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Smart Grids in the EU with smart regulation: Experiences from the UK, Italy and Portugal

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ABSTRACT

The paper describes the integration between what used to be a passive element of the energy value chain – the grid – and both upstream and downstream elements. The evolution of communications among the elements has permitted a more robust and adaptable structure that already is being implemented: the Smart Grid. The paper relates the evolution of EU policy concerning both the development and the rolling-out of solutions to exploit the potential of the Smart Grid concept and describes what has been done by the regulators of three countries that share the same goal but seek to attain it via distinct paths. The article starts with a justification of the need for more integrated networks and a definition of the Smart Grid. A second part covers the risks and difficulties of implementation within an established network, introducing the role of the regulator. The third part describes EU policy response and three different approaches by regulators in the UK, Italy and Portugal, showing how in each case policy is influenced by characteristics of their respective national electricity markets in terms of competition dynamics.

1. Introduction

Evolution in the electricity system was long considered to be a slow process. In recent decades, however, the pace has been accelerating, mainly due to climate change concerns, as sustainability policies have deep repercussions on the consumption of natural resources in everyday life (Agrell et al., 2013). This global trend is increasingly visible in the number of national or regional commitments to greenhouse gas reduction, efficient energy use, lower energy intensity, and other programs focused on limiting humanity's carbon footprint.

The European Union (EU) has been a leader in sponsoring such programs, with perhaps the best known being the 20/20/20 agenda for the year 2020. This agenda reflects the goals of increasing renewable energy supply up to 20% of total demand, reducing energy consumption by 20% compared to 2020 forecasts, and reducing greenhouse gas (GHG) emissions by 20% relative to 1990 levels.

As a major user of primary energy and source of GHG emissions, the electricity sector will play a major role in achieving the set targets, involving all its stakeholders in a sector-wide change. From the shift toward the integration of low predictability renewable energy generators of all sizes, to the ability to deliver information that may help consumers make more efficient choices, the whole value chain can contribute to meeting the sustainability goals embodied in the 2020 agenda and subsequent targets through 2050. This process will include the incremental roll out of new technologies that improve coordination between different market players, allowing the power grid to become a platform for new energy services (ERGEG, 2010) and providing stakeholders with access to added-value solutions.

As key players in this sector, regulatory authorities have the crucial task of creating incentives for the development of cost-effective innovative solutions that benefit society. In the business of operating transmission and distribution grids (natural monopolies where remuneration normally is coupled with the volume of power flow or the amount of investment in transport capacity), the challenge is to create appropriate incentives for economically

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effective grid development, while assuring the consumer that the cost increases are not met by higher rent-taking from firms and operators in the supply chain (Agrell et al., 2013).

Within this overall context, this paper aims to provide a succinct yet holistic account of what has been done in the EU to support the evolution of the grid into what is now called a "Smart Grid," a first step toward the creation of the future electricity system (Gangale et al., 2013). The account is organized into five main sections:

(i) a justification of the need for more integrated networks and the definition of the Smart Grid concept;
(ii) a summary of the main risks and difficulties of implementation within an established network, introducing the role of the regulator in providing for an appropriate return for investments in innovation, satisfying needs of both operators and consumers;
(iii) a brief description of the principal EU programs that promote the development of Smart Grids;
(iv) three different approaches by regulators in the UK, Italy and Portugal; and
(v) conclusions and policy implications, emphasising how different stages of market development, namely the degree of competition, serve to determine the choice of regulatory practices in each country.

2. The need for an alternative solution

2.1. The evolution of the network

Traditionally, the energy sector has been seen as a cascade of elements, with energy flowing from generation to transport, to distribution, and finally reaching the consumer. The consumer, on the other hand, has grown accustomed to taking energy availability for granted, with power always available at the flick of a switch (Healy and MacGill in Sioshansi, 2011). Both of these concepts are now evolving into a more complex reality, with some elements of bi-directionality being introduced in the network, with new constraints in dispatch and predictability, with the consumer now having the opportunity to take a more active role in the management of consumption and, in many cases, even producing energy, giving rise to the "prosumer" (producer + consumer) concept. The grid hence stands to shift from a demand-following principle to a potential supply-driven one (Verbong et al., 2013).

This new dynamic of electricity services has been made possible predominantly by the evolution in communication technologies. As once happened with the use of computers to enhance the grid with increased automation and real time responsiveness to faults, so does the communications boom stand to alter the management and capability of the grid.

Though there are almost as many definitions for the term Smart Grid as there are experts (Sioshansi, 2011), these may be aggregated into two types:

(i) the technology-based approach, focussing on the use of technology to enhance the intelligence of the grid through communication and electronic equipment installed on the premises of the network user (IEC, 2010); and
(ii) the output-based approach, focussing on the problems to be solved. Such is the approach of European regulators and will be the one used throughout the current paper. In this view (ERGEG, 2010), the Smart Grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.

The Smart Grid concept is often bundled with the Smart Metering concept, and many times mistaken as a synonym. Although the Smart Meter is an important part of the wider Smart Grid concept, it does not, of itself, constitute a Smart Grid. Acknowledging the broadness of this definition of the Smart Grid, it is pertinent to explore some of the many possibilities it opens and focus on the main drivers that support the transformation it implies.

