EUROPEAN PARLIAMENT

Smart grids/Energy grids

The techno-scientific developments of smart grids and the related political, societal and economic implications

Science and Technology
Options Assessment

STOA

This project has been carried out by ISIS, Enerdata, IZT and Tecnalia.

AUTHORS

Andrea Ricci and Stefano Faberi, ISIS (project coordinator)
Nicolas Brizard and Brieuc Bougnoux, Enerdata
Melanie Degel, IZT
Daniela Velte and Eduardo Garcia, Tecnalia

RESPONSIBLE ADMINISTRATORS

Miklós Györffi and Theodoros Karapiperis
Science and Technology Options Assessment
Directorate G: Impact Assessment and European Added Value
DG Internal Policies
European Parliament
Rue Wiertz 60 - RMD 00J008
B-1047 Brussels
E-mail: theodoros.karapiperis@ep.europa.eu

LINGUISTIC VERSION

Original: EN

ABOUT THE EDITOR

To contact STOA or to subscribe to its newsletter please write to:
stoa@ep.europa.eu

Manuscript completed in September 2012

This document is available on the Internet at:
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Final Report

IP/A/STOA/FWC/2008-096/LOT1/C1/SC2

November 2012

PE 488.797

Abstract

The report presents the results of a project on the future of Smart Grids/Energy Grids. It discusses technological issues associated with Smart Grids, analyses implications for policy-makers, citizens and society, industry and operators, as well as regulatory and financial conditions.

While current trends point to a continuing growth of the electricity demand in the future, the emergence of advanced thermal technologies may result in partly curbing such growth. Also, the predictable increase in the cost performance of distributed generation might contribute to making off-grid solutions more competitive.

In addition to privacy and security issues, and to the concerns at times expressed on possible health effects, a major change of attitude is needed on behalf of utilities to actively involve and empower end-users.

Full bi-directional interconnection between all network nodes, and the need to ensure real-time exchange of consumption data, call for radical changes in the business models of operators, based on a clear and reliable identification of the benefits induced by the new system and of the extent to which each actor can ultimately accrue a fair share of such benefits.

A new regulatory framework is necessary to ensure the most effective type and level of incentives to stimulate the investments required by the transition towards Smart Grids, while ensuring a level playing field in the sector.

Executive Summary

This document is the final report of a study carried out for STOA on the future of Smart Grids/Energy Grids.

The study primarily relied on intensive deskwork, supplemented by a series of informal interviews with selected stakeholders and by an intense debate between the experts within the consortium.

A first report was issued in April 2011[1], setting the scene and defining the scope of the in-depth investigation then carried out in the second phase of the study.

This Final Report is organized along a logical sequence that starts with the identification and discussion of the technological issues and challenges associated to the deployment of Smart Grids, then analyses constraints and implications for citizens and society, for industry and operators, as well as the regulatory and financial framework conditions. It finally illustrates the current policy perspective and presents a series of policy-relevant conclusions.

The various dimensions thus addressed (technical, economic, social, financial) are strongly inter-related, so much so that it is in fact impossible to deal with any of them without explicitly reflecting on the others.

Accordingly, some redundancies may be found across Chapters, which have deliberately been maintained to ensure that each Chapter is by and large self-sufficient.

Chapter 1 – Techno-Economic Analysis revolves around the three major trends characterizing the current dynamics of the electricity sector: the growth of the electricity share in the overall energy demand, the growth of the share of renewables in the overall electricity generation, and the emergence of efficient solutions to integrate electricity generated from intermittent sources into the grid. While the current trends, along with most of the available forecasts, point at a future continuing growth of the electricity demand, the emergence of advanced thermal technologies (solar, geothermal, biomass) may result in partly curbing such growth. On the other hand, the predictable increase in the cost performance of distributed generation might contribute to make off-grid solutions more competitive. In any instance, the deployment of Smart Grids calls for technological advances not only in the field of energy technologies, but even most importantly, in the area of ICT-based solutions for the extensive data exchange that characterizes Smart Grids.

Chapter 2 – Non-Technological challenges: concerns and critical voices analyses the main implications of Smart Grids deployment on citizens and users. In addition to the well-known privacy and security issues, and to the concerns at times expressed in relation to possible health effects, it shows that to address consumers' doubts on the energy saving effects of Smart Grids, as well as on their equity implication, a major change of attitude is needed on behalf to utilities to actively involve end users and facilitate their empowerment.

[1] Preparatory study: "Outline of the relevant policy and political issues related to the deployment of smart grids"

Chapter 3 – The New Value Chain and Business Models examines the profound restructuring of the value chain entailed by the transition from conventional grids to Smart Grids. Full and bidirectional interconnection between all nodes in the network, and the need to ensure real time exchange of consumption data calls for radical changes in the business models of operators, based on a clear and reliable identification of the benefits induced by the new system and of the extent that each actor can ultimately accrue its fair share of such benefits.

Chapter 4 – Financial and Regulatory Implications of Smart Grids Deployment is a natural complement to Chapter 2, in that it assesses the need for a new regulatory framework that adequately responds to the needs of an effective deployment of Smart Grids. Regulation should primarily aim at ensuring the most effective type and level of incentives to stimulate the investments required by the transition towards Smart Grids, while ensuring a level playing field in the sector.

Chapter 5 – The Policy Perspective illustrates the current state of play at the EU and at the international level, presenting the building blocks of the EU policy targeting the promotion and deployment of Smart Grids, along with the IEA roadmap which includes specific actions to improve the regulatory schemes directed to industrial players, but also to enhance the active role of customers.

Chapter 6 – Conclusions and Way Forward finally summarizes in 18 points the main findings of the study, grouped in 5 main headings: Technology, Regulation, Business, Economics and Society.

TABLE OF CONTENTS

1 TECHNO-ECONOMIC ANALYSIS

1.1 Smart Grids Future Development in the Wider Context of the European Electricity Sector

The expected functionalities of smart grid technologies, as well as the overall objectives pursued through the corresponding investments are presented and discussed in a variety of policy documents and in numerous technical publications that focus on Smart Grids.

From the policy perspective, the large-scale deployment of smart grids targets major impacts in all three dimensions of sustainability (environmental, social and economic). As spelled out by the European Commission[2] and by the EC Smart Grid Task Force, the goals are

- to transmit and distribute up to 35% of electricity generated from renewable sources – both dispersed and concentrated - by 2020, and to achieve a completely decarbonised electricity production by 2050;
- to integrate national networks into a market-based, truly pan-European network, to guarantee a high quality of electricity supply to all customers and to engage them as active participants in energy efficiency;
- to anticipate and prepare for new developments such as the electrification of transport.
- to substantially reduce capital and operational expenditure for the operation of the networks while fulfilling the objectives of a high-quality, low-carbon, pan-European, market based electricity system.

Prior, however, to discussing the implications of smart grid deployment in Europe, the concept of a smart grid should be clarified. The different elements composing a smart grid are best described graphically as in Figure 1.1. A modern electric grid combines the large-scale generation assets that connect to the transmission grid with distributed generation on lower voltage levels. It also allows for bidirectional communication between the network and both the generation and the consumption side, by integrating ICT solutions in the architecture of the electric grid.

[2]European Commission (2011), "Smart Grids: from innovation to deployment". COM (2011)202 final

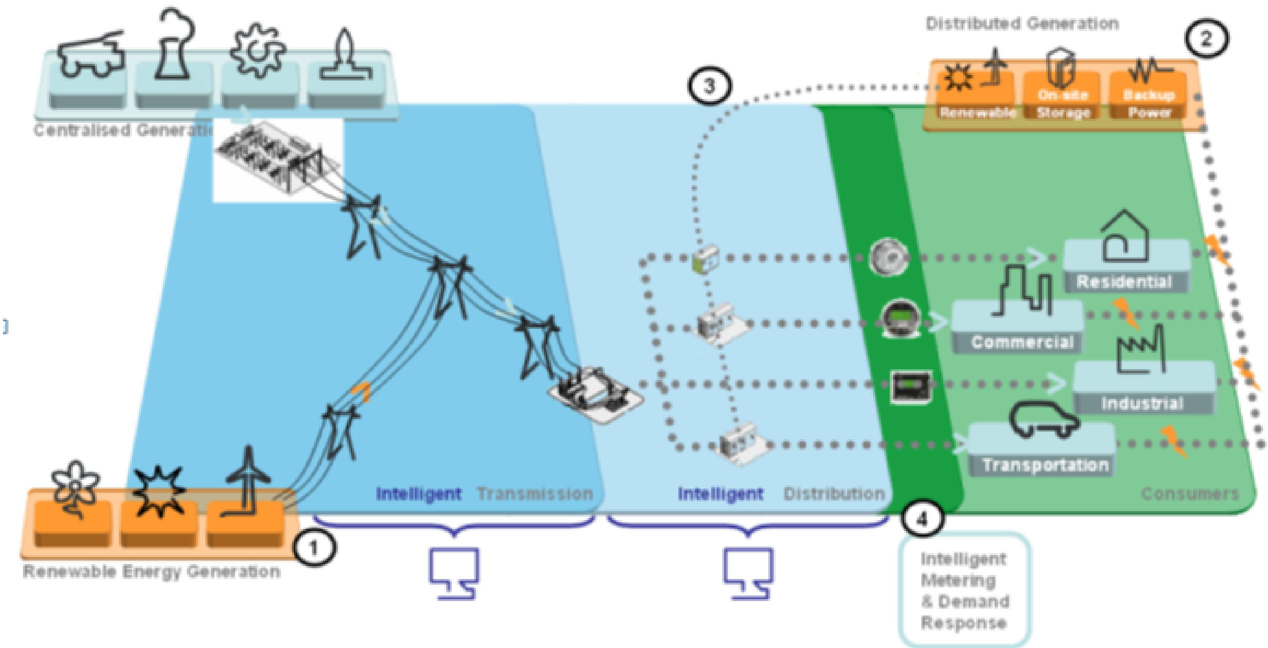


Figure 1.1 Components of a smart grid

Source, Schneider Electric

As previously remarked[3], three fundamental questions characterize the debate on the future development of the European electricity sector, which could strongly influence the deployment of smart grids and therefore need to be thoroughly discussed before analyzing technical and non-technical barriers, regulatory issues and future business models of smart grids:

1. **Which part of future energy consumption will actually be electrical?**
2. **Which part of the new, decentralized electricity production from renewables will actually be fed into the grid and how much will be used for own consumption?**
3. **Which are the most cost-effective solutions for integrating intermittent production from renewable sources and enhancing security of supply?**

These questions are clearly interrelated, as shown in Figure 1.2 below:

[3] ISIS, STOA Smarty Grids –Energy Grids, Preparatory Study. April 2011

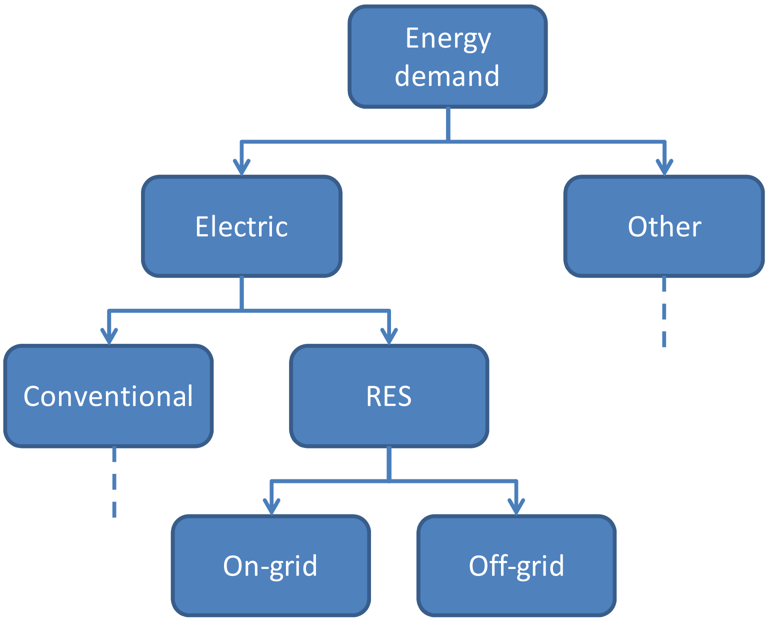


Figure 1.2 The energy production options

Source, ISIS

In the very abundant literature on smart grids, questions related to longer-term substitution trends and transition processes in the energy sector are largely ignored. Grids are seen as the backbones of the electricity supply system, and the main underlying trend is the increased use of electricity in households and the transport sector. In fact, a true "change of paradigm", seems to be presently occurring in the energy sector, which is likely to result in much deeper transformations than anticipated, as actors seek to make a more efficient use of all energy sources and try to bring costs down. Energy is turning from an abundant and rather cheap commodity to a rare and precious one, a fact that is likely to change attitudes and behaviours of consumers, investors and energy companies. The consequences of these changes are not fully grasped yet in scientific literature and mostly ignored in publications on smart grids. It is for this reason that this evaluation report starts by reviewing long-term trends in the energy sector and their implications, before analysing technical and non-technical barriers in detail.

The deployment of smart grids requires a stable, long-term policy framework (up to 2030) to guarantee the necessary investments by the utilities. The major part of these investments will have to be carried out by the distribution companies, which are not yet fully exposed to market competition. A large part of the costs will be passed on to the final electricity user, raising their bills by 8.4% to 12.8%, according to preliminary estimates (EPRI 2011). These assumptions are being made on the background of rising energy prices due to increasing supply restraints for fossil fuels and the outlook of considerable cost reductions for renewable energy technologies in the medium term. This raises the question if customers are able and willing to bear the costs of more expensive electricity supplied by the grid, once reliable supply alternatives come into reach. Furthermore, it is necessary to analyse whether the functionalities expected from smart grids in the electricity sector could be guaranteed by alternative innovative technology options with possibly lower costs and/or greater benefits, which could veer off investment from smart grids to alternative solutions.

In fact, several trends are currently observed that run contrary to an ever-greater reliance on grid-delivered electricity, as envisaged by the promoters of smart grids and e-mobility (see, for example the IEA Technology Roadmap Smart Grids, published in 2011). Among such trends are the increased penetration of renewable sources for heating, hot water and cooling, grid parity[4] of photovoltaic modules, and progress towards affordable storage solutions for the medium and low voltage grids. These innovations will have an impact on peak demand for electricity, as well as on the functions of smart grids and are therefore examined in detail below.

Finally, the techno-economic analysis must include the correct quantification of costs and benefits of smart grids in comparison to competing technologies, and their potential contribution to overarching policy objectives, such as enhanced security of supply.

1.2 The share of electricity in total energy demand

1.2.1 Changing patterns of energy uses

The International Energy Agency expects overall electricity consumption to increase slightly in OECD Europe until 2035, according to the *New Policies* Scenario. The greatest increase is anticipated in the transport sector, with an average growth of 2.3% between 2008 and 2035. However, these rather linear projections should be tested against the trend towards fuel substitution through greater use of "modern" renewables for heating, hot water and cooling (biomass and biofuels, geothermal, solar-thermal) and alternative, synthetic transport fuels (methanol, hydrogen). Also, a possible trend-break in the form of a major progress towards energy efficiency - in response to rising energy prices for households and industry – cannot be discarded.

Figure 1.3 shows the present growth rates for different energy sources worldwide.

So far, the switch from conventional to renewable resources is bearing the most visible impact not so much on electricity use, but rather on the decreasing consumption of oil and gas for heating and transport purposes, mainly in Central and Northern Europe. However, impacts on the electricity sector could become stronger with the spreading of renewable energy technologies in countries that rely massively on electricity for heating and cooling purposes. Figure 1.4. shows the differences in electricity consumption patterns in households in the EU Member States. Greater use of electricity for thermal purposes is made in countries with a high share of nuclear generation capacity, but also in Southern countries with limited demand for heating, such as Spain, remains to be ascertained is whether these demand patterns are likely to change, due to the increased use of, for instance, geothermal energy for heating purposes or solar-thermal energy for cooling. These two examples are discussed below in some detail.

[4] Grid parity means that the cost of self-consumption is lower than electricity sourced from the grid. A discussion can be found at http://thinkprogress.org/romm/2011/06/23/251120/pv-panel-prices-continue-dropping-grid-parity-not-magic-bullet-for-solar/

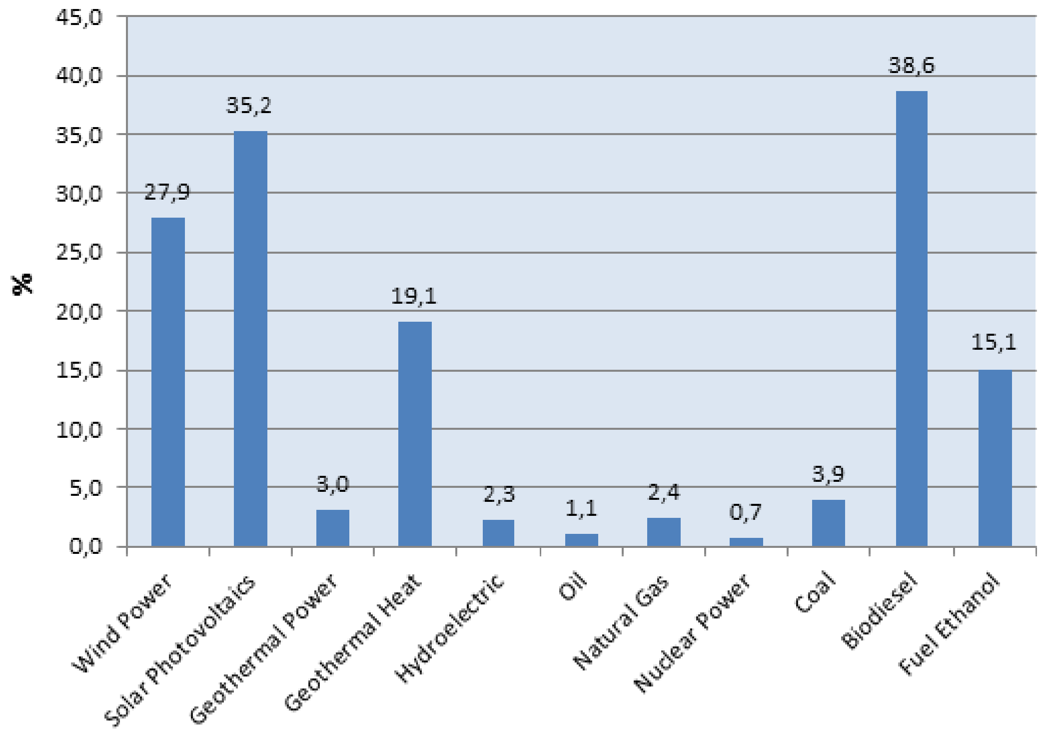


Figure 1.3: Word Energy Growth Rates by Source 2000 - 2009,

Source: Earth Policy Institute. (Data available online).

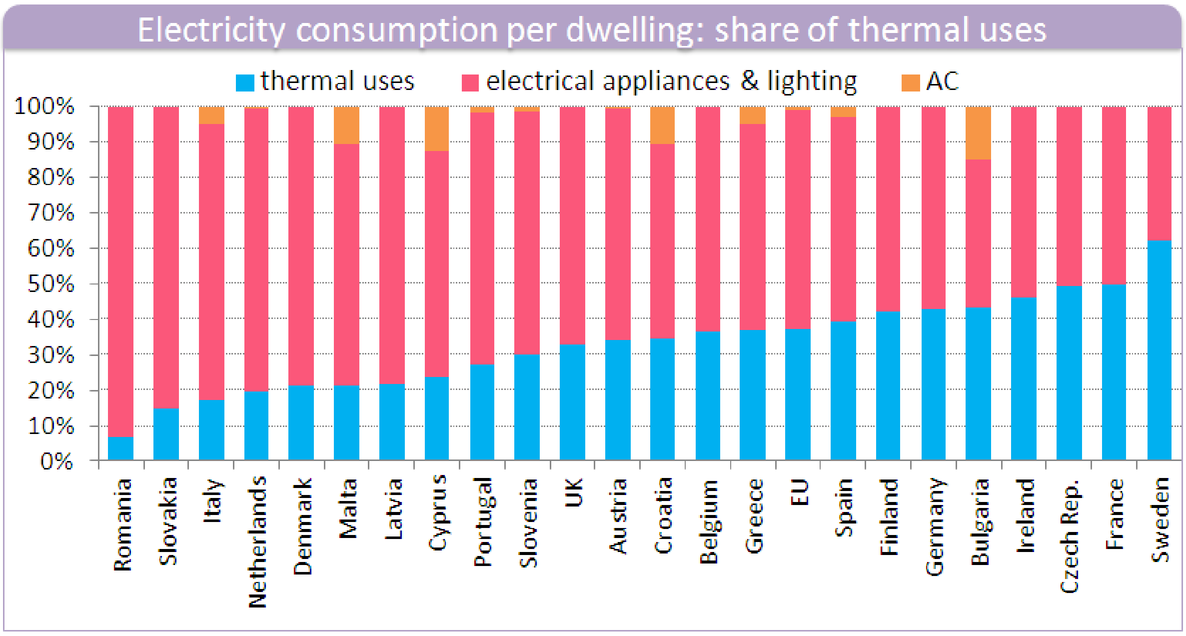


Figure 1.4. Electricity Uses per Dwelling in the EU Member States, share of thermal uses (Nov. 2011)

Source: Enerdata

1.2.2 Advanced Heating and Cooling Systems

The implications of present substitution trends on future electricity consumption are complex. A meaningful illustrative example of such complexity can be found in the market of geothermal energy and its direct use for heating purposes, in combination with heat pumps. Figure 1.5 shows how the use of geothermal energy is spreading from Northern and Central Europe to Eastern and Southern countries, according to industry representatives.

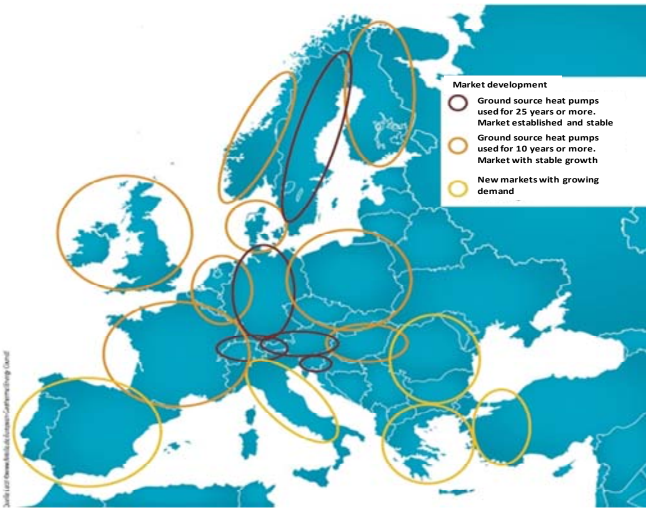


Figure 1.5 Geothermal Energy in Europe

Source: Adapted from European Geothermal Energy Council EGEC (Sanner et al 2010)

Direct use of geothermal energy for heating purposes is curbing the demand for oil and gas, but the heat pumps necessary for geothermal heating have induced a rise in electricity consumption, which is presently drawn from the grid. However, heat pumps that source their electricity from PV modules are already commercially available[5], so that the initial surge of electricity demand for heating could soon be reversed. The successive substitution processes, that could unfold quickly, are highlighted in Figure 1.6

[5] See, for example, http://www.centrosolar.de/, which combines PV modules with heat pumps for hot water supply

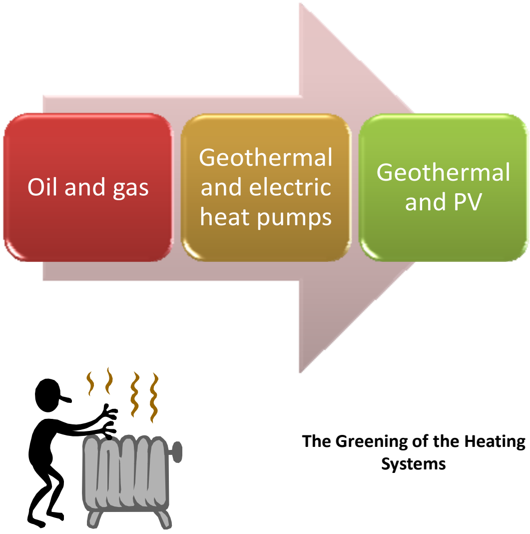


Figure 1.6. The Greening of the Heating Systems.

Source: Own elaboration

As concerns cooling systems, on the other hand, the substitution effect on electricity consumption through greater use of thermal energy will probably be stronger once solar cooling technologies enter the market, as cooling needs are increasing all over Europe and are presently mainly covered by electrical appliances.

The potential energy demand for cooling in Europe is nearly 1.400 TWhc, with ca. 41% attributed to the service sector and 59% to the residential sector. Should European countries reach saturation levels similar to the US in 1999 (70% for the residential sector and 73% for the service sector), the additional electricity demand for cooling for the EU 27 plus associated countries would further rise to 400 TWh / year (base year 2006). Figure 1.7 displays the expected growth in primary energy demand (MTOE) up to 2050 for cooling purposes in Europe.

