SG development and coordination.

Thus, a special treatment is needed in what concerns investments. We have seen that some solutions are already in place, such as increase in the regulatory period, better remuneration (cost of capital) for diverse SG related projects, and more frequent updates of the price cap (allowed tariffs). This means that the regulator shall be sensitive to a progressive implementation of SG, and for that, negotiation needs to be done deeply, and the regulatory process needs to call for more flexibility. Of course we shall take as important the fact that the regulated company still needs to focus on cost efficiency.

In our opinion, the UK and Italy cases can be seen as important reference examples for investment incentives. However, the costs of regulation shall be taken in account, as they imply a bigger involvement and control of DSO activities.

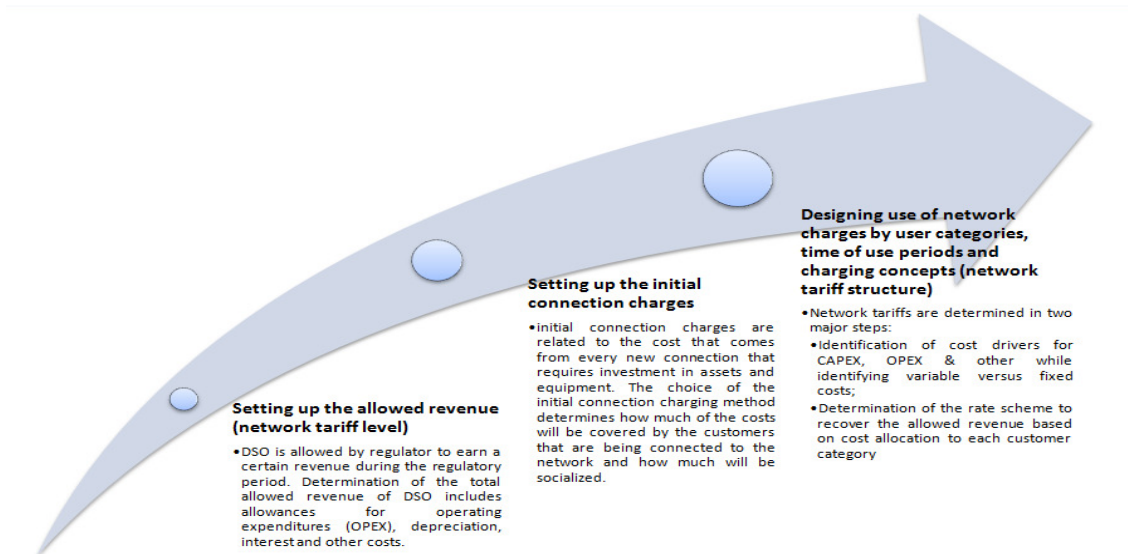
#### **4.4 Incentives for R&D**

R&D activities are key not only to develop innovative products and services, but also for the sake of testing new solutions. This is particularly important in the case of SGs where uncertainty and risk are two key factors for the coming massive investments. It helps to evaluate and test the benefits of innovative intelligent technology, estimate costs, learn about customer behavior and barriers to overcome in possible further deployments.

Besides regulation incentives (mainly for DSOs), funding programmes at MS and European level are still needed. Publicly funding R&D projects shall be able to bring benefits to society and increase the level of knowledge and expertise within the industry as a whole as well as of all actors in the value chain.

#### **4.5 Grids tariffs**

As we have seen, building a SG requires several network investments, mainly from DSOs. In this scenario, regulators shall allow DSOs to make the required revenue through network tariffs so that network costs and investments are covered. At the same time, tariffs shall also be able to create incentives in user behavior.



**Figure 7- Network Pricing Steps**  
*Adapted from (EURELECTRIC, 2013)*

According to (EURELECTRIC, 2013) network pricing comprises three major steps (see Figure 7 for reference). Allowed revenues affect DSO investment behavior as they have an impact on the recovery of network costs. Network tariffs are part of the electricity tariffs paid by customers and thus also affect customer behavior.

In Europe, depending on the countries, the legislation and the regulatory framework differ as regards determining allowed revenues as well as network tariffs. There are two main approaches to network tariff setting: in one approach, the NRA sets the limit on the allowed revenue for each regulatory period and outlines the methodology/guidelines for setting network tariffs – DSO determines network charges according to the defined methodology and how this total amount is divided between connection charges and the single tariffs; in the other approach the regulator has more control and sets both the level of connection charges as well as the level and structure of individual tariffs for a given period of time.