2.2. Drivers

The commitments of the EU concerning the sustainability of the energy sector call for a more dynamic concept of grid. Three main drivers stand out as important benefits that require the implementation of Smart Grids:

(i) integration of Renewable Energy Sources (RES) and Distributed Generation (DG);
(ii) promotion of Demand Response (DR); and
(iii) optimisation of new end-uses of electricity.

2.2.1. Integration of distributed generation and RES

Given the negative environmental externalities of carbon-intensive processes and fuels, several measures have been taken to promote the lowering of greenhouse gas emissions through the use of RES. However, factors such as exhaustion of good locations, "Not-In-My-Back-Yard" (NIMBY) resistance and lesser relevance of scale economies in production, have led to the conclusion that the initial concentrated (large-scale) RES formats may give way to more decentralized generation, connected to the distribution network (Agrell et al., 2013). This implies a potential shift from the centralized solutions to local cooperatives, with groups of houses sharing micro-generation production or even the "prosumer" concept referenced above (Geelen et al., 2013).

The fact that RES generation cannot be dispatched with the predictability of a conventional plant presents several grid-management challenges, such as the risk of grid overload due to excessive production, increased voltage levels due to the injection of active power in periods of low consumption (Hanser in Sioshansi, 2011), and decreased reliability due to fault protection triggers and islanding risks.

Although the first two situations may be dealt with by expanding the grid (more lines and transformers to provide further interconnectedness and power flow), this is a slow and capital-intensive approach that puts additional burden on the consumer and fails to drive incentives toward a rational allocation of resources.

2.2.2. Promotion of demand response

At the centre of the changes toward a more efficient use of energy, consumers are expected to evolve from a passive to an active role. The demand-response concept refers to changes in electricity consumption by end-users in response to supply conditions (Geelen et al., 2013). To achieve this, the consumer will have to be engaged and provided with information, additional services, and incentives in order to benefit from potential selective reductions in load. These reductions will come mainly from commercial and industrial users but also from households, coordinated and combined by aggregators and other energy services companies (ESCOs). Smart Grids are a tool to enable consumers to better manage their energy consumption for their own benefit and for that of the whole electricity system. Implementation will need to build on trust, as consumers shed resistance to new technical, regulatory, and market solutions (Gangale et al., 2013).

To provide a first element of information to the consumer and act as a platform for further energy services, Smart Meters have been developed and deployed in several EU countries (current EU legislation calls for the roll out of Smart Meters to at least 80% of consumers until 2020 in all member-states, except where a comprehensive Cost Benefit analysis yields a negative outcome (European Commission, 2014)). It should be noted however that the Smart Meter alone does not provide for user interaction and hence has little effect on user behaviour (Geelen et al., 2013).

The ability to collect and treat data should enable home automation solutions that focus on load management and overall energy efficiency as well as convenience and security (Slaboszewicz in Sioshansi, 2011). With household energy consumption related to a combination of technology and end-user behaviour, there is concern over the lack of product and service design to support consumers in their new roles (Geelen et al., 2013). Smarter grids and meters facilitate tariff innovation to improve end-use efficiency that results in direct savings to customers. Tariff solutions can also be designed for specific concerns, such as reliability and affordability.

For the wider system, the ability to reflect system conditions through price signals may lead to greater awareness and behavioural adjustments (Sanders in Sioshansi, 2011), resulting in reductions of peak demand and therefore deferred grid investments (Hindsberger in Sioshansi, 2011) (Pudjianto et al., 2013). The underlying assumption is that consumer decisions are affected by the economics of consumption and, though inelastic in terms of total demand, the consumer is at least flexible enough to shift the hours of consumption (Geelen et al., 2013) (Agrell et al., 2013).

However, the hardware is only a platform from which to build an informed consumer-driven response and ensure demand driven changes in the use of energy. An automated system to trigger the time for electrical appliance use would still require user intervention for adjustments that better suit consumer needs (Geelen et al., 2013), as well as the shift of choice toward "smarter" appliances (Verbong et al., 2013), making engagement crucial. The type of service contract expected by the consumer will vary, as users will require different incentives and solutions to adopt Demand Response schemes (He et al., 2013). To maximize potential adoption, the roll out must be accompanied by policy interventions that induce technology change in a purposeful direction (Jennings, 2013). Success also requires market design and regulations that promote dynamic-pricing tariffs as well as information campaigns to increase consumer awareness (Torriti et al., 2010).

2.2.3. New energy stakeholders

The main focus of Smart Grid discussions has been on the integration of new energy sources. However, increasing attention is turning to the impact of new forms of energy consumption, such as electrical vehicles (EV) and heat pumps (Verbong et al., 2013). Whereas the heat pump has the characteristics of conventional load, the storage capability of the EV offers possibilities for enhanced grid management and associated services. Additionally, with the transport sector being responsible for more than 25% of overall greenhouse emissions, with two thirds of these coming from road transport (EUROPA, 2011), this is one sector that sustainability policy cannot afford to ignore. Indeed, EVs are seen as key instruments to enable a redirection of the transport demand from fossil fuels to the electricity sector that relies increasingly on renewable and low-carbon electricity generation (Pudjianto et al., 2013); in fact, EVs are expected to almost double the average electricity demand per household (Verbong et al., 2013). The EU has understood the need to eradicate the barriers to the development of this cleaner technology through direct policy measures.