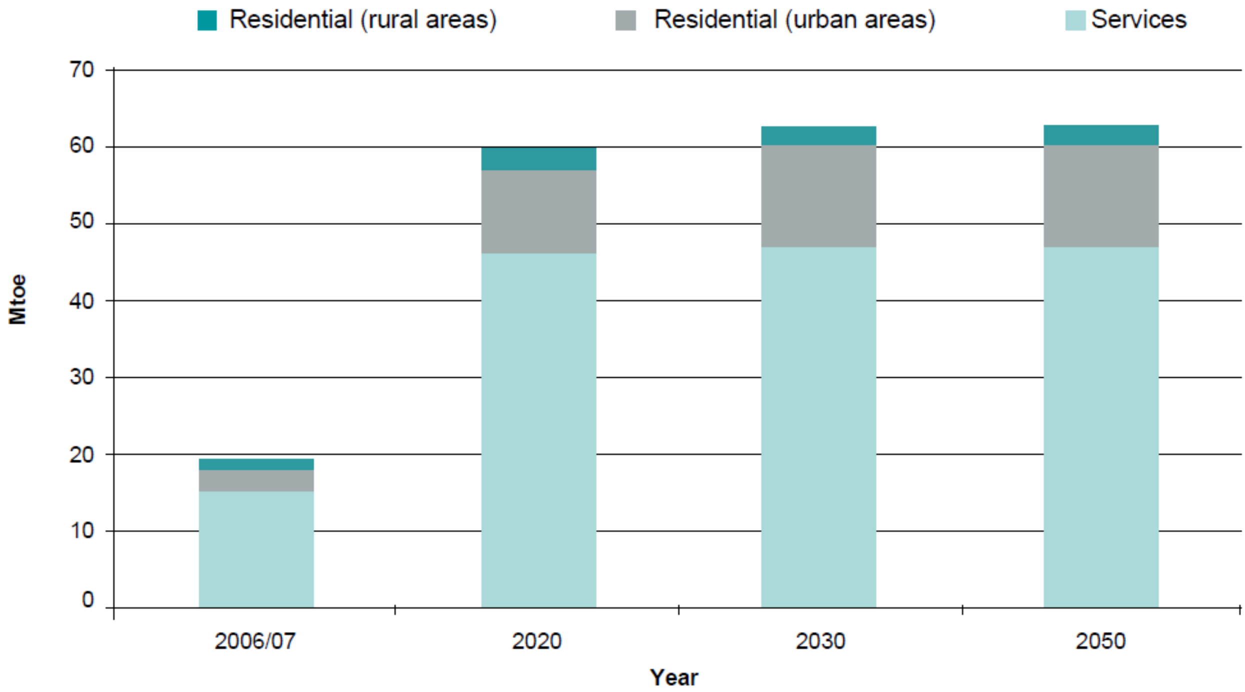


Figure 1.7. Expected evolution of cooling demand in EU

Source: European Technology Platform on Renewable Heating and Cooling

With commercially available solar-assisted cooling systems, primary energy savings in the range of 40 – 50% can be achieved in southern European and Mediterranean areas (Treberspurg, M. et al 2011). District cooling systems, which presently only account for 1-2% of the cooling market, are expected to become more widely diffused in coming years. Such systems will therefore perform one of the functions that Smart Grids are expected to fulfil – that of flattening out the demand curve, at least in Southern locations. Advanced district heating and cooling systems, operating at lower temperature than old-fashioned systems and supported by renewables (solar, geothermal, biomass) and / or combined heat and power (CHP) plants, are most profitable in economic and environmental terms in densely populated urban areas. The networks permit to tap a yet largely unexploited source of energy – waste heat from industrial and other incineration processes - and are therefore subject to in-depth studies by the International Energy Agency. The European DHC platform (2011) calculates that advanced networks could reduce primary energy consumption by 2.14 EJ (595 TWh) per year, corresponding to 2.6% of entire European primary energy demand as early as 2020.

The above summary review indicates that the presently observed surge of electricity demand for certain thermal uses will most likely be curbed by technologies favouring the direct use of thermal energy, assisted by renewable energy sources, reducing stress of peak consumption on the distribution networks. However, there may still be arguments for making the networks, including local ones, smarter, but proposals in this sense should be based on the realistic acknowledgment of all available alternatives.

1.3 The share of decentralized renewables in the total electricity demand

1.3.1 Competition between self-produced and grid-sourced electricity

Costs and market prices of renewable electricity are expected to steadily fall in coming years, as shown for example in Figure 1.8 for PV modules.

As a result, the International Energy Agency estimates that PV will be able to compete at end-user level with grid-distributed electricity from fossil fuels in some locations as early as 2020. A recent analysis by Ernst & Young (Ernst & Young 2011) foresees that, in the UK regions with the highest solar radiation, grid parity could even be achieved earlier, by 2017. According to the sector association EPIA, grid parity will first become a reality in the commercial market in some regions in Italy, probably by 2013, due to a combination of high electricity prices and strong solar potential. If affordable storage options become available, consumption patterns in the energy market could shift considerably towards more and more self-production and direct consumption of electricity. In the case of PV, future market and regulatory developments will play a major role in determining which share of the new capacity will ultimately be used for direct consumption and not be fed into the grid. The revised German law on renewable energy, for example, grants higher subsidies to projects where more than 30% of production is directly consumed (Chrometzka, 2010). Unfortunately, the issue of direct consumption is not discussed in the IEA reference scenarios for developed countries, calling for close monitoring of trends in PV installation, especially in countries that place forceful emphasis on the prioritization of direct consumption.

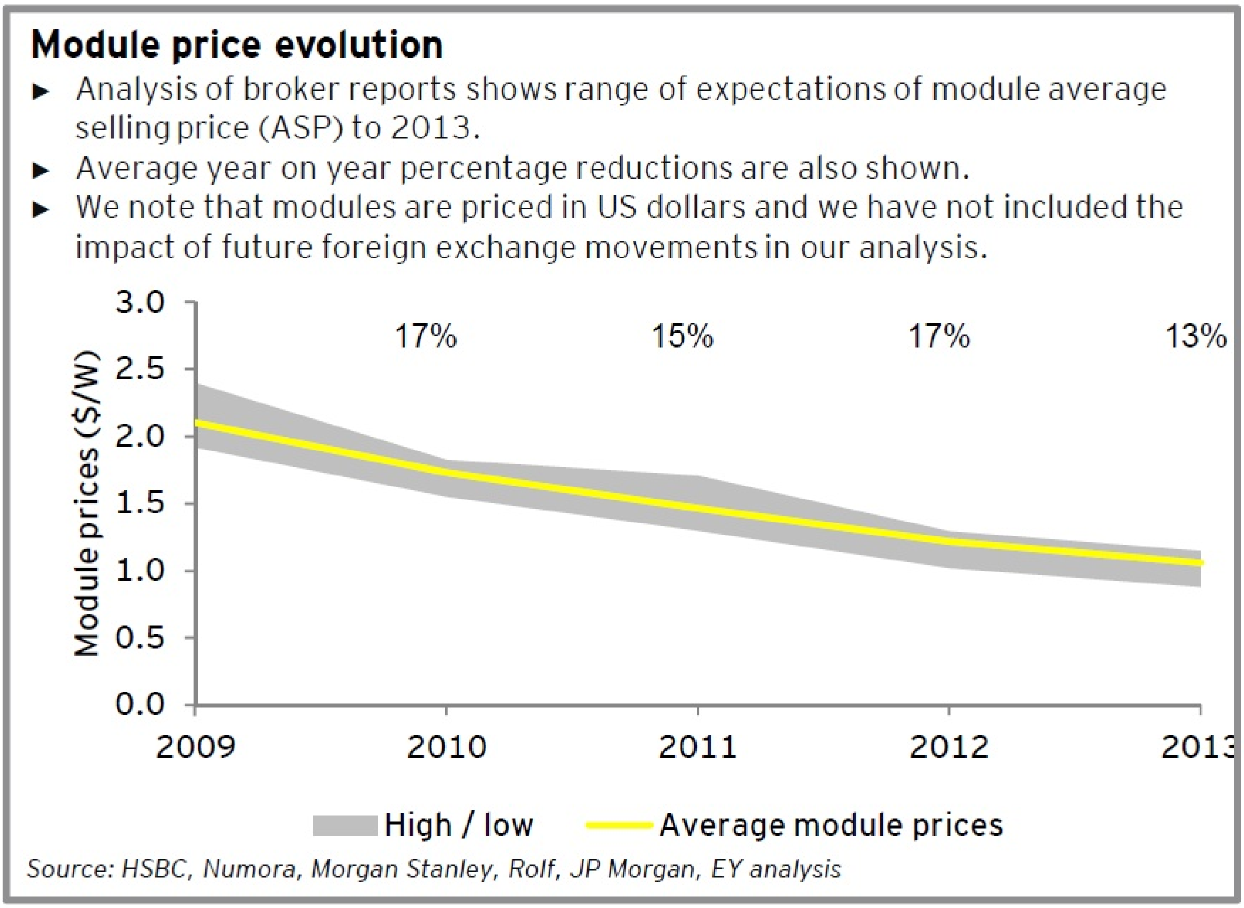


Figure 1.8: Expected cost reduction of solar panels for the years 2010 – 2013

Source Ernst & Young 2011

1.3.2 Smart Grid Benefits: The Value of Security of Supply

Against the uncertainties surrounding the future balance between grid-supplied electricity and self-consumption, smart grids feature a major advantage in terms of reliability.

Reliability – along with affordability and decarbonisation – are in fact the main challenges that the electricity sector is confronted with for time to come. Due to the penetration of ICT appliances in businesses and households, the world has become extremely vulnerable to supply interruptions, which can cause considerable costs to individual consumers and the overall economy, as shown in the examples below.

Table 1.1: Price and Value of Electricity Reliability in the Information Age

Industry	Average cost of down time ($)
Average small business	7 500 /day
Cellular communication	41 000 /hour
Telephone ticket sales	72 000 /hour
Airline reservations	90 000 /hour
Credit card operations	2 580 000 /hour
Brokerage operations	6 480 000 /hour

Source: Weinberg, 2001

This increased vulnerability of customers has motivated electricity providers to investigate the "value of lost load (VOLL)" for households, industry and the general economy. A comparison of recent studies carried out for RWE (Frontier Economics 2008) shows that the average cost of supply interruption is approximately 10 € / kWh, with however considerable variations, depending on sectors and scenario assumptions with regard to the length of supply interruptions (Figure 1.9)

An interesting country comparison in the same RWE study explains that if supply quality in Germany sank to Spanish levels, losses to the general economy would amount to 1,500 to 3,200 million € per year. The conclusion from this string of research is that technologies, which help to avoid power outages, have a much greater value from the macroeconomic point of view than the purchase price of electricity. If smart grids manage to contribute considerably to stabilizing the grid in feeble or "island" networks, the investment will pay off quickly in macroeconomic terms.

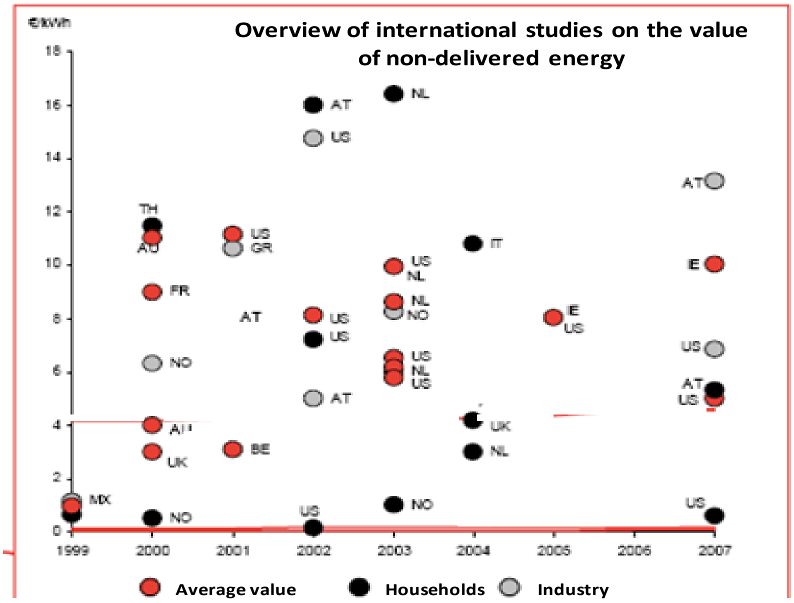


Figure 1.9: The value of non-delivered energy.

Source: Frontier Economics 2008

Indeed, security of supply has an economic value, which however needs to be assured by regulators, since utilities do not pay the full cost of power outages[6]. These costs can be divided in direct losses (damage) and indirect (loss of opportunity), with estimates varying considerably, especially with regard to the residential sector, as shown in Table 1.2

[6] See also page 18: "…Once the actual damage of the lack of power quality and power outages has been exactly determined and utilities can be fully held reliable for the costs incurred by the customers, investments in the upgrade of grids will likely be accelerated…"

Table 1.2: Comparison of Outage Cost Studies for Residential Consumers

Table 1
Comparison of outage cost studies for residential consumers[a].

Reference	Country	Method	Outage cost (€/kWh)
Anderson and Taylor (1985)	Sweden	Survey	3.57
Baarsma and Hop (2009)	Netherlands	Survey	3.66
Balducci, Roop et al. (2002)	USA	Survey	0.18
Bertazzi, Fumagalli et al. (2005)	Italy	Survey	10.89
Billinton and Wangdee (2000)	Norway	Survey	0.55
Bliem (2005)	Austria	Macroeconomic	16.63
Bliem (2008)	Austria	Survey	5.30
Burns and Gross (1990)	USA	Survey	5.72
de Nooij, Koopmansb et al. (2007)	Netherlands	Macroeconomic	16.38
Jenkins, Lim et al. (1999)	Mexico	Macroeconomic	0.75
Kjølle, Samdal et al. (2008)	Norway	Survey	1.08
Krohm (1978)	USA	Survey	2.46
Lawton, Sullivan et al. (2003)	USA	Survey	7.80
Tol (2007)	Ireland	Macroeconomic	68.00
Sanghvi (1982)	USA	Survey	0.48
Wilks and Bloemhof (2005)	Netherlands	Survey	21.62

[a] Outage costs in other currencies were first inflated to 2007 and were then converted into Euros. The necessary data were taken from International Monetary Fund (2010). World Economic Outlook Database.

Source, Praktiknjo, et al., 2011

Recent modelling calculations for a 1-hour supply interruption in Germany suggest that the average residential VoLL (Value of Lost Load) is 15.70 €/kWh, which is close to the results of the studies in the neighbouring countries also applying macroeconomic approaches (16.38 €/kWh in the Netherlands and 16.63 €/kWh in Austria). Damages are of similar dimension in the service and transportation sector, but considerably lower for agriculture, industry and public administration, as shown in Table 1.3 .

Table 1.3: Comparison of Outage Cost Studies for Residential Consumers.

Table 2
Results for outage costs for commercial, industrial and agricultural consumers.

	Value added or taxes in 10^9 €	Electricity consumption in TWh	VoLL in €/kWh
Agriculture	19.93	8.5	2.34
Industry	653.20	255.3	2.49
Commerce, service and transportation	1.499.05	91.7	16.35
Public administration	251.62	45.5	5.53

Source: Praktiknjo, et al., 2011

The quality of service and the frequency of interruptions vary considerably between the old and the new Member States, as shown in Figure 1.10 below.

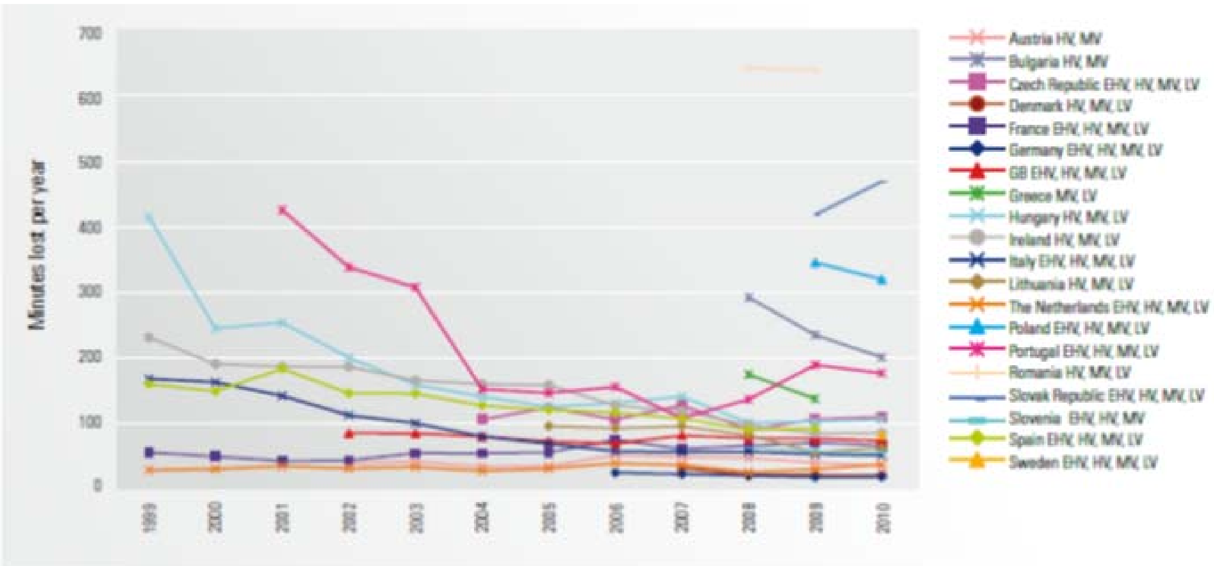


Figure 1.10: Power Outages (minutes lost per year) 1999 - 2010.

Source: CEER 2011

In general, however, concerns about power outages in the European Member States are growing, as the recent French System Adequacy Report shows.

Table 1.4: Risk of Power Outages in France. [7]

"Baseline" scenario

	2013	2014	2015	2016
Unsupplied energy expectation (GWh)	0.2	0.8	2.8	27.4
Loss of load expectation	0h05	0h22	1h14	8h50
Capacity shortfall	-	-	-	2.7 GW

Source: RTE, 2011

If it is demonstrated that smart grids contribute significantly to improving security of supply, the argument for "socializing" investment costs for this purpose is strong – if they are lower than the costs of power outages.

However, the actual cost of power outages needs to be researched further, as the macro-economic estimates used in most recent studies may tend to overestimate the damages, which vary not only between customer groups, but also depending on the season, the day of the week and the time of the day. The US Regulator NARUC (National Association of Regulatory Utility Commissioners 2011) recently mandated an analysis of the methodologies employed for defining the cost of power outages in different US States as a basis to estimate reliability benefits from smart grid deployment. The study concludes that the present database is insufficient and that the utilities should evaluate these costs on the basis of actual events (supply interruptions and power quality disturbances) and customer surveys, but not on macroeconomic estimates.

The European regulators are working in a similar direction, favouring survey or case study-based approaches, according to the "Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances", published in 2010. The report on which these guidelines are based (Hofman 2010) shows clearly how the cost of supply interruptions varies depending on the method of measurement and national particularities. The national studies are not comparable, so no definite range of damage estimates and possible smart grid reliability benefits can be given for the moment. Once the actual damage of the lack of power quality and power outages has been exactly determined and utilities can be fully held reliable for the costs incurred by the customers, investments in the upgrade of grids will likely be accelerated.

Utilities are, for their part, developing their own tools, for example the Smart Grid Maturity Model,[8] to calculate the most appropriate level of smartness in their grids, the costs and the associated return on investment.

7 The expected capacity shortfall in France derives from the closure of several thermal power plants (coal and fuel) in 2015 and the expected gradual decline of electricity imports to about 4 GW in 2016.

8 Software Engineering Institute, Carnegie Mellon USA (http://www.sei.cmu.edu/smartgrid/tools/index.cfm)

1.4 Technology trends affecting the deployment of smart grids

1.4.1 Developments in the Electricity Storage Market

This section addresses the third fundamental question surrounding the development of smart grids: which are the most cost-effective solutions for integrating intermittent production from renewable sources and enhancing security of supply? In this context, developments in the electricity storage market are critical. Efficient, reliable and economical storage options via advanced batteries are crucial for the further deployment of small and large-scale renewable sources and may either be a complementary element to smart grids or a competing technology. R&D efforts seeking to bring down the cost of electricity storage are presently being pushed both in the US and in Germany, as well as in some other EU Member States, but it is not yet clear which will be the winning technology. As shown in Appendix 1 there are approximately 40 promising technologies under development for just one storage option – flow batteries – and the number of demonstration projects is increasing. With some intervention from legislators economic realities could change quickly. Legislators in California, for example, approved in September 2010 a bill (AB 2514) that makes a storage capacity of 5% of peak load obligatory by 2020.

Small-scale storage on the low voltage grid is one of the main elements for smart grid concepts on the distribution and community level. It is also a key factor for the economic competitiveness of distributed generation, because smoothing the outputs from renewable energy sources such as wind, wave and photovoltaic allows the proportion of energy supplied by these technologies to increase from around 20% to 50% without creating instabilities in the network. Theoretically, advanced and cheap batteries could make it possible for households and communities, especially in rural areas, to become self-sufficient in terms of energy or to sell the locally produced energy to the grid when prices are high (see Box 1).

Box 1: The Ceramatec Battery

Ceramatec Battery, Salt Lake City, US

Ceramatec, R&D arm of CoorsTek, a worldwide producer of advanced materials and electrochemical devices, has announced that in 2011 it will start to test a new sodium-sulphur battery capable of storing 20 to 40 kWh of electricity in a package about the size of a refrigerator, which operates below 90º C. The battery can deliver a continuous flow of 5 kW of electricity over four hours with 3,650 daily discharge / recharge cycles over 10 years. At a price of $ 2,000, this translates to less than 3 US cents per kWh over the battery's life. The battery can be charged by PV modules or wind turbines. Full-scale production is slated for 2014. The company announcement, made in mid-2009, raised expectations in the public and among energy experts, since Ceramatec holds a long list of patents and is considered a serious player in the field. Since then, the company has not issued further news on the subject, but seems to be moving on to commercialization.

Table 1.5 in the following page offers an overview of the characteristics of the main storage technology families which are either mature or close to commercial development.

Information on the costs of the different storage technologies is rather abundant but often inconsistent and therefore hardly conclusive. First-time investment costs differ widely, from $ 1,000 to more than $ 4,000, as shown in Figure 1.11 at page 28. This figure actually shows the present density ranges of the different storage technologies (blue boxes), as well as their cost in relation to the different functions (for example short-term voltage regulation or long-term bulk storage) performed in the electricity system. The values have been estimated by the Electricity Storage Association (Electricity Storage Association, 2010) based on expert judgment on the compared “costs of ownership” of devices over ten years, therefore accounting for:

• The application itself,

• Efficiency,

• Cycle life

• Initial capital costs

• Operations and maintenance (O&M), and

• Storage-device replacement.

Table 1.5: Characteristics of Different Storage Technologies

Storage Technology	State of Development	Advantages	Disadvantages	Efficiency	Response time	Scale
Pumped hydro	Commercial	High capacity, low cost	Special site requirements	65-80%	Hours to days	**Large-scale (10 MW – 1 GW)**
CAES Compressed Air	Commercial	High capacity, low cost	Special site requirements, need gas fuel	70 - 80%	Hours to days	**Large-scale (100 MW – 1 GW)**
Flow Batteries: **PSB, VRB, ZnBr**	ZnBr: precommercial VRB: commercial	High capacity	Low energy density	70-95%	Seconds to weeks	**10 kW – 100 MW**
Lead-Acid Battery	Commercial	Low capital cost	Limited life-cycle when deeply charged	80 - 90%	Seconds to weeks	**Small-scale up to 20 MW**
Sodium Sulphur Battery	Commercial	High power and energy density, high efficiency	Production costs. Only one producer worldwide	85 - 90%	Seconds to weeks	**5 kW- 200 MW**
Lithium-Ion Batteries	Grid application: developmental	High power and energy density, high efficiency	High production cost, requires special charging circuit	70-95%	Seconds to weeks	**1 kW – 2 MW**
Flywheels	Commercial (local power quality); pre-commercial (grid device)	High power	Low energy density	90 – 95%	Minutes	**10 kW – 2 MW**
Superconducting (SMES)	Demonstration phase	High power	Low energy density, high production costs	90%	Seconds	**10 - 100 MW**
Supercapacitators	Demonstration phase	Long life-cycle, high efficiency	Suited for short-term, high power applications	>90%	Seconds to minutes	**Micro to large scale**
Hydrogen loop (underground tavern)	**Developmental**	**Low cost**	**Low efficiency, site-dependent**	**30-50%**	**Hours to days**	**Large-scale**

Source: Tecnalia

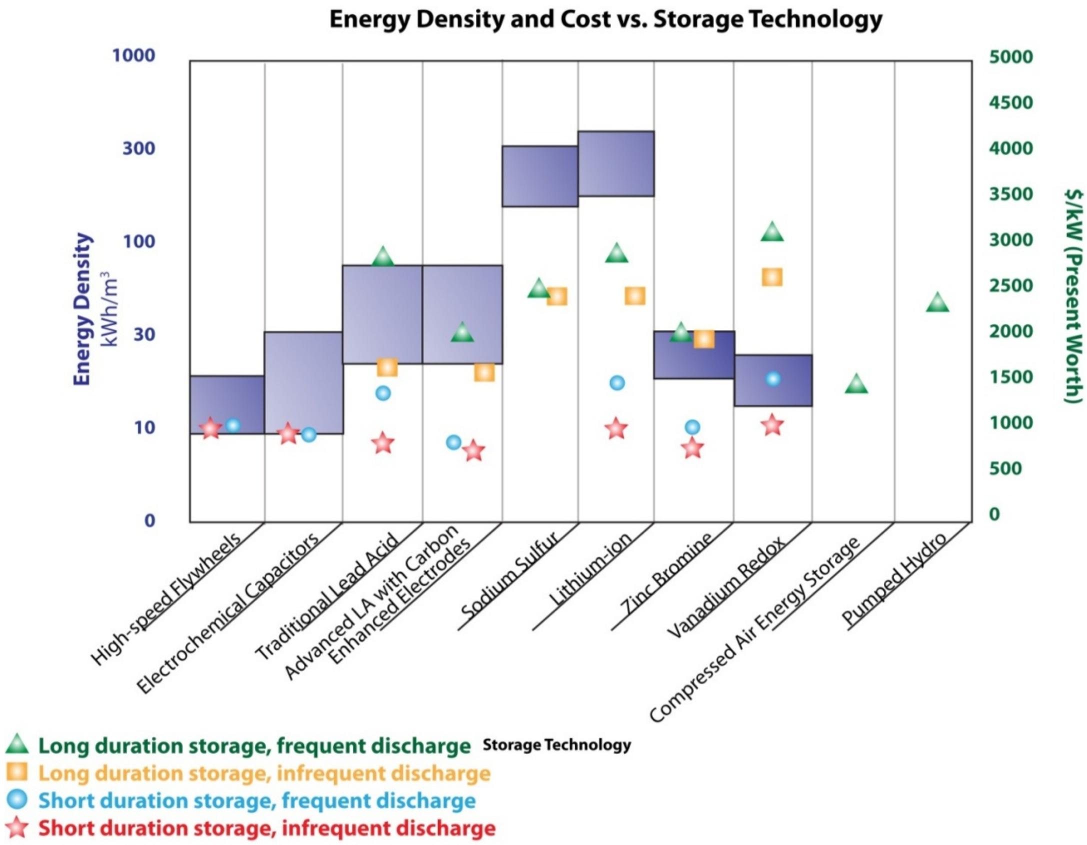


Figure 1.11– Cost and Capacity (density) of Electricity Storage Technologies.