In designing the network tariff structure, the architectural elements present in Table 3 are the ones usually taken in account. Connection charges are described in Figure 7. As for the other network charges, i.e., Use-of-System charges (UoS), network users are required to help recovering the recurring operating and capital expenses incurred in network operation and investment; Commercial Services Charges are related with administrative costs for providing services to consumers such as billing, meter reading,

and customer support that are independent of network operations; finally, Energy Policy Charges are used to cover network related costs that are policy driven (cross-subsidization of low income or rural communities, stranded costs of restructuring, feed-in tariffs for renewables, etc).

<b>Element</b>	<b>Purpose</b>	<b>Design Choices</b>	<b>Variations</b>
<b>Connection Charge</b>	to recover the initial, non-recurring connection costs for enabling the user to receive network services	<ul style="list-style-type: none"> <li>- shallow</li> <li>- deep</li> <li>- average</li> </ul>	may be levied <ul style="list-style-type: none"> <li>- up front</li> <li>- in limited installments</li> <li>- periodically</li> </ul>
<b>Use-of-System Charge</b>	to recover the recurring operating and capital costs for network maintenance and expansion	<ul style="list-style-type: none"> <li>- reference network model</li> <li>- postage stamp</li> <li>- megawatt mile</li> <li>- contract path</li> <li>- decoupling</li> <li>- gross- or net-metering</li> </ul>	may be differentiated by <ul style="list-style-type: none"> <li>- capacity demand (MW)</li> <li>- consumption (MWh)</li> <li>- time of day</li> <li>- season</li> <li>- average per connection</li> </ul>
<b>Commercial Services Charge</b>	to recover the cost of services such as billing, customer support, etc	<ul style="list-style-type: none"> <li>- average</li> <li>- transaction fees</li> </ul>	<ul style="list-style-type: none"> <li>- minimum fee</li> <li>- maximum fee</li> </ul>
<b>Energy Policy Charge</b>	to recover the cost of policy outcomes such cross-subsidization of low income or rural communities, stranded costs of restructuring, feed-in tariffs for renewables, etc	<ul style="list-style-type: none"> <li>- average fee</li> <li>- lump sums</li> </ul>	<ul style="list-style-type: none"> <li>- increasing over time</li> <li>- decreasing over time</li> </ul>

**Table 3 - Architectural elements for network tariffs**  
*Source: (Sakhrani and Parsons, 2011)*

Figure 8 summarizes several aspects from tariffs. As generation and network business are not a vertically integrated business, the cost of energy can be separated from network related cost of delivery. This separation results in two types of tariffs, Network or access tariffs (network related capital and operating costs) and Integral tariffs (cost of energy and network related capital and operating costs). This figure also spots the regulatory drivers that influence the decisions of network owners; the main high level principles that affect tariff design, directly or indirectly, are Universal Access, Quality of Service, Capacity Adequacy, and Energy Policy.

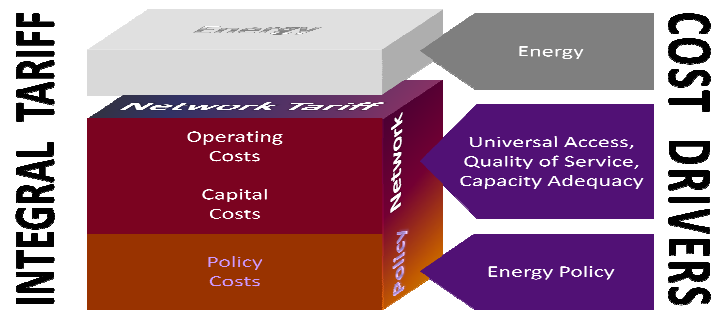


Figure 8 - Cost Categories and Regulatory Drivers influencing Tariff Types  
*(Adapted from (Sakhrani and Parsons, 2011))*