There are several key aspects to be dealt with before a significant adoption of the electric vehicle can be achieved, namely battery cost, autonomy, standardization, etc. Moreover, aspects related with dynamic management of the grid, namely the charging mechanism, are of utmost importance. On this issue, the EV presents new challenges, including power availability and legal constraints to having multiple meters in shared parking/charging spaces. On the other hand, the possibility of using the storage capacity of the electric vehicles to optimize energy supply over a specified time period is an interesting one due to its potential synergies with non-dispatchable RES (Zubaryeva and Thiel, 2013).

Equally important on the demand side is the activity of new intermediaries, such as aggregators and other electricity services providers. Technological innovation is reducing the cost of distributed generation and self-generation while new players are providing platforms for more efficient home energy management and for transacting energy savings from automated demand response, namely for short-term operating reserve power. This evolution of new stakeholders provides a challenge to regulators in terms of ensuring that market design and tariff structures provide incentives for new forms of energy efficiency and investments that permit energy bi-directionality.

3. Common challenges

3.1. The unbundled network

Competitive markets are generally accepted as being the most efficient mechanism for the allocation of goods and services, thereby achieving maximum total welfare. However, whereas generation and supply are potentially competitive activities, transmission and distribution functions are considered natural monopolies. In the absence of regulation, vertically integrated utilities that operate the grids may have opportunities to restrict competition in the upstream markets of electricity generation, and generally to constrain price competition through cross-subsidization. Full ownership unbundling is legislatively required to ensure competition in these markets (European Parliament and Council, 2009) and in some national policies (Braz and Esteves, 2008). Smart Grid investments bring benefits to several players along the value chain, rendering obsolete the previous investment models for assigning unique tasks to specific agents. This dispersion of costs and benefits of the value chain among various traditional stakeholders and new stakeholders (e.g., the communications sector and aggregators), justifies a more active role for the regulator in defining the roles, boundaries and responsibilities of the system operators (Ruester et al., 2014).

3.2. The regulator

In contrast with other jurisdictions, such as the USA, where energy policy is largely the responsibility of individual state authorities and varies greatly across states, energy policy in EU member states is largely determined by Community legislation. Successive "Energy Packages" (the latest is the 3rd Package, dating from 2009; European Parliament and Council, 2009) have established common rules for energy market organization and institutions. Focussing on the areas of transport and regulation, the objective was to "complete" the Internal Energy Market by 2014. Other legislation, including the Infrastructure Package (EUROPA, 2011), the Regulation on Energy Market Integrity and Transparency (European Parliament and Council, 2011) and the Energy Efficiency Directive (European Parliament and Council, 2012), sets common EU-wide guidelines and obligations in areas such as cross-border interconnectivity, wholesale market transactions reporting, security of supply, and the promotion of energy efficiency.

Within the context of the corresponding EU legislation, energy policy is the responsibility of each EU state's national government, which normally defines the structure of the electricity system and the rights and duties of different players, grants licences or concessions, and decides the choice of production technologies and subsidy structures (if any). The regulator, on the other hand, is the entity responsible for creating a framework that enables the integration of new services in the electricity network while apportioning any extra costs in a fair way among the stakeholders who benefit from the solutions. This goal is to be achieved while navigating through the government-defined policy and social objectives (Zinaman et al., 2014). In addition to dealing with the traditional problems of information asymmetry, the regulator must now also devise incentives to promote energy savings, and possibly including the challenging task of decoupling operator returns from the volume of energy supplied or distributed, in line with government policy determinations and commitments.

Considering new investments for the implementation of Smart Grids, the regulators' challenge stems from the challenge that the current (traditional) regulatory models may fail to elicit the intended response. Under traditional regulation, the operator would only be interested in grid innovations to the extent that they provide an investment opportunity, help in fraud prevention, or reduce grid maintenance costs. To address these limitations, the regulatory authority is tasked with complementing existing regulations with effective incentives for energy efficiency and decarbonisation, taking into consideration the specific structure of the energy markets in its jurisdiction.

3.3. Data protection

The amount of sensitive customer information transmitted by the grid to all relevant actors, the number of control devices implemented and very low physical security, the prospective use over the internet of energy-related apps and services, along with a potentially significant increase in the number of intervening players, are all factors that make data protection a major concern, especially for consumers. Even though users have been largely left out of other grid innovations, their acceptance of the changes needed to their homes and daily routines will be pivotal to the success of Smart Grid implementation (Verbong et al., 2013).

In addition, cyber security is increasingly acknowledged as an area of concern, given the enormous potential harm that can be inflicted on operators and consumers by malicious hacking into the systems that control grid operation. This calls for a careful separation of data systems between customer data provision (including billing data and smart-meter functioning) and systems operation data flows.

To better target the data protection concerns, the Joint Research Centre (JRC) identifies the need for a privacy-by-design approach, as integrated in Mandate M490 for European Smart Grid's Standards, issued in 2011. The mandate is intended to ensure that privacy concerns are at the very core of the development of Smart Grid solutions.

4. Smart Grid initiatives at EU level

Following the 2020 agenda, the Strategic Energy Technology Plan (SET-Plan) was created by the EU both to develop the technologies needed to meet the targets and to ensure that European companies benefit from this new approach to providing energy (European Union, 2010). However, the implementation of Smart Grids at a European level has not been as swift as was initially expected. Across member states, development has occurred at different speeds and based on different premises, which hinders the potential of a fully integrated network.

