Position Paper on Smart Grids

An ERGEG Public Consultation Paper

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INFORMATION PAGE

Abstract

On 17 December 2009, ERGEG launched a public consultation on its Position Paper on Smart Grids, E09-EQS-30-04.
This paper outlines a number of views and proposals regarding the regulatory aspects of electricity networks and seeks to further the discussion on the development of electricity grids and of their regulation in the future.

Target Audience

Electricity customers, consumer representative groups, network users, policy-makers, electricity industry, distribution system operators, transmission system operators, electric and electronic equipment manufacturers, standardisation organisations, energy suppliers, energy services providers, information and communication technology providers, academics, researchers and other interested parties.

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How to respond to this consultation

Deadline: **1 March 2010**

Comments should be sent by e-mail to **smartgrids@ergeg.org**

All responses except confidential material will be published on the website www.energy-regulators.eu.

Treatment of Confidential Responses

In the interest of transparency, ERGEG

i) will list the names of all respondents (whether confidential or not) or, alternatively, make public the number (but not the names) of confidential responses received;

ii) requests that any respondent requesting confidentiality submit those confidential aspects of their response in a “confidential appendix”. ERGEG will publish all parts of responses that are not marked confidential.

For further information on ERGEG's rules, see ERGEG's Guidelines on Consultation Practices.

Related Documents

CEER/ERGEG documents:

- CEER Public Consultation "Regulatory aspects of the integration of wind generation in European electricity markets", C09-SDE-TF-14-02, 10 December 2009. http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_CONSULT/OPEN%20PUBLIC%20CONSULTATIONS/Integration%20of%20Wind%20Generation
- ERGEG Status Review on Regulatory Aspects of Smart Metering (Electricity and Gas), E09-RMF-17-03, 19 October 2009, http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/Customers/Tab/E09-RMF-17-03_SmartMetering-SR_19-Oct-09.pdf
- CEER response to: the European Commission's Communication "Second Strategic Energy Review - An EU Energy Security and Solidarity Action Plan"; the European Commission's Consultation on the Green Paper "Towards a secure, sustainable and competitive European Energy Network" and the European Commission's Communication on Directive 2004/67/EC (concerning measures to safeguard security of natural gas supply)", C09-GA-49-07, 10 March 2009, http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/Cross-Sectoral/2009/C09-GA-49-07_2ndSER-CEER-Response_10-Mar-09.pdf
- ERGEG Position paper "Smart metering with a Focus on Electricity Regulation", E07-RMF-04-03, 31 October 2007, http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/Customers/2007/E07-RMF-04-03_SmartMetering_2007-10-31_0.pdf
- ERGEG Conclusions Paper "Cross Border Framework for Electricity Transmission Network Infrastructure", E07-ETN-01-03, 18 April 2007, http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_ERGEG_PAPERS/Electricity/2007/E07-ETN-01-03_CB-Frameword-ETNI_V24-04.pdf

External documents

- A list of references is available in Annex 4 "References".

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EXECUTIVE SUMMARY

This ERGEG position paper aims to initiate a dialogue with all stakeholders of the European electricity power systems and markets, in order to assist regulators in understanding how smart grids can benefit network users and, assuming that cost-effective benefits can be identified, to explore ways in which the development of smart grids can be encouraged. This paper explores the drivers and opportunities for ‘smarter’ networks from the users’ perspective. Most importantly, it discusses the regulatory challenges and priorities and proposes a number of questions and issues for stakeholders to respond to.

Key objectives of the European Union (EU) for the year 2020, in relation to energy, are to increase renewable energy supply to 20% of total demand, reduce energy consumption by 20% with respect to 2020 forecasts and reduce greenhouse gas emissions by 20% with respect to 1990 levels. More ambitious objectives are currently being developed for 2050. The electricity supply sector will make a major contribution to achieving these targets and the engagement and support of all stakeholders will be essential. Considering the different components of the electricity supply chain, it is clear that the most significant contribution to reducing greenhouse gas emissions will come from replacing fossil-fired generation with low or zero-carbon generation technologies. Nevertheless, other key components of the supply chain, networks and the demand side, will also have vital roles to play.

Existing electricity supply systems are still dominated by large, controllable generators connected to an inelastic demand side by transmission and distribution networks. However, the utilisation of renewable energy sources, some of which are less controllable and predictable, is growing steadily. These renewable resources include generators of all sizes whose their location is determined by the availability of the renewable energy resource (e.g. wind power, water, solar energy, etc.) and the consumer (e.g. a domestic dwelling). This leads to some fundamental challenges in the planning, design and operation of the electricity networks / power systems.

Future electricity networks will be required to connect generators of many different technologies and sizes, at all voltage levels, some of them highly controllable and others with their output strongly dependent on the instantaneous physical availability of their renewable primary energy resource (e.g. wind generation). Although the availability of the primary energy source can affect all generation technologies, it is much more controllable for fossil fuels (e.g. gas storage, coal stocks, etc.) than it is for renewable sources like wind. The increasing electrification of transport and heat (e.g. by electric vehicles and heat pumps) will modify further the energy demands of customers. In this new world, it may not be economically feasible to operate the system as it is done today. Significantly more system monitoring and intelligent control will need to be introduced to securely meet the demand for energy with the optimum level of generation and network capacity. This will be achieved by the evolution of electricity networks – in short smart grids.

The future smart grid will be structurally very similar to the today’s ‘conventional’ grid. It will be built of aluminium, copper and iron and will have very high voltage, high capacity circuits for bulk transfer of energy across and between countries and medium and low voltage networks to connect the majority of consumers. One of the major differences, however, will be the addition of a communications network to the electricity network. This will allow the intelligent control of generation and demand as well as the configuration of the network and recovery after faults. The cost-efficient integration of these communications systems, particularly at medium and low voltage levels, will be an important challenge. Exploiting beneficial synergies with smart metering infrastructure (where it is deployed) will be vital.

Even though there will be no substantial change in the physical ‘architecture’ of electricity networks (i.e. “hardware”), there will be a paradigm shift in the way electricity networks will be planned, operated and maintained in the future. This paradigm shift will be achieved by incremental deployment of innovative new technologies and solutions as networks are renewed and expanded. With this evolution, the power grid will become a platform for new energy services to be provided by new stakeholders and will be expected to offer added value for customers. Winning the hearts and minds of consumers will be vital to realising all of the benefits that a smart grid will be able to offer. It is also likely to require changes in market structure, commercial arrangements and regulation and it is this last issue which is the focus of this consultation.

European energy regulators approach this issue from a technology neutral perspective. The deployment of new technologies must be a means to an end, not an end in itself. Investment in ‘smarter’ networks must provide better value and direct benefits for all grid users, and indirect benefits such as greater diversity both for the electricity supply system and society as a whole. There is a growing consensus that ‘smarter’ networks will be required to meet the 2020 targets and it is vital that regulatory mechanisms stimulate such developments directly (e.g. by market rules and technical rules) and by efficient regulatory incentives. Regulators therefore act as key facilitators in this process, by identifying and removing possible barriers and by finding solutions that provide an appropriate balance between all the stakeholders’ positions.

As well as helping meet the 2020 targets, smarter grids may bring many improvements to grid operation, in terms of e.g. asset management, network engineering, dimensioning and planning, reduction of losses and balancing of phases, accuracy of maintenance and fault analysis. Their implementation may have an influence on network operators’ mission and could have a great impact on their efficiency as well as on quality of supply to end-users. The issues mentioned here are just some of the many elements which will characterise smart grids in the future.

It can be argued that incentive regulation alone should ensure that new technologies and solutions are pursued by network companies, provided that there are regulatory mechanisms in place that provide for quantified evaluation of the grid’s “smartness”. However, there is evidence that, while this will apply for incremental innovation, it is much less effective for more radical innovation which requires more substantial regulatory treatment. A major challenge for regulators is therefore to find ways of encouraging an adequate level and scope of more radical innovations while providing an appropriate degree of protection of customer interests and economically-effective development of the network. Regulators will critically assess incentivisation of network companies to pursue value for money of innovative solutions to the benefit of consumers. This challenge is also one of the characteristics of a monopoly business like electricity grid operation, where instead of competition or a technology “revolution” (which are the major forces driving innovation in market businesses), additional regulatory support is needed.

The paper proposes a number of key questions and issues for stakeholders to respond to. The responses of stakeholders will help enhance regulators' understanding and the development of future regulatory policy. Finalisation of the paper is planned following the public consultation, in the second quarter of 2010.

1 Introduction

1.1 Objective and purpose of this paper

The objective of this paper is to consult with stakeholders in order to help regulators understand how smart grids can benefit network users and, assuming that cost effective benefits can be identified, to explore ways in which the deployment of smart grids to help deliver the European Union's climate and energy objectives can be encouraged or incentivised.

In April 2009, EU adopted the Climate-Energy Legislative Package (see Annex 4 references: [1] [2] [3] [4] [5] [6])[1] setting the following key objectives to be achieved by 2020:

- cutting greenhouse gas emissions by at least 20% with respect to 1990 (30% if other developed countries commit to comparable cuts);
- increasing to 20% the share of renewable energies (wind, solar, biomass, etc) in overall energy consumption (currently about 8.5%).

A third objective of the European energy policy was established by the European Parliament[2] in January 2008:

- saving 20% of the projected energy consumption by improving energy efficiency.

Consistently with these 20/20/20 objectives for 2020, more ambitious objectives are being developed by the European Commission for 2050.

It is clear that these ambitious objectives can only be met with the engagement and support of all stakeholders in the electricity sector. While there is much attention focused on the development of zero and low-carbon electricity generation, there is a growing consensus that today's networks will not be able to effectively integrate this new generation into a coherent system including effective demand response. To achieve this single, coherent system, it is expected that new network technologies will need to be deployed, which provide networks with the intelligence to deliver this enhanced level of system integration – in short, smart grids.

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1 The "Green Package" was finally adopted on 23 April 2009. It includes 6 legislative acts: a Directive on the promotion of the use of energy from renewable sources (2009/28/EC); a Directive amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading system of the Community (2009/29/EC); a Decision on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020 (406/2009/EC); a Directive on the geological storage of carbon dioxide; a Directive amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions from the use of road transport fuels (2009/31/EC); and a Regulation setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles (Regulation (EC) No 443/2009).

2 European Parliament resolution on the Action Plan for Energy Efficiency: realising the Potential, 31 January 2008, Reference T6-0033/2008.

The renewal of Europe's electricity grids happens continuously and is one of the grid operators' primary duties. However, without the introduction of intelligent, "smart" solutions, there is a real risk that the renewal of grids will result in 'like-for-like' replacement of copper and iron, based on conventional technologies, without any efficiency gains. An overall view is that more intelligence is needed in the future grids, however the preciseness of this is not yet determined and the merits of each project must be considered. A lack of "smartness" in the future electricity grids may either cause costs to rise or constraints on the development of a low-carbon system. This may in turn lead to inefficient investment decisions, lost opportunities and failure to reach the European energy targets. The effect on customers and society may be detrimental and unacceptable.

The challenge of "smartness" is to transform the functionality of the present electricity transmission and distribution grids so that they are able to provide a more user-oriented service, enabling the achievement of the 20/20/20 targets and guaranteeing, in an electricity market environment, high security, quality and economic efficiency of electricity supply.

In recognition of the present opportunity to start actual deployment of smart grids, the concept of such grids has been introduced by Directive 2009/72/EC included in the 3rd EU Energy Legislative Package[3] recently approved by the EU bodies (see ref. [7] [8] [9] [10] [11]).

Changing the way regulated companies are governed is implicit in 20/20/20 targets. The EU objective of 20% saving of projected energy consumption by improving energy efficiency introduces the need for a decoupling between the network companies' profits and the amount of electrical energy delivered through their networks.

Regulators are not the main actors in the deployment of smart grids, but they have an important role to play, together with other stakeholders and prime movers. Network operators, network users, generation companies, suppliers, equipment manufacturers, standardisation organisations, service providers, ICT (information and communication technology) providers, academia and research, governments, politicians and eventually the general public are all deeply affected and must be involved accordingly for this electricity grid evolution to be successful.