(EURELECTRIC, 2013) elaborates on the development of network pricing pointing the new challenges for DSOs, pricing for DR and proposing network tariffs to provide incentives. During periods of relatively low energy consumption, a number of households with DER could be self-sufficient or even produce more energy than they consume. They would then deliver their production surplus to the grid. In systems with a high penetration of DG, the network usage time for ordinary consumption of electricity delivered from the network may decrease. Power would become an even more important cost driver as DG does not reduce overall network costs. When there is no production from DG, the network still needs to be designed to cover peak demand situations (EVs will usually even increase the maximum load in the network)<sup>62</sup>. With volumetric network tariffs<sup>63</sup>, the kWh charge might need to rise to offset the loss of consumption. Demand reduction resulting from DG in particular will require spreading the cost of grid investments and renewable subsidies over a smaller customer base. On the one hand, customers could be incentivized to reduce their overall consumption via energy efficiency measures. On the other hand, network costs incurred by consumers with DER would be shifted towards customers who do not have those at their disposal. Although volumetric tariffs send signs to reduce the consumption of energy, they don't reflect the costs that arise from peak hours. DR can be a way to tap into the potential of

<sup>62</sup> In combination with energy efficiency applied to residential, commercial and industrial load, the overall energy volume transported per customer is expected to decrease. However, with continued expansion of total power for household and commercial appliances, the peak load is likely not decreasing, or at least less than the total energy consumption (Agrell et al, 2013)

<sup>63</sup> In a survey that (EURELECTRIC, 2013) conducted, in all the participant countries, network tariffs are at least partially volumetric, i.e. based on energy (€/kWh). Network costs induced by household customers are almost entirely recovered from volumetric tariffs in most countries. In 62.5% of the countries some form of time-of-use network tariff options exist (e.g. peak/off-peak, day/night, seasonal: summer/winter).

energy efficient use of infrastructure by reducing demand at peak time (peak shaving), shifting demand between times of day or seasons (load shifting) or increasing demand at night hours (valley filing).

Today the relevant signals for DR are often missing: neither the regulated prices nor largely volumetric network tariffs incentivize retail customers to reduce peak consumption (network tariffs are calculated on the basis of the contribution of each customer group to peak demand). To make DR work, customers should be provided with options that allow them to actively participate in the energy system. They should be incentivized to shift their consumption so that the use of their electric appliances is more equally distributed throughout the day. New tariff options should incentivize customers to change their consumption behavior to shave peak load in order to ensure lower average network costs and energy bills. A new tariff structure should represent the different nature of fixed costs and of variable costs. Cost-reflective network charging could be achieved by more capacity based network tariffs such as two-part network tariffs with a power/capacity and an energy component or network tariffs that penalize energy use at peak hours.

Thus, by considering these observations, DR has an important impact on tariff design. However, there are other aspects important to consider, namely how is CAPEX going to be included in the tariffs; as SG entails huge investments, a raise in the tariffs is predicted. As we spotted before, this raise shall be perceived by consumers as a needed increase, and not as an increase of utility's rents. Thus, regulators are responsible to assure the inclusion of SG investment costs in the tariffs is done in a fair and rational way, and that the costs of some elements of current tariffs is redefined for current reality, or even eliminated (for example subsidization of renewable technologies).

#### **4.6 Standardization strategies**

Although standardization may not look an important aspect of the economy of SGs, we want to spot some important implications of standards. Because SG requires a systemic approach, standards for data format, information handling, and transfer protocols are an important requirement to assure easy and system wide exchange. In communication

(European Commission, 2011a), the EC recognizes the importance of standards and pushes for their development and implementation.

What is recommended are minimum common functionalities in all future SMs. When deciding on new requirements for SMs functionality, they should not apply retrospectively. Decision making bodies should take into account that changing standards and regulation regarding meter functionalities for already installed SMs will carry a significant cost which will ultimately be borne by the consumer.

The North American NIST (National Institute of Standards and Technology) adopted a strategy which increases its influence at the international level. NIST chose to rely on the largest possible extent on international standards. NIST SG working group was conceived as a forum whose decisions rules had to be designed to decrease the costs borne by US firms to consolidate their technological leadership. Moreover, although NIST is an American institution, it strategically opened membership to other countries keeping the majority of the votes for American companies. This move enables USA to lead the technical standards having the support of other countries. Another important fact is that, according to (Bellantuono, 2012), in NIST, SG utilities only represent 10% of the membership, while vendor and vendor-related categories represent 50%; this means that the approval of standards can be done without the agreement of utilities and regulators. In our view this is a weakness that may affect the adoption of standards.

Nevertheless, both USA and EU are trying to drive the international debate and export their standards and their regulatory models (USA with the model of consortia SDOs, and inviting other countries for their national SDOs - where NIST SG is an example, and the EU by redesigning the EU SDOs procedures).