The philosophy under which the EU operates stems from approaching Smart Grids innovation in several incremental steps:

(i) basic research and development;
(i) development of equipment;
(ii) pilot programs and additional data gathering;
(iii) implementation of solutions.

In order to ensure a coordinated effort to drive the study and implementation of Smart Grids throughout the EU, several programs have been developed and a special task force was created to facilitate the sharing of information, best practices, and lessons learnt across experiences.

4.1. EU 7th Framework Programme (FP7)

The FP7 joins the EU research-related initiatives under the same umbrella and groups them into four categories: Cooperation, Ideas, People and Capacities. Each objective is attributed to a programme corresponding to the main areas of EU research policy, facilitating collaboration and promoting the creation of European poles (or centres) of scientific excellence. The Smart Grid projects are within the Cooperation category, under the broader Energy programme, representing the efforts of member states to join forces for the cooperative development of Smart Grid solutions.

4.2. Horizon 2020

Merging the principles of the 7th Framework Programme, Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT), Horizon 2020 is EU's 80 billion euros Research and Innovation Programme. Running from 2014 to 2020, the programme aims at simplifying the rules of participation and closing the gap between innovation and market through 3 main pillars: Excellent Science, Industrial Leadership and Societal Changes (EUROPA, 2014a). The Smart Grid projects are addressed in the latter pillar, under the key challenge named “Secure, clean and efficient energy” with a budget of approximately 5.9B euro (EUROPA, 2014b).

4.3. EEGI

The European Electricity Grid Initiative (EEGI) is one of the European Industrial Initiatives under the SET-Plan. This initiative proposes a nine-year EU-wide research, development and demonstration programme to push forward the development of the Union's future electricity networks, ensuring the 2020 agenda objectives are met. The first EEGI roadmap 2010–2018, with costs estimated to reach around EUR 2 billion, not including the costs of deploying the final solutions, was approved by the European Commission in 2010 (EEGI, 2010). It has since been updated and upgraded by the GRID+ project in response to recent EU energy policy evolutions (Brunner et al., 2012).

4.4. Smart Grid Task Force

Created in 2009 and with an updated mandate in 2011, the Smart Grid Task Force (SGTF) is invested with the specific objective of assisting the Commission on policy and regulatory frameworks for the implementation of Smart Grids under the Third Energy Package. This task force brings together diverse stakeholders and is comprised of a Steering Committee and, currently, four Expert Groups focussing on Standardization, Data Protection, Regulatory Issues and Infrastructures, reporting periodically to the Commission and making the information available through the publishing of findings through the Commission website. (EUROPA, 2013a,b,c).

4.5. EU energy infrastructure legislative package

In October 2011, the European Commission (EC) proposed a legislative package called "The Connecting Europe Facility" (CEF) aimed at improving the links between the three infrastructure sectors (Energy, Transport and Communications), ensuring coordination of funding and reducing administrative overlaps. This strategy aims to attract financial resources from both the public and private sectors by increasing the credibility of infrastructure projects and lowering their risk profiles (European Commission, 2011).

The proposal for a "Regulation on guidelines for trans-European energy infrastructure" sought to put in place the necessary tools for the 2020 objectives. With it, the Commission stressed that an interconnected, reliable and modernized infrastructure is necessary for EU energy and climate policy goals as well as economic strategy. The Commission proposed that energy infrastructure projects of common interest (PCI), which are eligible for EU funding, should be approved by a single authority within the concerned Member State, responsible for coordinating the permit granting process of the projects, namely the ones that concern the evolution toward a "smarter" grid. In 2013, the European Parliament approved the regulation on Guidelines of the EU energy infrastructure package with a funding of 5.1 billion euros intended to leverage more funding from other private and public investors.

5. Three countries' experience

While sharing the EU's guiding principles as a background for implementation, countries preserved their independence regarding the choice of the most appropriate ways to pursue the common objective, also taking into account local conditions and market dynamics. As a consequence, the options taken to implement smarter grids were distinct, permitting a cross study of policy decisions and outcomes. The three markets chosen, UK, Italy and Portugal, present substantial diversity in terms of historical evolution, market size, and competition characteristics, having in common the fact that national energy policy and regulatory practice have explicitly promoted innovation, namely in the "smartening" of electricity grids.

5.1. UK[3]

5.1.1. Overview of the electricity sector in the UK

The UK electricity grid was constructed in the 1950s and 1960s to accommodate concentrated generation technologies heavily reliant on coal mining. With electricity generation representing approximately 30% of the UK's CO_2 emissions (Hammond and Pearson, 2013) and the Government having signed the EU Renewable Energy Directive, including a UK target of 15 per cent of energy from renewable energy by 2020 (a seven-fold increase from 2008 levels), the path is set for an ambitious increase of RES. The government has further mandated that every house be fitted with smart meters and internal home displays before 2020 (Jennings, 2013). The UK energy market has long been considered one of the most competitive in the EU, with a large number of producers, system operators, and suppliers.

5.1.2. Regulation

5.1.2.1. The traditional role. After the late 1980s privatization of the energy sector, the UK sought to provide for ownership unbundling of generation and transmission systems, while ensuring that network companies were regulated under the RPI-X framework (a price-cap mechanism where revenues are adjusted by inflation less an efficiency factor [X] each year), with periodic updates. The entity responsible for the regulation of the sector is the Office of Gas and Electricity Markets (OFGEM). As an independent regulator, its attributions include the issuing, modification, and enforcement of existing licenses as well as the setting of price controls for the Transmission System Operators (TSOs) and Distribution System Operators (DSOs). The current price control for the Distribution Network Operators (DPCR5) was published on the 1st of April 2010, and will remain in place up to 2015.