It is vital that regulators are able to respond to the questions and challenges that will be raised. A common understanding of the need for smarter grids and how they can be delivered is crucial for attaining a common European voice in this matter. This justifies the European energy regulators' position as being a key facilitator in this process of change, identifying and removing unnecessary barriers and finding solutions that provide an appropriate balance between all the stakeholders' positions. It is further important that new solutions foster market integration

[3] The 3rd legislative Package proposals for the European Internal Market in Energy were finally adopted on 13 July 2009 and include 5 legislative acts: 2 amended Directives on the Directives amending Directive 2003/54/EC and Directive 2003/55/EC concerning common rules for the internal market in electricity (2009/72/EC) and the internal market in natural gas (2009/73/EC), respectively; 2 amended Regulations Amending Regulation (EC) No 1228/2003 on conditions for access to the network for cross-border exchanges in electricity (No 714/2009)and Regulation (EC) No 1775/2005 on conditions for access to the natural gas transmission networks (No 715/2009); and a new Regulation establishing an Agency for the Cooperation of Energy Regulators (No 713/2009).

towards the European Internal Electricity Market (IEM). Regulation practices need to evolve too, so as to align with the EU Energy objectives and political goals.

In order to meet its fundamental objective, the paper sets out the understanding of the scope and different definitions of smart grids (Section. 1.2) and the drivers for their development (Section 2). The current views on the regulatory issues and challenges, also in relation to incentives for innovation are presented too (Sections 3 and 4). The benefits of a pan-European approach, in particular related to standardisation are explained. Of particular importance, Section 1.3 of the paper sets out the key questions to stakeholders, in order to help enhance regulators' understanding and the development of future regulatory policy. These will be refined and developed based on the consultation responses.

1.2 Definitions and understanding of the term "Smart Grids"

The term "smart grids" has been used for a plethora of concepts, solutions and products for several years. Various stakeholders who refer to it often strongly drive the understanding and the use of the term, which often results in different understandings and perhaps even a misuse of the term. When looking at the output values expected from a smart grid (efficient electricity supply, low costs, satisfactory quality and security of supply, etc), this coincides with the output values we already expect from today's "conventional" grid.

Though elements of smartness also exist in many parts of existing grids, the difference between today's grid and a smart grid of the future is mainly the grid's capability to handle more complexity than today in an efficient and effective way. This increased complexity is due to, inter alia:

- Massive implementation of distributed generation at LV and MV level including the need for an efficient regulatory treatment of licence applications;
- Implementation of large intermittent generation located geographically far away from the load centres;
- Changes in customers' behaviour (i.e. an active demand side);
- Reduction of losses (e.g. through appropriate distributed generation which is located close to areas with high consumption);
- Increased use of self-healing technologies.

There is as yet no internationally unified definition of a smart grid. At a global level, definitions are normally given by standard organisations like the International Electrotechnical Commission (IEC), which recently circulated among its members a proposal for a smart grid definition[4]. Additionally, several recent reports include a definition or an explanation of what a smart grid is:

[4] "Smart grid, intelligent grid, active grid:

Electric power network that utilizes two-way communication and control-technologies, distributed computing and associated sensors, including equipment installed on the premises of network users." www.iec.ch

"Strategic Deployment Document for Europe's Electricity Networks of the Future"[5] issued by the European Technology Platform on Smart Grids; "Smart Grids and Networks of the Future – EURELECTRIC view"[6]; and the report of Electric Power Research Institute (EPRI)[7] to the US National Institute of Standards and Technology (NIST) on the Smart Grid Interoperability Standards Roadmap (see ref. [12] [13] [14]).

From a regulatory point of view, a definition or an understanding of the concept of smart grids should be based upon the needs for them, i.e. what they are intended to solve, and what kind of functions and output values they can provide for the users of the transmission and distribution grids.

In this paper, smart grid refers to a future grid that is needed for reaching efficiently the EU targets for the year 2020 described in Section 1.1. It is not envisaged in the paper that the "smart grid concept" is applicable only to distribution networks, rather it comprises the transmission network even though the requirements are different (e.g. level of control and automation). In this respect, the definition provided by the European Technology Platform on SmartGrids is a good starting point, with some adjustments:

> *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.*

A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:

- Better facilitate the connection and operation of generators of all sizes and technologies;
- Allow consumers to play a part in optimising the operation of the system;
- Provide consumers with greater information and options for choice of supply;
- Significantly reduce the environmental impact of the whole electricity supply system;
- Maintain or even improve the existing high levels of system reliability, quality and security of supply;
- Maintain and improve the existing services efficiently;
- Foster market integration towards European integrated market.

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[5] "A SmartGrid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies." www.smartgrids.eu

[6] "Preliminary definition: A smart grid is an electricity grid that can intelligently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to efficiently ensure sustainable, economic and secure electricity supply." www.eurelectric.org

[7] "The term 'smart grid' refers to a modernization of the electricity delivery system so it monitors, protects and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices." www.nist.gov/smartgrid/

Smart grid deployment should consider not only technology, market and commercial considerations, environmental impact, regulatory framework, standardisation usage, ICT (Information & Communication Technology) but also societal requirements and governmental policies.

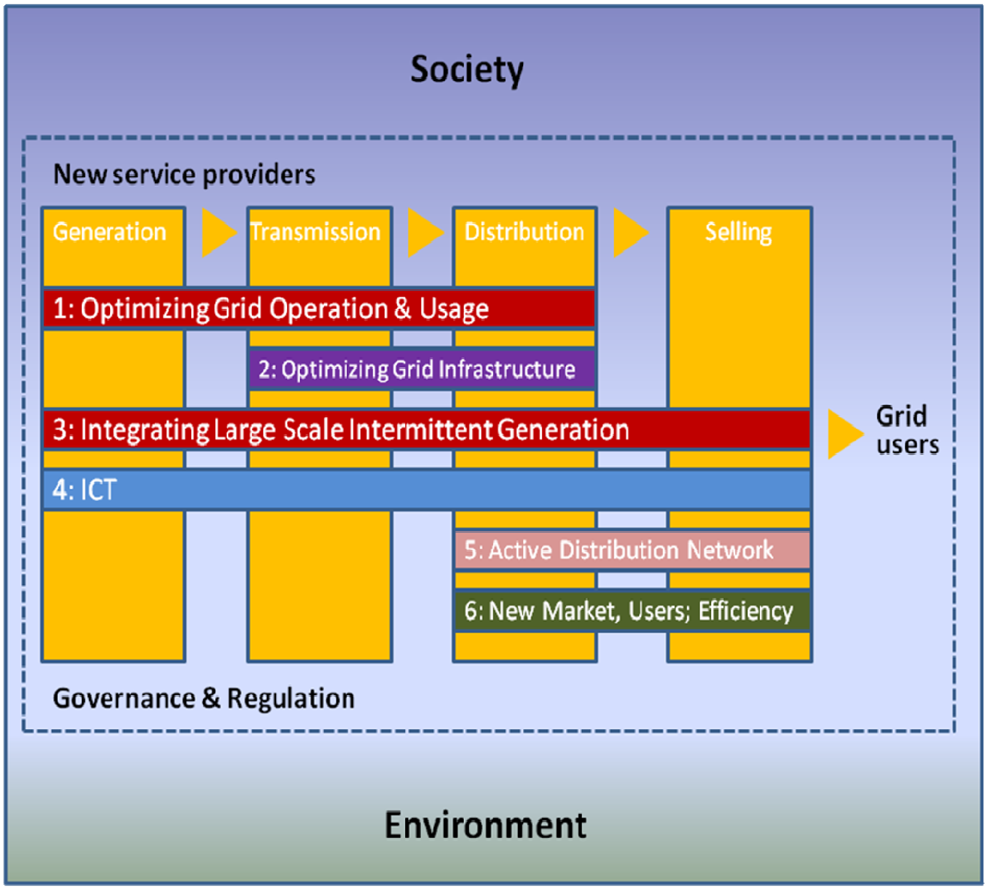

Figure 1: Smart Grids deployment priorities within the electricity supply chain, based on the position of the ETP[8]

The scope and priorities for smart grid deployment are illustrated in Figure 1 and consist of a number of features:

1. *Optimising grid operation & usage* concerns decentralised, coordinated grid operation, operational security, optimisation of losses and market based treatment of electric power flows;
2. *Optimising grid infrastructure* concerns building new and improving and optimising the existing grid facilities;

[8] *Strategic Deployment Document for Europe's Electricity Networks of the Future* issued by the European Technology Platform on SmartGrids. Being adopted from the work developed by the SmartGrids ETP, the scope and priorities presented in this figure could appear in some other way. For instance, some consider that priority "3: Integrating large-scale intermittent generation" must also be considered under the "selling" scope.

3. *Integrating large-scale intermittent generation* concerns integrating into the grid and the market large-scale generation (on/off-shore wind, large-scale solar, wave generation etc.);
4. *Information & communication technology* concerns the ICT tasks, standards and solutions;
5. *Active distribution grids* concerns “activating” the distribution grids towards (and beyond) the degree of automation and operation as is the case today with the transmission grids;
6. *New market places, users and energy efficiency* is finally about putting customer into focus.

These six deployment priorities developed by the European Technology Platform SmartGrids are considered as a good overview and basis for further considerations.

The terms smart grids and smart metering are often used together, sometimes even mistaken to have a similar or even the same meaning. Even though smart metering enables some features and functionalities of smart grids, the scope of smart grids is much larger than smart metering. This is illustrated in a simplified way in Figure 2.

Therefore, it is important to bear in mind that smart metering does not provide a smart grid, and on the other hand it is possible to have smarter distribution and transmission networks without smart metering.

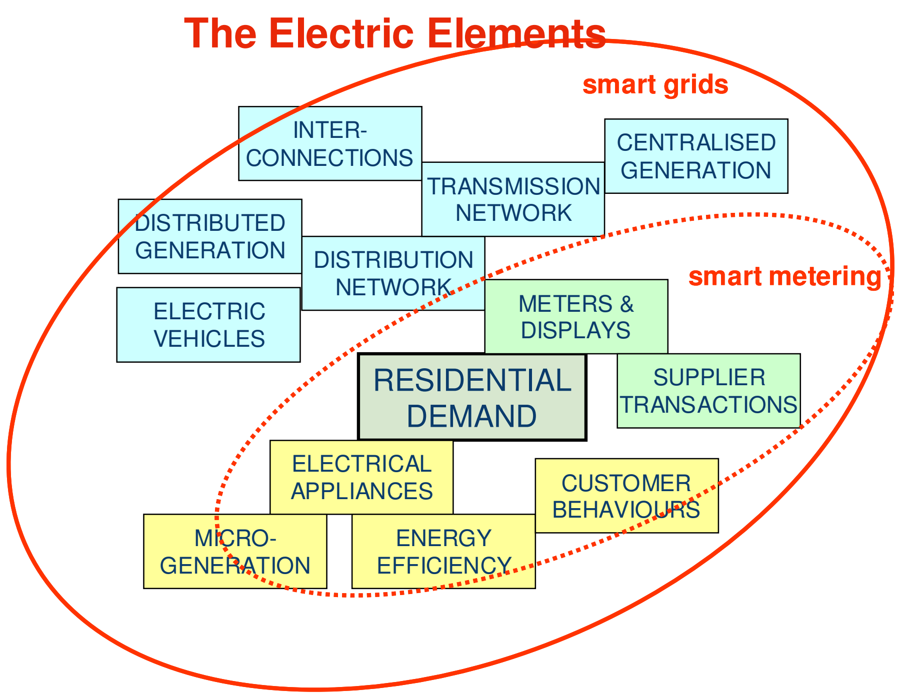

Figure 2: The elements of smart grids and smart metering[9]

[9] Source: P. Nabuurs, KEMA, presentation at CEER Workshop on Smart Grids 29th June 2009.

Smart metering systems allow interval metering for both active and reactive components of electricity consumed and injected into the network, so contributing to more accurate balancing, losses and power factor calculation, to promoting peak and off-peak prices and to discouraging bad practices in the use of the network. Smart metering technologies may further provide information on quality of electricity supply at each connection point, thus contributing to more effective investments and renovation plans of the grids, thereby increasing security of supply. The most important benefit is that, due to the accurate information and two-way communication that smart meters can provide on actual time of use, customers could be encouraged to modify their load profile. Customers could be encouraged to increase their efficiency in consuming energy and be part of demand response. However, it must be noted that increasing their efficiency in consuming energy will also depend of other parameters, e.g. the financial capability of customers to invest in more efficient appliances or the skill to understand the information provided by the smart meters, the need for energy and the ability to take optimal actions. Finally, smart metering systems can facilitate supplier-switching processes and in general increase innovation in commercial offers to customers.