#### **4.7 The importance of EU Institutions in a transforming sector**

We have seen from previous chapters that the EU objectives are very ambitious and there is already much work about the development of a SG. It is important to note that most of the documents regarding EU energy policy are only communications that have no legal binding effect on the MSs. This is because, according to the TFEU<sup>64</sup>, the EU

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<sup>64</sup> Article 194 of the Treaty on the Functioning of the European Union (TFEU).

can only regulate specific fields of the energy policy. In (Knödler, 2012), studies across EU countries show that none of the national energy policies lay down a clear time table and finance plan for establishing a SG, pointing as exception Hungary which has a clear strategy with a precise timetable on how and when to roll-out SMs and SGs, which both shall occur in 2014. In opposite, USA and China have been devoting substantial resources in their territories to the development of SGs.

Nevertheless, we can surely state that, because SGs ease the efficient integration of DG and RES, they have a substantial political and financial support in the EU. As a matter of fact, and as we summarized in section 3.1, the EU released several directives in that direction: Renewable Directive (2009/28/EC), Internal Market Directive (2009/72/EC), and Directive on energy end-use efficiency and energy services (2006/32/EC), which are supportive of intelligent networks or intelligent metering. Financial support is given in the context of Seventh Framework Programme for Research and Technological Development (FP7) for R&D in SGs, ICT, and Green Cars & Electromobility<sup>65</sup>. However, we have seen that reaching consensus and meeting the deadlines of regulations and their implementation is sometimes an headache for EU as a single entity. The institutions of the EU should be given more discretion. Binding EU regulation or directives should be created so that implementation of EU wide SG is feasible. It should be clear who is charged and who supervises the SM and SG deployment on a national and European level. This would remove, or at least reduce the existent holdup on these investments.

In Europe, despite of the legislative packages adopted by MSs and transposed to national law by NRAs, there is a variety of regulation methods being applied (one directive, several methods). We see this as advantages and disadvantages. The obvious advantage is that NRA has better knowledge of its country culture, habits and social dynamics. The disadvantage is that it may difficult the coordination and harmonization of EU policies. We witnessed this problem in the Third Package where achieving consensus over unbundling was a difficult process. This is also a reason for the non-

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<sup>65</sup> FP7 runs from 2007 to 2013 ([http://cordis.europa.eu/fp7/energy/home\\_en.html](http://cordis.europa.eu/fp7/energy/home_en.html), last visited August 8, 2013 ), and a new framework for R&D from 2014 to 2020, Horizon 2020 (The EU Framework Programme for Research and Innovation), is already being elaborated ([http://ec.europa.eu/research/horizon2020/index\\_en.cfm?pg=h2020](http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=h2020), last visited August 8, 2013 ).

bindingness of some EU regulations. We could think that if SG becomes a political objective of EU Energy Policy that could help to ease the adherence of some MSs to the existent regulations, but given the considerations done, that may prove difficult. Furthermore, in a time where the project of the European Union itself is being questioned.

# Chapter 5

## Conclusions

In this dissertation, we intended to give an answer to our Research Questions which were the following:

1. *“Will Smart Grid be able to give an answer to main today’s questions such as energy security, energy cost and environment impact?”*
2. *What is the role of economic regulation in providing the incentives to invest in Smart Grid?*

We also used the sub-questions as guidelines for our reasearch:

1. *Is the European regulation designed so that it promotes the implementation of Smart Grids (directives, financial funds, support)?*
2. *What is the rule of standards on the choices of Smart Grid technologies, and how does the global governance of standards can influence those choices (taking in account that interoperability is important in network industries)?*

During this work, we had the opportunity to see that, in what concerns to Energy Policy, the European Union has as driving forces the environment concerns, the rising cost of energy, and geopolitical issues which have an important impact on European energy security. These are the main motivations to build a European Smart Grid.

Having monopoly been a way of organizing the electric sector in several European countries, and public enterprise the way of regulating it, moving to a liberalized market resulted in applying regulation mechanisms that have the roots on the work of Littlechild in the United Kingdom (and which emanated from there to many other countries). This regulation gives emphasis to operational efficiency of the network operators.