Source: Electricity Storage Association

The target set in the US research program ARPA is a final cost for storing energy of less than $ 100 / kWh, an objective that all financed projects have vowed to comply with.

Advanced storage systems are presently installed in island networks, such as Cyprus and Hawaii, and are being tested by utilities in areas with high penetration of renewable energy installations. These are the same niche markets that smart grids are aiming at during the initial phase of deployment (JRC, 2011), but smart grid promoters foresee, in the longer run, to make use of a large fleet of electric vehicles for storing electricity, instead of other storage options.

The technology that looks most promising today for mobile applications is that of lithium-ion batteries, with considerable funding going into research projects, for example in the UK and in Germany. The German "Innovation-Alliance LIB 2015" groups sixty stakeholders from industry and research with the objective of delivering, by 2015, a more efficient, cheaper and safer battery for electric cars and thus achieving progress in the "National Development Plan for Electromobility". The batteries need improvements with regard to cost, energy density, weight, lifetime and charging speeds, but also to recyclability (Innovationsforschung, 2010).

The economic viability of storage technologies depends on the same set of regulatory key actions that determine the competitiveness of smart grid appliances. For households, the following factors are decisive:

Development of household prices for electricity and real-time pricing that reflects price oscillations during times of higher and lower demand: Modelling exercises (Ahlert 2009) suggest that at least eight different types of tariffs need to be established to make optimum use of price differences. This would allow households to save up to 17% of their annual electricity bills, even without selling electricity back to the network. These economic saving potentials would materialize if prices sink to 175€ / kWh for lead batteries and 375 € / kWh for lithium-ion batteries (due to the greater capacity of the latter). These calculations were made assuming a household electricity price of 18 c/kWh and higher electricity prices would obviously make investments in storage pay off earlier.

The factors are slightly different for network-based appliances, as the evaluation of costs and benefit largely depends of the concrete design of a specific network, as well as on the pricing of the so-called "arbitrage" or "ancillary services", which provide stability to the grid. Modelling calculations for a typical distribution system structure in Germany (Schroeder 2011) indicate that storage devices will pay off at an investment cost of 350 € / kWh, which however increases up to 850 € / kWh when intermittent and uncertain wind production and demand patterns are considered. This means that even more expensive nickel-cadmium or nickel-metal hybrid batteries are already profitable in networks with strong fluctuations of production and demand.

Limits to the profitability of demand-side management measures are much tighter, with the model suggesting that all-inclusive investment must not go beyond 200€ per customer. However, the break-even point for investment into DSM increases up to 700€ when 10% of consumers own electric vehicles, as it is more profitable for EV owners to use smart charging options than central storage.

1.4.2 Integration of renewables

Feeble or "island" networks are limited in their capacity to integrate intermittent generation, while larger grids can absorb a 30% penetration rate of wind power, with already available technologies (Deholm et al 2010), since a higher number of production sites in different locations levels out the intermittency of wind parks (as the wind is blowing at different times in different areas). The effect of PV systems on the network has not been as widely studied as that of wind power, and the question if PV can be more easily incorporated into the network by smart grids or advanced batteries is not yet resolved. In any instance, both types of technologies are being deployed in parallel, so that investors will be able to carefully weigh these alternatives as regards their technical and economic impact.

1.4.2.1 Forecasts of New Generation Capacity from Renewable Sources in the European Union

Overall, it should be noted that the need for upgrading and extending the high-voltage network is primarily related to the construction of large offshore wind parks with high levels of production that must be adequately integrated and stored. Many renewable energy sources, and especially wind power, feature two characteristics that pose problems for grid operators: they are generally spatially dispersed and their production is intermittent, depending on variable climate conditions. Wind turbines, furthermore, tend to disconnect from the grid in response to disturbances, which can lead to a sudden fall-out of a major part of electricity production. The higher the share of renewables in total electricity production and the lower the level of interconnectedness of the grid, the greater are the challenges of managing the integration of this type of production. Ultimately, if capacities to balance the power grid are not sufficient to cover the instabilities of wind power production, this generation capacity is simply considered "non-usable" by grid managers (ETSO, 2008)

On the other hand, production from renewables will have to be increased considerably to meet the EU's 20-20-20 objectives. This is reflected in different reference documents, for example the International Energy Agency's most recent forecast ("New Policy Scenario"), which foresees 134 GW of new wind power capacity by 2020 in the European Union, as shown in Figure 1.12 below:

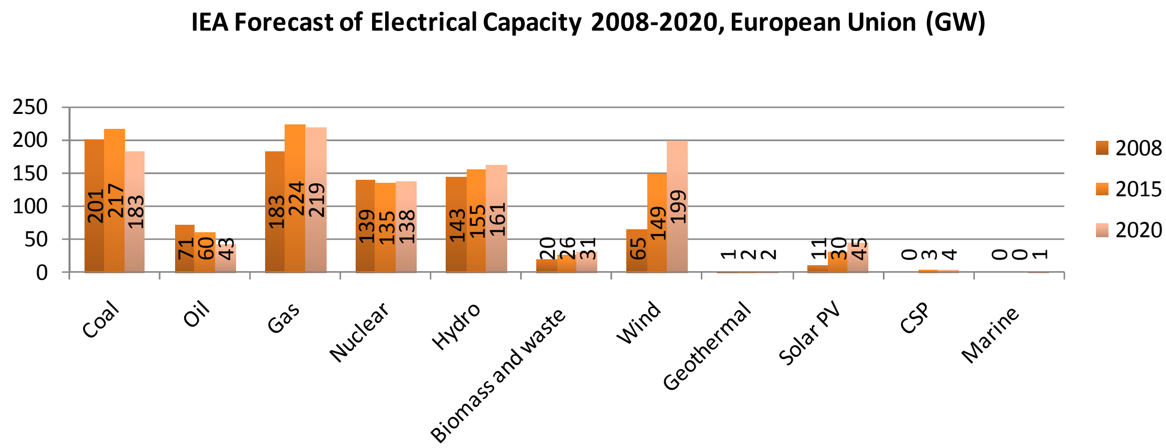


Figure 1.12: IEA Forecast of New Electrical Generation Capacity in the European Union 2008 - 2020

Source: Tecnalia elaboration based on IEA data (IEA, 2010)

The European grid operators' projections for newly installed wind capacity are slightly higher than the IEA forecast. According to the two scenarios (A and B) elaborated by the European Network of Transmission System Operators, ENTSO (ENTSO-E, 2011) as a planning base, the contribution of renewable energy facilities to installed capacity will increase heavily until 2025 – between 6.02% and 7.95% per year. The higher figures in Scenario B reflect a situation in which nuclear capacity is not being expanded. The operators have also calculated - in a third top-down scenario "EU 2020" – the future generation mix resulting from the implementation of the National Renewable Energy Action Plans, in which fossil fuel generation is 4% lower than in the conservative scenario B.

	Scenario EU 2020				Scenario B				
[GW]	2011	2015	2016	2020	2011	2015	2016	2020	2025
Nuclear Power	135	138	136	145	135	138	136	146	154
Fossil Fuels	453	469	463	435	458	489	485	475	472
Total RES Capacity	288	386	411	512	278	355	372	440	489
Non-RES Hydro Power Plants	52	56	60	70	52	57	60	71	75
Not Clearly Identifiable Energy Sources	7	9	9	11	7	9	9	11	12
NGC	936	1057	1079	1173	930	1048	1062	1143	1203

Table 4.8:
The comparison of ENTSO-E total NGC between Scenario EU 2020 and Scenario B, January, 7 p.m.

Figure 1.13, Comparison of ENTSO-E total installed capacity between Scenario EU 2020 and Scenario B

Source ENTSO-E, 2011

The operators have also estimated how the new renewable capacity that needs to come on-line to comply with the EU's 20-20-20 objective could be attributed to the different renewable energy sources as shown in Table 1.6

Table 1.1 which shows the foreseen renewable capacity for the EU 27 countries plus Norway, Croatia and Iceland. At country level, the greatest contributors in terms of new production from renewables will be Germany (45.8 GW), Spain (39.9 GW), France (26.8 GW), Italy and Great Britain (both about 17.5 GW).

Table 1.6: ENTSO Forecast of New Renewable Generation Capacity 2020

	2015					2020				
GW	Wind	Solar	Biomass	Hydro	Total RES	Wind	Solar	Biomass	Hydro	Total RES
Total*	**142**	**55**	**29**	**154**	**385**	**219**	**87**	**39**	**163**	**512**

Source: Own elaboration based on ENTSO data (ENTSO-E, 2011)

1.4.2.2 *Integration of wind energy*

The European Wind Energy Association (EWEA) goes even further and estimates that meeting the European Commission's ambitions would in fact require as much as 265 GW of wind power capacity, including 55 GW of offshore wind by 2020 (EWEA 2009), but this implies that present grid access barriers can be overcome. Bottlenecks in the form of overloads have already been observed in times of high wind production in Germany, Czech Republic, Poland, Belgium and the Netherlands: as noted by the European Transmission System Operators, "*A regional concentrated high wind power generation which is producing a high surplus of power generation such as in Northern Germany results in temporary large load flows through the neighbouring transmission systems. These unscheduled flows could reduce system stability and increasingly affect trading capacities*" (ETSO, 2007)

Advanced control systems

To address this challenge, grid operators are increasingly recurring to advanced ICT instruments in order to better integrate the production from wind parks. One example is the CECRE Renewable Energy Control Center, a pioneer project of the Spanish grid operator Red Electrica (REE), started in 2006. CECRE receives real-time information from twenty-three control centres every twelve seconds, indicating the state of connections, production and load. This data is continuously evaluated by a sophisticated software program that determines how much of the production from renewable sources can be fed safely into the grid. When the production from wind parks is higher than needed or unstable, CECRE sends an order to switch off turbines and the wind park operator is then compelled to shut production down within 15 minutes. This situation typically occurs with higher than average wind speeds, which provoke power surges, or during times of low demand, for example at night. As explained by the system operator REE, such a tool is essential for the Spanish electricity market that, owing to its low interconnectedness, does not allow for exporting excess wind energy production.

Improved forecast

A further option to better handle wind production is improved forecast. Present systems can correctly estimate 80% of wind power production of a single wind park (Klobasa, et al., 2009) and up to 95% in larger production areas (day-ahead forecast, according to Giebel (Giebel G. et al, 2007)). The tools for forecasting wind energy production have improved considerably and error margins (RMSE - Root Mean Square Error) have been reduced from 10% in 2001 to below 7% in 2006 in the German region served by grid operator EON (Lange, et al., 2006), as shown in Figure 1.14 below

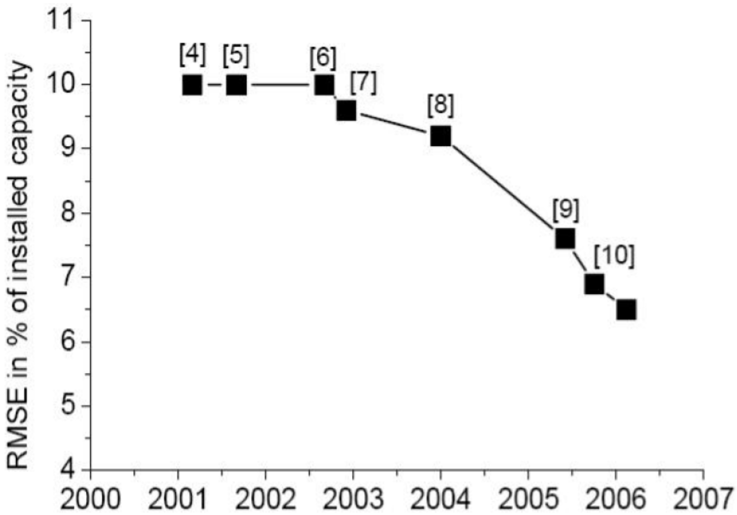


Figure 1.14: Forecast Accuracy of Wind Production 2000 – 2006

Researchers claim that there is still room for improvement in forecasting the production from wind, (Klobasa, et al., 2009) especially for offshore wind parks, by integrating additional data and using advanced models. According to empirical findings from Cali et al (Cali, 2009), the integration of additional parameters such as wave and wind measurements decreases the forecasting error of presently 6-7%. Accuracy improvements of up to 27.41 % in short-term forecasts are realistic.

1.4.2.3 *Integration of solar power*

Major increments of production from solar technologies (photovoltaics - PV - and concentrated solar power - CSP) are also expected over the coming years, but the challenges for grid integration are slightly different from those of wind energy. CSP plants, although still in the demonstration phase, can store their energy production in the form of heat, for example in molten salts, and release it when needed. The planned medium-sized plants (100 – 150 MW) are therefore candidates for substituting baseload power from fossil fuels, although smaller-scale applications are also under development (EESI 2009,). Photovoltaic installations, on the other hand, do present the problem of intermittent production, and are generally even more spatially dispersed than wind power production facilities. According to estimates from the German Solar Industry Association BSW Solar, about 80% of all PV projects in Germany are decentralized installations with a production capacity of less than 100 kWp. i.e. maximum production capacity with full solar radiation (see Figure 1.15 below)

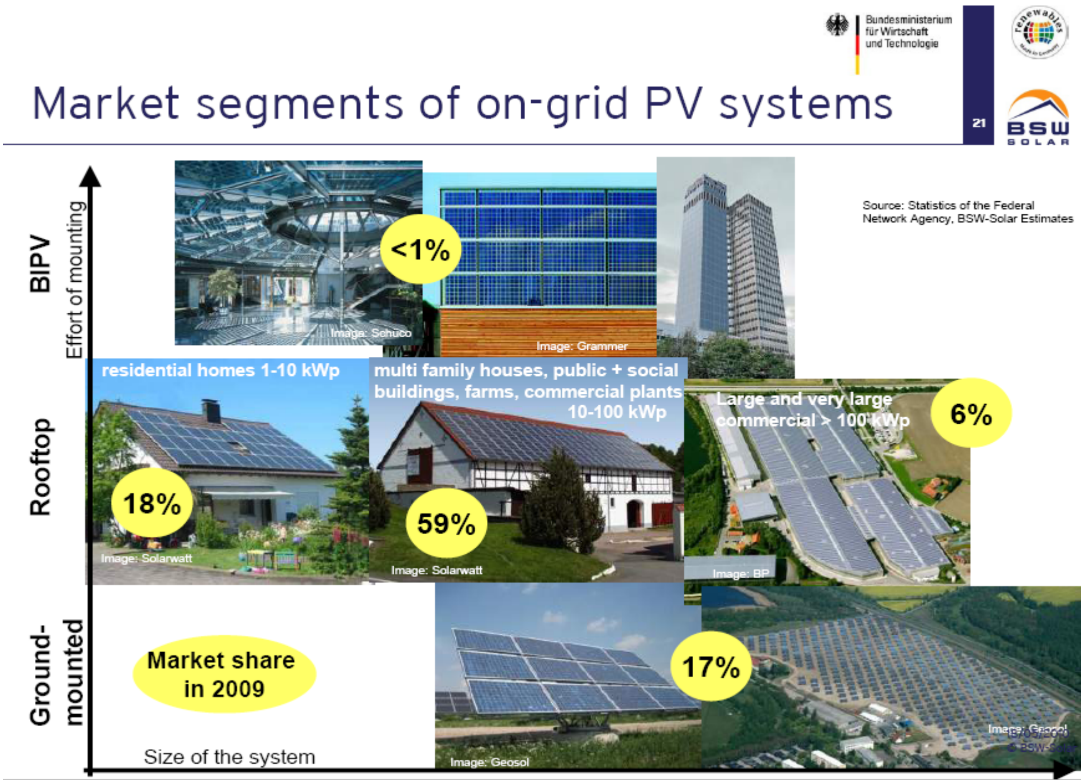


Figure 1.15: Market Segments of On-Grid PV Systems

Source: (Chrometzka, 2010)

1.4.2.4 High Voltage Direct Current lines for the transmission grid

As mentioned above, the level of interconnectedness is a central element of grid management at the high-voltage level. The European system operators therefore continually evaluate the "system adequacy" (ENTSO-E, 2011) so as to determine the need for new interconnections between national grids, presently placing the focus of investment in the more peripheral areas in Europe and on linking the hydro-power dominated Norwegian and the continental grid, which relies heavily on thermal power productions. Further investments (about 30 billion Euros, according to European Wind Energy Association) are necessary to incorporate production from the projected offshore wind parks. Work is also under way on national and regional level[9] to assess the upgrades of the grid that are necessary to implement renewable energy strategies. However, due to environmental concerns, planners are trying to limit the construction of new overhead transmission lines and are instead looking at increasing network efficiency through new HVDC (High Voltage Direct Current) and subsea cables. The HVDC technology has the advantage of reduced network losses, which, up to now, have seriously limited long-distance transport of electricity. HVDC also offers new opportunities for control strategies and storage, for example through high-capacity Li-ion batteries (JRC 2010). It can therefore be expected that HVDC interconnections will contribute to the shaving of the overall demand curve on the transmission level.

[9] See for example "SCOTLAND'S OFFSHORE WIND ROUTE MAP "Developing Scotland's Offshore Wind Industry to 2020." and OUR ELECTRICITY TRANSMISSION NETWORK: A VISION FOR 2020

1.4.3 Technological Challenges towards the Deployment of Smart Grids

1.4.3.1 The transition towards Smart Grids: overall context and drivers

Based on the review of the available technical literature, there seems to be a general agreement that most of the technologies necessary to make the electricity grid smarter are already developed and that the main challenges for deployment lay in the interoperability of ICT technologies, as well as in their integration in the management of the electricity infrastructure.

More specifically, the development of the Smart Grid faces a number technical and non-technical constraints deriving from the present architecture of the electricity grid:

- Smart grids must be deployed in both existing (sometimes over 40 years old) and new electric systems, thus overcoming their functional and technological differences.
- Compliance is required with different policy and regulatory frameworks
- Installation must be carried out with minimum impact and disruption of the regular operation of the electricity systems.
- Acceptance and engagement of all actors involved is necessary, with particular attention to consumers and their advocates.
- Smart grids comprise a heterogeneous set of evolving technologies and their deployment must be possible at different paces depending on the regional conditions (regulatory and investment frameworks, commercial attractiveness, compatibility with already existing technologies, etc.).

The smartening of the electricity grid is a gradual process driven by economic interests and technical feasibility. Policy and decision makers are therefore confronted with a dual query:

- Isn't such process bound to occur anyway over time, albeit with lower speed and lower investment levels?
- Are there existing technologies that would achieve the same purpose at lower cost?

Traditional solutions can in theory be applied to address many of the challenges of managing the electricity networks. An example of a traditional approach is to build new lines and substations to integrate more renewable generation, whereas the "Smart Grids" approach involves the development of more ICT solutions in the network to allow a higher penetration of Renewable Energy Systems connected to existing lines and substations. In this case the traditional approach would indeed bring a solution, but a much more expensive one, according to Smart Grids advocates[10], which might not even be feasible because of resistance to new infrastructure construction. This does not mean that more traditional infrastructure is not needed even with the "Smart Grids" approach, but rather that the Smart Grids approach is driven by efficiency optimization requirements and is expected to be less expensive in the long run.

10 EEGI, Roadmap 2010-18 and Detailed Implementation Plan 2010-12

The current electricity networks in Europe are based on technology that was developed more than 30 years ago, and the perceived need for innovation has so far been limited. The networks were designed to accommodate one-way energy flows from large, centralized, fully controllable power plants to the customers at the other end of the network. This linear and rigid topology (generation → transport → distribution → consumption) is now undergoing substantial changes and is starting to evolve into a more intricate grid, in which generation can be located at any voltage level and where bidirectional communications can be established between any pair of grid components. The drivers for change are both external to the network, like the ambition to prepare for a low-carbon future, as well as internal, like the need for replacement of an aging infrastructure, or the emergence of new electricity market players.

Changes are mainly affecting the distribution network, whereas the transmission grid is already subject to monitoring and remote control, usually performed by the technical manager of the electricity system. Information and communication devices incorporated at the transmission level already make it possible to absorb the production from renewable sources, as explained above. But this "smartness" is not yet integrated downstream, in the distribution networks. In a way, the grid smartening tendency could be seen as an extension of the intelligent capabilities of the transmission to the distribution grid, with however a major difference whereby there are usually several owners and system operators at the distribution level. This implies the definition of standards and the creation of tools based on mature technologies, which allow the feasible integration of all sort of generation technologies at every grid level, distribution automation and metering services supported by a communication system that reaches the final user.

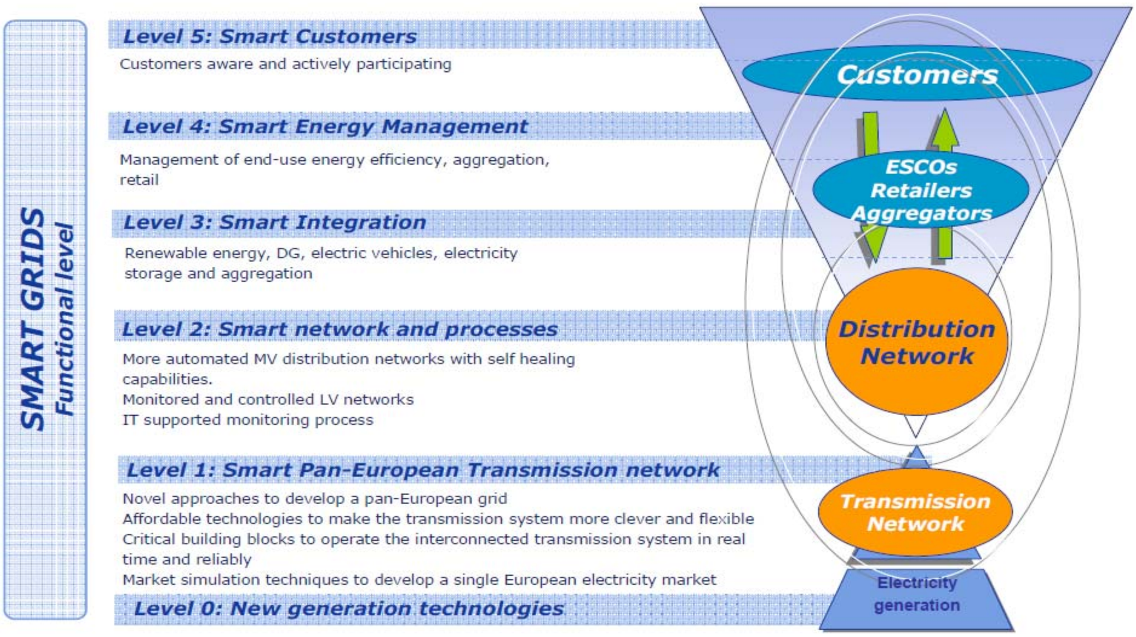


Figure 1.16. Smart Grids functional levels

Source ECGI, 2010

Furthermore, as opposed to transmission, the distribution network is not meshed. Its large extension and the high number of points to be supplied do not allow for the full integration of all elements within the grid topology. These characteristics make real time monitoring and control of the entire grid difficult.

Most utilities have automated the upper level of distribution grid voltages (between 125 kV and, in the better cases, 30 kV), but hardly perform remote control, and even less remote operation, on the medium voltage network (between 1 kV and 30 kV, up to 66 kV in some distribution companies). As a general rule, substations can be remotely controlled and some of them can be remote-managed, but there is limited capability of remote metering downstream beyond the substations. On the contrary, there is no control neither is there any metering in the transformation centres for medium to low voltage.

The following table presents a comparison between the main features of Smart Grids and those offered by the present electricity grid.