5.1.2.2. Evolution of the regulatory role. Prompted by the commitments the UK made toward sustainability, the regulator has been an active party in the search for solutions. The fourth carbon budget requires greenhouse gas (GHG) emissions to fall by 50% by 2025 relative to 1990 levels and by 32% relative to 2009 levels. The Renewable Energy Directive also sets a target for 15% of consumed energy to be provided by renewable energy sources by 2020. To meet these goals, OFGEM started working in March 2008 on a complete review of the RPI-X regime used to regulate gas and electricity transmission, and distribution companies, having presented on October 2010 the RPI-X@20 document that laid the foundations for the RIIO model (standing for Revenue using Incentives to deliver Innovation and Outputs). The new model is considered an evolution of the RPI-X framework, adding elements to ensure that operators work toward ensuring a sustainable energy sector, with long-term value for money and added encouragement for innovation. These elements include: (i) an upfront (ex ante) specification of the outputs that network companies are required to deliver and the revenue they are able to earn for delivering these outputs efficiently; and (ii) a time-limited innovation stimulus for network companies and non-network parties. In March 2013, OFGEM published what is to be the new regulatory framework for DNOs, running from 2015 to 2023, and known as the RIIO-ED1.

5.1.2.3. Supporting the sustainability project. The Department of Energy and Climate Change (DECC) is one of the entities committed to driving the action on RES penetration on the grid (Agrell et al., 2013) while assuring energy affordability for consumers. In the period of 2012–2013, this entity assumed the priority to set in place a framework backed by the Energy Bill to enable the estimated £110 billion needed for energy infrastructure. In April 2011, OFGEM and DECC established the Smart Grids Forum (SGF) to provide further leadership to the industry on smart-grid issues. The SGF is a combination of key opinion leaders, experts and stakeholders in the development of smart grids and aims at providing strategic input to help shape OFGEM's and DECC's role in this area. The Electricity Networks Strategy Group (ENSG) is another forum that brings together key stakeholders in electricity networks, supporting the government in meeting the long-term challenges of providing sustainable energy solutions. The ENSG is jointly chaired by DECC and OFGEM and its broad aim is to identify and coordinate work to help address key strategic issues that affect the electricity networks in the transition to a low-carbon future. The ENSG aims to deliver a range of well-targeted pilot projects between 2010 and 2015 in the expectation that many of them will prove to be technically and

[3] The global policy guidelines refer to the UK. However, it should be noted that the scope of the energy regulator (and the regulatory measures mentioned in the text) are limited to Great Britain; regulation in Northern Ireland is autonomous.

economically successful and therefore available for UK-wide application from 2015 onwards. Work undertaken by the ENSG has included the publishing of a smart grid Vision and Routemap outlining a potential path to test the feasibility, costs, and benefits of smart grid technology and the means by which the UK could realize the smart grid Vision. In 2013 the Central Delivery Body was also set up, realising the need for consumer engagement for a successful roll-out activity. This organization will be responsible for creating confidence and awareness of users as to how to take advantage of the smart meters (SGF, 2014).

5.1.2.4. Special funding for innovation and specific programs. In December 2009, OFGEM announced a funding mechanism of £500m over the period 2010 to 2015 to support competitive tenders for "large-scale trials of advanced technology including smart grids", as part of DPCR5, and only applicable to electricity distribution companies. The aim of the Low Carbon Network Fund (LCNF) is to provide assistance to projects that help release the spare capacity built into the distribution network via a more intelligent management of supply and demand with the Transform Model, created by the SGF, estimating savings of 25–30% of reinforcement costs to 2050. The objective is to permit the validation of technology that can realistically be deployed across the network at the end of the project.

Later, in 2012, the DECC notified the EU of the development of a first version of the technical specification for smart meters (SMETS 1), currently under revision (SMETS 2). Privacy and data-access arrangements for suppliers and DNOs were also established in 2012. To promote the roll out of smart meters, the supplier license was amended, placing a duty on suppliers to have meters replaced by 2019. Under the LCNF several pilots have been launched, including a £53.6 million project lasting from 2010 to 2013, to create incentives for higher demand response through smart meters and ancillary services.

5.1.3. Final remarks on the UK

With a pragmatic approach in a competitive market that has a large number of operators, the UK is currently making use of its flexible regulation mechanisms to create the necessary incentives for Smart Grid solutions. It is also now ranked by the Joint Research Centre as the leading country in levels of investment in Smart Grid research and demonstration projects. Through programmes and councils, the UK is attaining thought leadership on the subject that can, with the correct strategy alignment, shape the European standards and boost the supply chain and therefore the economy (SGF, 2014).

The SGF clearly states that, given uncertainties in supply and demand, it is not possible, nor is it the regulator's intention, to map out the evolution of the network. The LCNF is thus promoting DSO competition for funding. Information from the pilot programs will help tailor the roll-out solution and provide both industry and regulators with tools to devise incentives for this alternative to expensive and time-constrained grid expansion.