In summary, smart metering enhances and enables a number of smart grid functions. Nevertheless, smart grids encompass a much wider area of technologies and solutions and are by no means restricted or strictly delimited by the introduction of smart metering.

1.3 Questions for public consultation

Section 1 – Introduction

1. Do you consider that networks, transmission and distribution, are facing new challenges that will require significant innovation in the near future?
2. Do you agree with the ERGEG's understanding of smart grid? If not, please specify why not.
3. Do you agree that objectives of reducing energy consumption impose the need for decoupling regulated companies' profit from the volume of energy supplied? How can this be implemented?

Section 2 – Drivers for smart grids

4. Do you agree with the drivers that have been identified in the consultation document? If not, please offer your comments on the drivers including additional ones.

Section 3 – Smart grid opportunities and regulatory challenges

5. Do you agree that a user-centric approach should be adopted when considering the deployment of smart grids?
6. How should energy suppliers and energy service companies act in the process of deploying smart grids solution?

7. Do you think that the current and future needs of network users have been properly identified in Section 3.3?
8. Do you think that the main future network challenges and possible solutions have been identified in Section 3.4 and 3.5 respectively? If not, please provide details of additional challenges/solutions.
9. Do you expect smarter grid solutions to be essential and/or lower cost than conventional solutions in the next few years? Do you have any evidence that they already are? If so, please provide details.
10. Would you add to or change the regulatory challenges set out in Section 3.6?

Section 4 – Priorities for Regulation

11. Do you agree that regulators should focus on outputs (i.e. the benefits of smart grids) rather than inputs (i.e. the technical details)?
12. Which effects and benefits of smartness could be added to the list (1) - (7) presented in Section 4.1, Table 1? Which effects in this list are more significant to achieving EU targets? How can medium and long-term benefits (e.g. generation diversification and sustainability) be taken into account and measured in a future regulation?
13. Which output measures should be in place to incentivise the performance of network companies? Which performance indicators can easily be assessed and cleansed of grid external effects? Which are suitable for European-level benchmarking and which others could suffer significant differences due to peculiar features of national/regional networks?
14. Do you think that network companies need to be incentivised to pursue innovative solutions? How and what output measures could be set to ensure that the network companies pursue innovative solutions/technologies?
15. Do you consider that existing standards or lack of standards represent a barrier to the deployment of smart grids?
16. Do you think that other barriers to deployment than those mentioned in this paper can be already identified?
17. Do you believe new smart grid technologies could create cross subsidies between DSO and TSO network activities and other non-network activities?
18. What do you consider to be the regulatory priorities for electricity networks in relation to meeting the 2020 targets?

2 Drivers for Smart Grids

2.1 Introduction

There exist two different but directly related drivers for electricity networks evolution and the innovation which is needed for that. First, legislation is the primary external driver, albeit an indirect one. Of specific relevance here is the European legislation relating to electricity supply and the 20/20/20 targets, see Section 2.2. Member States have to put in place their own legislation and policies to meet the environmental targets that they have committed to deliver. These legislative targets do not in themselves directly determine future network performance requirements. However, they do encourage or require the adoption of particular generation and other technologies. These *means* (Section 2.3) in turn drive the needs of individual users of electricity networks.

It is the needs of these network users that together form the second, direct driver for network innovation and evolution and it is these user needs that are introduced in Section 2.4 (*Drivers*) and discussed in more detail in Section 3. Because Member States are free to apply different policies to meet their commitments, it follows that the direct drivers for network innovation will be different in different countries.

2.2 Objectives of the European Union

The 20/20/20 objectives are set to secure Europe's energy supply and reduce the emission of greenhouse gases. In this way, the 20/20/20 targets cover the sustainability and security of supply objectives of the three core objectives in implementing a European energy policy[10]:

1. sustainability - to actively combat climate change by promoting renewable energy sources and energy efficiency;
2. security of supply - to better coordinate the EU's supply of and demand for energy within European integrated market;
3. competitiveness - to support the development of a truly competitive internal energy market by improving the performance of the European electricity grid.

In Article 3 (Public service obligations and customer protection) of the 3rd Package's Directive 2009/72/EC (see Section 1.1), two paragraphs are of special importance when considering smart grids.

In paragraph 2 of Article 3, a set of measures is given which need to be taken into consideration by Member States:

> *"Having full regard to the relevant provisions of the Treaty, in particular Article 86 thereof, Member States may impose on undertakings operating in the electricity sector, in the general economic interest, public service obligations which may relate to security, including security of supply, regularity, quality and price of supplies and*

[10] European Commission, Green Paper "A European strategy for sustainable, competitive and secure energy", COM(2006) 105, 8 March 2006. Communication from the Commission to the European Council and the European Parliament "An Energy Policy for Europe", COM(2007) 1 final, of 10 January 2007. European Commission, Green paper "Towards a secure, sustainable and competitive European energy network", COM(2008) 782 final, 13 November 2008.

environmental protection, including energy efficiency, energy from renewable sources and climate protection. Such obligations shall be clearly defined, transparent, non-discriminatory, verifiable and shall guarantee equality of access for electricity undertakings of the Community to national consumers. In relation to security of supply, energy efficiency/demand-side management and for the fulfilment of environmental goals and goals for energy from renewable sources, as referred to in this paragraph, Member States may introduce the implementation of long-term planning, taking into account the possibility of third parties seeking access to the system."

In paragraph 11 of the same Article, the requirements for the optimisation of the use of electricity and the promotion of energy efficiency are described:

"*In order to promote energy efficiency, Member States or, where a Member State has so provided, the regulatory authority shall strongly recommend that electricity undertakings optimise the use of electricity, for example by providing energy management services, developing innovative pricing formulas, or introducing intelligent metering systems or smart grids, where appropriate."*

2.3 Means

The sustainability objective can be reached by means of a more efficient use of energy by all consumers. This requires a more active role of the consumer in the electricity supply chain (demand-side *user participation*). On the production side, an increasing amount of production units that use *renewable energy sources* (RES) or that use primary energy more efficiently, e.g. combined heat and power (CHP) units, can contribute to the sustainability objective. These units can be divided into large-scale (connected to EHV or HV, e.g. large wind or solar parks, large hydro plants) and small-scale (connected to LV and MV, e.g. individual wind mills or solar cells, small hydro plants, micro-CHP). This small-scale generation, or *distributed generation* (DG), can, depending on its location and penetration level, contribute to energy efficiency by reducing losses in the distribution networks, although it can also result in an opposite effect, depending on grid structure and sitting of generators. An increase in DG can also lead to a more active role of consumers, in which they act also as producers (production-side *user participation*).

The security of supply objective can receive contributions from RES, because the dependency on fossil fuels decreases; nonetheless, this beneficial effect can be jeopardised if the grid protection system is not largely redesigned in order to exploit the DG potential for security. However, intermittent generation puts pressure on continuity of supply and DG can put pressure on voltage quality and safety, which means that new measures have to be taken to ensure the security and quality of electricity supply. Cross-border interconnections and integration of markets are also important for security of supply on a European level.

The competitiveness objective requires that electricity grids support the development of a truly competitive internal market. At the transmission/wholesale level, this includes increased interconnections between Member States, which allow improved competition (with expected reduction of market prices) and may improve the ability of parties to balance their energy requirements, minimising balancing costs associated with intermittency. Any infrastructure project should be developed in the most economically-efficient way and with a final net benefit to consumers, evaluated by cost-benefit analyses (CBA) and impact assessments. Transparency in the operation of electricity networks has an important role. Minimum and harmonised requirements on the availability of "grid information" to markets are crucial to enabling cross-border trade, generation investment decisions and the entry of new market participants. At the retail level, grid support to the development of well-functioning markets includes a clear definition of roles and responsibilities (especially of DSOs and of suppliers, see also Section 3.2), frequent accurate meter reads to ensure quality of information and harmonised solutions based on open standards for good data exchange (allowing suppliers to deliver their products across national boundaries).

At all levels, benchmarking of planning criteria and of infrastructure costs between network operators could help to characterise best practices and performances. User participation is also important to increase competitiveness and for monitoring and balancing intermittent generation, as further discussed in Section 2.4.

It should be noted that the influence of system operators on some specific factors which impact the achievement of these objectives is limited (e.g. about the location of generation facilities and about the reduction of electricity demand by customers).

2.4 Drivers

In the previous paragraph, the means to reach the 2020 targets have been identified. These means lead to the drivers for smart grids from a technical perspective. These include the following:

1. Large-scale renewable energy sources including intermittent generation;
2. Distributed generation including small-scale renewable energy sources;
3. Active end-user participation;
4. Market integration and market accessibility;
5. Improved operational security.

The significance of these means as the drivers for smart grids is analysed below.

Large-scale renewable energy sources will mainly affect the transmission network. Firstly, cost effective connection solutions need to be developed, particularly as renewable resources are usually distant from load centres. Also, because of the intermittent character of e.g. wind energy (the most mature RES technology), monitoring and balancing on the transmission level will become more challenging and measures to maintain balance (e.g. management of supply, interconnection capacity) need to be enhanced[11]. Furthermore, new smart technologies are required to connect e.g. off-shore wind.

Distributed generation will mainly affect the distribution network, even though a large concentration can influence transmission network (e.g. congestion on national networks). The connection of generation to the distribution network has a number of adverse consequences. Generation can not be considered during the design of the distribution network, but in most cases sufficient margins are available to connect small-scaled generation.
If the network operator can no longer guarantee the quality and reliability for the network users, additional measures, ranging from simple changes in protection or control setting to massive network investments, are needed.

[11] For further discussion on these issues, see "Regulatory aspects of the integration of wind generation in European electricity markets: A CEER Public Consultation", 10 December 2009, www.energy-regulators.eu.

End-user participation of consumers is paramount in increasing energy efficiency and demand response. The activity of the consumer can be small (by e.g. taking a cheaper contract that allows the operator to manage within bounds the demand) or large (by e.g. managing his/her appliances in such a way that the price of electricity consumption is lowest). The possibilities for activity are largely dependent on the functionalities of metering system. Users can not only participate as consumers, but also as producers and shall be able to feed in the energy they generate whenever it is available. A more active participation of the user is not only a goal in itself, but a possible means to integrate renewable and other more energy-efficient sources of energy in the electrical network. This will be even more the case if electrical vehicles are widely employed in the medium-long term, in which case storage of energy on the distribution level is easily available. These new consumption technologies could also contribute to reducing or "leveraging" large portions of the demand.

Market integration across national borders and market accessibility for new network users favour competitiveness and are based upon the developments of networks and grid technologies. Indeed, a more integrated market will need some intelligence in networks to operate and manage the increased and more fluctuating flows and ensure system security when congested.

Improved operational security at all voltage levels relates to monitoring flows, the power system state and triggering remedial actions in advance of severe contingencies, with the final objective to improve the quality and the security of electricity supply.

Having identified the drivers from a largely technical perspective, it is now necessary to consider them from a network user's perspective, consistent with the high level driver described in Section 2.1. This user-centric approach is now developed in Section 3.

3 Smart Grid opportunities and regulatory challenges

3.1 User-centric approach to smart grids

In this section, the opportunities for the development of more smart grid solutions are considered and the consequential regulatory challenges are identified. This is done by approaching the regulatory issues from a network user's perspective in a number of steps.

Firstly, network services are needed as the overall electricity supply chain develops towards a low/zero-carbon system and an integrated market is identified, together with the challenges that they will present. Consideration is then given to the smart grid solutions that have the potential to deliver these new services in a more cost-efficient way. Finally, the regulatory challenges related to the delivery of these services are discussed.

3.2 Roles of stakeholders

For the benefits of smart grids to become a reality, the roles and responsibilities of relevant stakeholders and authorities must be clearly defined and duly committed.

TSOs and DSOs are the prime movers for the deployment of smart grids. Their task is to implement the network infrastructure that will allows the flow of both energy and information between customers, producers, suppliers and all the other grid users in the new smart grid framework. They shall focus their efforts on understanding and taking into account the needs of the grid users and the customers. Smart grid deployment projects and processes shall be conducted in a transparent way, supporting and cooperating with the R&D institutions.

Research & Development institutions need to cooperate closely with TSOs and DSOs and with suppliers acting as the interface with final customers. In their work, time constraints and "real world circumstances" need to be taken into account. Moreover, improvements and enhancements of existing solutions are an essential activity, equally significant as the new concepts.