Table 1.7. Smart Grid Characteristics

	Current/Traditional Grid	Smart grid
Automation	Limited grid monitoring components mainly reduced to the transmission network.	Massive integration of sensoring, handling and measuring technologies along with automation schemes at all the grid levels (low, medium and high voltage).
Intelligence and control	Present grid, especially at distribution level, lacks intelligence. manual handling is predominant.	A complete information and intelligence system distributed over the entire electricity system.
Self-healing	Only protection of specific devices in the event of grid failures.	Based on automatic prevention coming from the continuous supervision of the grid and decision taken over failure patterns.
Consumer participation and distributed generation.	Consumers are not informed and do not take part in the grid operation, nor do they exercise control of consumption.	Strong presence and integration of distributed generation that can be coordinated through the Smart Grid with the active participation of the consumer (real-time pricing, control of consumption, sales of excess energy to the grid,)
Security	Highly vulnerable infrastructure	Rapid and high self-recovery capabilities in case of natural disasters and attacks.
Demand management	There are no management capacities for electric appliances discerning daytime intervals or demand patterns.	Incorporation of intelligent appliances and electric equipment that allow to develop energy efficiency schemes, adapted to price evolution and according to a predefined grid operation scheduling.
Electricity quality	Only power cuts can be resolved, but not energy quality problems such as voltage dips, electrical disturbances, electric noise, etc.	Electricity quality that satisfies every kind of consumers (industrial, residential, etc.). Automated identification of energy quality and correction. Different kind of electricity tariffs for different energy qualities.
Electric vehicle	Recently, EV charging points are being connected to the grid just to recharge vehicle batteries with no or very limited charging management capabilities.	New infrastructure, not only for EV recharging, but also to use and exploit the vehicles as storage resource and thus balance electricity for electricity generation and consumption with benefits for grid operation stability.
Integrating renewables and storage	Large generation plants, usually connected to the transmission grid, with serious difficulties for connecting distributed energy resources.	Full integration of distributed renewable energy sources connected to any section of the grid under plug-and-play philosophy.
Assets optimization and efficient operation.	Minimum integration of operation data and electric assets. Maintenance policies based on predefined time planning.	Permanent and complete grid conditions sensing and metering by means of integrated technologies in assets. Automated and real-time grid condition-based maintenance.

Source: Tecnalia.

Such evolution from the present electricity grid to future Smart Grids will be progressive, strongly depending on advances in technology but also on policies, regulations and evolving business models.

1.4.3.2 Priorities for technological development

The following actions are considered of high priority for the deployment of smart grids in Europe:

- **Transformation centres:**

  Transformers are in general terms highly reliable devices, with an operation life between 20-35 years, with a minimum of 25 years at working temperature of 65-95ºC. However, in practice, the life of these equipments could reach 60 years with appropriate maintenance.

  Apart from the development and evolution of the transformer itself (robustness, new security-oriented designs, durability, etc.), selected additional improvements are expected to increase the performance of transformers in the perspective of their participation in a Smart Grid scenario, notably in the area of sensoring, auto-diagnosis or remote monitoring and operation through appropriate telecommunication devices.

- **High Voltage Equipment.**

  Apart from the grid improvements that are necessary to match the increasing energy demand (Ultra High Voltage, line commuting, new switch-disconnectors, etc.), Smart Grids require the optimization and enlargement of the electricity infrastructure by means of new methods of monitoring and visualization of critical parameters. Optical voltage and current provide an excellent isolation in high voltage environments allowing for the efficient measurement of high voltage and currents in a non-intrusive way.

- **Substations.**

  The increasing population, urbanization and industrialization, along with the deployment of distributed energy generation, especially from renewable energies, demand the transmission of bigger energy volumes over longer distances, thus pointing at substations as key elements in the collection and delivery of energy.

  In the Smart Grid perspective, innovation is therefore required at the level of substations to ensure the integration of those computation and communication capabilities that permit automation and remote monitoring, as well as control and coordination with other grid components.

- **Smart Metering.**

  Although originally promoted in the interest of utilities, smart meters are in fact the most obvious contributors to the growing deployment of Smart Grid among consumers. Their initial aim was to facilitate the remote and automatic reading of the energy consumption. However, the incorporation of bidirectional communication channels and the processing capacity incorporated to the meter open multiple opportunities for the remote, automatic and rational management of the energy consumer space. In addition to solving technical problems such as control of energy consumption, breakdowns, loads programming, energy quality, etc., this remote management capability bears a variety of economic implications (invoicing, price selection, etc.) and of environmental benefits (prioritization of renewables, energy saving and efficiency surveillance, etc.)

Overall, smart meters can provide, by means of an information management system, the monitoring and control of quality parameters and the service programming together with the measuring software update via telecommunication devices. It includes communication to both the information management system on one direction and the Home Area Network (consumer networked appliances and loads) on the other.

1.4.3.3 System innovation and organizational advances

- **Information and Communication Systems.**

At the higher level, Smart Grid technologies can be split into three main layers:

- The Energy Layer, including energy generation, the transmission grid, substations, the distribution grid and energy consumption.
- The Communication Layer, which ensures the interconnection of energy components and communication devices, such as Local Area Networks (LAN), Wide Area Networks (WAN), Field Area Networks (FAM) and Home Area Networks (HAN).
- The Application Layer, providing intelligence to the Grid, in the form of demand response control, invoicing, failure control, load monitoring, real-time energy markets, innovative client services, etc.

Although changes are expected in all three layers along the transition path towards Smart Grids, the most prominent and decisive innovations are expected in the communication layer.

Usually, communications between different components of the transformation centre and the control centre do not respond to compatible standards, making an efficient data interchange impossible. As a consequence, the implementation of SCADA[11] Systems in transformation centres is difficult.

In order to solve this problem, international protocols like IEC-61850, were defined. These standards specify the communication protocols between devices connected to communication networks, normally local area networks. These communication capabilities are implemented in dedicated devices that are integrated into the transformation centre components to allow for their remote control.

[11] SCADA: Supervisory Control And Data Acquisition

- **Integration of Components**

The large set of components that need to be integrated in a smart grid has been classified in five groups by US experts (NETL 2009), distinguishing between:

a. advanced components
b. advanced control methods,
c. sensing and measurement,
d. improved interfaces and decision support,
e. integrated communications.

The sets of technologies grouped under each heading are discussed in detail in Annex 1 with regard to their functions in the smart grid architecture, their present maturity level and the related ongoing R&D efforts.

As stated above, most of the technologies considered as key for the Smart Grid achievement are mature by themselves. The real challenge is the adequate integration of the five technology areas listed above. Integrated communications will allow real-time information and power exchange for the grid users to interact with various intelligent electronic devices in a system, which is sensitive to the various speed requirements (including near real-time) of the interconnected applications.

These communication technologies must fulfil the following criteria:

- Interoperability thanks to common standards and protocols.
- Confidentiality.
- Required bandwidth.
- Required speed.
- Different information media.
- Security and integrity.

Future developments will need to address current shortcomings, specifically

- The presence of heterogeneous technologies and standards. An open communication architecture is needed to ensure interoperability and support "plug and play" equipment connectivity to the grid. Further, universally accepted standards for these communications must be defined and agreed upon in the industry
- The currently insufficient bandwidth of some technologies, which are too localized to support the quasi-real-time and full-connection communications envisaged for the Smart Grids.

The SG-ETP accordingly considers that the following technologies have to be prioritized for research, development and demonstration:

- Real time energy use metering and system state monitoring systems. These systems will increase the real-time knowledge of the grid status and its ongoing processes (frequency, voltage, current, short circuit, assets configuration, etc.). This will permit that the system controls critical measures before and after real incidences, providing self-healing capabilities, not only in the distribution grid but also in the potential HVDC-based transmission layer.
- Distributed storage systems on the medium and low-voltage grid, mainly small-scale, to allow for massive penetration of intermittent renewable energy sources.

1.4.3.4 Establishing the conditions for smart grids acceptance and uptake

When it comes to operationally promoting and facilitating the transition towards large-scale implementation of Smart Grids, the SG-ETP's Strategic Research Agenda (SRA) identifies a series of necessary actions:

- To design new transmission and distribution systems, including HVDC, adapted AC medium and low voltage distribution and the new DC consumer home grids and systems, and validate their performance through demonstration projects.
- To monitor in real-time the ageing of the materials that are presently used in electricity grids and develop cost efficient, signal-based, predictive maintenance and repair, as well as adequate replacement times.
- To enable the secure exchange of information among the many newly involved stakeholders for an efficient, low-cost and sustainable operation of the electricity system, from the transmission level down to the consumer (prosumer) of electric products and services.
- To predict ahead of delivery and measure in real-time the output of large amounts of volatile, intermittent generators and the demand of many flexible electricity consumers.
- To enable small-scale island systems (with feeble or no connection to the synchronized European power system) to securely handle distributed, renewable-based production sources and to connect to and disconnect from the synchronized grid.
- Protection systems need to be in place, so that the distribution grids can cope with a high level of penetration of renewables on all voltage levels, without endangering security of supply.

Ultimately, there is a widespread consensus that priority actions must focus (i) vertically on the distribution grid and on the consumer side, and (ii) transversally on integrated hardware and software systems in order to advance towards the technical and functional exploitation of the grid, especially at the final user level applications.

As concerns the extension of smart grid elements into the homes of the final users and its implication for security of supply, the following main barriers require specific attention:

- The perception of insecurity, mainly associated to the ICT component, which is observed at consumer level (confidentiality, privacy, etc.), but also at grid level (cyber-terrorism, grid manipulation, etc.) and for the entire electricity market (spying price strategies, commercial conditions, etc.).
- Different environments for the (technically) homogeneous deployment of smart home energy management systems.
- The market adoption of new technologies, which generally faces not only technology-related barriers, but also those coming from established business practices, consumers' behaviour and regulation.

Accordingly, the following recommendations can be issued:

- Pushing global standardization initiatives, mainly in data models and communication protocols and intelligent electronic devices (IED) integrated in the grid assets, to ensure interoperability among different equipment vendors and cost reduction in the development and operation of the grid. The present activity of the Technical Committee TC57, from the International Electrotechnical Commission, on the standardization of electricity system communications (data models, generic interfaces, communication protocols, etc.), and some specific standards (IEC60870[12], IEC61334[13], IEC61400-25[14], IEC61850[15], IEC61968[16], IEC61970[17], IEC62351[18], etc.) can be considered as a starting point for this Smart Grid standardization task.
- Involving all Smart Grid services multidisciplinary agents, at both providers' and consumers' sides, in the whole life cycle of research, development and demonstration initiatives of Smart Grids in order to take into account their needs and requirements from the beginning.
- Raising/increasing awareness among final users in order to ensure the acceptance of Smart Grid technology and functionalities, mainly those related to active Demand Response management.
- Prioritize projects and pilot studies of technologies with high impact on the European sustainability policies, especially those related to renewable energy penetration and energy efficiency. Relevant technologies are:

[12] *IEC 60870. Telecontrol equipment and systems.*

[13] *IEC 61334. Distributed Automation Using Distribution Line Carrier Systems*

[14] *IEC 61400-25 (Communications for monitoring and control of wind power plants).*

[15] *IEC 61850. Communication networks and systems in substations.*

[16] *IEC 61968. Application integration at electric utilities - System interfaces for distribution Management.*

[17] *IEC 61970. Energy management system application program interface (EMS-API).*

[18] *IEC 62351. Power systems management and associated information exchange - Data and communications security*

- Load management systems with special attention to industrial loads and Electric Vehicle (EV). Related technologies are grid-friendly appliance/load controllers, smart appliance/load interface units, consumer gateways and portals, intelligent multi-EV storage managers, intelligent user interfaces, etc.
- Technical, functional and economical integration of renewable energy sources, especially in the distribution grid. Related technologies are distributed energy resources controllers, and microgrids, including their control software.

Integration and interoperability of components must be achieved both vertically (electrical technologies with ICT technologies) and horizontally (among grid elements), independently from the providers of these components. The first step towards *vertical* integration is the incorporation of devices (new generation power electronics such as new generation of power electronics: static converters, static compensators, FACTS, etc), which permit remote monitoring and operation of the electricity grid. In a second step, vertical integration can be extended through the telecommunication network, which interconnects the intelligent devices. *Horizontal* integration implies the seamless interoperability of grid components, sub-systems or systems in the electricity grid itself.

The technical challenges of integration have been well described by ABB in the context of the pilot project “AURA – NMP”, which combined smart grid solutions with a storage facility (battery) in an existing distribution network, as shown in Figure 1.17.

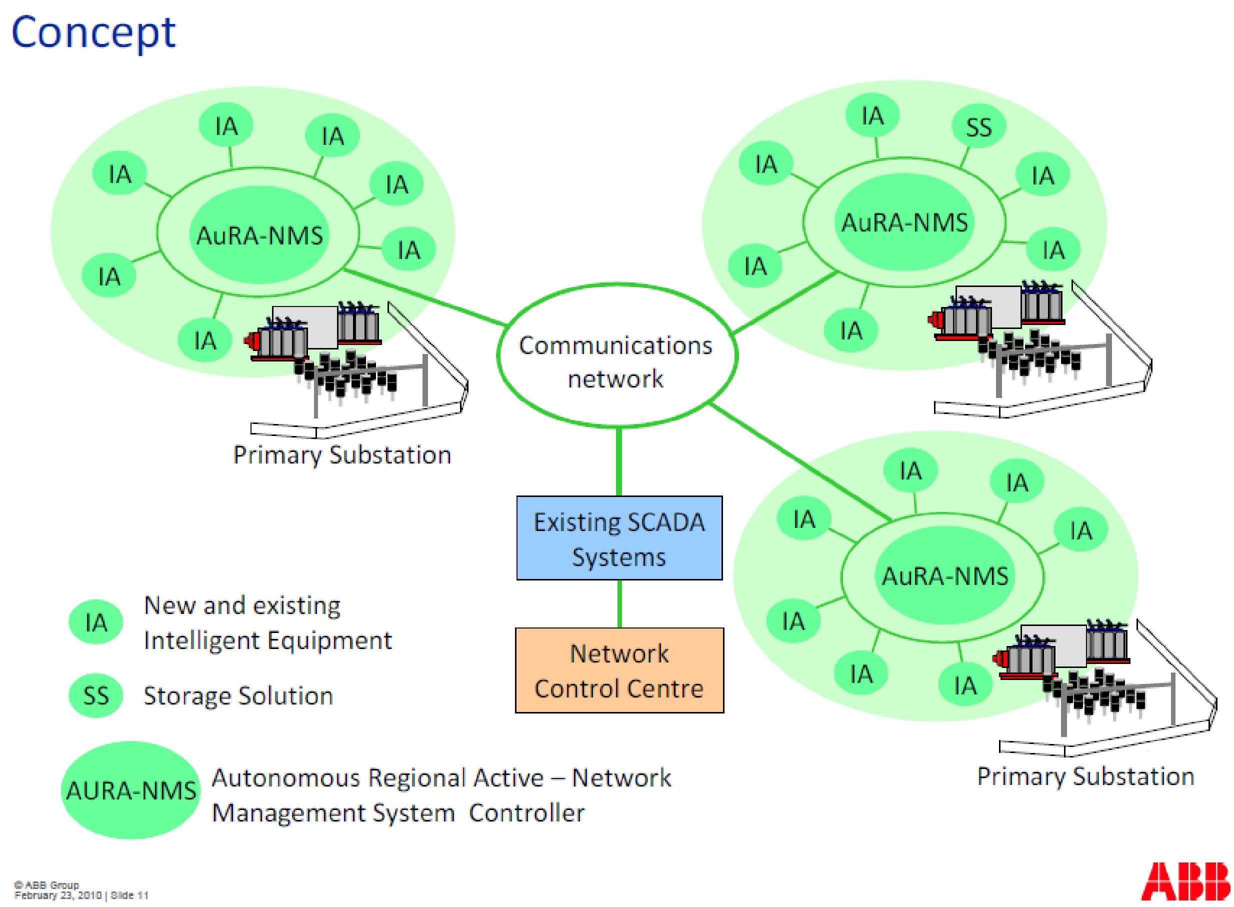


Figure 1.17: Integration of components in an Autonomous Regional Active Network

Source: ABB 2010

However, this desired interoperability is the result of the interaction between a large set of actors (ICT suppliers, distribution companies, electrical equipment suppliers, etc.), which operate in different market environments and business models (free market versus regulated). In order to harmonize their efforts, different levels of formalization (from mandatory standardization to partial industrial agreements) are needed. Standards are critically important in the electric power industry because they affect interoperability, compatibility, reliability, and efficiency. The smart label opens a door of new business opportunities, and companies feverishly develop solutions for the Smart Electricity Grid. As a consequence, new standards emerge rapidly with different speed and scope. Once a standard is effective, those who fail to adapt quickly will find themselves heading down dead-end paths.

The Smart Grid standardization process therefore requires coordination, harmonization and cooperation between the different initiatives and entities involved (i.e. ITU-International Telecommunications Union, IEEE-Institute of Electrical and Electronics Engineers, CEN-The European Committee for Standardization and CENELEC-The European Committee for Electrotechnical Standardization, ETSI- European Telecommunications Standards Institute, NIST-USA National Institute of Standards and Technology or the Japan Smart Community Alliance).

In order to accelerate the process and set a level playing field for companies, regulators should pay attention to the following aspects:

- Try to avoid independent, usually industry-driven, standardization initiatives on the same object.
- Involve all relevant agents.
- Promote coordination and harmonization among the different standardization initiatives both by different standardization bodies (IEC, IEEE, CEN-CENELEC, ITU, etc.) and at different national and international levels.
- Facilitate the adoption of standards.
- Consider the whole standardization life cycle including the final standards assessment and certification services.

Figure 1.18 summarizes all elements needed to achieve the desired level of integration of elements, both technological and non-technological:

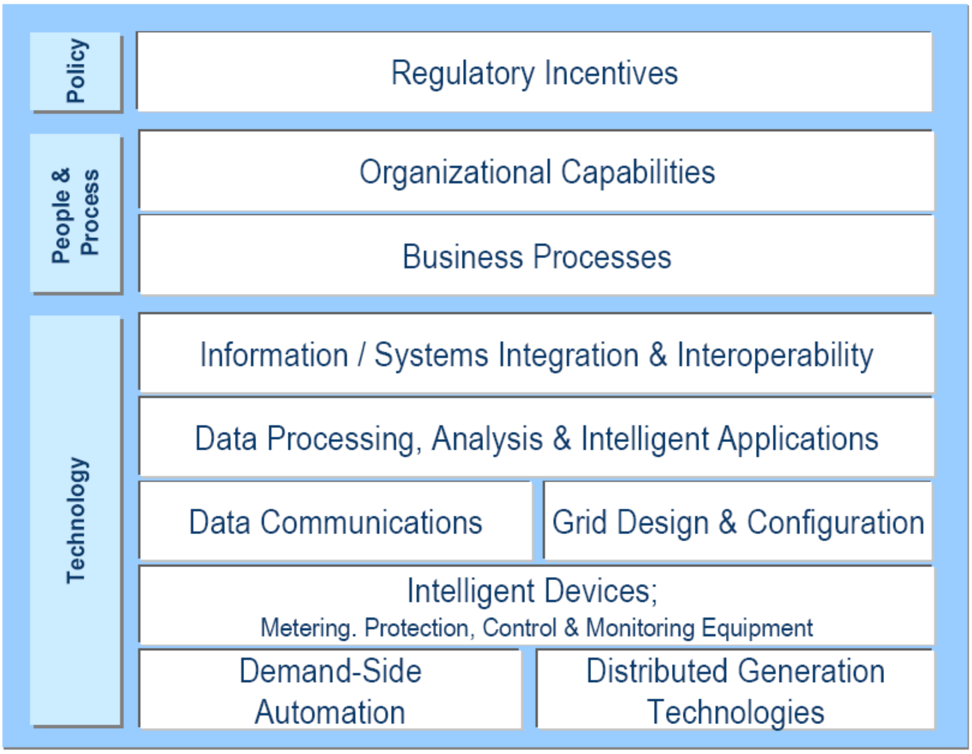


Figure 1.18: Interoperability as a result of policy, technology and business strategies

Source: Ipakchi, A 2007

Demand-side automation will require special consideration from the regulators in order to guarantee that smart grid investments actually benefit the final customer.

1.4.4 Conclusions on Technological Barriers

The main challenge facing smart grid operators is the need to standardize the different components in the system on grid level, while guaranteeing privacy and security. On the other hand, customers will only be able to benefit from smart grids investments if home automation systems match their needs and economic constraints: home automation systems will therefore have to be extremely easy to install and to use, low cost (retrofitting of appliances) and completely secure. They should be made available to electricity consumers as smart meters are being deployed, so that benefits can be seen immediately.

If the solutions proposed do not allow to meet the full range of users' requirements, customers should be allowed to opt out of services that are of no direct advantage to them, unless there are major environmental or social benefits associated to these innovations. This is especially important for plug-ins for electric vehicles and can be highlighted as follows: there may be a strong argument for subsidizing the transitioning of the fleet of scooters in big cities to electric motors, as this would bring down emissions and noise levels, with immediate and obvious benefits for all inhabitants of the city. In this case, creating parking lots with plug-ins could be financed by public investment or by a special supplement for electricity consumed for this purpose. However, financing a new infrastructure for charging electric cars via electricity rates is raising serious equity concerns, as these vehicles are presently out of reach for large parts of the population and may never become attractive for certain groups, for example people, who do not own a car or do not have access to charging stations at home. In the case of electric cars, benefits for society and environment are much more dispersed and will only become apparent in the longer term, while economic benefits are unevenly distributed among the population.

Electricity companies and policy makers should keep in mind that own consumption is becoming increasingly competitive with electricity sourced from the grid and electricity prices are a growing strain on household budgets. Many customers will not remain passive and "captive" for much longer, if suitable alternatives for heating, cooling and other electricity uses come into sight.

2 NON-TECHNOLOGICAL CHALLENGES: CONCERNS AND CRITICAL VOICES

Public concerns voiced in relation to smart grids should be duly taken into account, also considering that acceptance or non-acceptance of the associated technologies will have a strong influence on the speed of deployment of Smart Grids in Europe. This chapter discusses the main concerns raised so far and the measures/actions that can be taken to address them.

2.1 Privacy

In its evaluation of ongoing smart grid projects in Europe, the Joint Research Centre (Giordano, 2011) issues a warning concerning privacy whereby "detailed information about electricity use could be used by insurers, market analysts, or even criminals to track the daily routine of consumers; 35% of customers would not allow the utility to control thermostats in their homes at any price". Legal concerns related to privacy not only affect customers, but are in fact shared by utilities, which fear potential liabilities that may arise from data transfer and management, including responsibilities for data accuracy, availability, security, timeliness, and authority to access and transfer such data – as well as the costs associated with managing such a large amount of data. Third parties, on the other hand, see the access to consumer data as generating potential market opportunities.

2.2 *Health Effects: Exposure to Radiofrequency Radiation (RF)*

Health effects are at the heart of the protest movement in California, where ten counties and 37 towns and cities have made public their opposition to Pacific Gas and Electric's rollout of smart meters. Municipal ordinances banning smart meters may well spread out to other states in the country and the issue has been taken to federal court by an Illinois public interest group.

In response to concerns of increased radio-frequency exposure levels, the Electric Power Research Institute run a test at the beginning of 2011, finding that exposure levels "fall substantially below the protective limits set by the Federal Communications Commission (FCC) for the general public" (EPRI Press Release, 22/2/2011). This, however, did not stop public debate, which is fuelled by possible negative health effects of cell phones, as these have not yet been confirmed beyond doubt nor completely discarded (International Agency for Research on Cancer 2010).

2.3 Doubts about Energy-saving Effects

Recent field trials in the US indicate that demand response programs help to shift energy use from peak hours to non-peak hours, but do not lead to energy savings, as the same amount of energy is consumed at times of lower prices (Chassin, 2010). Yet, demand management programs can have also energy-saving effects if they single out those actions, such as light dimming, that do not lead to increased consumption during another moment of the day. Demand response requires an adequate system of time-based pricing, which needs to be simple enough for customers to make the right choices in the right moment, for example switching off the air-conditioner at a given moment. This is much easier to do with automated appliances, but customers may resist the idea that they are not allowed to override the system's decision, or may not be able to act in accordance with price signals for health reasons (elderly) or otherwise. Also, for demand response to spread quickly through markets, retrofitting of conventional household appliances with add-on devices is required.

The Alliance to Save Energy (Simchak, 2011) offers a series of recommendations on the additional measures necessary to actually achieve lower energy consumption levels in combination with smart grid developments, arguing that the system for data display is critical, especially among households, in which computer literacy is low. Displays will only be successful if

1. Information is easily accessible and immediately useful for the consumer, and remains compelling over time.
2. Close to real-time data (second intervals) is provided to give detailed information on appliances, not only overall patterns of energy consumption.
3. Data does not encourage to make greater use of devices that use comparatively little energy, for example electronic components.
4. Data on energy use is associated to financing and support for larger efficiency measures.
5. Data on individual energy use is combined with the overall energy performance of buildings to allow for optimization measures, including retrofits.

2.4 Empowerment of Customers?

So, what do customers expect with regard to smart grids? The natural connection between the customer and the grid is the meter, but even "smart" meters do not supply information to the user, unless they are combined with "intelligent" appliances or a home automation system. A US survey (Krishnamurti 2011) has discovered that misconceptions about smart meters are quite frequent among customers, leading them to expect too much from this innovation. More precisely:

1. Customers confuse smart meters with enabling technology, such as displays
2. Interviewees expected a smart meter to come with an in-home display that provides detailed feedback about energy use.

3. Loss of control: A second misconception was that smart meters were designed to control residents' electricity use, both by direct load control of their air conditioning and by shutting off their electricity completely. Indeed, a common concern across interviews was loss of control, with some interviewees worrying about their electricity company using smart meters to act like ''big brother''.
4. Some interviewees believed that the goal of smart meter installation was to help them to save money each month

Overall, the interviewees viewed smart meters as a technology designed to serve the consumer and tailored specifically to their individual needs. In general, misconceptions tended to overestimate rather than underestimate the personal impact of smart-meter deployment. Interviewees felt that they would receive more benefits than would likely occur, at least in the immediate future, and also be exposed to more risks (intrusion, disconnection) than are likely.