The “idea of Europe”, in particular of the European Union, has in its architecture the construction of an internal market and its liberalization; this vision was consubstantiated by the production of legislation at European level that resulted in a new landscape of the market and regulation of the electricity sector. Currently, there are areas of the electricity value chain that are liberalized (generation and supply), having the monopolist structure been preserved for transmission and distribution. During the decades in which distribution and transmission have been regulated, the dominant idea has been that the main objective of regulation should be to assure the operational efficiency of those companies. This objective has been, we can say, successfully achieved; however, in what concerns to innovation, the regulation mechanisms didn't have the same success in its promotion to the regulated companies. As a consequence, we observe that in some European countries, the age of networks is a problem due to lack of innovation and inadequate investment incentives. Nevertheless, the present panorama requests the same networks to answer the problems raised by the increasing energy cost, an increasing pressure from environment issues, and to answer the question of energy security. For that it is necessary to promote investment so that electric networks are updated. There are two ways to do it: one is keeping with the traditional network expansion strategies (laying more transmission lines, etc), and the other is the construction of Smart Grids.

We have seen that from the economic point of view, Smart Grids are more attractive, but their implementation is seen as a complex process, mainly from the organizational point of view. We also noted that Smart Grids are advantageous in what concerns RES integration and also in what concerns the management of their intermittency. Another point that answers to part of the energy costs is the transformation of the demand/supply paradigm in which Smart Grid promises that demand can follow supply (in opposition of current paradigm where what is intended is that generation follows the logic of satisfying demand). We can say that regulations produced by the European Union have thrown the basis in which Smart Grid can sit. We have seen that the diverse directives try to organize the market in a way that energetic efficiency, renewables, and essential infrastructures (both electric and communications), essential for Smart Grid development, are encouraged. However, it seems to us that main obstacles to the progression of Smart Grid may be the non-binding character of European regulations,

and the difficulties in reaching consensus in some important points at European level (as we have seen for the case of the Third Package). Besides that, finding the proper regulation incentives has been last years' grail quest of Smart Grid regulation.

So, we think that a way forward to a feasible SG involves a complex web of actors and concepts that need to be coordinated. This coordination should be directed by Regulators of the MSs guided by the experience of EU Institutions and based on the lessons learnt with SG pilots that happened and are still ongoing. We also agree on the importance of bringing the consumer to the center of the Smart Grid as without his engagement, DR cannot bring the expected results; besides that, it is essential to clarify that Smart Grid will not push their electricity bills down, but it can avoid that electricity bills grow as it would if the traditional way of network expansion continues. Regulators need to create the right conditions so that DSOs (and even DG companies) feel incentivized to invest. As we have seen, this can be made by improving the regulation schemes to increase CAPEX. In what concerns DG, an important point was raised in this dissertation, which is the potential that DSOs have to discriminate when it comes to connect DG; this point should also become subject of EU regulation as TSO unbundling was. Smart Meters are essential for Demand Response implementation. Being Smart Meters focused on the benefits for energy suppliers, and Smart Grids for network operators, it is important to know how DR impacts each of them. While energy suppliers will encourage consumers to smooth consumption via price signals, network operators are more concerned about reducing consumption peaks. So this raises some interesting (unanswered) questions, such as who shall have the control of DR – the suppliers or DSOs? Which signals shall be given to consumers? Shall network signals come via time of use tariffs or other mechanisms such as differential connection charges? Another apparently unrelated question is who will have the control of the user related information along the value chain? This information is needed both for suppliers and also for network operation (e.g. balance the intermittency of renewable DG). These rules shall obey EU regulations in what concerns privacy of information.

Network externalities are a very important feature of network industries. Besides interoperability along the electricity value chain, SG also wants to bring services to the electric network; for that, it is essential that service providers adhere to interoperable

technologies, making the electric grid a platform where customer can connect their appliances in a vendor independent way. Furthermore, DSOs shall be able to integrate interoperable communication devices in their networks, reducing that way their dependency on proprietary solutions. The way to make it possible is by means of standardization. The European Union has made considerable efforts by creating several mandates where SM and SG standards were developed. However, competition for standards is aggressively taking place on the other side of the Atlantic. In order to gain advantage on the global arena, the European Union should position itself as a candidate for global standards leadership so that European companies can reap the benefits of technological investments and innovation.