Grid users (electricity consumers and producers) are the ultimate beneficiaries of the deployment of smart grids. The proposed objectives will be only attained with a more active participation of these stakeholder groups. Moreover, since the grid operators will also be beneficiaries of smart grids, their commitment and active participation is both crucial and already now well-incentivised through a number of foreseeable benefits (e.g. better real-time and close-to-real-time information through controllable two-way protection devices, higher degree of automation in alarm and fault management, etc.)

Retail suppliers and energy service companies (ESCo) are the entities that, in a liberalised market, are in direct contact with final customers. As smart grids will be a platform for a large number of new energy services offering added value for customers, the stakeholder group will be reinforced by the introduction of new providers of new energy services. As active participation of demand (leading to "smart customers") is a key feature of smart grids, the full involvement of these actors is really crucial to extracting the maximum benefit from smart grids without jeopardising retail competition.

The Electricity industry, equipment vendors and system integrators are those who will have the solutions for the deployment of smart grids. Whereas competition drives the industrial innovation in the free market, accomplishing that in the monopoly environment of electricity grids is more challenging. Success will depend on the electricity industry, on the independence of the grid operators and on the appropriate regulatory environment. Detection of barriers during smart grid deployment and the implementation of regulatory solutions allowing these barriers to be removed is their major task in the process.

EU authorities, Member States and regulators focus on the interests and needs of the European customers and society. Although different national implementations of the European Electricity Directive exist, there is a common objective of efficient, sustainable and secure supply of electricity, in a competitive market environment.

3.3 New network services – What do network users need?

Electricity networks have the sole purpose of facilitating the actions of parties that require their services – connecting producers of electricity to consumers and operating the system safely and securely. Their form and functionality should therefore be driven primarily by the needs of these parties. In considering the opportunities that smart grids might bring, it is necessary firstly to identify the new services that are expected to be required, especially where existing network solutions cannot accommodate the required functionality. As the transition towards smart grids is an evolutionary process and new elements are expected to arise in the future, some of the new required services will probably evolve in the future.

Network users have in the past been divided into two main groups behind the connection point, a small group of users that produces electricity and a large group that consumes it – typically referred to as generators and customers, respectively. There has always been a third, smaller group, those that both produce and consume. This group is expected to grow further in the future. This change alone presents significant challenges to the design, operation and regulation of electricity networks. Furthermore, new generation technologies have emerged introducing challenges to network business as well as increased quality of supply requirements from the consumer side.

The services that the two key network user groups require are summarised here.

3.3.1 Services needed by generators and “prosumers”

The fundamental user needs for generators will remain:

- Timely connection and operational access, with minimum constraints;
- Transparent, non-discriminatory terms for grid connection and access based on the costs of an efficient network;
- Opportunity to participate in the electricity market with the same opportunities as competing generators (e.g. without disadvantages due to lack of interconnection capacity and

consequent congestion) ensuring a level playing field of same "quality" for all market participants;
- Appropriate remuneration for ancillary services provided by the generator to the grid.

The new network services that generators will require in order to deliver the environmental targets include:

- Efficient provision of connections at all voltages levels and at all locations (including offshore);
- Access products designed for intermittent sources of generation;
- Balancing services that better manage intermittent generation;
- Enhanced trade within national and integrated markets including intra-day trade until near the operating hour.

It is also expected that new storage technologies will become available and economically-viable in the medium term. These devices are likely to be smaller and more widely distributed than current, usually pumped-hydro, plants. There will further be a need for a common understanding of how such technologies are integrated into the market so that they are fairly rewarded for the services they provide.

3.3.2 Services needed by (particularly small) customers

The overwhelming majority of small customers today are passive parties in the electricity supply chain. The service that they currently receive appears to the customer as an infinite supply of electricity of defined quality with very high availability and usefulness – every demand they make on the system is met instantaneously, usually at a fixed price.

If there were no additional constraints, customers would probably be content to continue receiving a supply having these characteristics. Future customers will continue to expect:

- A competitive, affordable price for the electricity they use (which implies fairly regulated network charges consistent with safe, efficient networks as well as a competitive energy market);
- Fair fees for their connection to the network;
- A quality of supply comparable to the one they have received in the past (with significant variations for the continuity of supply due to local differences);
- No electricity shortages or unreasonable price increases due to external conditions (e.g. availability or price of fuels or network constraints).

3.3.3 Services provided by network companies, retail suppliers and ESCo

It is expected that the decarbonisation of electricity supply will cause real price increases and/or reduction in quality and reliability. As a result, customers will seek ways to reduce the amount of energy they consume and the price they pay while maintaining the existing quality and reliability. At the same time some customers may be willing to accept a lower quality and reliability in return for a lower price. Therefore, there will be an incentive for network and supply companies to offer new products and services that will help customers achieve both these goals, becoming active participants in the supply chain, increasing the elasticity of the demand side. These services could include:

- Dynamic pricing information and time of use energy pricing;
- Financial incentives to actively manage demand – the customer could offer demand management to the party balancing the system, the supplier or the network company;
- For those customers who choose to also generate electricity, it will also be necessary to fully incorporate this activity in the marketplace;
- For those customers who prefer an improved quality of supply, tailored contracts between the customers and the network operator for enhanced continuity of supply or voltage quality (not forgetting the customer responsibility in immunising its own electrical plants from non-severe disturbances);
- The opportunity for aggregators to provide services on behalf of customers to network companies and the energy markets;

The challenge for network companies is to employ more monitoring, intelligence and control to be able to deliver these new services to consumers and generators more cost effectively than with existing technologies.

Retail suppliers and the new energy services providers will develop their customer-facing activities as aggregators of customers' participation in the electric supply chain and detecting and directly answering the network users needs. The new energy services to be provided by this stakeholder group will justify all the expected network evolutions and will be fundamental for attaining the defined goals.

In order to ensure that the power grid evolution delivers an extra added value for customers, covering their needs, with new services developed by services providers and retail suppliers, it must be ensured also that these stakeholder groups have direct participation in the definition of the new functionalities to be achieved by the smart grids.

3.4 Network challenges

The shift in character of network users and the integration of the new services present a number of new challenges for network operators.

3.4.1 Challenges related to needs of generators and "prosumers"

The new challenges include:

- Network capacity planning – to ensure economic and efficient network planning, methodologies that allow network capacity to be shared effectively, particularly for intermittent generation, will be required together with appropriate network access tariffs. Network capacity delivery has to adapt to changing needs of customers;
- Providing new connections – the increasingly diverse range of generating technologies will need to be connected in efficient ways without endangering the quality and reliability of other network users. Appropriate connection requirements will need to be developed for generators of all sizes and technologies – the smaller the generator, the easier the

connection will need to be (plug and play access). The connection of large offshore wind farms poses particular challenges;

- Providing economic access products for intermittent generation – recognising that intermittent generation may need a different access product than a conventional thermal plant;
- For a more efficient use of transport capacity between voltage levels and between geographical regions, balancing between consumption and production will be needed at different voltage levels and within geographical regions;
- Facilitating trading between Member States, by means of both interconnection capacity and contractual arrangements;
- Ancillary services: developing a remuneration framework or market schemes to compensate generators proportionally to the value of services they provide to the local or global system.

3.4.2 Challenges related to needs of customers (end-users)

The new challenges include:

- Higher electricity prices and stronger time-dependency of prices will make that customers will require more details about their consumption patterns than today;
- Interoperable communication facilities: developing industry-wide protocols for interoperability between customer-owned devices and the network and between networks nationally and internationally;
- Developing a remuneration framework or market schemes to compensate customers who manage their consumption (i.e. using generation, storage or demand control) according to system requirements;
- Tailored quality of supply;
- Activities 'beyond the (smart) meter', e.g. remote control of final appliances;
- Active demand management.

3.4.3 Traditional challenges for network owners/operators

There are also a number of 'traditional' challenges that are internal to network companies. The decarbonisation of electricity supply might well make these even more challenging:

- Ensuring network operational security;
- Providing an optimal amount of network capacity (at transmission and distribution level);
- Minimising transmission and distribution losses;
- Minimising demand for ancillary services (e.g. reserve);
- Guaranteeing satisfactory quality of electricity supply.

3.4.4 Support from the electricity industry, equipment vendors and system integrators

Electricity and electronic manufacturers' industry are a key element for delivering cost-efficient equipment and solutions allowing demand side participation, more energy efficiency and more DG and RES integration and all the expected technical evolutions envisaged for the electric system. This covers all the electric system equipment, from the electric equipment that composes the electric network to the electric and electronic appliances equipping our homes. R&D activities already in development by this stakeholder group are fundamental and their capability of previewing the future needs is an advantage of the European industry.

3.5 Smart grid solutions

The defining characteristic of smart grid solutions is that they apply increased intelligence to the way that networks are planned, operated and maintained. There is a general confidence among relevant stakeholders that by doing this, new services will be delivered at lower cost than with existing solutions. It should be stressed however, that this cannot be considered as proven at this stage. Unless smart solutions are developed and approved through demonstration projects, there is a real risk that opportunities that could offer benefits to network users will be missed or delayed. More significantly, lack of active network evolution could constrain the delivery of the 20/20/20 and other future targets. Some services may not be even delivered without smart grids technologies.

3.5.1 Network planning

Networks can be planned using many techniques. Historically, it has been sufficient to focus on the performance of the system for specific operating conditions, in particular at maximum demand (and eventually at minimum load). The maximum demand condition usually represented the maximum system stress. Therefore, provided that this operating condition could be securely managed, it was assumed that all other operating conditions could also be managed. However, it should be emphasised that in the current transition process, network capacity requirements might not necessary be highest at maximum demand.

More complex system modelling techniques are already in use but these will need further development to deal with future networks that have millions of active devices connected to them, significant intermittent generation and much greater international trading capability.

While it is always possible to increase capacity margins to ensure secure operation this will be costly. With better, more intelligent, system modelling, capacity margins and, therefore, costs will be able to be optimised. Specific network planning solutions include:

- Probabilistic system modelling, possibly with (simplified) representation of system conditions across a whole year;
- More accurate modelling at lower voltage levels based on better network monitoring, new methodologies for a more ‘active’ distribution, improving the previous ‘fit and forget’ approach, exploiting control capabilities on demand and eventually intermittent generation;
- Improved tools for network planning, including joint T&D planning and implementation of the above mentioned methodologies;
- Better cost-benefit analysis (CBA), with the aim to improve capacity where it is most beneficial (especially important for interconnection capacity favouring cross-border trades);
- Increased participation of market actors in CBA, for a better evaluation of benefits they receive from smart grids;
- Coordinated transmission grid planning across neighbouring countries and synchronous areas;

- Exploitation of economies of scale for infrastructure connecting remote generation (e.g. by offshore or onshore collector substations);
- Investments for cabling lower voltage grids, especially where lightning phenomena determine poor quality of supply.

3.5.2 Network operation

We have already moved some way from the position where all generators were centrally dispatched to meet the demand which had no ability to respond to generator or network capacity. It is expected that this trend will increase possibly to the point where the majority of devices or distinct customers (e.g. a single dwelling) will have some ability to respond to some form of control signal (either automatically or manually). This signal could be related to cost, available capacity or carbon emissions.

Just as the challenge of designing the network in this future will become more difficult so will system operation. The range of possible operating scenarios will dramatically increase. Current and voltage will need to be monitored extensively across the network, even at the lowest voltages, and on-line network analysis will have to be included so that automatic or manual actions can be taken to make sure that circuit capacities are not exceeded. This data from networks will be used locally or regionally to signal to generators and respons demand customers how they should operate in real-time. The data could also be used to reconfigure the network to avoid customer interruptions or constraints.

Improved (automatic) procedures would help grid recovery and self-healing following an occurrence of faults or cascading events.

Losses in networks represent by far their most significant carbon impact. Smart grid technologies will allow better management of network flows to minimise losses, in particular by reducing peak demand and therefore improving the overall load factor of the system. The presence of DG can decrease losses in some cases (while they will increase in other cases, depending on the grid structure and generator siting).

Specific network operation solutions include:

- More accurate monitoring of the network and analysis of the operational state of the network, including lower voltage levels;
- Increasingly efficient allocation of cross-border interconnection capacity;
- Power flow control (e.g. by phase shifting transformers, FACTS and HVDC devices);
- Improved coordination of operation across countries;
- Exploitation of real-time thermal monitoring for power cables and/or critical overhead lines;
- Increasingly intelligent post-contingency corrective actions and defence schemes;
- Activation of pre-contingency preventive actions after exceeding pre-defined stability limits and thresholds;
- Improved automation in distribution grids and optimal use of grid reconfiguration after faults.