In order for smart grids to actually deliver benefits to the customer, utilities must drastically change their communication behaviour and engage in reciprocal actions (Honebein, et al., 2011). Other experts, such as Chassin (Chassin 2010), warn that if the connection fails, "then utilities and consumers hardly see any enduring benefit at all and the investment made in the underlying infrastructure justified on the basis of those benefits is wasted."

Pilot projects show that

1. Monetary savings for the customer must be substantial (at least 10% of the bill) for them to enter a cooperation with the utility.
2. Home automation systems and other enabling technologies must be easy to use ("fire and forget") and must not require repeated action and attention from the customer.
3. Customers want to retain control over their energy consumption and the functioning of their appliances.
4. Participating in demand response programs should never lead to losses for the customers, which also means that up-front investment in "smart" appliances must be avoided.
5. One golden application that should be offered after smart metering is installed is "bill-to-date," which gives consumers a preliminary estimate of energy spending as they move through the billing month (Healy, 2011)

Customers have a right to benefit from smart grid penetration, especially when they pay for a large part of the investment, as discussed below.

2.5 Economics and Equity

Who takes the burden, who gets the benefits of Smart Grids? Three parties are involved when it comes to burden-sharing – the customers, the distribution companies and the generators. All three may benefit from smart grids, but – at the moment - they are not equally involved in financing. The distribution of electricity is a regulated business that passes its investment costs on to the customers, while generation is liberalized and profits go to the energy companies. Within such a framework, (Felder, 2011) warns that "There is no guarantee that the potential net societal benefits will occur, either for society as a whole or for particular segments of society, particularly low-income families." Presently, profitability calculations for smart grids do not take into account investments that customers have to make into enabling technologies beyond the meter in order to better manage their energy demand, nor cost-benefit analysis for generation assets.

Investments to be carried out before the meter to make smart grids work are not subject to customer choice, although "opt-out" solutions for smart meters are being discussed presently by regulators in some US states (Healy, 2011), (Simchak, 2011). It is not even clear if the smart features of advanced household appliances can be disabled by the user or if communication between appliances and network will be automatic (Levitt, 2011). In order to achieve a fair distribution of burdens and returns, some delicate issues need to be discussed, as highlighted by the examples below.

2.5.1 Deployment of Smart Meters – Costs and Benefits for Customers and Utilities

Smart meters, which permit the utility to obtain information on their customers' energy consumption through remote readings, are presently being deployed in several Member States. Each meter costs between €70 and €450 and the investment is financed by the distribution companies, which can eventually recover the cost via tariffs. Cost recovery is compulsory and affects all customers, independently from their income or electricity consumption patterns, thus harming lower income consumers more than higher income ones, as energy bills are a much greater strain for low-income households (Felder, 2011). Additionally, there is the risk (for the customer) that smart meters may lead to higher electricity bills, due to improved bill accuracy.

Benefits for companies are much clearer. Smart meters are expected to improve operational efficiency and reliability, as well as reduce labour costs (Siddiqui, 2008), all of which would accrue savings to the utility that may or may not be passed on to consumers. For example, after smart meter penetration in the US in 2009 almost doubled that in 2007 (8.7% vs. 4.7%) (Faruqui A. Wood,l. 2011) estimated the savings in labour costs alone to be up to $24 per meter over a 20-year horizon, from no longer needing to have an employee physically read the meter (Krishnamurti, 2011).

Cost-benefit estimates of smart meter roll-out in Europe for the European market (Faruqui A. Harris, D. 2011) indicates that only part of the 51,000 million € investment will be recovered through operational savings, leaving a gap of €10–25,000 million between benefits and costs, unless dynamic pricing is introduced. Italian utility ENEL, which is by far the most experienced company in Europe with smart meter installation (at a cost of €70 per meter and a total investment of 2,100 million €), calculates that the investment paid off in five years due to yearly savings of 500 million € from:

- A 70% reduction in purchasing and logistic costs.

- A 90% reduction in field operation costs.
- A 20% reduction in customer service costs.
- An 80% reduction in the costs of revenue losses such as thefts and failures.

2.5.2 Cost of Enabling Technologies

Consumers may obtain indirect benefits if they purchase or are provided with enabling technologies that respond to smart meter signals. Most likely, one or more of the following options will be made available to at least some consumers:

a) Central air-conditioning control,
b) Direct load control, and
c) In-home displays

In-home displays typically cost $100–250 and these investments are not accounted for in cost-benefit analysis of smart grids.

2.5.3 Cost – Benefit of Electric Vehicles

Equity concerns also extend to enabling technologies for electric vehicles, as described very graphically by Felder (2011) "This issue of aligning costs with benefits also arises with plug-in electric vehicles. It is not clear why anyone, particularly low-income ratepayers, should have to buy a meter that is capable of supporting an electric plug-in vehicle if they do not have such a vehicle. Presumably, families with low income own fewer newer cars than higher income families and therefore are not likely to have a new plug-in electric vehicle. Requiring all ratepayers, particularly low-income ones, to purchase a meter in the unlikely event that sometime in the future they will have a plug-in electric vehicle does not make sense, particularly given the high cost of plug-in electric vehicles and the lack of high market penetration of these vehicles anytime soon."

Yet, from a policy point of view, public investments in the electrification of transport can be justified, if this solves general problems related to security of supply, emissions or health concerns, but this should be done on a fleet-to-fleet basis. The first fleets to transition from fossil fuel to electricity will be the so-called captive fleets, i.e. scooters or city buses, which are used within a limited radius. But going electric may not be the optimum solution for all types of fleets. Agricultural vehicles, for example, are more likely to turn to biofuels as an alternative to gasoline. The idea of fleet-by-fleet solutions runs contrary to the financing of charging stations via electricity tariffs. However, from the point of view of the electricity providers, it is essential that electric vehicles be charged slowly and over night, so that they would have to be connected at the place of residence (RTE 2011). In consequence, tariff design will not only have to take into account the different needs in the residential sector, but also the requirements of the grid operators.

2.5.4 Demand Response – Equity among Groups of Customers

Demand response can make the entire electricity supply in a distribution network more flexible and thus lower the cost of purchases in the wholesale market. Cost reductions, if handed on to the customer side, could benefit all clients alike, whether they have been active participants in the demand response programs or not. Active participation should therefore be rewarded by the utilities.

2.5.5 Burden-sharing between Smart Grid Beneficiaries

The European Commission recognizes that network operators are those who will mainly benefit from the investment in smart grids and will therefore have to assume the largest share of the funding. However, since these are regulated businesses, investments will eventually be recovered via electricity rates.

It is clear that a well-functioning and stable electricity network is – presently and for time to come - in the interest of consumers and society and that it is the operators' responsibility to guarantee the functioning of the networks through the necessary investments. There are, however, a series of direct and indirect beneficiaries – apart from the aforementioned generators – from investments in smart grid infrastructures that are generally omitted in policy documents, such as industries providing smart meters and ICT, or the automotive industry.

Benefits can also be expected on the production side of energy. Spees and Lave (Spees, 2008) estimate that lowering peak demand by 5% in the United States could reduce the demand for peaking generation by 50%. The Smart Energy Demand Coalition estimates that demand response can reduce European peak consumption by 6 -11%. Chassin (Chassin, 2010) reports that in field trials, demand response led to significant reductions in peak load (up to 60%) for very short periods of time and of sustained reductions between 15 and 20% for longer periods (three days or more) on distribution grids. However, virtually no proposals have been found on how avoided investments on the generation side will contribute to finance the deployment of smart grids on the lower grid levels. The "unbundling" of activities in the electricity sector makes it difficult for the companies to apply concepts such as integrated resource planning, which would permit to calculate the distribution of costs and benefits along the entire production and distribution chain and allocate investments accordingly. It can, of course, be argued that lower peak demand will entail economic losses on the generation side, in spite of creating benefits for the entire system, but figures highlighting this debate are presently not publicly available.

Energy efficiency gains may also materialize in grid operation, but estimates for savings vary considerably, even coming from a single, highly qualified source, such as the Edison Electric Power Institute, EPRI, which indicates a range of reductions in line loss of 3.5 to 28 (US) billions kWh in 2030 (EPRI 2008). "Line loss" is, however, not a well-defined concept, as it not only includes the normal transport losses of 6 – 8% of energy consumption, but also concepts such as non-delivered energy due to network congestions or thefts. The only published statistics on this issue for Europe are network losses, which accounted for 6.6% (181.9 TWh) of total electricity demand in the EU 27 in 2010 and are expected to be slightly lower in 2030 (6.1%), according to Eurelectric (2010). Further information from the utilities will be necessary to feed into cost-benefit analysis of investment in smart grids.

A summary of the most relevant objectives cited in the reference documents is offered in Table 2.1, distinguishing between the prime beneficiaries of each targeted achievement.

Table 2.1 Overview table: Beneficiaries of Smart Grid Deployment

BENEFICIARY	*Generation*	*TSOs*	*DSOs*	*Customers*	*New Entrants*
1 Smart Grid Task Force (SGTF):					
Enabling the network to integrate users with new requirements	■	■	■		
Enhancing efficiency in day-to-day grid operation		■	■		
Ensuring network security, system control and quality of supply		■	■		
Improvement market functioning and customer service			■	■	
Enabling stronger and more direct involvement of consumers in their energy usage and management				■	
2 IEA Smart Grid Technology Roadmap 2050:					
Accommodates all generation and storage options	■	■	■		
Enables informed participation by customers			.	■	
Enables new products, services and markets			■		■ Aggregators, ESCOs, ICT providers
Provides the power quality for the range of needs		■	■	■	
Optimizes asset utilization and operating efficiency	■	■	■		
Provides resilience to disturbances, attacks and natural disasters.		■	■	■	
3 EEGI European electricity grid initiative:					
Integrate new intermittent renewable resources at the different voltage levels	■	■	■		
Enable and integrate active demand from end users			.	■	
Enable and integrate new electricity uses, in particular recharging infrastructure for electric vehicles and increasing electric heating (heat pumps)	■		■		■ Automotive: installers
Support and enable energy efficiency by end users					
Enable new business opportunities and innovations for market players			■		Aggregators, ESCOs,
Coordinated planning and operation of the whole Electricity Network		■	■		

3 THE NEW VALUE CHAIN AND BUSINESS MODELS

3.1 Smart grid value chain and new business challenges

The core innovative feature of Smart Grids – both conceptual and technological - is the integration of distributed resources (DR). Managing and integrating DR such as distributed generation, storage, electric vehicles, as well as the capacity resources potentially achievable through demand response practice, calls for substantial developments in advanced communication and control technologies and, most importantly, for radically innovative business and regulatory models for distributors, along with a shift in the cultural and behavioural paradigm of end users. This translates into major changes in the power system value chain (see Figure 3.1). In the traditional system, power is generated in large centralized plants, transmitted to regional utilities at high voltage, then transformed into medium and low voltage power, and finally delivered to the customer. To manage and integrate the new distributed resources the power system has to evolve from a centralized "one-way-street" to a "two-way communicating smart system" ruled and controlled by new communication and information facilities. New business opportunities will arise and new participants will enter in the value chain attracted by these new market opportunities. At the same time the existing companies are bound to renew their business models in order to remain competitive (Atos, 2009).

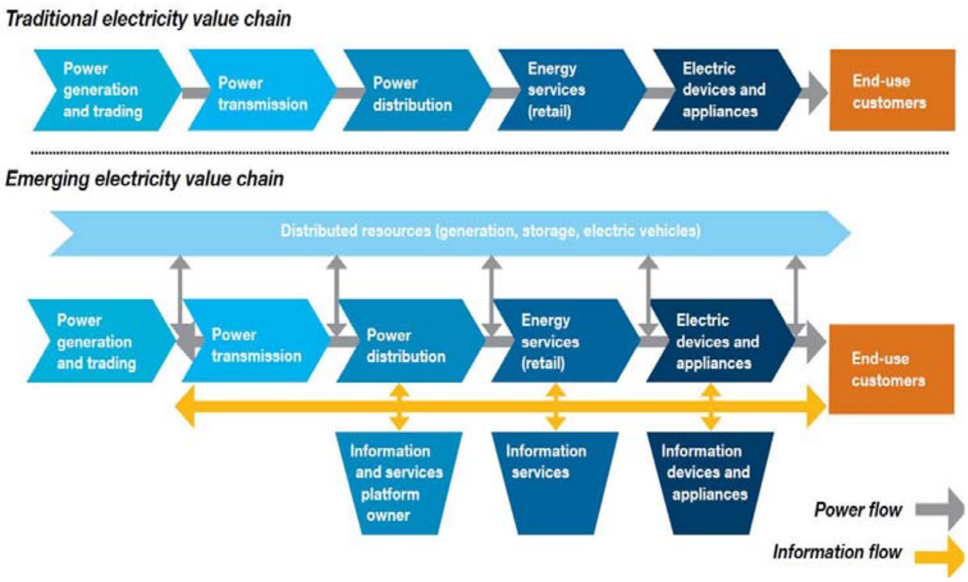


Figure 3.1 Comparison of the traditional and the newly emerging electricity value chain

source: IBM 2010

As previously illustrated, a variety of technological advances are needed to make the transition possible. The key challenge for utilities, however, is not technology itself, but rather the definition and reliable assessment of future benefits and, accordingly, the identification of the necessary changes in the existing business processes (Smartgridnews, 2011). There are different definitions for the term "business model" for electricity production and distribution. Generally, a business model is a framework for the management of the commercial relationships among market entities, intended to create value along the entire electricity value chain. It can be seen as a logical sequence of benefit-generating steps and includes the identification of the stakeholders involved, their roles and most important transactions. For a business model to be sustainable it must define (Strebl, 2010):

- Actors, such as different companies involved including their roles;
- Products and services, such as load modification;
- Contractual relationships between the actors, including pricing and penalties;
- Transactions between actors: energy, information and economic flows;
- Enabling technologies, e.g. those for sufficient communication;
- Values/benefits for the actors, such as ability to integrate distributed and intermitted generation;
- Drivers and barriers of the implementation, such as regulatory constraints to the adoption.
- the development of smart grid business models leads to the identification of a number of open issues (Strebl, 2010), notably concerning:
    - the benefits generated by smart grid technologies / applications and those accruing them and those bearing the corresponding costs
    - the nature of arising costs and benefits
    - the identification of incentives that are needed to achieve the expected benefits
    - The compatibility of the present business-model with the current (electricity) market model in ?

The development of innovative business models in the smart grid market is driven by energy utilities. A systematic development approach is shown in Table 3.1, featuring four main business categories: value proposition, customer, added value structure and financial aspects. The key questions are summarised below (Knab/Konnertz, 2011).

Table 3.1: key elements of business models

<table>
<tr><th>Value proposition</th><th>Customer</th><th>Added value structure</th><th>Financial aspects</th></tr>
<tr><td>Which values generate the business model?</td><td>Who are the customers and how can we reach them?</td><td>How to build the service?</td><td>How to earn money/where are the incurring costs?</td></tr>
<tr><td rowspan="3">Value proposition
• Which value can we offer to the customer?
• Which additional value can we offer?
• Which customer-challenges can we help to solve?
• Which range of products or services do we offer to what kind of customer?
• What kind of customer needs can be satisfied by our business model?</td><td>Customer relation
• Which relation do customers expect from us?
• Who are the customers and how do they want to be treated?</td><td>Key activities
• Which activities are needed to run our business model?</td><td>Revenue generating model
• Which benefit leads to which willingness to pay?
• What is the favourite way of paying for our customers (e.g. tariffs)?</td></tr>
<tr><td>Sales channels
• How to address customers?
• How can the created value achieve customers?</td><td>Key partners
• Who are our key partners?
• Who are our key suppliers?</td><td rowspan="2">Cost structure
• What cost blocks does our business model have?
• Which key resources and key factors are the most expensive?</td></tr>
<tr><td>Customer segments
To whom can we offer relevant benefits?
How to segment our customers?</td><td>Key resources
• Which are the needed resources to run our business model?</td></tr>
</table>

Source (Knab/Konnertz, 2011)

Actual business cases are still mostly in pilot phases and are built in accordance with the current market structure. With reference to the electricity value chain, they can be categorized into upstream and downstream businesses, the latter including the emerging electric vehicle market.

1. The upstream business, that mainly involves TSOs and DSOs, provides ancillary services (e.g. back-up, power quality control etc.) both to the grid operator and to large-scale consumers. The development of these business models depends on the pricing schemes they adopt as well as on the customers´ willingness to pay. Along with distributed generation facilities, storage technologies will most likely be part of this business. Should the implementation of ancillary services allow to reduce the amount of investment in peak generation capacities, then network operators might use the corresponding savings to finance the development of the ancillary services themselves. The regulator interferes here by defining the payments for ancillary services and determining how avoided investments on the generation side can be used to finance investment in grid capacity.

2. The downstream business (beyond the meter), offers both new services (e.g. billing, prepaid meters, smart home service packages etc.), and direct economic savings (e.g. benefits from load shifting, demand response) or even indirect savings through energy efficiency measures. Downstream business include mainly telecommunication companies, ESCOs, utilities as well as ICT manufacturers. Regulation should encourage these businesses to establish dynamic tariffs by obliging utilities to offer peak-time pricing and / or discounts for energy efficiency improvements in residential and commercial sectors.
3. The electric vehicle market comprises plug-in-stations, charging, as well as the sale of cars, scooters etc. The main beneficiaries are the automotive industry and the utilities themselves. Regulators have to establish a framework which ensures that the increased electricity demand for mobility does not negatively affect grid reliability.

The business models and pilot cases concerning the downstream business deserve particular attention.. In relation to the key elements listed in Table 3.1, current business cases show that answers depend on the market architecture (structured or non-structured). Furthermore, they rely on the development of the technical environment, which in turn influences business key partners. In summary, the future development of the smart grid should be primarily market-driven, with system operators as the main investors and beneficiaries. On the other hand, the regulatory framework should encourage a fair distribution of risks and benefits among all actors, as business models that do not allow for the sharing of short-term investment costs and of long-term benefits are bound to fail. Incentives from the regulatory framework should encourage the actors to seek benefits from efficiency increases rather than additional sales. Only under these circumstances the transition from the "volume-based" to the "efficiency-based" business model might take place (IEA, 2011).

3.1.1 Existing Business models

Four mainstream business models encompassing customer participation through demand response and energy efficiency programs are summarized below.

Traditional utility model

Customer participation is enabled from utility account representatives signing up individual firms to participate in utility-run offerings. Utilities offer site assessments to companies to identify their demand response opportunities and develop a demand response plan. It is mostly used in non-restructured markets without a further evolution of the relationship between utility and customer.

CSP or aggregator model

In restructured markets, participation is enacted through an intermediary. The intermediaries are demand response firms in the aggregation business like the US company EnerNOC or curtailment service providers (CSP) like the US company CPower. The aggregators benefit from participating in existing demand response programs of utilities or regional transmission organizations (the Council of ISO/RTO in North America). The company EnerNOC implemented this business model with a focus on industry and commercial customers. One business case is the aggregation of on-site backup diesel generation for demand response purposes. On the whole, EnerNOC operates an aggregated capacity of 5,3 GW from 3.600 customers under contract (Knab/Konnertz, 2011)

Customer-provisioned model

In this model, customers purchase demand response technology in their own interest. Many large retail chains, such as Wal-Mart, have their own demand response policies. It enables them to manage operating costs and benefit from participation in national programs. In many cases such firms (Sioshansi Fereidon P, 2011) have implemented real-time operation monitoring and can use the same information for demand response purposes. The achievable benefits of this model vary greatly because the standardized systems have to intersect with many different ISO/RTO and utility programs. Further development of clearer standards combined with declining costs for technical devices could make this model attractive for smaller customers as well.

The ESCO model

The fundamental idea behind this model is the installation of more efficient equipment to create savings which are shared between customers and utilities which act as installers (sometimes it is referred as "the shared savings model"). Due to the success recorded in many companies this model was thought to be exceptionally fortunate. But the lack of real-time information about energy usage makes it very difficult to validate savings from a single technological change. Furthermore, it is difficult to set benchmarks that define shared savings mechanisms. Because of limited data access and availability of usage information the model has not become successful on a larger scale (Sioshansi Fereidon P, 2011)

3.1.2 Development of new business models

In restructured markets new integrated business models are already emerging. They combine energy supply, demand response and saving opportunities. Thereby, they allow companies to monetize the use of energy savings, load shifts and energy efficiency gains. A major advantage of these models is that they do not necessarily require the customer to invest into efficiency up-front. Main value streams are the hedges against rising prices in competitive markets. As a part of the electricity bill, the hedge can be leveraged to finance efficiency improvements or technical upgrades. While the required technology for this new integrated model does exist, targeted solutions are still needed. Solutions such as smart home and efficient building operation enable actors to monetize their actions through physical systems as to replace the purchase of financial hedges in energy markets (Sioshansi Fereidon P, 2011)

3.1.2.1 Smart home

In the year 2000 the first major attempt to introduce the concept and practice of Smart Home failed, owing to a combination of complexity of products, insufficient user-friendliness, high costs of technology and a lack of qualified staff.

Today, the different smart home applications are provided on ad hoc platforms that contain modular technical components, each enabling different functions. For smart home applications to be profitable, on should:

- Minimize costs by concentrating on technologies which enable many functions
- Maximize revenues by concentrating on functions with a high willingness to pay

A typical example of a high potential smart home application is that of window sensors. These are technical components that recognize the state of a window and can trigger actions like detecting an intrusion or shutting down the heating system. They can be combined with an engine to close and open an automatic air conditioning system. As a result, several benefits occur:

- For house owners: higher degree of comfort and security
- For EU-Member States: economic benefits from energy efficiency
- For insurance companies: lower risk of intrusion (Knab/Konnertz, 2011)

Another example of the smart home application are the smart meters and their related communication devices like home displays and IT modules. Smart meters are actually key enablers for consumer empowerment and for smart home energy service markets. With a whole system in place major benefits can be foreseen. This fosters deployment costs of smart meters which are lower than the expected benefits. Home energy controllers are seen as a complement to smart meters that, through sensors located across the home, allow for the exchange of monitoring and control data on smart appliances and EVs. Home energy controllers are the gateway for consumers to access tailored energy services (e.g. demand response). Both devices combined offer consumer data that allow tailoring energy services to specific needs and requirements of different customer segments.

On this basis deregulated energy market players e.g. aggregators can build a ***smart home service platform business model*** in order to subsidize home energy controllers. The platform consists of a physical and a service part. While the service part is owned by the aggregator, the physical platform is considered a regulated asset, which is built by the DSO under regulatory incentive schemes (DSO role: ensuring functioning and non-discriminatory platform access). DSOs recover their investments through fees from platform participants and operational savings through active demand (e.g. voltage regulation, power flow control, ancillary services, smart load reduction for grid maintenance). Nevertheless, the platform set-up requires up-front and risky investments that pay back once it is up and running. A key function of the aggregator is the provision of access and incentives to consumers to actively participate in the electricity market and furthermore to use new technologies (e.g. micro-generators, EVs, smart appliances) in their home.

The profitability of a smart home platform is not directly coupled with electricity power flows, but rather with the establishment of synergies and transactions among platform participants to offer new services and products. Systemic effects resulting from the establishment of platforms may create a business case for several participants who may not enter the market individually. Therefore, new regulation should encourage and strengthen synergies. Most likely aggregators compete in offering energy conservation and efficiency services to mitigate energy bills to attract new customers. Such a business model can shift the business value from electricity supply to services and move the electricity sector away from the consumption-driven approach. From the DSO point of view new revenues coming from the provision of platform services (e.g. dispatching services, provision of metering data etc.) could encourage the active pursuit of energy efficiency measures by making up for declining electricity sales. This requires new regulation to support DSO transition from volume-based to service based business models (Faruqui, A., Harris, D., Hledik, L. 2011).

3.1.2.2 Dynamic efficient building operation

Today, building managers operate a building as to optimize tenant comfort on the one hand, and minimize total energy consumption on the other. However, from the economic perspective the timing of energy usage is more important than total consumption. Therefore, building operation should be able to respond to price signals from wholesale electricity markets.

Advanced metering systems increase the granularity of communication and control, thus offering many new opportunities for demand response. With the concept of dynamic efficiency in buildings an operational solution to optimize multiple, unrelated inputs in real-time is possible.

Today, large commercial buildings operate with advanced building energy management systems (BEMS). But most of those systems optimize tenant comfort and total energy consumption rather than enabling dynamic limitation of high pricing and participation in demand response programs. To increase the dynamic efficiency of building operation, real-time information on the usage of equipment in a building must be enhanced.

Dynamic efficient building operation benefits building owners thanks to reduced operation costs, tenants in the form of reduced energy costs, and system operators through a more effective real-time operation of the system. To make these potential benefits available through sustainable business models, the actors must focus on solutions that maximize the available granularity of real-time communication and control.

Business models devised for commercial buildings can be transferred to residential customers, as only the size of the potential load is different. The model which operates large loads can be applicable for small loads as similar technologies exist e.g. for residential cooling systems. Acceptance by the customer is crucial for existing as well as for new business models and has to be highly increased. With further developed devices, increased penetration of AMI combined with declining costs automated demand response can increase. Then the value of loads involved through rate designs, time-of-use rates the impact on peak-loads can get significant (Sioshansi Fereidon P, 2011).