Following these considerations would result in bigger involvement of the regulator, which means that the regulation costs would be higher. However, that may compensate the social costs of not building a SG. Given this, changing the regulatory mindset is important; the regulatory process needs to be aligned with consumer protection (there should be sufficient investment to protect consumers from potential materially adverse outcomes). In the vein of (Ernest & Young, 2012), given the level of uncertainty, the concern is that trying to find the optimal solution may unnecessarily delay the development of Smart Grid. Thus, the rule of regulator is crucial in pushing forward the transformation of the grid.

Ultimately, the costs of building a Smart Grid will be borne by consumers. Thus, tariff design is a critical tool to achieve revenues for these transformations. This is also a good opportunity to redeploy existent charges and evaluate how cost-reflective current tariffs are.

A final word shall be written about the current European crisis and Smart Grid. Nowadays the European Union project is constantly being questioned, as are its institutions. The global competition has been putting at proof even the stronger economies. We believe that the security of supply and the raising costs of energy are very strong arguments to build a more efficient and cost effective grid as current society strongly relies on electricity. This is also the time for the EU institutions are given credibility and legitimacy in the case we all decide to move with the European project forward. This crisis is also teaching us that the European (and even the World) economy

is deeply intertwined, and economic blocks such as the USA and China are taking the lead in many crucial economic sectors. It would be desirable that EU could (re)organize itself so that their institutions could proceed with their aims.

In what concerns to Smart Grid, and now coming back to our research questions, we think that EU has provided the needed foundations to develop the Smart Grid. However, it seems to us that although the Member States borders are open, sometimes they reappear in Brussels institutions, which can hamper some important decisions. Beyond that, corporate power is also something we cannot deny, and that is a transnational phenomenon that political power needs to tackle. Finally, not building the Smart Grid may result in a negative outlook for energy security, energy cost and environment impact.

# Appendix I

Stakeholder	Main Smart Grids system needs and roles
Consumers	Consumption of energy products and services. This is the end-user of electricity. Categories of consumers are residentials, households, and communities. As consumers we also consider SMEs, industries and electricity-intensive industries. A specific example of a consumer category is the set of users with specialized mobility requirements for hybrid or pure electric vehicles. These users need mobility interface .
Prosumers	Consumers with the additional role of self-provided (owned) electricity generation and/or storage for private, daily life needs, comfort and SME business needs.
Energy Retailers	Selling energy and other (related) services and products to consumers. Retailers will develop consumer oriented programmes and offerings.
Aggregators	Broking energy on behalf of a group or groups of prosumers
Energy Service Companies (ESCOs)	Provision of a broad range of comprehensive energy solutions, including designs and implementation of energy savings projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply and risk management.
Electric Appliance users	The use of electrical appliances at consumer sites for daily life and business needs will increase due to substitution of (fossil based) space heating requirements. The users will be required to interface their needs with quality and security of supply needs of the electricity system.
Electric Vehicle users	A hybrid or pure electric vehicle is a specialized electricity consumer with mobility requirements. The users will be required to interface mobility needs with quality and security of supply needs of the electricity system.
Generators	Large scale centralized generation including wind farms.
Distributed Generators	Small- and medium-scale generation of mainly renewable based electricity either for third party consumers or for own consumption.
Storage Providers	Delivery of storage products and services, including their maintenance and operation thereby shifting electricity and energy consumption in time either for third parties or own purposes.
Ancillary Service Providers	Provision of services such as Power Balancing, Voltage Profile Support, Frequency and Time and Blackstart

ICT equipment and systems providers	Sales of Information and Communication Technology (ICT System) products and services.
Telecommunications providers	Provision of telecommunication services, based on dedicated or public infrastructure
Data processing service providers	Provision of data processing services respecting consumer privacy
Energy Equipment & Systems Manufacturers	Sales of Electro-technology (System) products and services.
Distribution System Operators (DSOs)	Provision of services for secure, efficient and sustainable operation of electricity distribution systems. Legal obligation of a high quality, secure planning, operation and maintenance of the distribution grid.
Transmission System Operators (TSOs)	Provision of services for a secure, efficient and sustainable operation of transmission system. Legal obligation of a high quality, secure planning, operation and maintenance of the transmission grid.
Wholesale Electricity Market Traders	Provision of market based prices for products and services by liquid electricity markets.
Policy makers, Regulators	Setup and control of natural monopoly requirements and for highly effective electricity markets.
Electricity Market Operators	Operators of market places for energy and other energy products and services

**Table 4 - Smart Grid stakeholders**  
*Source: (European SmartGrids, 2012)*

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