3.5.3 Network solutions for generators

Specific generator solutions include:

- Exchange of real-time information on actual active/reactive production level and remaining capability (especially for intermittent generation) to a local or global dispatching operator;
- Improved schemes for voltage control, including voltage support by distributed generation with power electronics, in order to minimise losses and to support during disturbances;
- Connection solutions to support a balanced distribution, as far as possible, of distributed generation in lower voltage grids.

3.5.4 Network solutions for customers

Probably the most significant difference between today's networks and the smart grid of tomorrow will be seen at the customer/network interface. For the vast majority of customers connected today, no real-time information crosses this boundary. The network and the customer operate as independent entities exchanging only metering information for billing.

A smart grid will have the potential to be in continuous communication with each customer/generator connected to it. The presence of smart meters would beneficially support this potential. When a roll-out is decided, two-way communication is a necessary requisite. Smart grid technologies, will be able to ask or instruct the customer to modify its behaviour to assist overall system performance and it will be able to signal opportunities to the customer, for instance times when the carbon intensity or price of energy is low, or there is surplus network capacity available. The presence of beyond-the-meter services provided by energy service companies external to the distribution network operators or supply companies (therefore fully exploiting competition opportunities in favour of customers) would usefully complement the step change in communication, provided that interoperability is ensured from the first steps towards smart grids.

Specific customer solutions include:

- Intelligent control of customer load, based on signals from the generator/supplier/system operator/network operator, ranging from modifying customer behaviour e.g. real-time demand response influenced by and influencing electricity prices to load curtailment actions smoothing the effects of grid disturbances and improving network security and performance;
- Full exploitation of benefits coming from smart metering (in the countries where their roll out is assessed positively), e.g. interval metering for both injections and withdrawals, easier metering data aggregation, easier losses calculation, reactive power and energy measurements, monitoring of continuity of supply and voltage quality;
- Infrastructural support for new beyond-the-meter services provided by market participants;
- Optimisation of time pattern of electrical energy demand by electric vehicles and heat storage.

3.5.5 Involvement of electricity and electronic industry, information and communications developers and system integrators

Smart grid solutions will deeply involve electric and electronic equipments with information and communication solutions. System integration is also vital for their success and for the contribution of the smart grid solution to a cost-efficient evolution of future electric network investments. Not being a new reality, the systematic approach that will result in a less “only copper and iron” electric network imposes new strategies to be developed by this stakeholder group jointly with all the other players. Open standards of communication allowing the participation of all the equipment manufacturers and systems developers are crucial for the success of smart grid solutions. The involvement of experts from this stakeholder group in the standardisation process can prevent future difficulties.

3.6 Regulatory challenges

The previously-mentioned drivers behind smart grids and their deployment will result in changes in the electricity networks. These may be “classical solutions” like building new lines, cables or transformers, or more advanced solutions based on some new technology. The regulatory framework will play an important role in the resulting electricity network of the future. The regulatory framework should enable the integration of the new services in the electricity network, sharing the possible extra costs in a fair way among those shareholders who incur them. At the same time, any unnecessary barrier to the renewable sources of generation or more efficient use of energy should be avoided.

Regulators consider themselves to be a key facilitator in the process, by identifying and removing possible barriers and by finding solutions that provide an appropriate balance between all the stakeholders’ positions. One example of a barrier is when an increase in the energy supplied is equal to automatic increases in the companies’ profits. The volume of energy supplied should be decoupled from companies’ profits in new regulatory models.

In Section 2, the two main drivers for the development of smart grids were identified: legislation for carbon reduction and energy efficiency, a macro driver; and the specific needs of customers that will result from this legislation. The regulatory challenges also fall into two similar categories. The overarching or macro challenge is to find ways to incentivise network companies to be more innovative. The second challenge is to enable the network companies to identify and prioritise specific smart grid solutions that can more efficiently meet network users’ needs and incentivise them to be deployed. Finally, regulators have a legal obligation to identify and address any barriers that could prevent cost-effective solutions from being adopted which would benefit network users, taking particular account of environmental issues.

3.6.1 Encouraging innovation

For decades, network companies have been considered to be low risk businesses due to their monopoly nature. They present themselves to their owners on this basis and their value and financing arrangements assume that they will continue to operate in this way.

The challenges of transforming the energy infrastructure and in particular the electricity networks, to achieve our carbon reduction goals will impact the businesses involved. Network companies could approach these challenges by using existing technologies and solutions. However, such an approach may induce another kind of risk, constraining low-carbon solutions throughout the electricity supply chain and/or resulting in higher costs than more innovative solutions.

It is vital, therefore, that in addition to pursuing established incentive regulation, regulators find ways of incentivising network companies to pursue innovative solutions where this can be considered as beneficial, taking account of direct and indirect benefits. Depending of the regulatory framework, regulators will critically assess incentivisation of network companies to pursue value for money of innovative solutions to the benefit of consumers. This overarching change of approach, including the expected effects and measurable quantities resulting from the deployment of the appropriate innovative solutions, is the key challenge for regulators. Finally, this change and the evolution of the electricity grids is either an already defined or near-future legal obligation for the network operator, within existing national legal frameworks and within the 3rd Package (e.g. Articles 3, 14, 25 of the new Electricity Directive 2009/72/EC).

3.6.2 Meeting users' needs

It is assumed that the electricity network businesses will continue to be natural monopolies that need to be regulated to ensure that their users get the services they need at a fair price. Bearing in mind that we expect consumers to play a much more active part in the operation of the electricity system, there would appear to be a real need for network companies to develop a much more user-centric approach, explaining the role they play and proactively engaging with the users of their networks and with supply companies and providers of energy services to find optimum efficient solutions.

It is vital that the network challenges described here (Section 3.4.1 and Section 3.4.2) are understood by regulators and combined together with the "traditional" network challenges (Section 3.4.3), so that they can consider how regulatory policy can ensure that the best solutions (examples of which are provided in Section 3.5) are delivered to the benefit of network users. However, it is also important that regulators do not attempt to choose or impose specific solutions – they must remain technologically neutral – leaving the network companies to manage their business which they have ultimate control over in the most appropriate way.

EU authorities, Member States and Regulators must anticipate the possible barriers to the development of smart grids and act through legislative and regulatory measures in order to overcome the expected difficulties. They are also crucial for ensuring a transparent and stable framework allowing entrepreneurs to ensure the long-term return of their investments. The involvement of the institutional authorities group must also ensure a balanced participation of the different stakeholders and clarification of the task of each stakeholder in the process.

4 Priorities for regulation

A key principle of good regulation – not just in the electricity sector but also in other regulated businesses – is to concentrate on outputs of the regulated entity and the effects of a given activity or service, instead of trying to influence internal processes and activities of the regulated company (e.g. by interfering in management decision-making). It is assumed that the regulated industry – electricity grid operators in this case – has the best competences, know-how and capability to accomplish all the necessary solutions and activities within its own business; a regulator will (and shall) never be able to “do the job better”.

Regulation of outputs can be done by direct regulation, i.e. minimum requirements for certain parameters, and/or by incentive regulation providing penalties and rewards related to certain criteria, as further discussed in paragraph 4.1. It is also of paramount importance that no regulatory scheme or requirement represents an (unintended) barrier for necessary development in technology and applied solutions in the grid.

Tight benchmarking of cost/performance might however become a drawback, as it could favour the postponement by grid operators of innovative solutions in favour of traditional solutions. There are indications that it favours the increase of efficiency rather than step changes, which are more likely in a competitive market environment. As some step changes are needed in operation and planning of electricity grids (especially of distribution), it might be necessary to complement the incentive regulation of “smartness” by encouraging innovation, which is further discussed in paragraph 4.2.

4.1 A path towards regulation favouring “smart” solutions

A good regulatory model, which could be used as the basis for a regulatory approach to smart grids, are the incentive regulation mechanisms adopted to promote other aspects of network business, e.g. the quality of supply in electricity distribution (see ref. [20] [21] [22] [23]). This proposed approach of incentive regulation fits well the new Electricity Directive 2009/72/EC[12] and applies to a number of regulatory topics. An alternative or complementary option is the use of direct regulation by minimum requirements[13], or eventually a hybrid solution relying on both approaches.

Regulation of outputs, either by incentives or by minimum requirements, requires predefined definitions of performance targets and indicators. Clear and transparent measurement rules are very important to make possible to observe, quantify and verify such targets. Performance targets must be strictly related to the pursued objectives and should therefore be cleansed of external effects outside the control of network operators. Indicators must be benchmarked at

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12 Directive 2009/72/EC, 37.8: “In fixing or approving the tariffs or methodologies and the balancing services, the regulatory authorities shall ensure that transmission and distribution system operators are granted appropriate incentive, over both the short and long term, to increase efficiencies, foster market integration and security of supply and support the related research activities.”

13 Today, quality of supply regulation includes both incentives and minimum requirements; the latter part mainly applies for voltage disturbances. If network operators are obliged to connect distributed generation in their grids, minimum voltage quality requirements will largely determine the investments necessary in the grid. This in addition to requirements for minimising costs may provoke smarter solutions than the conventional ones.

national or international level[14] before their adoption in order to define the expected performance targets[15]. Then, in case of incentive regulation, regulated entities are either rewarded if they overperform or penalised if they underperform with respect to such targets.

A regulatory scheme for promoting improvements in performance of electricity networks requires the quantification, through appropriate indicators, of the effects and benefits of “smartness”. In order to be able to use such an approach in practice, the key effects and parameters will have to be precisely identified according to defined metrics.

A set of effects and potential related parameters (performance indicators) from where measures of smartness may be extracted and eventually adopted in the future are proposed in Table 1. It is, however, important to ensure a complete regulation and long-term reasonable rate of return and to avoid sub-optimisation for some indicators. The indicators that will be the best ones to consider can vary from country to country.

[14] In the aforementioned example of quality regulation of electricity distribution, CEER has a long benchmarking experience, witnessed by the series of its Benchmarking Reports on quality of electricity supply (2001, 2003, 2005, 2008).

[15] The definition of targets must take into account the comparability of grid operators (e.g. distribution grid operators within one country) and the history and trends of the respective relevant parameters.

Benefit	Potential performance indicators[16]
(1) Increased sustainability	Quantified reduction of carbon emissions
(2) Adequate capacity of transmission and distribution grids for "collecting" and bringing electricity to consumers	Hosting capacity for distributed energy resources ('DER hosting capacity') in distribution grids Allowable maximum injection of power without congestion risks in transmission networks Energy not withdrawn from renewable sources due to congestion and/or security risks
(3) Uniform grid connection and access for all kind of grid users	Benefit (3) could be partly assessed by: - first connection charges for generators, prosumers and customers - grid tariffs for generators, prosumers and customers - methods adopted to calculate charges and tariffs - time to connect a new user
(4) Higher security and quality of supply	Ratio of reliably available generation capacity and peak demand Share of electrical energy produced by renewable sources Duration and frequency of interruptions per customer Voltage quality performance of electricity grids (e.g. voltage dips, voltage and frequency deviations)
(5) Enhanced efficiency and better service in electricity supply and grid operation	Level of losses in transmission and in distribution networks (absolute or percentage)[17] Ratio between minimum and maximum electricity demand within a defined time period (e.g. one day, one week)[18] Demand side participation in electricity markets and in energy efficiency measures Availability of network components (related to planned and unplanned maintenance) and its impact on network performances Actual availability of network capacity with respect to its standard value (e.g. net transfer capacity in transmission grids, DER hosting capacity in distribution grids)
(6) Effective support of trans-national electricity markets by load-flow control to alleviate loop-flows and increased interconnection capacities	Ratio between interconnection capacity of one country/region and its electricity demand Exploitation of interconnection capacity (ratio between mono-directional energy transfers and net transfer capacity), particularly related to maximisation of capacity according to the Regulation on electricity cross-border exchanges and the congestion management guidelines Congestion rents across interconnections
(7) Coordinated grid development through common European, regional and local grid planning to optimise transmission grid infrastructure	Benefit (7) could be partly assessed by: - impact of congestion on outcomes and prices of national/regional markets - societal benefit/cost ratio of a proposed infrastructure investment - overall welfare increase, i.e. always running the cheapest generators to supply the actual demand) → this is also an indicator for benefit (6) above.

Table 1: Effects/benefits of smartness and list of potential performance indicators

[16] Some of these indicators are already in force in some countries today.