3.2 Business models in pilot business cases

The full potential benefits of smart grids can only be achieved in the long-term, when the entire system is in place. But smart grids have to be built up step by step with the challenge to support investments at each step by business cases and ensure intermediate benefits on the way. Key elements are:

- system integration of single smart grid technologies and equally shared costs among all stakeholders,
- the complete engagement of consumers by tangible benefits, achieved through

- The following section provides an overview of existing business models from the EU-DEEP and FENIX research projects. The focus of these business models is to support the integration of renewable energies through the aggregation of demand response (DR), distributed generation (DG) and distributed energy storages (DS) referred to as distributed energy resources (DER). The different functions of DER operation are carried out by an independent organization (aggregator) or an existing market participant (e.g. an electricity retailer). Aggregators act as intermediaries between customers (to whom they provide DER) and system operators (for which they play the role of users). In restructured markets aggregators provide market access to DER.

In addition to the EU DEEP and FENIX business models, the setup of a market platform in two pilot projects will be presented. The first project includes a market platform for demand response by the DSO ENEL (Italy). The second comprises a market platform for DER aggregation by Energinet (Denmark) and RWE (Germany).

Furthermore, consumer benefits of smart grid business models from several EU projects are summarized at the end of the chapter.

3.2.1 Aggregation

Aggregators are intermediaries between a group of consumers and energy markets. They are defined as entities, which group demand or generation of small consumers into diversified portfolios of distributed energy resources (DER). Thereby, they provide next to total energy amounts, energy shifts and services to other market participants. Thus small energy consumers and producers can acquire access to electricity markets (EU-DEEP Project 2011). The combination of increased flexibility with lower operation costs will reduce the gap to profitability - and therefore the need for subsidies decreases - which will foster DER integration in the power system. Four main drivers of aggregation can be identified:

- **Lower market entry barriers** for small consumers and generators. Aggregation enables them to enter the market in the short/medium term, which is economically beneficial, and thus increases DER market penetration
- **Rollout of smart metering** as enabler of aggregation.
- **The optimization of generation and consumption** through controlled operation of a large number of DER units.
- **Lower overall operating costs** through the combination of energy-related services from ESCOs, retailers etc. with aggregation business models.

Future aggregation businesses can be independent or a part of a larger company. Due to EU “Unbundling Regulation” system operators cannot act as commercial aggregators.

Furthermore, as a multi-player business (see Figure 3.2), aggregation requires a stable legal and contractual framework.

Figure 3.2 Aggregator, a facility portfolio manager in a multi player energy game

Source: EU-DEEP Project 2011

The following part of the chapter presents concepts and results from the EU-projects EU-DEEP and FENIX, which investigated aggregation business models.

3.2.1.1 EU-DEEP business models

The EU-DEEP project (EU-DEEP, 2011) has been carried out over five years by a consortium of 42 partners from 16 countries. Starting point of the project was an increased need for DER-aggregation due to the given European market architecture and in order to ensure the reliability of the power system with a high share of distributed generation (DG). The main focus of EU-DEEP was on the development of aggregation business models.

Three aggregation models have been evaluated in three different EU-countries. The objective was to highlight the most promising directions to ensure efficient and sustainable integration of DER in the current energy and regulation framework. On basis of the three business models the potential tangible benefits of aggregated DG were investigated:

- Business model I: Aggregating commercial and industrial demand response to balance intermittent generation
- Business model II: Integrating residential scale flexible Micro-Combined-Heat and Power (CHP) into electricity markets

- Business model III: Leveraging on the flexibility of aggregated CHP units and demand response to extend the conventional energy service company (ESCO) business.

The considered DER technologies included intermittent renewable energy resources (RES), CHP and flexible demand (demand response). The market segments covered residential customers (small size), commercial customers (small to medium size) and industrial customers (medium to large). Companies such as electricity suppliers, energy suppliers (electricity and gas) and ESCO were selected to implement the business models (see Table 3.2.)

Table 3.2: Overview of the three business models in the EU-DEEP project

Business n°	DER technology	Customers	Company
1	RES + Flexible demand	Medium commercial + Industrial	Electricity supplier
2	CHP	Small residential	Energy suppli-er
3	CHP + Flexible demand	Medium commercial	ESCO

Source: Hashmi, 2011

The the EU-DEEP business models show that aggregation has the potential to reduce the gap to profitability and thereby gradually reduce the need for public subsidies (Hashmi, 2011, p.53). To aggregate both DG and DR is expected to be a key element for exploiting the potentials of DER. Aggregation business models provide a way to integrate local energy resources into dynamic electricity markets. By using aggregated DER flexibility a certain volume for entry in service markets of system operation can be reached so that the business models can ensure a fair rate of return to aggregators and involved stakeholders. Main benefits will be the reduction of customer energy costs, new flexible system operation, and the overall reduction of CO_2-emissions. Business model I has a low level of risk and can be applied in a short-term perspective, while business model II, due to higher risks, can be applied for medium- and long term. Business model III is an extension of the existing ESCO model for new emerging services. In the following paragraphs, business model I is discussed in more detail, whereas business models II and III are characterized on a more general level. (Hashmi M. 2011, p.35).

Business Model I
Aggregating commercial and industrial demand response to balance variable-output generation

In this business case an electricity retailer aggregates demand response and distributed generation from commercial and small industrial customers (e.g. offices and waste water treatment plants). The supply of reserve capacities to meet the demand from the high share of intermittent generation in electricity markets can be provided from customer DR as well. A future retail activity could be the operation of Virtual Power Plants (VPP), by using their expertise in customers´ consumption and participating in electricity markets. To enable a profitable participation in the electricity market, aggregators will handle a number of 1.000 to 100.000 flexibility contracts. Options to benefit from this are either to balance the own retail portfolio or to provide ancillary services. Figure 3.3 3.3 provides an overview over the business relationships between actors. The consumption account balances DG and customer consumption.

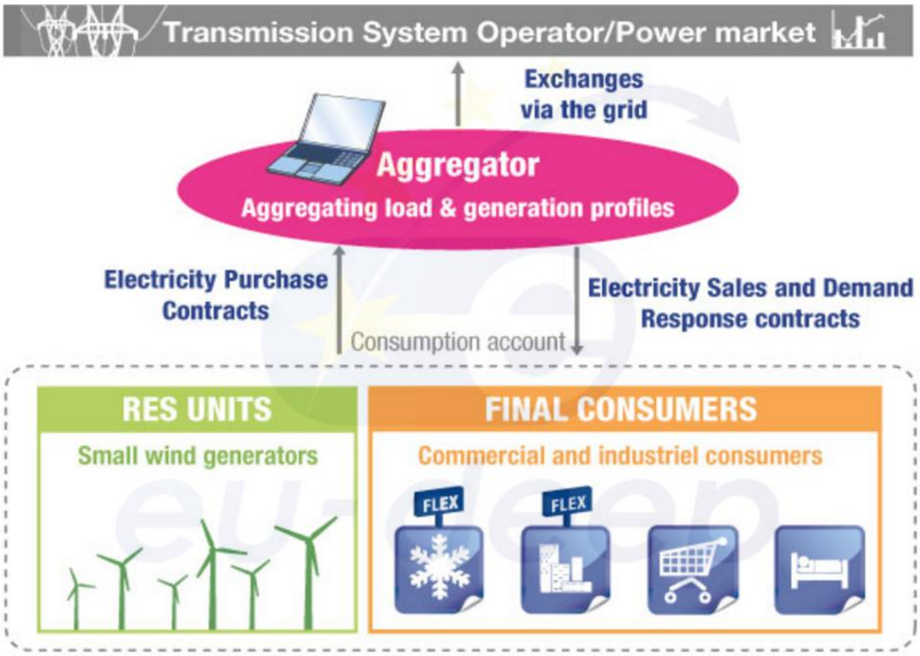


Figure 3.3 Graphical description of Business Model I

source: EU-DEEP, 2011

Flexibility is defined as the potential of the customer load for rapid modification and for maintaining it over a period of time, related to the request from system operation. Figure 3.4 shows a range of minimum flexibility (red bars) between 40 and 140 kW of each customer. Large offices have the highest level due to unavailable flexibility of air conditioning in winter. The field tests indicated a minimum required customer flexibility of 50 kW.

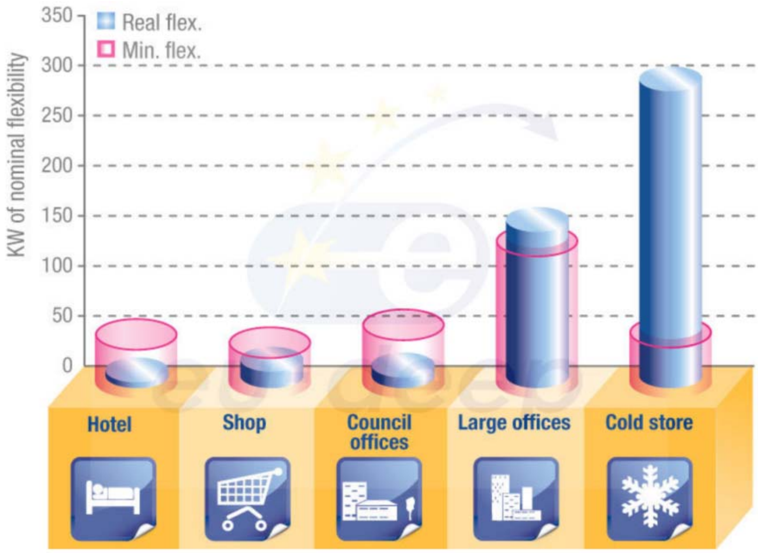


Figure 3.4 Potential of customer flexibility

source: EU-DEEP, 2011

The first task of the aggregator is to determine the right moment to take advantage of the flexibility portfolio. Thereafter, the second task is to build up sustainable and transparent structures to share the revenues among the customers. This model is based on close customer relationships, which allow transparent and effective information flow about potential profits. This also includes in-depth knowledge of needs and habits of individual customers involved. Nonetheless, the aggregator needs to transform complex electricity market mechanisms into simple transaction mechanisms for customers. Figure 3.5 shows one conceivable remuneration system between aggregators and customers based on payments for the offered flexibility and provision on request in electricity markets (EU-DEEP, 2011).

Figure 3.5 Remuneration system between aggregator and customer

Source: EU-DEEP, 2011

Benefits and Obstacles

With the management of flexibilities aggregators gain their own and customers´ revenues through:

- Frequency control services to TSOs
- Reduction of transmission and distribution charges
    - This is enabled in the UK by a specific use-of-system charge called "Triad". This transparent mechanism is based on annually charged payments by the TSO according to the load contribution in three peak hours. The displaced consumption from the peak hours leads to lower transmission charges.
- Power sales on the wholesale electricity market during high price periods
- The reduction of imbalance costs (RIC) by managing imbalances during high penalty moments

The amounts of savings and benefits for both aggregator and customer depend on the monetized value of customer's inconvenience caused by load flexibility. Apart from the direct business participants, society also benefits from the CO_2-reduction and improved balanced intermittent generation. Expenditures consist mainly of the operating costs of operating personnel, maintenance, and software.

The greatest obstacle to this business model is the customer's fear of harming his operations. Furthermore, the technology needed requires high customer intrusion compared to relatively low saving potential on the electricity bill. The technical risks of aggregation business are mainly linked to the load control architecture and were regarded as limited. More relevant are risks from emerging businesses such as:

- The full acceptance of the needed customer's involvement
- Development of new contract structures for easy subscriptions
- Detailed knowledge of customer's technical devices equipment to minimize installation risks and to offer cost-effective contracts in the context of e.g. smart energy use approaches

Business Model II

Integrating residential scale flexible Micro-CHP into electricity market

In this business case, an energy retailer of electricity and gas aggregates flexible micro-CHP units owned by residential customers. CHP-units need to be aggregated in order to participate in the electricity market. This aggregation can be taken from electricity retailers (acting as virtual power plant operator), as they will negotiate optimal prices before selling electricity outputs. The provision of generation flexibility was analysed by means of using heat storages. Main focus is the required decoupling level between electricity and heat production and the minimum size of a CHP-portfolio. Figure 3.6 illustrates the intended functionality of the business model.

Benefits and Obstacles

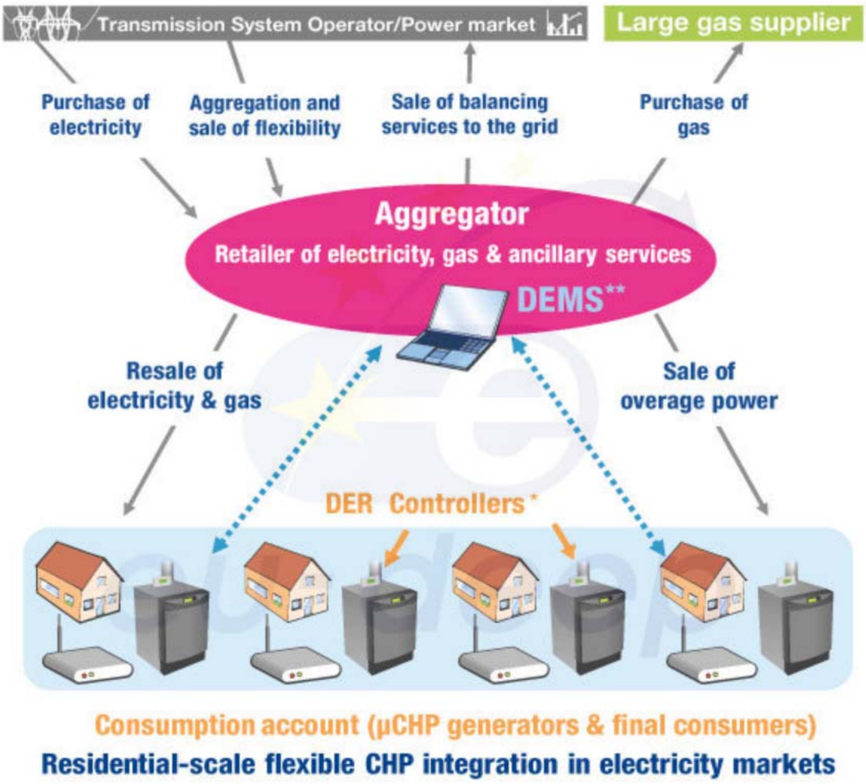
The business model has the following expected revenues:

- Selling energy to customers with the type depending on ownership:
    - Customer-owned: gas sales
    - Aggregator-owned: heat and electricity sales
- Selling more power than needed for consumption in high price periods
- Effective response to price signals requires a flexible operating CHP-park
- Reduction of portfolio imbalance penalties by optimized use of DG
- Selling balancing services to system operators

DER-owners benefit by participating in different energy markets. Aggregators benefit by offering services in energy markets, e.g. the balancing market. DER flexibility can be used to balance the deviations portfolio of the aggregator or realising higher benefit by selling them. Society as a whole also benefits from the deviation between demand and supply as well as from less expensive and pollutant power plants.

However, significant operational costs incurred through the implemented soft- and hardware.

The main obstacles regarding the business model are the commercial and regulatory framework as well as the lack of standards for information and communication between virtual power plants (VPP) and relevant actors. Policy regulation is recommended to decrease sizes for market entry in energy markets (e.g. balancing markets).



**DEMS: Decentralised Energy Management System

Figure 3.6 Graphical description of business model II

source: EU-DEEP, 2011

Business Model III: Leveraging on the flexibility of aggregated CHP units and demand response to extend the conventional ESCO business

The business model expands the existing CHP-business model II through addition of demand response. This business case includes ESCOs as owners of CHP-units proposing demand response contracts to their commercial customers. Flexibility is offered from both demand and supply (CHP) side. The CHP-flexibility is provided from boilers and heat storage tanks. The installation of small CHP-units with storage in customer sites reduces power losses and increases energy efficiency. Such efficiency measures are profitable in form of feed-in tariffs linked to efficiency certificates. Down to a certain level of heat demand the model is already profitable today. The aggregation of flexible loads and CHP-units creates new benefits such as services for system operators and avoided balancing penalties. Figure 3.7 shows the principle of this model.

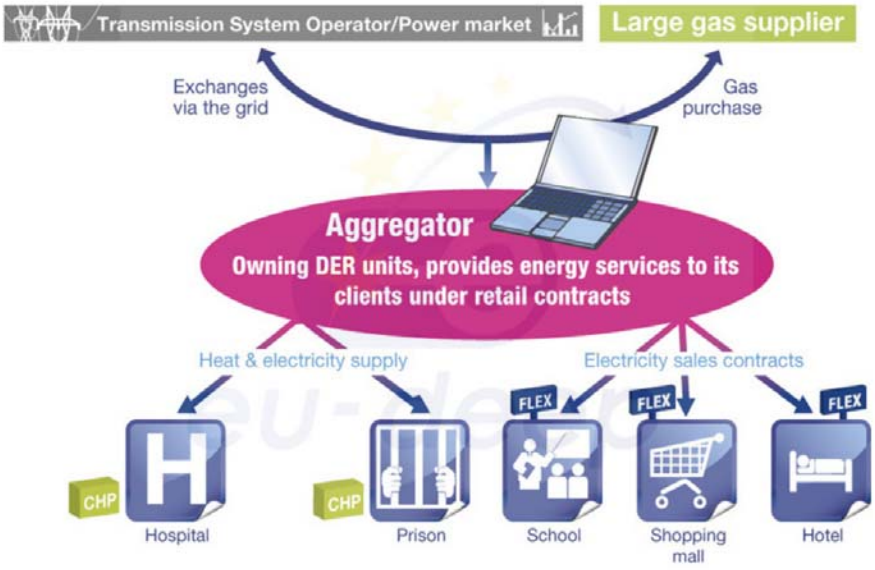


Figure 3.7 Graphical description business model III

source: EU-DEEP, 2011

Benefits and Obstacles

DER-owners benefit from the participation in energy markets to offer generation, reduction of consumption or both. Customer benefits through demand response are the reduction of energy costs between 2 - 6% (in the field test). Aggregators benefit from the sale of customer flexibilities in balancing and other energy markets. Furthermore, the reduction of portfolio imbalance risks increases their benefits between 1,5 - 2%.

Similar to business model II, society benefits from less expensive and less pollutant power plants and improved balance between demand and supply.

Due to the need for a heat storage tank this business model has higher operational costs compared to business model II. Furthermore, the necessary ICT operation and maintenance costs are higher.

Again, similar to model II, the main obstacles are the commercial and regulatory framework as well as the lack of standards for information and communication between VPP and relevant actors. The profitable operation of this model requires high heat demands. From the regulatory side flexible support schemes (such as bonuses or green certificates) are more appropriate than feed-in tariffs.

3.2.1.2 *FENIX business models*

The FENIX (Flexible Electricity Network to Integrate the expected energy evolution) research project (2005-2009, ref: (FENIX project, 2009)) had a consortium of 20 partners. The overall objective was to develop DER-units as cost-efficient, secure and sustainable parts of the EU power system with a focus on the concept of virtual power plants (VPP).

VPP transform diverse DER-capacities into one operating load profile. With its aggregated output the VPP reacts to impacts of the grid. A single DER gets access and visibility in energy markets. The concept optimizes individual DER positions and maximizes benefit opportunities. From this concept not only the DER-owner, but also the system operator benefits due to optimal use of connected grid capacity and high operation efficiency. The flexible DER-portfolio of VPP can be used in wholesale energy markets or as service provider to system operators.

The FENIX project comprised two types of business models that differ in the pressure of DER integration

- Business Model I: Access to the market through a commercial aggregator, in absence of strong pressure to integrate DER.
- Business Model II: Access to the market through a commercial aggregator, in presence of strong pressure to integrate DER.

The concepts were tested in Spain (Southern Scenario) and in the UK (Northern scenario) and had different sizes of DER capacity (kW-size in the UK and MW-size in Spain) (SEESGEN-ICT 2010, p.13). The business case including a DER-owner and a VPP operator was organised and operated in a commercial virtual power plant (CVPP), which is responsive to market price signals (FENIX results 2009).

Business Model I: Access to the market through commercial aggregator, in absence of strong pressure to integrate DER.

The CVPP as a competitive market player appears like a single power plant. It aggregates and optimizes DER returns and carries out market transactions. Risks are not absorbed by the CVPP, but shifted to clients. The model considers only financial but no operational integration of aggregated DER.

Figure 3.8 illustrates the essential economic flows of the model:

- CVPP receives payments for electricity from the wholesale market,
- CVPP receives payments from TSO for balancing and other ancillary services
- CVPP pays DER-operators and receives the payments for balancing deviations
- Not shown in the figure: The payments from DER-operators for received grid services

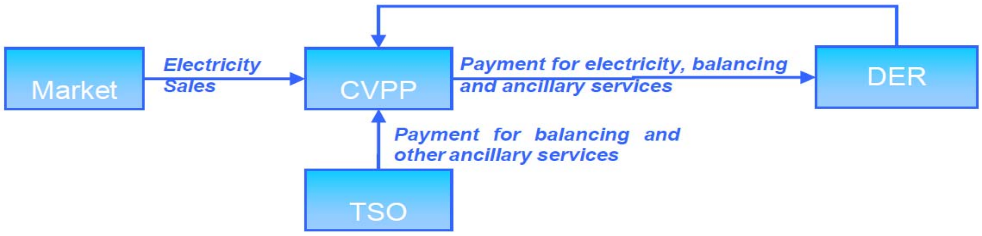


Figure 3.8 Economic flows between the actors of business model I

source: SEESGEN-ICT Project, 2010

The business model is based on relationships between actors in a robust set of contracts. The following concrete details should be included in contracts between DER and CVPP:

- billing and payment;
- metering of the power flow from and to the DER;
- protocols that have to be used for the communication between DER
- real time dispatching of the DER by means of CVPP;
- bid submission from DER to CVPP.

Contracts between CVPP and "the market" should include agreements about:

- billing and payment;
- metering of CVPP output;
- bid submission from CVPP to market;
- real time dispatching of the CVPP by means of system-operation.

Benefits and Obstacles

The CVPP enables market-entry for small DER by minimizing investment costs and market fees and maximizing benefits. DER utilization rates are optimized due to real-time market operation. Society as a whole benefits from improved integration of small renewable energy sources into the grid. Operating costs result from expenditures for network equipment, outsourced maintenance, ICT by TSO and DSO. This business model needs a stable commercial and regulatory framework and strong ICT standards between CVPP and relevant actors.

Business Model II: Access to the Market through commercial aggregator, in presence of strong pressure to integrate DER

The concept of this business model is similar to FENIX model I. Model II was set in an advanced policy scenario framework (FENIX scenario), which assumed much stronger pressure for DER integration. This model helps to overcome obstacles of renewable generation from energy transport through providing fast start-up power capacity. A main improvement can be seen in a less intermittency of renewable power generation, which fosters its further deployment and coevally reduces fossil fuel generation. Additionally, grid reliability increased due to ancillary services from VPP. The fact that renewable production was expected to increase on the local distributed level decreased power line losses on high voltage level. Accordingly, postponed grid investments are reduced. Additional operational costs – as compared to model I – resulted from grid reinforcement investment costs in sections with high DER share.

3.2.2 Platforms

The term platform refers to a common architecture. Essentially it is a design for products, services and infrastructure facilitating interactions of users. This also includes a set of rules, like protocols and pricing terms that provide a fundament for transactions among two or more parties. In the information technology (IT) many platform-types exist, for example Internet platforms with social networking sites. Highly diverse participants in combination with a set of business processes enable competition and new value creation.

Smart grid platforms have to link all kind of market actors and provide the data for system operation. The need for dedicated platforms, which were not required with the old value chain due to low communication needs with customers, forcefully arises with the emerging smart grid. The owner of the platform creates a value by providing access to different applications and through the delivery of data to the supply and demand side (IBM 2010, p.7).

The unresolved questions include data responsibility and the future platform operator. One central platform cannot take the high risk of data privacy and security – decentralized distribution approaches, similar to today's meter service operator are more likely. All actors on the future data platforms need a clear regulation framework concerning access rules. Regulation should pay close attention to encourage participation of small consumers and integrate peak-shaving and cost saving mechanisms through demand response on the network operation-side (EC JRC, p.38). Non-discriminatory access in compliance with data protection and privacy requirements is needed for technical and economic efficient activities.

The following part of the chapter discusses two research projects that investigated market platforms; one focussed on the demand and the other one the supply side.

3.2.2.1 Market platform for demand response

The overall aim of the projects in Figure 3.9 was the shift from smart meter rollout to the setup of a demand response market platform. The framework was a multi-disciplinary consortium between ENEL, several manufacturers, a telecom company, other DSOs, energy retailers and research centres.

Project Name	Leading Organisation	Budget (€ million)	Stage	Location	Dates	Description
Telegestore	Enel	2100	Deployment	IT	2001-2006	Roll-out of 32 million smart meters. Focus on the physical layer
StAMI	Enel	2,1	Deployment	IT	2010-2011	Use of smart metering data for grid optimisation. Focus on the physical layer
Energy@Home	Enel	n/a	R&D	IT	2009-2011	Interface between smart meter and home energy management device for the provision of value added services. Focus on the link between the physical and market layers
ADDRESS	Enel	4.27	R&D	IT	2008-2012	Market structure to aggregate and integrate Demand Response. Focus on the market layer

Figure 3.9 The set of ENEL Projects

Source: JRC, 2011

Project content

ENEL refinanced the investment of €2.1 billion for the rollout of 32 million smart meters through tariffs and the reduction of operational costs of €500 million per year. Investments focused on concrete benefits on the utility side and should trickle down to customers through reduced tariffs. The investment in new smart meter applications such as demand response was not included.

In 2008 ENEL installed in-home displays (Smart Info) in 1.000 households to offer consumption monitoring and prices to customers. The installation of the displays led to a behavioural change of 57% of customers. In the ADDRESS project an aggregator operated multi-side-platform (MSP) was used to analyze demand response. The MSP offers participants the opportunity to sell and buy load flexibility. The operating platform provided new benefits to the participants. Potential benefits from this business case are linked to the number of platform users.