5.2. Italy

5.2.1. Overview of the electricity sector in Italy

According to the Italian regulator "Autorità per l'Energia Elettrica e il Gas" (AEEG), about 30% of the nation's 2011 electricity production was accounted for by RES, with a majority contribution (56%) from hydro resources. None the less, the impressive 2010 to 2011 increment of 466% from photovoltaic technologies, or even the 14% and 8% increments from biomass and wind, respectively, are proof of a continued drive toward RES.

Further characterizing the RES operators, it is important to note that most of the wind farms are above the 10 MW threshold, have a high geographic concentration in the south of Italy, and are connected to the transmission grids. The photovoltaic surge is also a direct response to the stimulus provided by a favourable feed-in tariff, with these resources located mainly in the centre and south of Italy and connected directly to the distribution grids.

These characteristics make Italy one of the EU member states that has been most impacted by the increase of intermittent generation, with RES serving over two-thirds of overall demand for some summer days (Lo Schiavo et al., 2013).

5.2.2. Regulation

5.2.2.1. The traditional role. Italy's energy regulator was given the task of "protecting the interests of consumers and to promote competition, efficiency and deployment of services with adequate levels of quality, through the activity of regulation and control" (AEEG, 2011). AEEG has prompted TSOs and DSOs to trim down OPEX costs by a factor X year-on-year, while the invested capital is remunerated at a rate that is fixed in periods of four years. Regulatory measures also address service quality, congestion management and losses, to which the regulator has granted additional remuneration for the cost of capital for a pre-specified time period (e.g., for specific investments addressing network losses, the DSO is granted a 2% premium over the cost of capital for eight years).

5.2.2.2. Evolution of the regulatory role. The European objectives for renewable energy production and overall system efficiency have had an impact on the role of the Italian regulator. The need to consider the integration of distributed generation (DG) and large scale renewable energy providers, stimulate efficiency measures on the demand side (Demand Response), and allow for innovative uses of energy, such as the case of electrical mobility, has brought a new dynamic to AEEG's activity.

5.2.2.2.1. Integration of DG. Acknowledging the lack of experience in the development of innovative solutions and respective technological uncertainties, the Italian regulator focused on a three step approach – Research, Pilot Programs and Roll Out – that would allow for the acquisition of knowledge prior to defining the output based incentive scheme for a full deployment scenario. Under the first step, research by Italian universities was commissioned with the objective of understanding the medium-voltage (MV) grid capacity for connection of DG without recourse to grid expansion. Collateral information provided by these studies was used to create a network performance indicator: the *Reverse Powerflow Time* (RPT), or the amount of time the power flows from the distribution network to the transport grid when DG injection exceeds actual local demand in a specific time frame.

Using the knowledge from the initial study phase, specific geographies were targeted for pilot programs and specifications were drawn up to ensure the positive impact on the RPT indicator, while assuring that the technology used abided by standard and non-proprietary protocols. These specifications were key to ensure that a roll-out phase would not be constrained by a specific technology that would ultimately drive up prices. To generate interest on the promoters' side (DSOs), these pilot programs allowed for a 2% premium over the cost of capital for a limited time period (12 years). The selection of the programs was conducted by the regulator and projects were evaluated based on technical and economic parameters. A new indicator, *Psmart*, accounts for the amount of DG energy that could further be injected into the network without its expansion, thereby rendering unnecessary grid expansions and creating conditions for efficient network usage.

These programs aimed at providing a comprehensive test of the indicators and assumptions drawn from the initial research to support the roll-out phase. The major regulatory concerns outlined were as follows (AEEG, 2011):

(i) An incentive-type system was to direct investment toward critical geographies through the use of indicators such as the RPT and other critical parameters, including the amount of DG connected in a specific area;
(ii) Admissible energy was to be maximised after a non-structural grid upgrade, using one simple indicator (*Psmart*), based on the added value of the Smart Grid upgrade when making investment decisions;
(iii) Minimum levels of innovation were set for interventions, such as voltage control at DG plants through reactive power control or real-time adaptive measures to ensure anti-islanding protection.

These concerns envision an output-based incentive scheme for the future roll-out phase that includes an incentive that is proportional to *Psmart*, an RPT threshold, or a minimum level of DG for MV networks, and the application of a regulator-defined set of minimum requirements.

5.2.2.2.2. Demand response (DR). To promote a more interactive role by consumers, AEEG rolled out programs to push the deployment of smart meters, allowing operators to recover investment costs through tariffs. These programs were a success, with smart meters currently covering more than 95% of the Italian low-voltage (LV) consumer base. More sophisticated internet-linked meters that can engage consumers and make them a dynamic part of the system to enable benefit sharing throughout the value chain, are also being developed. Such new demonstration projects should promote innovation and adoption, and lead to active management of the grid.

As of 2010, AEEG introduced a Time-of-Use (ToU) tariff for residential and small commercial consumers within the Universal Supply Regime that became fully operational in 2012. These tariffs are gradually creating consumer awareness of the differences in the price of energy throughout the day and leading to shifts in consumption habits.

5.2.3. Final remarks on Italy

In its approach to Smart Grids, Italy has devised a structured effort that draws knowledge from its institutions and creates incentives for the development of what is centrally acknowledged as the sustainable solutions. The use of an additional remuneration for investments related to Smart Grids is consistent with the models already in use for upgrades related to service quality and efficiency. Furthermore, the feedback loop created for the analysis of data related to the pilot programs provides the necessary tools for building a fully tested approach to full deployment.