[17] In case of comparison, the level of losses should be corrected by structural parameters (e.g. by the presence of distributed generation in distribution grids and its production pattern).

[18] In case of comparison, a structural difference in the indicator should be taken into account due e.g. to electrical heating and weather conditions, shares of industrial and domestic loads.

As already mentioned, performance targets and indicators should be "purified" from external effects outside the control of network operators. For example, the benefit (1) of reducing carbon emissions is related to different sub-effects:

- Direct effect through reduction of losses in the grids (when reduced losses save energy produced by carbon-based technologies);
- Indirect effect by integration of renewable and distributed generation;
- Indirect effect by supporting demand side participation in electricity markets and in energy efficiency measures;
- Indirect effect by supporting efficient end-use by plug-in electricity vehicles and storage technologies for intermittent renewable production.

Some indicators are already adopted in EU policy or benchmarked in European practice. For example, the 'reliably available generation capacity' indicator under benefit (4) is commonly used by European Network of Transmission System Operators – Electricity (ENTSO-E) in "System Adequacy" reports; the first indicator under benefit (6) is similar to the ratio of interconnection capacity versus the installed generation capacity in one country (minimum 10%), adopted in EU policy for market competition purposes. Transmission grid tariffs have been benchmarked in last years by ETSO which published yearly "Overview of transmission tariffs in Europe". Continuity indicators (SAIDI, SAIFI, ENS) are commonly adopted in Europe by regulators and grid operators to evaluate continuity of supply. Other indicators (e.g. 'DER hosting capacity'[19]) have been proposed more recently.

Defining metrics for quantification of effects and benefits of smart grids – including as the most important part, the evaluation of efficiency, effectiveness and comparative cost analysis in relation to a conventional "non-smart" approach – is a challenging but necessary task in order to be able to perform the cost / benefit analysis, before cost recovery and eventual introduction of incentives for the deployment of smart grids. This is a high priority and complex issue for regulators.

The definition of a list of quantifiable and measurable effects and benefits of smart solutions is a prerequisite for the effective implementation of incentive regulation, e.g. to define incentives for infrastructure investments or to consider a 'RES-DG factor' in defining the tariff for the distribution service, allowing extra-rewards to grid operators which have to deal with large amounts of RES-DG.

Tariffs could act as important signals to grid users and should encourage them to make efficient use of the networks. It is vital to ensure non-discriminatory access for all kinds of users (consumers, prosumers and producers) to the network and the common market. Use-of-system charges (UoS) dependent on the time-of-use (ToU) that reflect the impact of grid users on the system are examples of how tariffs can act as signals to grid users. This could either be

[19] For DER hosting capacity: M. Delfanti et al. "Limits to Dispersed Generation on Italian MV Networks", Paper 0400, Proceedings CIRED 20th Conference on Electricity Distribution, Prague, 8-11 June 2009; M. Bollen et al. "Integration of Distributed Generation in the Power System – A Power Quality Approach", Keynote paper presented at the 13th International Conference on Harmonics and Quality of Power, Wollongong, Australia, 28 September – 1 October 2008; T. Kapetanovic et al. "Provision of Ancillary Services by Dispersed Generation and Demand Response - Needs, Barriers and Solutions", CIGRE Session 2008, C6-107.

achieved by charging the actual use of the network or offering a discount for allowing the network to control energy use with certain boundary conditions. The application of ToU charges could favour e.g. a reduction in the ratio between minimum and maximum electricity demand within a defined time period, with a consequent reduction of balancing costs and requirements for installed generation capacity (whose costs are finally reflected in energy prices).

4.2 Role of regulators concerning cooperation, research and innovation

In addition to the envisaged priority of output regulation, a second priority for regulators should be to have an active role in favouring cooperation among stakeholders, to achieve national and European targets by the various smart grid concepts, innovations and solutions.

One role for regulators is to facilitate 'smart grids' discussions, definition of common views, and cooperation among all stakeholders (operators, network users, customers and generation companies, governments, suppliers, standardisation organisations, electric and electronic equipment manufacturers, new energy service providers, information and communication technology providers, academia and research). Such cooperation should be especially devoted to agreeing which smart grid concepts will provide clear and greater net benefits (i.e. the benefits minus the possible additional costs) to customers, to identifying the possible presence of regulatory barriers to such smart grid concepts and to finding the best solutions to eliminate them.

Cooperation among stakeholders is of special importance in the field of standardisation. EERs and some NRAs are already active in cooperation with European and national standardisation bodies, grid operators and manufacturers. This cooperation should further improve open protocols and standards for information management and data exchange, in order to achieve interoperability of smart grid devices and systems and to avoid standards becoming a barrier to their deployment. European energy regulators are actively cooperating with European Standardisation Organisations in the field of metering (see Annex A3.4). Furthermore, regulators are cooperating with CENELEC (Comité Européen de Normalisation ÉLECtrotechnique) in the field of quality of supply and national cooperation activities dealing with technical conditions for grid access.

Regulators should further support the increasing efforts and international cooperation in research and development in the field of electricity grids and smart solutions and promote their effectiveness. Regulators, acting as observers in such activities, should favour an approach targeted to define performance indicators for specific smart solutions, and later identify their costs and the benefits to customers. Regulators should also support the link between research & development projects and demonstration & initial deployment of selected promising solutions.

Finally and relying on a subsidiarity principle, it will remain up to each NRA to evaluate the benefits and the costs of the possible lighthouse or demonstration projects, according to national priorities and in coherence with the applicable national regulation systems. In case demonstration projects will be (whole or partly) recovered by grid tariffs paid by network users, ERGEG recommends to NRAs to ensure dissemination of the results and lessons learned from the demonstration projects to all interested parties including other network operators, market participants, etc. Moreover, ERGEG strongly urges the NRAs to clearly distinguish between the costs / benefits for the grid users and the external costs / benefits which can by no means be attributed to the network users. A commitment on required dissemination activities (e.g. training) and/or minimum share of the budget for dissemination should be envisaged.

The definition of research and development and related funding is in many countries a theme for National Governments and Ministries (as well as for the European Commission, under e.g. Framework Programmes for Research and Technological Development) and should therefore be treated under the principle of subsidiarity.

R&D activities in smart grids with non-proprietary solutions, for example using public protocols, could extend the benefits of these projects to all firms and customers, avoiding possible competition distortions or entry barriers in the near future. The main reasons are cost efficiency, to avoid entry barriers and to allow that the new technologies to be accessible to all customers, regardless of their supplier and to all DSOs regardless their size.

Supporting the transition process from R&D over demonstration[20] to full deployment of smart solutions, when it is profitable from the point of view of the whole society, while incentivising only economical and technologically efficient technologies, should also be one of the future tasks for the NRA. The participation of regulators in this process could reduce the risk of having duplication of costs and financial burden for the final customers in the RD&DD chain. These new technology developments of smart grids should not introduce distortions to effective and efficient remunerating procedures in the EU Member States, and by no means should they lead to new sources for cross subsidies between network activities by TSOs or DSOs and market-based activities.

[20] The following definition applies within the 7th Framework Programme funded by the European Commission: "Research and technology development activities means directly aimed at creating new knowledge, new technology, and products, including scientific coordination. Demonstration activities means activities designed to prove the viability of new technologies that offer a potential economic advantage, but which cannot be commercialised directly (e.g. testing of products such as prototypes)."

5 Next steps

5.1 ERGEG Conclusions Paper

The objective of this paper is to consult with stakeholders in order to help regulators understand how smart grids can benefit network users. The responses of stakeholders will help enhance regulators' understanding and the development of future regulatory policy. Current views will be refined and developed based on the consultation responses. The finalisation of the paper is planned in the second quarter of 2010, after completion of the public consultation. In addition to the position paper, in the interest of transparency, ERGEG will publish all non-confidential responses to this consultation.

5.2 CEER/ERGEG ongoing activities related to future smart grids

European energy regulators state their commitment to cooperate with the Directorate General Research and the Directorate General Energy and Transport of the European Commission, which are responsible for most relevant EC funds for research, development and demonstration on smart electricity networks, in order to promote linking research & development projects and demonstration & initial deployment by the grid operators of selected promising solutions. Regulators hope that their collective and individual expertise can provide a positive contribution to define beneficial effects and performance indicators for specific smart solutions. Performance indicators are needed to perform i) preliminary cost-benefit analyses before carrying out demonstration projects, and, most important, ii) final cost-benefit assessments after the demonstration phase in order to evaluate the opportunity for full scale roll-out of the tested solutions.

EERs state further their willingness to cooperate also with European standardisation bodies, in order to promote open protocols and standard models for information management and data exchange, to achieve interoperability of smart grid devices and to avoid standards being a barrier to the development of more efficient electricity grids.

In this paper, due to the complexity of smart grids, the focus was on key elements only: the development of a network-user centric approach, a path towards incentive-based regulation of network output measures and the encouragement of appropriate network evolution and innovation needed for that. New elements of market design and even marketplaces are expected to arise together with the future deployment of smart grids. To give a significant example, there seems to be a growing consensus on the need for market integration of distributed resources, which will be necessarily based on a two-way communication layer. Further, future work of the European energy regulators in investigating the strict relationship between electricity grids, wholesale and retail markets and new market places will be considered in order to remove any regulatory barriers to the development of truly efficient electricity grids and markets.

Annex 1 – CEER and ERGEG

In 2000, ten national energy regulatory authorities signed the "Memorandum of Understanding for the establishment of the Council of European Energy Regulators" (CEER). They had voluntarily formed the council to facilitate cooperation in their common interests for the promotion of the internal electricity and gas market. In order to cope with a growing number of issues and to improve cooperation at the operational level, the regulators decided in 2003 to formally establish themselves as a not-for-profit association under Belgian law and to set up a small secretariat in Brussels. The Statutes (English version, Statutes amendment) were published in the annex of the Belgian State Gazette on October 21st, 2003. The CEER now has 29 members - the energy regulators from the 27 EU-Member States plus Iceland and Norway. CEER and the European Regulators Group for Electricity and Gas (ERGEG) share similar objectives and the work and achievements of the CEER and ERGEG are intrinsically linked.

The European Regulators for Electricity and Gas (ERGEG) was set up by the European Commission in 2003 as its advisory group on internal energy market issues. Its members are the energy regulatory authorities of Europe. The work of the CEER and ERGEG is structured according to a number of working groups, composed of staff members of the national energy regulatory authorities. These working groups deal with different topics, according to their members' fields of expertise.

This report was prepared by the Electricity Quality of Supply (EQS) Task Force of the Electricity Working Group.

Annex 2 – List of abbreviations

Term	Definition
CEER	Council of European Energy Regulators
EER(s)	European Energy Regulator(s)
Electricity WG	Electricity Working Group
EQS TF	Electricity Quality of Supply Task Force
ERGEG	European Regulators Group for Electricity and Gas
NRA(s)	National Regulatory Authority (Authorities)
CBA	Cost-benefit analysis
CENELEC	Comité Européen de Normalisation Électrotechnique
CHP	Combined heat and power
DER	Distributed energy resources
DG	Distributed generation
DNO	Distribution network operator(s)
DOE	Department of Energy (US)
DSO	Distribution system operator(s)
EC	European Commission
EHV	Extra high voltage
EISA	energy independence and security act (US)
ENS	Energy not supplied
ENTSO-E	European Network of Transmission System Operators – Electricity
EPACT	Energy Policy Act (US)
EPRI	Electric Power Research Institute
ESCo	Energy service companies
ESO(s)	European standardisation organisation(s)
ETP	European Technology Platform
ETSO	European Transmission System Operators
EU	European Union
FACTS	Flexible alternating current transmission systems
FERC	Federal Energy Regulatory Commission
FP (5/6/7)	(European) Framework Programme (for research)
HV	High voltage
HVDC	High voltage direct current
ICT	Information & communication technology

Term	Definition
IEC	International Electrotechnical Commission
IEM	Internal Energy Market
LV	Low voltage
MV	Medium voltage
NIST	National Institute of Standards and Technology
NTP	National Technology Platform
OEDER	Office of Electricity Delivery and Energy Reliability (US)
OETD	Office of Electricity Transmission and Distribution (US)
Ofgem	Office of Gas and Electricity Markets
PV	Photovoltaic
R&D	Research and development
RD&DD	Research, development, demonstration, deployment
RES	Renewable energy sources
SAIDI	System average interruption duration index
SAIFI	System average interruption frequency index
SGD	Smart Grid Demonstration Program
SGIG	Smart Grid Investment Grant Program (US)
T&D	Transmission and distribution
ToU	Time-of-use
TSO(s)	Transmission system operator(s)
UoS	Use-of-system
US	United States

Table 2: List of Abbreviations

Annex 3 – Smart grids of the future: references, experiences and lessons learned

A3.1 Experiences on the European level

The European Technology Platform on SmartGrids

The European Commission's Directorate General for Research (DG Research) developed the concept of a Technology Platform for the Electricity Networks of the Future and its guiding principles with the support of the FP5 FP6 IRED research cluster.