The new benefits can be shared between participants. The DSO benefits from demand-side-management, shifted peak-loads, less need for grid enforcements and more optional ancillary services. Aggregators benefit from offered energy services and participating customers benefit from selling load-flexibilities, optimizing consumption and purchasing DER (EC JRC 2011, p.39).

Project results

The project results showed that the approach to plug-in a single technology into the existing power system is conservative because it did not include future applications and functionalities enabled through new technology. As a consequence, the related smart grid investments are difficult and unclear and long-term benefits are dependent on the system architecture surrounding the new technology.

Especially the relationship between DSO and aggregator require clear coordination mechanisms. Compatibility of energy services with physical constraints has to be ensured through mapping geographical areas to grid users. That means that geographical information should be available to relevant platform participants.

Grid operators are expected to be the main platform investors, while all participants receive benefits from it. The recovery management of the ENEL smart meter investments was irrespective from the demand response platform. Therefore, this business case cannot provide a basis for other projects. Progressing from demonstration to deployment of platforms requires systemic benefits right from the start. A fair cost-sharing model has to balance short-term costs and long-term benefits to induce further investment.

In general, a rising number of participants increase the profit of demand response platforms. High participation implies high levels of transparency, privacy issues and user friendliness. However, the full potential of benefits is only available with the whole physical and market system in place.

3.2.2.2 Market platform for DER aggregation

The overall aim of the projects in Figure 3.10 was the setup of DER aggregation market platform.

Project Name	Leading Organisation	Budget (€ million)	Stage	Dates	Location	Description
Cell Controller	Energinet	13.4	Demo	2004-2011	DK	Control architecture for the central coordination of DERs
Virtual Power Plant	RWE	0.8	Demo	2008-2010	DE	Demonstration of the technical and economical feasibility of the VPP concept (aggregation of CHP, Biomass or Windturbines).
EcoGrid EU	Energinet	8.3	Demo	2011-2014	DK	Set-up of a complete platform for the transactions of electricity services through DERs

Figure 3.10 The set of Projects from Energinet and RWE

Source: JRC, 2011

Content and results of the "Market platform for DER aggregation" project

The setup of the platform requires two previous steps:

- A physical layer consisting of advanced grid monitoring, control and ICT infrastructure to interconnect DER units
- A market layer consisting technical and commercial DER aggregation on the supply and demand side as VPP.

The physical layer ensures the safe access of distributed generation. An open, reliable, secure platform to offer and transmit information and price signals to participants is the fundament to integrate aggregation in the electricity market. The market layer establishes aggregation market mechanisms.

Within the setup of the "Market platform for DER aggregation" project it was analysed which new services are emerging through the new platform infrastructure. DSO e.g. will increase to dispatch distributed generation (relying on voltage control through DG in tight coordination with the TSO). As a result, the IT infrastructure of the DSO needs to be tightly linked to the TSO. DER integration on supply side reached already commercial maturity. Contrarily, much more demonstration is required on the demand side (EC JRC 2011, p.42).

3.2.3 Consumer benefits

Reduction of outages, highly transparent and frequent billing information, energy savings and market entry via aggregation - potential customer benefits of the emerging smart grid are manifold. In the long run, systemic benefits will even broaden achievable benefits once the entire system is in place. The consumers´ benefit from smart grid applications depends on their participation in demand response to shift consumption. Beside the technical devices and transparency regulations, consumers need to be educated on the whole range of new options, functions and benefits (EU JRC 2011,p.44). The following section summarizes attained consumer-side benefits in a number of EU-projects.

The deployment of 32 million smart meters in the ENEL project (Italy), presented above, allows an assessment of the potential outcome of a national rollout. Results show that the smart meters combined with in-home-displays encouraged 57% of the customers to behavioural changes. In relation to that group of customers, detailed analyses illustrate that 29% delayed the use of domestic appliances to the evening; 12% avoided the simultaneous use of different appliances; 8% switched off appliances instead of leaving them in standby and 7% decreased their usage of white-goods. Furthermore, the introduction of time-based rates is expected to reduce energy consumption between 5 and 10%. Currently only 1% shifted their demand to low peak times, however, upcoming projects predict higher shares.

In the Storstad project (Sweden) the deployment of 370.000 smart meters resulted in a significant change of customers´ interest in their electricity consumption. This can be confirmed from more customer contacts related to energy consumption or usage, and the decline in meter reading related contacts about 60 %. Smart meter rollout in the AMR project (Sweden) decreased the time for billing settlement and correction from 13 to 2 months. Furthermore, the lead-time to export meter readings to suppliers was significantly reduced from 30 to 5 days.

The Iberdrola GAD (Spain) project results confirmed the positive influence of dynamic pricing on consumer-side load-modification to reduce energy bills. Further estimations assume a saving potential of 15% for the consumption of average customers.

Smart meters are an enabling technology that changes the position of customers, who at times turn into suppliers. Under specific market conditions, tested aggregation business models in the frame of the EU-DEEP project achieved savings of up to 3% of today's annual electricity bill. The emergence of active and non-active customers can lead to unexpected effects between market actors, e.g. if aggregators hurt the business of retailers, the retailers might increase customer rates to cover their losses as the ADDRESS project investigated (ADDRESS project 2010).

Research results from establishment and operation of market platforms show a strong interdependence between platform profitability and consumer engagement. Platform benefits increase with the number of participating consumers. To increase both it is imperative to grant easy access, fair competition among actors combined with tangible benefits, and high privacy standards. Project results have proven that given these conditions, energy management devices and aggregators can offer more effective and compelling incentives to take advantage of efficiency, conservation and sustainability opportunities enabled by new smart grid technologies to customers (JRC, 2011)

3.2.4 Results of business cases

Aggregation and VPP business models (FENIX and EU DEEP) improve the integration of fluctuating renewables at lower costs, increase active demand, reduce CO_2 emissions and improve market operation. According to the scenarios developed within the FENIX project, by 2020 CO_2 emissions in the electricity sector could be reduced by 7.5 kg CO_2 per kW of flexible generation unit per year in a northern European scenario and by 13 kg CO_2 per kW of flexible generation unit per year in a southern European scenario, compared to the reference case (JRC, p.49). Results demonstrated that the integration of DER on the supply side in some cases has already reached commercial maturity (EU DEEP Business model I). Although aggregation businesses can achieve a fair rate of benefit under current market conditions, all models entail significant investment, operation, soft- and hardware, ICT, and maintenance costs. For the demand side integration still more demonstration is required. The development of enabling structures and technologies, e.g. smart meters, fosters synergies between actors and thus turns customers into active suppliers. In general, future businesses are based on close relationships between actors , which require in-depth knowledge of customers´ needs and habits to minimize risks and maximize cost effectiveness. Therefore, acceptance of the needed customer involvement must be ensured as precondition for success.

Platform profitability depends on consumer engagement. Ensuring tangible benefits, privacy and easy access and operation for consumers encourages fair competition among participating market players. Thus the number of actors and the business value of the platform increase simultaneously. Projects results confirm that by means of energy management devices (e.g. the "Energy Butler" in the Model City Mannheim Project) consumers can accrue advantages in efficiency, conservation and sustainability by seizing the opportunities offered by new smart grid technologies. Free competition of aggregators has to be ensured. High level of internal platform control can lead to locked platforms with a dominant market position. Regulation should take that into account.

Results of the ADDRESS project showed clashes between different market actors. Aggregators potentially hurt the business of retailers in competition for active customers. The implementation of active demand services can hurt the predictability of retailer portfolios. Thus the overall financial savings on the active customer side disappear on the non-active customer side, as retailers try to recoup losses through higher rates for non-active consumers (JRC, p. 45). Therefore transparency on the use of active demand services needs to be assured. Any modifying aggregation action should be reflected of the corresponding retailers balancing position. Since retailers should not be adversely affected by balancing market penalties due to unpredictable aggregation activities in their portfolios.

To configure a smooth and predictable design of active demand services activation the aggregator should be responsible for actions towards the portfolio of a particular retailer. Consequently the change of demand in retail must be transferred to its product service customers. Another approach could be an additional fee paid from aggregators for impacting another actor´s portfolio.

If aggregator and retailer are not two independent market participants (aggregator-retailer) the potential for relaxation of established marked rules must be examined. As this combination allows economies of scale, since. retailers already have customer relationships and thus balancing anomalies can be matched automatically with active demand products. In this case regulation has to weigh the potential increases in benefits (e.g. making aggregation a simpler business, avoiding potential balancing problems for retailers, decreasing overall risk) against the potential loss in competition and innovation for single aggregators and retailers in the market place (ADDRESS Project 2010).

3.3 New Business potential and challenges

To complete this overview on the new business models for the smart grids deployment it is crucial to cast a glance beyond the smart meter. Actually, from the business perspective, the main challenge arising from the future deployment of smart grids is to identify and exploit the potential benefits of advanced technologies for utilities, customers and society as a whole. Pilot initiatives so far, notably the roll out of smart meters, point at the urgent need for change on both the utility and the customer side, as the traditional business model of utilities does not allow to reap the full benefits of smart meter investments. Radical changes are called for in how utilities collect, store and process information, and newly emerging integrated business models represent a major challenge for utilities and an even bigger one for the customer beyond the meter.

In the traditional value chain the customer was not at the centre of utilities' concerns. In fact, the role of customers amounted to pay rates periodically and passively based on usage information drawn from the meters. So far established regulatory incentives (see 4.1.3) for utilities to grow and maintain their grids lead them to encourage customers to consistently use more electricity. This trend towards increasing consumption – which is invoiced on a monthly basis using average cost rates – hardly leaves to consumers the possibility of questioning their bills. Conversely, actively engaged customers who expect to receive real-time price signals as a precondition for their consumption represent a new challenge.

Utilities investing in smart meters expect their customers to respond to price signals by modifying their electricity usage patterns. Accordingly, the emerging new energy business requires models that are tailored on customers who increasingly relate their personal electricity consumption to the increasing price of resources, to the security of the energy system and to environmental concerns. Furthermore, reaping the full benefits of smart meter investments requires advanced technology in the homes of customers. However, even though a complete set of technologies is available, customer interest and acceptance differs widely. The aim of policy makers, entrepreneurs, manufacturers and other actors should therefore be to find the most economically convenient solution to transmit price signals to the customer beyond the meter, including the identification of the most effective technologies and models for customer engagement. In the short and medium term, mostly large commercial and residential buildings will be able to take advantage of these technologies and business models. In the long run, however, many of these models are expected to become profitable for small residential customers as well, due to declining costs of technology and increasing energy costs.

3.3.1 Demand Response

Today, demand response is used (by utilities) as a capacity resource. System planners consider demand response as an asset for system operation in peak times. New concepts of demand response include customer response to price signals, allowing for granular balancing and thus reducing the overall consumption. The most important driving factor here is combing dynamic prices with advanced technology ("prices to devices"). The transformation from a central power system with passive customers to a decentralized system with engaged responding customers leads to a dramatic change in system planning and operation. The design of new business models must support this change (Sioshansi Fereidon P, 2011).

A special challenge in this respect is the integration of residential customers, whose motivation is expected to be generally low in terms of economic benefit owing to minimal individual gains. Furthermore, their precise flexibility opportunities are not easy to predict and not easy to satisfy in classical market structures (JRC, 2011). Hence, aggregation of small customer flexibilities into larger amounts ensures better participation opportunities in energy markets and thus higher benefits.

3.3.2 Current state of customer engagement

The backlash of early smart meter installations mainly results from the fact that customers are not involved in the discussion between policy makers and utilities. Customers need to be actively involved in the process, as simply expecting them to adopt technology and discover its value bound to fail. Their engagement can be increased with effective communication, education and by offering them alternative choices about dynamic prices from the utility side.

Current pilot pricing and technology programs for customers can be classified into two categories:

- Technologies with direct customer feedback and
- Technologies with non-direct feedback, that allow customer to "set it and forget it"

Direct feedback technologies

Early research results have shown that behavioural changes on the customer side triggered by direct feedback technologies led to significant energy savings. However, the lack of direct feedback in the existing power system is so dramatic that the actors are sceptical regarding customer acceptance of the available technologies. Current research projects focus on two main direct feedback mechanisms:

- In-home energy display devices and
- Web-based energy usage monitoring

In-home displays (IHD) are developed to improve the knowledge of customers as to how and when their homes use energy. The first primitive generation devices required technologically savvy customers, while current technologies are considerably user-friendlier. A wide range of devices is available, ranging from a display linked to a full automation home system featuring energy usage analysis to a simple energy meter compiling daily energy usage. Notwithstanding, whether customers will become more engaged with either simple or more complex solutions, and whether they will just pick up their favourite device and use all its functions remains to be seen. This increases the uncertainty about the potential of mass deployment even if the devices are user-friendlier and less expensive. In contrast to physical devices, web-based approaches to engage customers are less costly and evolve more rapidly. However, such approaches face big challenges due to the current limited relation between customer and utility. Even if electric utilities seem to be less successful in moving customers to online-functions, they realize the potential of the smart grid to transform the relationship with their customers. Accordingly, a formerly tight message system begins to evolve into a new third party business linked to social media: web-based feedback mechanisms are highly interesting and exciting, especially to engage small customers.

For instance, telecommunication companies, which operate in a much more dynamic and innovative market environment than utilities, anticipate far-reaching changes to the energy business as soon as energy consumption data is widely made available to consumers. Google representative Michael Lock recently explained these expected changes, which are related to a phenomenon in social media dubbed "MoSoLoCo" (Mobile, Social, Local, Connected).

- **Mo**(bile): Consumers will expect their energy information to show up on mobile devices too, and to be able to control their home energy settings from the same place
- **So**(cial): Consumers will expect comparisons to other, similar homes, the ability to share tips and tricks, or even efficiency "games" and competitions
- **Lo**(cal): Consumers will soon come to expect that they'll be able to see local infrastructure as another layer in Google Maps. And doesn't it make sense that homeowners could check online for the location of underground lines on their own property? Or see where crews are during storms and disasters? (Long Island Power Authority is doing this already.)

- **Co**(nnected): many consumers will want to move from control to "cruise control." They will want to maintain overall control of the parameters (you can cycle my air conditioner no more than x times per year and the temperature cannot go past x degrees). But once they set the boundaries, they'll want the devices to operate automatically. Why should I need to remember to start my dishwasher at 9 p.m., my EV charging at 11 p.m. and my hot water pre-heating at 5 a.m. when my utility can do it for me?

Moreover, third party software platforms or behavioural change programs (The PEER program from the company Efficiency 2.0) begin to emerge and are being promoted. Furthermore, web-based feedback mechanisms are highly interesting and exciting, especially to engage small customers. Whether large players such as Google or small start-ups will be more successful is hard to predict.

The future development of direct feedback

As mentioned earlier, significantly lower capital costs are the most attractive driver for non-physical web-based energy management tools. The challenge for future web-based mechanisms is to move them from the computer to e.g. smart phones. The main attraction of IHD devices is precisely their physicality, but the costs are a big barrier for households compared to the extent of average energy bills. Even with AMI technologies emerging, the lack of quality energy use data is a limiting factor in further development for both non- and web-based technologies. Furthermore, the acceptance and the usage of new tools by households remain to be checked. Despite these challenges, manufacturers from the appliance industry such as GE and LG are preparing for the web-based change.

Non-direct feedback technologies

Direct feedback tools are based on active customer engagement. In order to reach customers who cannot (or do not wish to) actively monitor and change their behaviour, a new class of technologies is developing. This is sometimes referred to as “prices to devices” or “set it and forget it” technologies which enable automated response to prices and lower energy costs without daily monitoring and behavioural change. With increasing granularity of communication and control these technologies are expected to have a high penetration potential. Thereby, it remains to be seen who the future technology providers will be and which main providing channels and business models will be employed. Two examples of “prices to devices” technologies for residential customers are “Smart Thermostats” and “Smart Appliances”. The market for smart appliances is projected to grow and many manufacturers are already piloting technologies such as smart household appliances (e.g. smart refrigerator, washers, dryers, dishwashers and water heaters) that are able to adjust energy use to low price off-peak-times. In fact, of all the physical devices on the residential customer side beyond the meter, smart appliances seem to generate the biggest value for both customers and the electricity grid and offer the highest potentials. However, the exploitation of these potentials requires minimized installation costs. Lack of granular usage information, dynamic pricing programs and missing interconnection standards are currently the biggest barriers of further development (Sioshansi Fereidon P, 2011).

3.4 Conclusions and policy recommendations

It can be concluded that the core feature of smart grids is the integration of increasingly distributed resources, along with a shift of the behavioural paradigm of customers and active relations from utility-side. Such evolution from the present electricity grid to future smart grids will be progressive, strongly depending on advances in technology but also on policies, regulations and evolving business models. New business must sustainably create value along the newly transformed power system value chain. Incentives by the regulatory framework should encourage market actors to seek benefits from efficiency increases rather than additional sales to support the transition from the "volume-based" to the "efficiency-based" business model (IEA, 2011).

Existing business models like the traditional utility model, the aggregator model, the customer-provisioned model, and the ESCO model are designed to function within the existent infrastructural context. They already engage customers´ participation in demand response and energy efficiency programs, but with less real-time opportunities. Though each model differs in terms of intermediaries and level of customer commitment, all four are similar as they mainly rely on large-scale customers to create significant demand volumes. The hitherto limited availability of applications for residential customers is due to the lack of interoperability and communication standards, as well as high operation costs. As opposed to the existing business models, newly emerging models go beyond current infrastructure and allow utilities to monetize the use of energy savings, load shifts and energy efficiency gains on a real-time basis. They are innovative as they do not require the customer to invest into assets upfront, but generate value streams by hedging in competitive markets. Furthermore, both smart home as well as dynamic efficient building operation focus on automated systems that react dynamically, the former in terms of reacting to customer behaviour, the latter by transmitting real-time information through new metering systems and thus allowing for more active demand response.

The future development of active demand response requires an adequate system of real-time pricing models, which enables customers to participate in real time markets. Modelling exercises (Ahlert 2009) suggest that at least eight different types of tariffs need to be established to make optimum use of price differences. This would allow households to save up to 17% of their annual electricity bills. Both smart meter and downstream devices should be made available to consumers, so that benefits can be seen immediately. Promising approaches are automated appliances, which are easy to install and to use, affordable and completely secure. Although originally promoted in the interest of utilities, smart meters are in fact the most obvious contributors to the growing deployment of smart grids among consumers. On the other hand, both existing and new, innovative business models need to be embedded into a yet to emerge full smart grid system. Most of the benefits of smart grids will come from the increased synergies between the various components and players of electricity networks. Thus costs have to be shared among all stakeholders. Nevertheless, it is clear from the EPRI analysis that most of the costs will be borne by distribution grid operators (approximately 70%) whereas end-users will bear less than 10% (see, page 22 and page 88).

If the solutions proposed do not allow meeting the full range of users' requirements, customers should be allowed to opt out of services that are of no direct advantage to them. Also clear rules and procedures regarding the treatment of in home devices in case of a change of service provider are necessary in order to reduce resistance. In its evaluation of ongoing smart grid projects in Europe, the Joint Research Centre (Giordano, 2011) issues a warning concerning privacy whereby "detailed information about electricity use could be used by insurers, market analysts, or even criminals to track the daily routine of consumers; 35% of customers would not allow the utility to control thermostats in their homes at any price". However, smart grid services and products, which are not part of the regulated network activities such as home automation, small distributed generation, aggregation services, smart appliances and in some instances smart meters will only develop and reach their full potential if the main parts of the grid integrate them.

Market architectures remain highly country-specific. In the coming years a convergence process at least at the spot market level must take place, adapted to the interconnected pan-European transmission system. Some existing regulatory frameworks for the smart grid transition partially hinder the transition itself:iIn many cases, for instance, the utilities expected earnings are still based on the volume of electricity consumption, rather than supporting energy conservation. However, regulation schemes which include electricity outages and cost of carbon such as the British and the Australian markets, already offer more smart grid solutions. Close attention should be paid to how and where risks are managed and how they are passed on to the consumer. Trials and tests of innovative business models are part of the utility learning process. Thus utilities and their partners need to be given a "permission to fail" because the loss of capital invested is a strong barrier of innovation. Regulators need to focus on mechanisms, which allow utilities to benefit from their newly developed intellectual properties. In this regard the achievable return should be based on the utilities' taken risk (WEF 2010). In summary, what is actually required on the regulatory side is:

- Market access regulations (capacity size, fees etc.) for small-scale intermediary actors (e.g. aggregators) focussing on balancing markets and wholesale markets
- The development of a framework of DER real-time operation for the integration of ancillary services with high need for real-time communication and control between their participants.
- The improvement of price-policies to encourage business innovations which connect real costs to real prices on the utility-side and encourage a broad range of customers to participate in active demand response
- The implementation of smart meters, which could enable trading operations as well as near real-time remote control by network operators and commercial third parties
- The encouragement of the installation of technical devices on consumer side beyond the smart meter, e.g. controller, management software and communication devices
- A focus on strong ICT standards for all relevant market actors in recognition that the cost of communication between the aggregator and end-users is a key driver in business cases
- The convergence of the market architecture at spot market level

- The connection of retail and wholesale electricity markets[19]
- Fostering the collaboration of network companies with third parties, in order to develop commercial business models that deliver low carbon, safe and secure energy services
- Enabling market testing of large new network infrastructure projects encouraging competition between existing and new market players to compete in building new infrastructure (WEF 2010)
- Preventing dominant market positions to avoid locked platforms with control schemes that hinder both access and competition
- Allowing utilities a "permission to fail" as part of development of innovative business models
- Clear provisions to allow innovators to benefit from their developed intellectual property

An outlook to the US and Chinese market will conclude this chapter. For the US, EPRI estimates the market for smart grid related projects around $13 billion per year. A more recently Morgan Stanley report gives even higher estimations of the market around $20 billion per year and to over $100 billion per year by 2030. Nation´s utilities are actively involved in developing some form of smart grid (e.g. the participation in pilot studies) with approximately 80% of investor-owned utilities. A PNNL study provided residential consumers with smart grid technologies to monitor and adjust their energy consumption. The average household reduced its annual electricity bill by 10%. Developing this approach could reduced peak loads up to 15% annually and save up to $200 billion in capital expenditures in plant and grid investments. In the US GridWise Project demand response was addressed in a new way. In a virtual market environment customers were provided with real cash consequences from various market structures. Due to the mismatch between energy supply and load centres China made the decision to deploy an interconnected UHV grid system. Furthermore the growth of renewable energy generation is primarily driven by large-scale projects that do not directly connect end-users. The Chinese smart grid plan is supposed to focus on the ability of controlling and transport bulk electricity first. Thereafter in the next stages the plan will move to the end-users and service integration (WEF 2010).

[19] In most EU electricity markets the spot market price is set on an hourly basis. Retail business prices are mostly on monthly or even longer basis (future markets), which leads to insensitive retail demand curves to spot market prices and a disconnection between both markets. Thus real-time spot market prices will not influence customer behaviour through active demand response. Connection of retail and sport market can incentive a stronger sensitivity of the retail demand curve and real time prices business (Huang, Y, p.37).

4 FINANCIAL AND REGULATORY IMPLICATIONS OF SMART GRIDS DEPLOYMENT

4.1 Overview of the current market structure and regulatory situation

4.1.1 From vertical integration to network unbundling

The organisation of the existing European electricity system is the result of a process that started shortly after World War II. National or regional vertically integrated monopolies rapidly became the dominant business model in the electricity industry. Monopolistic firms owned and operated the entire electricity value chain, from power generation, transmission and distribution down to the supply of electricity to customers including metering and billing. With the exception of final electricity use by customers, electricity products and services (generation, transmission, distribution, ancillary services, etc.) used to be demanded and delivered within the electric utility. This regulatory model has been very efficient at electrifying European countries in times of rapid economic growth.

Following the market liberalisation experience initiated in the UK and the US in the 80's and 90's, continental European electricity markets have been progressively liberalised and the various component of the value chain have been separated or unbundled. The European Commission has pushed the electricity supply industry towards unbundling through a series of energy Directives, the last of which came into effect in March 2011 ("third energy package"). Unbundling rules had to be complied with by March 3rd, 2012.

The degree to which networks are unbundled across Europe varies from country to country. Countries such as the Netherlands or the UK went as far as requiring full ownership unbundling whereas others (France, Germany) limited themselves to legal unbundling and the creation of an Independent Transport Operator (ITO).

The reasons often proposed as a rationale for network unbundling are:

- To provide alternative suppliers with a non-discriminatory access to markets and to create the conditions for market competition in other segments of the value chain (retail, generation...)
- To remove cross-subsidies between regulated and commercial elements of the electricity value chain
- To stimulate infrastructure investments
- To increase the productivity of network activities
- To ensure price control through improved cost efficiency both for OPEX (operational expenditure) and CAPEX (capital expenditure).

Whatever the unbundling model, the revenues of transmission and distribution grid operators stem primarily from regulatory formulas from which tariffs are ultimately derived.

The consequence of the regulatory status quo in the electricity network industry is that the bulk of grid related investments including future smart grid investments are placed under the responsibility of regulated businesses i.e. Transmission System Operators (TSOs) and Distribution System Operators (DSOs). The design and implementation of regulatory models are therefore a crucial factor to consider when it comes to analysing incentives to invest in smart grid technologies and solutions. Poor regulation design can inhibit progress and hamper innovation. It can translate into loss of synergies between the different participants in the value chain, excessive administrative burden, and disincentives to invest and innovate.