5.3. Portugal

5.3.1. Overview of the electricity sector in Portugal

The energy sector in Portugal in the 1970's was nationalized as a vertically integrated monopoly; the unbundling process started in 1995, with a legislative package that re-organized the electricity sector, preceding the EU directive 96/92/EC that instructed member states to do so. The package provided for the legal separation of production, transport, distribution and supply, as well as establishing the rules for access to the transmission and distribution grids. Unlike the UK and Italy, the main distribution grid is entrusted to a single company (EDP Distribuição, 2011).

Regarding the energy mix, Portugal now has a 21% level of renewable energy penetration in primary energy consumption, with large hydro and wind responsible for most of this share (Pordata, 2014). This value corresponds to 44% when measured as the renewable mix in the production of electricity. Through generous feed-in tariff incentives, Portugal has witnessed a rapid rise in renewable energy production. Efficiency has also been promoted, namely through incentive programs for solar thermal collectors. It is estimated that, in 2011, the thermal contribution was twice that of photovoltaic (Pordata, 2014). The expansion of the electricity grid has accompanied the need for connecting renewable generation. However, the economic downturn in Portugal increased interest by the DSO and the regulator in a more efficient strategy to foster the development of "prosumers."

5.3.2. Regulation

5.3.2.1. The traditional role. Portugal's regulator "Entidade Reguladora dos Serviços Energéticos" (ERSE) was established in 1997 with the mission to protect consumers through appropriate pricing and quality of service, while assuring an adequate economic return to the regulated companies and promoting the internal energy market. Since 1999, Portugal has chosen to use the price-cap model of regulation, applying it based on efficiency measures and the definition of returns calculated for both CAPEX and OPEX. In the allowed returns, CAPEX is fully considered and only the OPEX figure is affected by the efficiency measures (ERSE, 2011). If performance is better than agreed on, the company reaps all of the extra benefits, thus ensuring an incentive toward efficiency. If, however, the company fails to meet established targets and goes over-budget, the consumer is safeguarded and the DSO will assume the loss. Historically this strategy achieved declining OPEX unit costs, though to a lesser extent than forecast and revealing possible limitations of this model.

5.3.2.2. Evolution of the regulator role. Understanding the potential savings for consumers that can result from efficiency enhancements provided by Smart Grids, and the savings these can ensure by avoiding grid expansion, ERSE has established incentives for the development of these solutions. The incentive scheme differentiates the common grid expansion solutions from the ones that might be considered "smart." As the latter are acknowledged as riskier investments, they can earn a premium over the cost of capital, implying a sharing of the innovation's risk by consumers. However, just as the risk is shared, so are the achieved benefits. This is conveyed by an extra efficiency target for overall OPEX, added to the target of 3.5% that is currently used for standard solutions. This target is calculated considering the investment costs and forecast efficiency gains so as to compensate for the premium in the cost of capital. For the current regulatory period and considering the period's allowed investment on "smart" solutions, this extra efficiency target amounts to 0.1%. The attribution of the "smart" designation to a project depends on the DSO's research into the potential benefits of a proposed solution. As no specific guidelines or requirements are set for the technologies or equipment used, the DSO is free to procure the solutions that best fit the need. The detailed study must be reviewed by the regulator to test the validity of assumptions and validate the cost–benefit analysis. If the project is expected to provide for an overall efficiency gain (with OPEX savings over time compensating for initial extra CAPEX), the regulator allows the DSO the 1.5% premium return on the "smart" investments.

5.3.2.3. Specific programs and timings. Starting in 2007, the DSO partnered with entities that include an academic institute, technology and innovation firms, and a metering equipment supplier to create the InovGrid project, which aimed to promote innovation in the interaction between energy companies and their customers. InovGrid's first investment was in May 2009, with the implementation of a Distribution Transformer Controller (DTC) that managed communications with intelligent grid terminals (Energy Boxes or "EB") that incorporate electricity meters and allow customers to interact with electrical appliances as well as monitor consumption. This unit was installed in the DSO's premises and resulted in the active control of public lighting and measurement taking. The concept test was rolled out to other locations and further developed to provide consumption data to consumers, innovative methods of tracking grid faults to enhance the fault correction, remote control over home appliances, and the integration of micro-generation.

With the experience gathered from the InovGrid project, InovCity was developed as a larger scale concept to further evaluate technologies and functionalities, test the interoperability, better understand the mechanisms related to cost–benefits analysis (CBA) and acquire valuable know-how and deployment experience. Choosing Évora (a medium-sized Portuguese city), Portugal's DSO implemented a pilot project that installed 31,000 smart meters and 340 DTC. This project was selected as a pilot on the validation of the Electric Power Research Institute's (EPRI) Cost–Benefit Analysis by the JRC. Currently, EDP is rolling out a new project that aims at the consolidation of results and validation of data through the installing of 100,000 EB in six different locations throughout Portugal. The target for a plug-and-play solution is one of the major aspects important to the full roll-out phase.

The Mobi.e project took its first steps in 2008, tasked with developing all the necessary equipment for electric vehicle utilization. With 1300 standard and 50 quick points of charge for electric vehicles, the Mobi.e programme has a network that covers 25 cities (Mobi.e, 2010). The programme joins the DSO, Portuguese software and hardware solution companies, as well as international partners, and is considered a "Smart" solution as it integrates all charging and electric mobility systems into a single open platform. As it is open to all operators, the dynamics of a competitive energy retailer market is at the core of the solution and enables the tracking of all financial and energy flows and establishing the communication between energy providers and customers. Aimed at potential international expansion, the equipment was designed to support all types of grid connections.