The SmartGrids European Technology Platform (ETP) for Electricity Networks of the Future began its work in 2005 and had its final meeting in May 2009. It has been succeeded by the SmartGrids Forum.

The ETP's initial aim was to formulate and promote a vision for the development of European electricity networks looking towards 2020 and beyond.

In general, the aim of ETP was to provide a framework for stakeholders, led by industry, to define research and development priorities, timeframes and action plans on a number of strategically important issues.

ETPs are supported financially by the European Commission to provide key guidance to the European research projects co-financed under the Seventh Framework Programme for Research and Technological Development (FP7). ETPs carry out work their work under the supervision of DG Research.

SmartGrids ETP was steered and monitored by an Advisory Council, which included representatives from European Energy Regulators (E-Control and Ofgem). Other members represented TSO, DNO, manufacturers, research centres and consultants.

The activities of ETP were carried out by working groups focused on specific subjects.

The SmartGrids European Technology Platform resulted in the preparation of:

- a document containing a vision for future networks ("Vision and Strategy for Europe's Electricity Networks of the Future" report of April 2006);
- a roadmap defining the key research projects to be pursued ("Strategic Research Agenda for Europe's electricity networks of the future" report of 2007);
- a deployment document ("Strategic Deployment Document for Europe's Electricity Networks of the Future"), released in draft version on 25 September 2008.

The Strategic Deployment Document of the European Technology Platform SmartGrids [12] explains in a concise way the need for electricity networks evolution and for SmartGrids:

"The need for SmartGrids:

It is vital that Europe's electricity networks are able to integrate all low-carbon generation technologies as well as to encourage the demand side to play an active part in the supply chain. This must be done by upgrading and evolving the networks efficiently and economically. It will involve network development at all voltage levels. For example, substantial offshore and improved onshore transmission infrastructure will be required in the near term to facilitate the development of wind power across Europe. Distribution networks will need to embrace active network management technologies to efficiently integrate distributed generation (DG), including residential micro generation, on a large scale. There are many other examples but all will require the connectivity that networks provide to achieve the targets for energy security and environmental sustainability."

Document [12] introduces the definition:

"A SmartGrid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

A SmartGrid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- *better facilitate the connection and operation of generators of all sizes and technologies;*
- *allow consumers to play a part in optimising the operation of the system;*
- *provide consumers with greater information and choice of supply;*
- *significantly reduce the environmental impact of the whole electricity supply system;*
- *deliver enhanced levels of reliability and security of supply."*

SmartGrids deployment must include not only technology, market and commercial considerations, environmental impact, regulatory framework, standardisation usage, ICT (Information & Communication Technology) and migration strategy but also societal requirements and governmental policies.

The priorities for the SmartGrids deployment outlined in [12] are:

- Optimising Grid Operation and Usage
- Optimising Grid Infrastructure
- Integrating Large-scale Intermittent Generation
- Information and Communication Technology
- Active Distribution Networks
- New Market Places, Users and Energy Efficiency

The position of each of the above priorities within the electricity supply chain and within the external environment of society, environment, governance and regulation is illustrated in paragraph 1.2 of this consultation paper.

The European Industrial Initiative on Electricity Grids

The European Industrial Initiative on electricity grids[21] is launched by the European Commission within the European Strategic Energy Technology (SET) Plan.

The SET-Plan was proposed by the European Commission's General Directorates for Energy and for Research on 22 November 2007 with the aim to accelerate the availability of new energy technologies and to create a long term EU framework for energy technology development. The SET-Plan brings together the coordination of the European Commission, the research capacities of the major European institutes and universities, the engagement of European industry and the commitment of the Member States. One of two challenges addressed by the SET-Plan is mobilising additional financial resources, for research and related infrastructures, industrial-scale demonstration and market replication projects. In the SET-Plan communication, the Commission informed about the increased budgets of the Seventh Framework Programme of the European Communities (2007-2013), as well as the Intelligent Energy Europe Programme. The average annual budget dedicated to energy research (EC and Euratom) will be €886 million, compared to €574 million in the previous programmes [28]. The average annual budget dedicated to the Intelligent Energy Europe Programme will be €100 million, doubling previous values.

To engage the European industry, the European Commission proposed to launch in spring 2009 six European Industrial Initiatives (EII) in the areas of wind; solar; bio-energy; CO2 capture, transport and storage; electricity grids and nuclear fission. EIIs are devoted to strengthen energy research and innovation, to accelerate deployment of technologies and to progress beyond business-as-usual approach. EIIs bring together appropriate resources and actors in industrial sectors, in which sharing of risks, public-private partnerships and financing at European level gives additional value.

The EII on electricity grids is expected to focus on the development of the smart electricity system, including storage, and on the creation of a European Centre to implement a research programme for the European transmission network[22], with the final objective to enable a single, smart European electricity grid able to accommodate the massive integration of renewable and decentralised energy sources [29]. As for other European Industrial Initiatives, EII on electricity grids shall have measurable objectives in terms of cost reduction or improved performance.

A3.2 National experiences and platforms

National Technology Platform – Smart Grids Austria

Significant contributions to innovative technologies - both at distribution and transmission level - from all stakeholders are needed in order to come up with sustainable solutions in the area of smart grids. In order to utilise upcoming economic opportunities most efficiently, a strategy

[21] References: European Commission, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions "A European strategic energy technology plan (SET-Plan) - Towards a low carbon future", COM(2007) 723 final, 22 November 2007
European Commission, "Energy for the Future of Europe: The Strategic Energy Technology (SET) Plan", MEMO/08/657, 28 October 2008

[22] The proposal to constitute a European Centre for Electricity Networks came from the 6FP RELIANCE project, in which eight European transmission system operators participated.

process, initialised by the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) and the Federal Ministry of Economics and Labour (BMWA), enables the implementation of an adequate Austrian cooperation basis in the sector of smart grids. This is why the "National Technology Platform - Smart Grids Austria" (NTP) was raised on a common strategic basis.

The Austrian Technology Platform aims to bundle the strength of different stakeholders (industry, network operators, research, power generators, regulation and politics) for smarter electricity grids in the future in order to support an energy-efficient and cost-effective system operation. Synergies of the stakeholders from industry, energy sector and research can thus be efficiently used. National competence in the area of smart grids shall be strengthened by light-house projects and made visible at national and international level. It is envisaged to define, describe and support the necessary framework conditions for the implementation of improved R&D. An additional objective is to position the NTP – Smart Grids Austria as a central communication and information instrument for national and international strategies and projects (e.g. ETP Smart Grids). Furthermore, the platform should coordinate the national smart grid R&D, demonstration as well as dissemination activities.

As an outcome the platform will publish a National Smart Grid Strategic Roadmap for Research & Development and Demonstration with detailed information on possible market strategies and business cases as well as guidelines for requested legal and regulatory framework conditions.

National Technology Platform – Smart Grids United Kingdom

The Electricity Networks Strategy Group[23], jointly chaired by Government[24] and Ofgem[25] has established a smart grid stakeholder group to develop a Vision and Routemap for the development of smart grids in the UK. The group will complete and publish its initial work by the end of 2009. The development of smart grid technologies is expected to be a key enabler in meeting the UK's 2020 targets under the EU's climate-energy legislative package.

An important output from the group's work will be the identification of smart grid network solutions that could be deployed in the immediate future. Ofgem is proposing to introduce the Low Carbon Networks Fund[26] for electricity DNOs which will become active in April 2010. It is intended that the smart grid solutions identified by the ENSG group could be built and trialled under this fund in the period to 2015.

A number of smart grid projects are already being pursued under existing incentive arrangements – the Innovation Funding Incentive and Registered Power Zones. Projects employing dynamic line ratings, intelligent generator constraint management and advanced voltage control are already operational.

[23] http://www.ensg.gov.uk/

[24] Department for Energy and Climate Change

[25] The Office of Gas and Electricity Markets – the UK's energy regulator

[26] http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=254&refer=NETWORKS/ELECDIST/PRICECNTRLS/DPCR5

National Technology Platform – Smart Grids Portugal

The concept of smart grid development in Portugal was presented by Portuguese DSO, EDP Distribuição, with a first pilot demonstration trial already under implementation. The concept is called INOVGRID and the pilot trial has the objective of connecting, during 2009, 500 customers in 4 different geographical areas of Portugal and 50 000 customers during 2010. The cost of this pilot demonstration trial (15 M€) was accepted by the Portuguese NRA and incorporated at the actual regulatory period tariffs.

Another dimension of smart grid developments in Portugal can be considered with the “Mobi-E” initiative, a national spread structure of electric vehicles recharging stations at public spaces, promoted by the Portuguese government for facilitating the electric vehicles introduction. Twenty one Portuguese cities are involved in “Mobi-E” and the short-term goal is the installation of 320 recharging stations by end-2010 and to have active 1 300 recharging stations at the end of 2011, the planned timing of a larger electric vehicles introduction in Portugal. A consortium of Portuguese companies is organised under the “Mobi-E” initiative involving EDP, several industrial and consultant companies and research centres.

31% is the Portuguese target to be attained by 2020 for the share of energy from renewable sources in gross final consumption of energy. Contribution from the electric sector is fundamental in a country where traditionally the big hydro generation was already relevant (representing more than 20% of the electric generation mix). More recently a great effort on investment on other renewable solutions has been developed with special attention given to wind generation and more recently to the solar photovoltaic generation. Also, some experiments with wave generation are in testing. Last year, micro-generation with solar photovoltaic and wind turbines connected to the low voltage distribution network began to be actively promoted with more than 5 000 households already being simultaneously electric consumers and producers. This option for renewable and dispersed sources imposed some challenges to all the levels of the electric network that was able to overcome the difficulties with new investments and some changes on the operational procedures. Attaining more than 40% during 2008 (a wet year), penetration of renewable electric generation can be considered successful in Portugal.

National Technology Platform – Smart Grids Germany

"E-Energy: ICT-based Energy System of the Future[27]" is a new support and funding priority and part of the technology policy of the Federal Government. Just like the terms "E-Commerce" or "E-Government", the abbreviation "E-Energy" stands for the comprehensive digital interconnection and computer-based control and monitoring of the entire energy supply system. It was decided that the electricity sector would be the first area addressed by the project, as the challenges with regard to real-time interaction and computer intelligence are particularly high due to electricity's limited ability to be stored. The primary goal of E-Energy is to create E-Energy model regions that demonstrate how the tremendous potential for optimisation presented by information and communication technologies (ICT) can best be tapped to achieve greater efficiency, supply security and environmental compatibility (cornerstones of energy and climate policy) in power supply, and how, in turn, new jobs and markets can be developed. What is particularly innovative about this project is that integrative ICT system concepts, which optimise

[27] http://www.e-energy.de/en/

the efficiency, supply security and environmental compatibility of the entire electricity supply system all along the chain - from generation and transport to distribution and consumption - are developed and tested in real-time in regional E-Energy model projects.

To force the pace on the innovative development needed and to broaden the impact of the results, the E-Energy programme focused on the following three aspects:

1. Creation of an E-Energy marketplace that facilitates electronic legal transactions and business dealings between all market participants;

2. Digital interconnection and computerisation of the technical systems and components, and the process control and maintenance activities based on these systems and components, such that the largely independent monitoring, analysis, control and regulation of the overall technical system is ensured;

3. Online linking of the electronic energy marketplace and overall technical system so that real-time digital interaction of business and technology operations is guaranteed.

An E-Energy technology competition was held and six model projects were declared the winners. They each pursue an integral system approach, covering all energy-relevant economic activities both at market and technical operating levels.

The programme will run for a 4-year term and mobilises, together with the equity capital of the participating companies, some €140 million for the development of six E-Energy model regions:

- eTelligence, model region of Cuxhaven,
  Subject: Intelligence for energy, markets and power grids
- E-DeMa, Ruhr area model region
  Subject: decentralised integrated energy systems on the way towards the E-Energy marketplace of the future
- MeRegio,
  Subject: Minimum Emission Region
- Mannheim model city
  Subject: Model city of Mannheim in the model region of Rhein-Neckar
- RegModHarz
  Subject: Regenerative model region of Harz
- Smart Watts, model region Aachen
  Subject: Greater efficiency and consumer benefit with the Internet of Energy

Besides the project coordinators, others like vendors of electrical equipment, system integrators, service providers, research institutes and universities are involved.

By 2012, the selected model regions are to develop their promising proposals up to the stage at which they are ready for market launching and to test their marketability in everyday application.

A3.3 Ongoing experiences in the United States of America

The United States adopted in December 2007 an energy independence and security act (EISA), which paved the way for research, development and demonstration of smart grid technologies. Before the enforcement of the EISA, the National transmission grid study and the "Grid 2030" set of reports by the US department of energy (DOE) could be considered as initial movers towards smart grids.

The 2002 grid study [30] put in evidence that the US transmission system was in urgent need of modernisation, that the system became congested because of insufficient investment in new transmission facilities, causing daily transmission constraints or "bottlenecks" with consequent increase of electricity costs to consumers and increase of risk of blackouts. The study proposed introducing advanced transmission technologies and improved operating practices, siting generation closer to areas where electricity is needed, and reducing electricity use through targeted energy efficiency and distributed generation. Main recommendations were to:

- increase regulatory certainty by completing the transition to competitive regional wholesale markets;
- develop a process for identifying and addressing national-interest transmission bottlenecks;
- improve transmission system operations and fully utilising existing facilities by regional planning processes;
- provide opportunities for customers to reduce their electricity demands voluntarily, and for targeted energy-efficiency and distributed generation;
- ensure mandatory compliance with reliability rules, including enforceable penalties for non-compliance that are commensurate with the risks that the violations create;
- creating a new Office of Electricity Transmission and Distribution (OETD) to give DOE an increased leadership role in transmission R&D and policy.

The aforementioned OETD of DOE promoted the Grid 2030 initiative, which resulted in the preparation of a vision report ("Grid 2030") [31], an action agenda (Technologies Roadmap report) [32], and a research plan (Gridworks) [33].

The vision sketched Grid 2030 as a fully-automated power delivery network ensuring a two-way flow of electricity and information between the power plants and appliances and all points in between. According to the vision report, '*Grid 2030 energises a competitive North American marketplace for electricity. It connects everyone to abundant, affordable, clean, efficient, and reliable electric power anytime, anywhere. It provides the best and most secure electric services available in the world*'. The vision pointed out, among other conclusions, the need to accelerate the "technology readiness" of critical electric systems, particularly high-temperature superconducting cables and transformers, lower-cost electricity storage devices, standardised architectures and techniques for distributed intelligence and "smart" power systems, and cleaner power generation systems.

The action agenda in the following roadmap document (which was published after the blackout of 14 August 2003 in the Great Lakes region) focused on five subjects:

1. designing a flexible and robust "Grid 2030" architecture with different targets for its three major elements (the national electricity backbone, regional interconnections and local distribution grids);
2. developing "critical" technologies (the five technologies identified for research, development and demonstration - R&D&D - were advanced conductors, high temperature superconductors, electric storage, distributed sensors and intelligence and smart controls, power electronics);
3. accelerating acceptance of advanced technologies by strengthening technology transfer and expanding education and training on new technologies;
4. strengthening electric market operations by improving planning and operations, siting and permitting, and regulatory frameworks;
5. building public-private partnerships.

Regulatory frameworks were addressed by the action agenda points dealing with acceptance of advanced technologies and with improved market operations. The roadmap observed that the existing regulatory framework was fostering a business environment '*that is known to discourage risk taking and entrepreneurial behaviour*'. As an alternative to the existing framework, sharing risks among companies, regulators, investors, and the federal government was envisaged, by the establishment of more effective regulation and business practices to spur innovation and increase testing of new technologies and techniques. The roadmap underlined the need to identify regulatory and market-based mechanisms to encourage innovation and prudent risk sharing.

The roadmap observed that the level of private investment in grids had to increase, with support by a more attractive investment climate in the electric sector. Contribution was asked of federal and state electricity and environmental regulators to improving investment conditions by streamlining siting and permitting processes for new electricity facilities and using market-based mechanisms wherever feasible for setting rates and rates-of-return.

The roadmap also highlighted the need for an effort at the federal level to implement laws and regulations that clearly assign responsibility for grid reliability, including monitoring performance and holding the responsible parties accountable for both successes and failures. Laws and regulations were expected to involve enforceable mandatory reliability standards, followed by complementary provisions at the regional, state, and local levels. The need of spending on R&D&D for grid reliability technologies was also put in evidence, as previous R&D&D funding has been mainly focused on energy efficiency and renewable sources.

Finally, the roadmap recalled the ongoing work of U.S. state and federal agencies in addressing the lack of uniform grid interconnection standards.

In summary, the following priorities for regulation were envisaged by the roadmap:

- support an attractive investment climate;
- assign responsibility and define mandatory standards for grid reliability;
- conduct studies and simulations to assess the relative merits of alternative regulatory approaches to efficient and reliable market operations such as performance-based regulations, price and revenue caps, and market power penalties;

- adopt federal and state incentives to encourage technological innovations in grids and greater levels of spending particularly on R&D&D for grid reliability technologies;
- encourage state and local regulators and code officials to eliminate unnecessary barriers to the expanded use of advanced electric grid technologies, including distributed energy resources and demand side management.

The 2005 Gridworks report detailed the research plan towards the introduction of “next generation” hardware for cables and conductors, substations and protective systems, and power electronics. A more comprehensive research, development, and demonstration programme to ensure the reliability, efficiency, and environmental integrity of electric transmission and distribution systems was later implemented by the Energy Policy Act (EPACT) of 2005 under its section 925. EPACT also envisaged the introduction of time-based ‘smart’ metering, time-based rate schedule and time-of-use pricing.

The path towards smart grids was then driven by the EISA 2007 [34], which stated the US policy to support grid modernisation and decided, among other provisions:

- the establishment of an advisory committee on smart grids and of a cross-cutting task force on smart grids, including participation from the Federal Energy Regulatory Commission (FERC) and the National Institute of Standards and Technology (NIST);
- the establishment of an R&D&D program, initially named ‘Smart grid regional demonstration initiative’, allowing financial assistance for 50% of the costs of grid technology investments to carry out demonstration projects;
- the establishment of a funding scheme to recover 20% of smart grid investments;
- the development of an interoperability framework for protocols and standards to achieve interoperability of smart grid devices and systems under coordination of NIST and a follow-up rulemaking proceeding by FERC for its adoption;
- the publication of a periodical report by the Office of Electricity Delivery and Energy Reliability (OEDER, created in 2005 by restructuring OETD) concerning the status of smart grid deployments nationwide and any regulatory or government barriers to continued deployment.

The American Recovery and Reinvestment Act of 2009 (ARRA 2009) [35] modified smart grid funding. Indeed, cost recovery percentage for Smart Grid Investment Grant (SGIG) Program was increased up to 50% and funding was set at $3375 million, whereas $615 million was allocated for Smart Grid Demonstration Program (SGD) focused on regional smart grid, utility-scale energy storage, and grid monitoring demonstrations.

The objective of the SGIG is to provide grants to qualifying smart grid investments to support the manufacturing, purchasing and installation of smart grid devices and related technologies, tools, and techniques for immediate commercial use in electric system. The intent of the SGD is to provide financial support to demonstrate how a suite of existing and emerging smart grid technologies can be innovatively applied and integrated to prove technical, operational and business-model feasibility. The ultimate aim is to demonstrate new and more cost-effective smart grid technologies, tools, techniques, and system configurations that significantly improve upon the ones that are either in common practice today or are likely to be proposed in the SGIG Program.

Concerning interoperability, FERC proposed in March 2009 a policy (adopted in July 2009) to prioritise the development of standards for cyber and physical security and for enabling effective communication and coordination at the boundaries of utility systems and to prioritise four key grid functionalities (wide-area situational awareness, demand response, electric storage, and electric transportation) involving interfaces among utilities, customers and other systems. Furthermore, FERC observed that smart grid policies should encourage utilities to deploy systems that advance efficiency, security, and interoperability in the near term and therefore proposed an interim rate policy for cost recovering of such deployments for the interim period until final interoperability standards are adopted.

FERC proposed cost recovery be allowed if three conditions are satisfied: i) the absence of adverse impact of smart grid deployments on the reliability and security of the bulk-power system; ii) the intended minimisation of possible stranded investment in smart grid equipment due to later adoption of interoperability standards by '*designing for the ability to be upgraded*', 3) the provision, particularly for early pilot and demonstration projects, of feedbacks useful to the interoperability standards development process.

A3.4 CEER/ERGEG activities on smart metering

Triggered by the publication of EU Directive 2006/32/EC on energy end-use efficiency and energy services, in particular by Article 13, ERGEG launched its activities on smart metering in 2006, with a status review report (2006 Status Review Report on Smart Metering, an ERGEG internal document, Ref: E06-CSW-05-04 13 November 2007) which examined the following issues:

- legal framework of metering activities;
- public policies aimed at fostering the adoption of smart meters;
- status and expected future development of installations;
- economic issues related to meters and smart meters;
- functionalities of smart meters and applications in use.

In 2007, ERGEG published the position paper Smart metering with a Focus on Electricity Regulation (E07-RMF-04-03, 31 October 2007, freely available on http://www.energy-regulators.eu/portal/page/portal/EER_HOME). The paper, which includes in its Annex I a synthesis of the 2006 Status Review Report, analysed some major aspects relevant to smart meters: the new customer perspective, taking shape from the full opening of the electricity market as from 1st July 2007, costs (capital, operation and management, stranded) and benefits (consumer and system benefits, network and metering operational savings, retailer and third parties opportunities) issues, technical aspects, like meter data management and functional requirements.

The paper identified a range of policies that NRAs can adopt to promote smart metering, in particular: obligatory roll-out of smart meters and financial incentives preferably for regulated meter markets; the introduction of minimum functional requirements and more frequent meter reads preferably for liberalised markets. A list of recommendations to NRAs was also drawn up:

- assessment of costs and benefits, to be carried out in particular for large-scale roll-outs;
- access to meter data, which must be guaranteed to authorised third parties;
- introduction of minimum functional requirements, among which:
  - load profile data;
  - provision of variable time of use tariffs;
  - remote meter management;
  - remote demand reduction and connection/disconnection;
  - price signal to customer.

Driven by the European Union's 3rd Package, containing provisions regarding the installation of intelligent metering systems, ERGEG published a Status Review on Regulatory Aspects of Smart Metering (Electricity and Gas) in 2009 (E09-RMF-17-03, freely available on http://www.energy-regulators.eu/portal/page/portal/EER_HOME).

This Status Review provides an overview of the state of play regarding the introduction of smart meters in ERGEG member and observer countries. The report examines the issue from a regulatory perspective; that is to say according to 4 areas of particular importance when considering intelligent metering systems: meter value management; roll-out policy; access to data and privacy issues; and functional and technical aspects. Among other things, the report illustrates the diversity of approaches to smart metering, visible in part by the lack of common definitions to key concepts, even at national level.

Future ERGEG output on smart metering is expected in 2010, by means of Recommendations on regulatory aspects of smart metering. This paper shall be based on the above-mentioned ERGEG work on smart metering and take into account two recent initiatives by the European Commission:

- the 3rd Package, envisaging that, subject to the assessment of related costs and benefits, Member States shall ensure the implementation of intelligent metering systems that shall assist the active participation of consumers in the electricity supply market and that Member States shall ensure the interoperability of those metering systems to be implemented within their territories and shall have due regard to the use of appropriate standards and best practice and the importance of the development of the internal market in electricity;
- the mandate M/441 of 12 March 2009 to CEN, CENELEC and ETSI for the development of an open architecture for utility meters involving communication protocols and functionalities enabling interoperability, with the general objective to create European Standards that will enable interoperability of utility meters (water, gas, electricity, heat), which can then improve the means by which customers' awareness of actual consumptions can be raised in order to allow timely adaptation to their demands.

CEER/ERGEG is fully involved in this work and has nominated a permanent representative to the Smart Metering Coordination Group established by ESOs (CEN, CENELEC, ETSI) in order to implement the M/441 mandate.

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