5.3.3. Final remarks on Portugal

The Portuguese approach to Smart Grid innovation is one based exclusively on the potential benefits of the solution. Technology is seen as means to an end, and is not, therefore, the subject of the regulator's specific attention.

The lack of competition in distribution (a single DSO covers all of continental Portugal) has required a more intrusive role for the regulator in terms of defining criteria, allocating incentives and measuring compliance.

The expansion of the Portuguese grid in recent decades and the boost in renewable energy sources, coupled with the slowing of energy needs due to a slowdown in the economy, make for a current state of affairs that is compatible with a slow adoption of the smart grid concept. However, the DSO's initiative pushed for the roll-out of several pilot programmes and the development of equipment in partnership with local hardware and software suppliers. The testing phase has produced important data that supports the solutions found and is now being used to improve the equipment and the potential complementary services for the scaling-up phase.

6. Conclusions

This paper aims at transmitting an overview of the current smart-grid policies and key regulatory trends that are being carried forward in the European Union (EU).

To address the issues, the paper introduced the need for an alternative to the conventional grid system. The measures now being considered concentrate on three vectors:

(i) Focussing on the need to lower the impact of the energy conversion systems on greenhouse gases, the EU has adopted concrete measures that imply the generalized use of renewable energy sources. However, as high concentration locations become exhausted, the need arises to focus on the possibility of dispersion in production. This, too, poses significant challenges to the grid, as the management of the grid no longer deals only with unidirectional power flow. The need to create systems that can cope with the integration of variable, unpredictable, and distributed generation is, thus, the first vector.

(ii) As communications permeate the energy grid, the amount of information being supplied to the consumer increases greatly, and with it the possibility to offer new services. These new grid attributes may help consumer habits to diversify, thus allowing the management of the grid to create incentives that better suit efficiency improvement. This implies abandoning the tradition of providing enough supply to meet expected demand, replacing it with a system that adjusts to meet the moment's conditions for supply by means of demand response.

(iii) The emergence of new energy consumers that may not behave in the classical way is the third vector. Elements like the electric vehicle have the potential to change the way that consumers are looked at, having the potential to constitute, in aggregate, a storage battery for use by the grid. Naturally, to manage the system in a way to take advantage of these possibilities depends on the bi-directionality of power flows, as well as creating new charging infrastructure and tariff schemes to optimise the usage of such equipment.

Although the vectors remain the same throughout Europe, different member states have approached the challenge in different ways, both in terms of energy policy choice and in terms of regulatory practice. In this paper three different models are referred and are synthesized in Table 1.

Despite the different choices of member states in pursuing objective of collecting data to guide the implementation of the Smart Grid concept, the various pilot programmes implemented have provided useful insights to both industry and regulatory authorities. In Portugal, for example, the Inovgrid pilot helped to gauge the strengths and limitations of different data transmission technologies and their appropriateness to different urban and rural population densities. As in various other pilots, Inovgrid also tested the proclivity of customers to respond to different types of energy-

Table 1
Cross country comparison of incentives.

	Portugal	Italy	UK
Classic regulation	PC	RoR	PC
Regulation of "Smart" elements	PC and Efficiency increase	RoR increase	RIIO
Definition of "Smart" elements	Case by case; CBA (DSO + Reg)	CBA + requirements (DSO + Reg)	Case by case (DSO + Reg)
Current phase	Pilot programs	Pilot programs and SM roll-out	Pilot programs

PC – Price Cap; RoR – Rate of return; RIIO – UK's incentive regulation; CBA – Cost benefit analysis; DSO – Distribution System Operator; Reg – Regulator; SM – Smart Meter.

efficiency incentives, helping to better profile the population in terms of alternative tariff incentives. In all three countries analysed, the process has actively involved the regulators in a constructive dialogue with stakeholders, and led to proposals to alter the regulatory framework as necessary to provide incentives for "smart" investments and permit the involvement of new market players (such as aggregators) that were not foreseen in existing regulations. In Italy, the pilots helped the regulator develop specific metrics, such as RPT and P-Smart, to assess the "smartness" of proposed new investments while in the UK, the SGF, and LCNF are good examples of beneficial multi-stakeholder involvement, with operators competing for available assistance.

It also is clear that different regulatory approaches are, to a very significant degree, determined by the respective market structures in terms of the degree of competition among market players. In situations with a large number of operators and a tradition of competitive markets, such as the UK, incentives can be allocated on the basis of competition between operators, with a fair expectation that this will call forth efficient solutions. In smaller markets with a single incumbent DSO, as in Portugal, the regulator's role is of necessity more direct in terms of negotiating incentives and monitoring outcomes. Between these two extremes, the Italian regulator has developed regulatory guidelines and metrics that are more susceptible of cross-operator application than those in Portugal but less market-dependent in their formulation than the UK variety.

As the implementation phase advances in different markets, further research will help to understand the impact of the eventual withdrawal of incentives and the balance between initial investment costs and longer-term efficiency benefits to the consumer. The rapid pace at which several countries are advancing with regard to the introduction of Smart Grid innovations promises to provide ample opportunities for interested parties to seek answers to these and other relevant questions.

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