Smart grid services and products which are not part of the regulated network activities such as home automation, small distributed generation, aggregation services, smart appliances and in some instances smart meters will only develop and reach their full potential if the main parts of the grid can integrate them. Transmission and distribution grid represent the backbone of any future smart electricity system.

From this point of view, ensuring an adequate and supportive regulatory framework for the development of smart grids in the regulated area is a prerequisite for the emergence of a healthy and vibrant smart grid business and ecosystem.

4.1.2 Electricity grids and the regulatory status quo

Electricity transmission and distribution grids display natural monopoly characteristics: high capital costs, barriers to entry, significant economies of scale, network effects, etc. They cannot be easily transformed into "competitive businesses" and therefore have to be regulated to avoid a rent-seeking behaviour by the monopolist and to ensure efficient allocation of resources as well as maximisation of social welfare.

Economic objectives i.e. price and revenue controls are central in the existing regulatory models in place across most European countries. The primary objective of market liberalisation was to lower costs for network users and therefore end-consumers. Accordingly, the first regulatory phase that followed unbundling was geared towards a cost-efficient management of existing grids through the minimisation of OPEX and the rationalisation of investments.

This economic objective was to be achieved without endangering the quality of power and the security of supply. In a context of market liberalisation and sometimes privatisation, regulation is also designed to make sure that non-economic objectives are met: security of supply, power quality, grid integrity, non-discriminatory access to the grid, etc.

4.1.3 Overview of the various regulation models

Unbundled grid companies in liberalised markets are in most cases placed under the supervision of an energy regulator and their profits determined by a mathematical formula, the so-called regulatory formula. Various regulation models have been applied to electricity network businesses. They are usually grouped in two main families:

- Cost-based or rate-of-return models
- Incentive models

4.1.3.1 *Cost-based regulation*

Cost-based regimes[20] allow grid companies to fully recover their capital and operational costs on the basis of accounting information communicated to the regulator. Operational expenditures (OPEX) are fully recovered. For capital expenditures (CAPEX), a rate-of-return is applied on the regulatory asset base (RAB[21]). The RAB is calculated as the value of assets in place plus new investments minus depreciation. New investments generally have to be vetted by the regulator ex-ante or ex-post.

The rate-of-return is set in such a way that it maintains the willingness of the grid company to invest in necessary upgrades and grid extensions ("fair return"). Profits are capped but only in relative terms as the cost base itself (OPEX + CAPEX) is not capped. It does however put limits on excess profits or losses.

The main drawback of this model is that it is inflationary as all costs are passed through to the end-user. Since operational and capital costs are fully reimbursed, there is no incentive to reduce them. Also, because the asset base is the base for profits (through the application of a risk-free rate), it frequently leads to over-investment or "gold plating" behaviour. In this regime, the price risk is fully borne by the end-user.

Cost-based regimes have been used extensively in the US and the UK but have been abandoned or improved progressively due to high administrative costs and poor results in terms of efficiency gains.

4.1.3.2 Incentive or performance-based regulation

Cost-reduction incentive mechanisms such as price and revenue caps or yardstick competition have been designed and implemented by regulators to address the main shortcomings of cost-based models.

This is done by attempting to mimic market competition. Revenues of the grid company are decoupled from its controllable cost base and its earnings linked to its performance. Because prices or revenues are capped, the grid company has to reduce inefficient costs to increase its profits. The allocation of a portion of cost savings to the grid company during the regulatory period rewards its productive efficiency.

Cap regulation

In such regimes, prices (or a basket of prices) or revenues received by the grid operator are capped over a given regulatory period typically 3 to 5-year long. Prior to the start of a regulatory period, new price or revenue caps are determined (ex-ante[22]) and fixed using a forecast of the controllable costs for the period. If network operators are able to realise efficiency gains i.e. reduce costs below the fixed level, they are allowed to retain the corresponding profits.

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[20] Also called "cost-of-service" or "cost-recovery" regulation regimes

[21] The Regulatory Asset Base corresponds to the valuation of the assets used to provide a regulated service. It is the investment base upon which the return is calculated the grid operator is permitted to make a return.

[22] The allowed revenue of a grid company is fixed prior to the start of the regulatory period.

A new level of prices/revenues that takes into account the new level of costs/efficiency reached is recalculated prior to the following regulatory period. Initially delayed, efficiency gains are therefore passed through to the end-user for good at the start of each new regulatory period.

CPI-X models are a refinement of cap models. Revenue or price caps are indexed to a consumer price index (CPI) and an efficiency (X) factor is applied to the indexed caps. The X-Factor reflects the minimum efficiency effort that is required by the regulator over the regulatory period. If the grid company is able to increase its productivity by a higher rate than the X-factor, it will increase its profits. The X factor can be the same for all the industry or company specific.

Cap models have been adopted by a majority of European regulators.

Yardstick competition

In this model, prices or revenues that can be claimed by grid companies are established on the basis of the average operational costs or productivity improvements of a peer group of comparable firms active in a given regulated market and geography. Each firm is thus incentivised to reduce costs relative to other firms. Over time, this quasi-competition process improves the overall efficiency of the industry.

A key advantage of yardstick models is that revenues are determined ex-post. There is no need for the regulator to determine a cost level in absolute terms. Yardstick models rely on observed data from the sample of network companies and not on ex-ante estimates of future costs as in cap regulation models. In theory (only), yardstick regimes are considered innovation and investment friendly because innovation is a source of productivity gains.

In practice, regulation models tend to mix some elements of the theoretical models described above. Different models can also be applied to different components of the regulated activities (e.g. cost-based regulation for CAPEX and incentive regulation for OPEX).

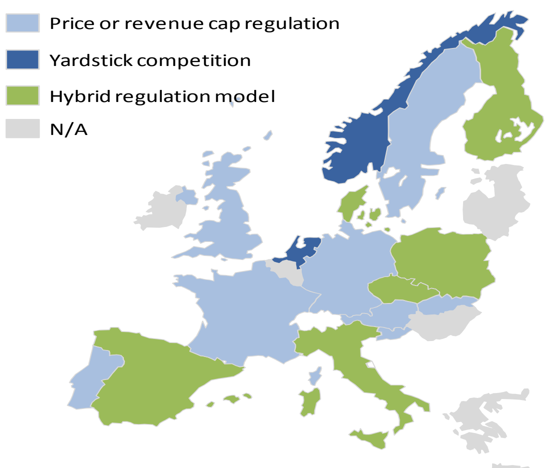

Figure 4.1, Grid regulation models in European countries,

Source: Enerdata from Eurelectric

Box 2: Example of an incentive regulation formula: German regulatory formula setting the allowed revenue of a grid company (in use since 2009)

$$R_t = C_{ni,t} + [\, C_{iB,0} + (1 - V_t) \times C_{i,0} \,] \times \left(\frac{CPI_{t-2}}{CPI_0} - XF_t \right) \times EF_t + Q_t$$

R_t = Allowed revenue in the year t

$C_{ni,t}$ = Costs that cannot be influenced, i.e. employee benefit costs and grid fees for higher voltage levels (e.g. transport grid fees), applicable for year t

$C_{iB,0}$ = Influenceable costs of the benchmark company in the reference year

V_t = Percentage of inefficiency that has to be reduced by the end of year t

C_i = Costs that are caused by inefficiency of the individual company

CPI = Consumer price index

XF = General X-factor, based on 1.25% in the 1st regulatory period;

$XF_{2009} = 0.0125 = 1.25\%$

$XF_{2010} = 1.0125 \times 1.0125 - 1 = 0.025 = 2.52\%$

EF = Expansion factor; dependent on number of connections to grid (50%) and on the size of the service area (50%)

Q = Quality component (not yet implemented)

t = index running from 1 to 5 (basis 0 is reference year)

Source: (RWE fact book, 2008)

Benchmarking

In order to set caps or yardsticks, it is necessary to assess realistic levels and targets. This can be done by using benchmarking techniques and by comparing the various grid companies across a number of operational or financial performance indicators.

Benchmarks generally focus on OPEX but can also be used for CAPEX. The recognition of new CAPEX in the RAB of a grid company can be done ex-ante or ex-post. In ex-ante recognition, the energy regulator agrees beforehand on an investment plan or projection proposed by the grid operator and makes controls along the way or at the end of the regulatory period. In ex-post recognition, the regulator approves actual investments using benchmarks. In some countries, the comparison is carried out on the basis of total costs (TOTEX = CAPEX + OPEX).

The relative efficiency of a company is assessed by comparing its level of inputs (number of employees, O&M costs, etc.) and outputs (energy delivered, amount of losses, etc.) with those of other grid companies.

Of course, the benchmarking approach requires a minimum number of participating firms with somewhat comparable activities and cost structures. A small sample can create a risk of collusion between firms. International benchmarks can help resolve this issue but are more difficult to put in place at the DSO level[23].

[23] International benchmarks exist at the TSO level. See for instance the e3GRID initiative launched by the Council of European Energy Regulators (CEER) and coordinated by Sumicsid. e3GRID is a regulatory benchmarking of European Electricity Transmission System Operators (TSO)

In order to avoid a degradation of service quality in the long term due to the focus on cost reduction and its corollary, underinvestment, energy regulators have progressively implemented quality schemes and targets.

In a direct regulation scheme, energy regulators can set minimum quality standards or technical requirements for certain parameters. In the context of an incentive-based regime, they may define performance indicators for which grid companies are rewarded or penalised depending on their ability to reach the target or not. Performance indicators should be quantifiable and verifiable in an objective manner.

Examples of output targets for electricity networks are "interruption frequency" (number of interruptions per year), the "duration of interruption" or the total amount of "no supply" time (in minutes per year).

One regulatory pitfall of quality regulation is that there is a risk of delivering unnecessary quality at too high a cost. A possible solution used in Norway is to define a Cost of Energy not Supplied (CENS) which is estimated using an estimate of the customer's willingness to pay for network reliability[24]. The CENS generally diminishes with an increase in CAPEX and OPEX because the latter increase network reliability.

A number of European countries have implemented quality regulation (UK, Sweden, Italy, Norway, Finland, etc.). Germany intends to add a quality component to the regulatory formula (see box above) but has not implemented it yet.

4.2 Regulatory challenges for the implementation of smart grids

4.2.1 Volatility and flexibility: the two key parameters

Each second, production and consumption of electricity must be balanced. To this end, the level of flexibility in the system must overcome the level of volatility. Production of electricity is both flexible and volatile, for instance a gas power plant can be shut down or activate at any time, based on the level of the demand. Production of electricity is volatile as well, for instance wind power can be produced during days or night, without any link to the level of the demand.

It is broadly the same for consumption that is both flexible and volatile. The residential demand of electricity can be partially handled, for instance the run of some electrical appliances can be postponed, but some others cannot and will on the contrary be erratic (heating or cooling mostly depend on climatic conditions for instance) and can then be characterized as volatile. The industrial demand of electricity is also both flexible and volatile, even if for this part is more characterized by flexibility than volatility.

In the current system, volatility comes mainly from the demand side and especially from the residential demand. And flexibility is mainly brought by the production side and by the industrial consumption side. The scheme below summarises this balance:

[24] Gaia-Sumicsid: "Scientific Review on Regulation Models for Electricity Distribution Networks".

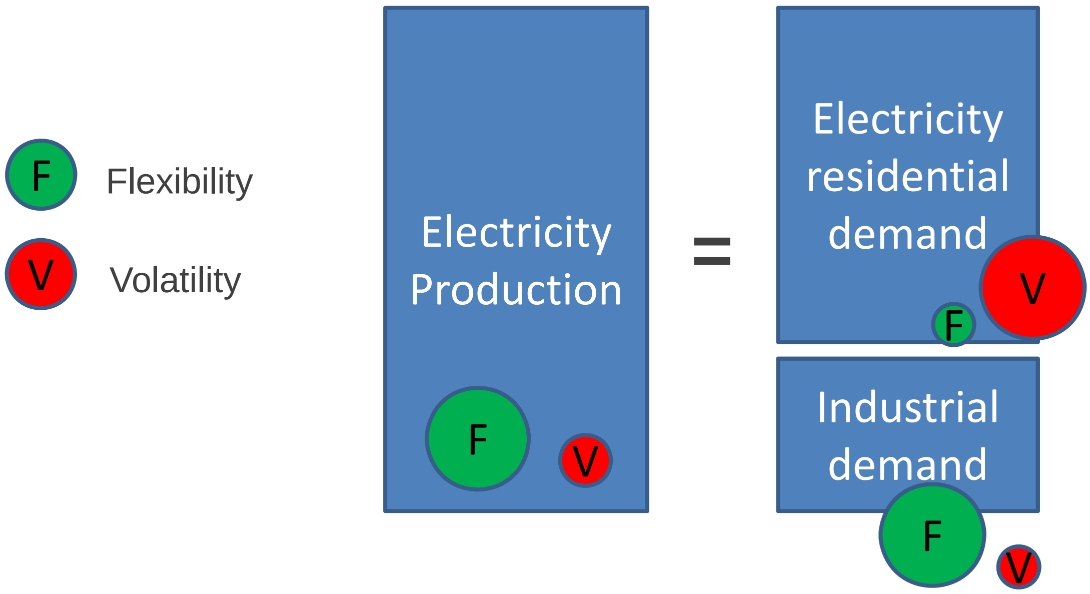

Figure 4.2 The current situation : flexibility capacities overcome volatily

Source: Enerdata

In the future, with increasing amount of renewables, electricity production will become more and more volatile. Moreover, the flexibility that industrials bring into the system may decrease because of the loss of some industrial capacities due to the competitiveness of emerging countries. The system will keep working if more flexibility is brought, in order to counterbalance the increasing volatility. The figure below summarises the new situation we might have to face, in the future:

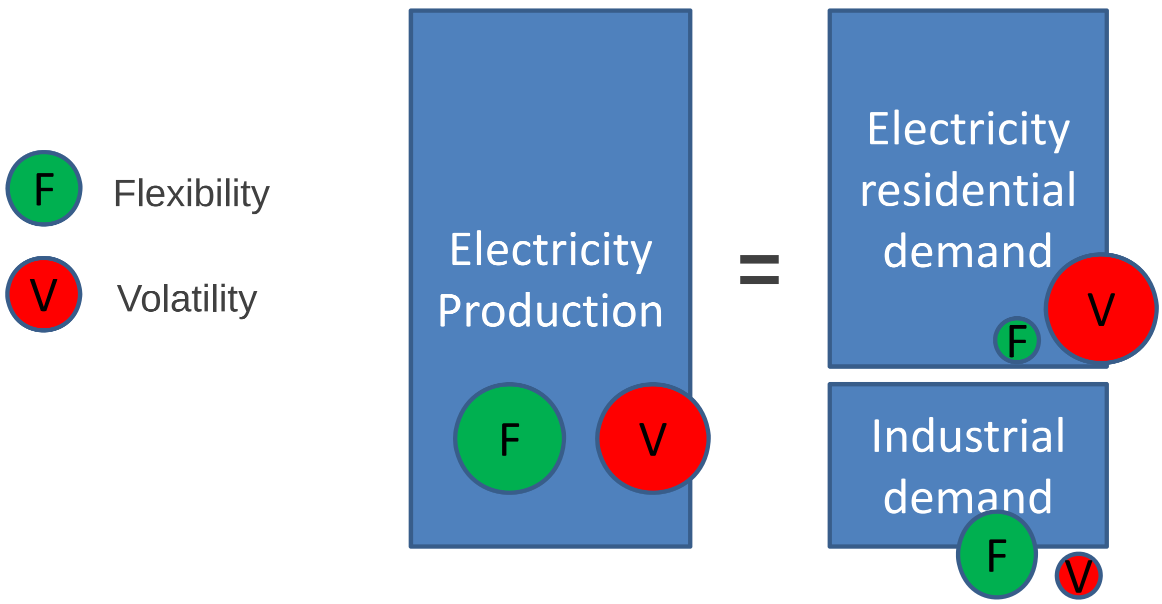

Figure 4.3 The future situation : more and more volatily in the system

Source: Enerdata

4.2.2 The current regulatory framework does not favour investments in smart grids

If grid operators on which the burden of smart grid costs is laid cannot recoup their investments, smart grids will not develop. Inadequate regulation can counterbalance the perceived benefits of smart grids and skew investment decision-making towards a conservative attitude and a strictly cost-efficiency approach[25]. Treading a fine line, regulators will have to find the right balance between two main considerations:

- The need to contain network costs, an objective that remains fully valid
- The need to enable smart grid investments

In addition to being new costs for TSOs & DSOs, smart grids could also represent less revenue if the latter depends, at least in part, on the amount of electricity transported. Network pricing models across Europe often comprise an energy charge (amount of electricity) and/or a demand charge (load). If energy charges are not frequent in tariff design at the TSO level (Germany is an exception), they are almost always found in the tariff design for DSOs.

One of the objectives of smart grids is to enhance energy efficiency and demand response that is to lower or to slow the growth of electricity demand. In that sense, the implementation of smart grids concerns more the DSO level than the TSO level. The spread of distributed generation and the emergence of microgrids may cause a revenue loss for DSOs, as less electricity will transit through their network. This issue might require the decoupling of DSOs' revenues from the volume of power transported.

Another difficulty is that so far, electricity networks have performed well in terms of reliability without the help of smart grid technologies. One challenge for grid companies and regulators is therefore to demonstrate and communicate convincingly that smart grids are an attractive value proposition in face of the costs incurred. Decision-makers have to deal with tangible short-term costs and less tangible long-term benefits.

The key question becomes: "how can incentive regulation be adapted to provide the right incentives to invest in new grid technologies with tangible customer benefits and without causing costs to explode?" Smart grids are still rarely considered an investment priority by regulators because benefits and overall costs are difficult to assess.

In spite of all these hurdles, carefully designed regulatory schemes should be implemented to accelerate the deployment of smart grids and avoid higher long-term costs for the electricity system.

[25] Already, grid operators do not seem to be adequately remunerated for their conventional investments. A 2007 Eurelectric report showed that three quarters of the surveyed DSOs had a return on invested capital lower than their WACC (weighted average cost of capital) thus destroying shareholder value.

4.2.3 Enable demand response in the residential sector as well

Energy Pool is a French private company created in 2008. With 1000 MW demand response capacity, Energy Pool is the largest European demand response provider. Energy Pool targets industrial actors. Energy pool is able to shave peak demand by cutting or lowering electricity supply to a portfolio of industrials actors. Those actors are financially compensated when their electricity supply is lowered. At the end of the year, industrial actors can save more or less 5% of their electricity bill. The French TSO pays Energy Pool for this service.

Today, in most European countries, demand response in the industrial sector is possible, while it is not in the residential sector. Once can guess why demand response works in industrial sector and not in residential sector. In the Energy Pool example, there are two fundamental functions that are activated:

- Existence of dynamic tariff: this characteristic is at the core of the system; it gives economic value to flexibility and allows then the possibility to organize peak shaving.
- Existence of remote control of the demand: in the Energy Pool case, some of the control of the industrial process is handled from Energy Pool's offices. Those intrusive tools are an important way to facilitate demand response solutions. Of course, this must be accepted by the industrial actor.

Today, both dynamic tariff and remote control of the demand is not really possible for households, as it is for industries. Development of demand response in the residential sector will need to implement those two mechanisms.

4.2.4 Contours of a regulation regime favourable to smart grid investments

Near future regulatory regimes favourable to smart grid investments will most likely be adapted from the current situation to accommodate new technology and market requirements. Some new players will emerge but overall, the business models of TSOs and DSOs will remain similar after much needed adjustments.

Such an "Enlightened regulation" model is probable in the short and medium term i.e. until 2020 or 2030[26] and may include some of the following characteristics.

[26] Beyond, one should not exclude the advent of an "Internet-type" regulation i.e. a system of distributed control placed under a global protocol. That would entail a complete overhaul of the existing situation and a regulation-light approach to grid management. Such a system would be highly decentralised at all levels with a large number of new players and business models.

4.2.4.1 *Inclusion of smart grid investments in the regulatory asset base and assurance of a fair rate-of-return*

Smart grid technologies (ICT, smart meters) are new and somewhat unusual for DSOs and Energy regulators but their deployment is crucial for the future reliability of networks. The recognition of new investments will become even more crucial for DSOs as the scope for reducing OPEX and increase operational efficiency has probably diminished significantly in most countries since liberalisation and unbundling took place. In the future, it is probable that the CAPEX revenue component[27] in the overall revenue requirements for TSOs and DSOs will grow in importance.

In its report on regulation for smart grids, Eurelectric mentions the fact that energy regulators in several EU Member States do not recognise smart grid investments in the regulatory asset base of DSOs.

In addition to smart grids being recognised in the regulatory asset base, regulators must also ensure a fair rate-of-return on new smart grid CAPEX. If the rate of return is too low or risks being too low, TSOs and DSOs will not carry out these investments. This also implies to solve the CAPEX time-shift problem where it still exists.

Finally, incentive regulation needs to be adapted to take into account the specifics of smart grid technologies (e.g. shorter economic lifetime, higher cost of smart components vs. conventional ones, etc.). Also, the needs of end-users and other market players will probably go beyond what is deemed necessary by grid operators and energy regulators from the strict point of view of grid operation. Grid operators may have to be incentivised to invest in smart grid elements that go beyond their scope of responsibility.

4.2.4.2 *Regulatory stability and clarity*

Because networks investments have a very long technical or economic lifetime, regulators should ensure long-term regulatory stability and visibility. The regulatory risk is probably one of the strongest deterrents to capital-intensive investments.

In general, grid operators can cope fairly well with technical, financial and economic risks when they develop business cases for new investments. Assessing these risks is part of their expertise. On the contrary, regulatory uncertainty is difficult to assess and anticipate. If the regulatory regime is instable, companies will postpone their decision or become reluctant to invest in costly equipment.

Another type of regulatory risk is linked to the complexity of incentive schemes and benchmarking techniques. If these are unclear, too complex or subject to interpretation, it becomes difficult for grid companies to develop a sound business case.

It is therefore absolutely crucial for energy regulators to establish and maintain their reputation of stability, transparency and coherence.

[27] i.e. the rate-of-return applied to the RAB

4.2.4.3 *Output regulation*

Output regulation is seen as a solution for energy regulators not to be dragged into detailed input monitoring. State-of-the-art regulatory regimes have added or are considering the addition of explicit output objectives in their incentive schemes. Output regulation concentrates on the outputs of the regulated entity and its effects on the satisfaction of end-user's needs.

As stressed by EURELECTRIC, output performance indicators may be difficult to define and challenging to implement. In its view, DSOs should be in the position to influence the output measured by a given indicator. Output regulation should also remain flexible in order to cope with various national and regional situations (demand characteristics, climate, population density…).

In this respect, Eurelectric calls for existing regulatory barriers to smart grid investments to be removed before implementing output regulation.

4.2.4.4 *Technology neutrality*

Electricity grids are bound to face increasingly complex challenges. It is extremely difficult for energy regulators to determine today what will be the most cost-efficient and optimal solutions for future smart grids. No attempt should be made by regulators to "pick winners" i.e. to choose or promote specific smart grid technologies and configurations. Because they do not have the expertise or the manpower to select the right technologies, regulators should leave this task to grid companies.

Regulation should remain "technology neutral" and incentivise grid companies to select the smart grid solutions that will meet end-users' requirements. Regulators should also promote a common definition of standards across European countries.

4.2.4.5 *Promotion of R&D and demonstration projects*

It has been observed that deregulation and unbundling of regulated industries often leads to lower R&D levels[28]. Accordingly, policy makers need to promote directly and specifically the R&D and demonstration projects that will support the development of the 21st century electricity networks.

Smart grids are not fully proven concepts yet even if most of the technology bricks already exist. A lot still needs to be done in terms of R&D and demonstration projects if start grids are to become a reality. Because grid companies are traditionally risk adverse and may be reluctant to abandon a proven business model for a riskier model driven by innovation, regulators and policy-makers will have to design ad hoc innovation and R&D funding schemes.

Incentive regulation is not sufficient to drive significant R&D spending and large scale demonstration projects. In other words, R&D expenditures needs to be differentiated from capital expenditures aimed at grid replacement, grid extension and even grid improvement with first level smart grid technologies.

[28] Jamasb and Pollitt, 2008 (quoted in the Gaia-Sumicsid report)

As a general rule, incentives to innovate and engage in R&D or demonstration projects should not be paid by the customer. Because R&D offers no direct and measurable benefits for the customer, it should not be considered as a recoverable cost through regulated tariffs. According to Eurelectric, "R&D and smart grid pilots should be excluded from the benchmarking process".

DSOs may not be the natural owners of such R&D and demonstration projects but will be key players in the implementation of concrete smart grid solutions emanating from R&D programmes and technology roadmaps.

4.2.5 Defining the scope of cost recovery for grid operators

In theory, TSOs and DSOs should have a strong incentive to make their grids smarter to mitigate the impact on costs of renewables and enable demand response. In practice however, the willingness of grid operators to take on these new costs depends for a large part on the way these costs are allocated and made recoverable by regulatory regimes.

One key issue is the scope and the treatment of costs associated with intermittent generation technologies and demand response. Should costs be fully allocated to renewable projects or should they be allocated to grid operators? In the first case, isn't there a risk to deter renewable generation investments? In the second case, to what extent can grid operators be allowed to pass through these costs to end-users? Can they recognise smart grid investments in their regulatory asset base?

The distinction might not always be easy to operate between smart grid investments and investments related to the connection of intermittent energy sources to the main grid i.e. balancing costs, back up costs, the necessary reinforcement of existing lines (cables, transformers, switchgears), etc. Similarly, it might prove difficult to differentiate between costs linked to traditional grid replacement made necessary by ageing grid infrastructure and those linked to smart grid solutions strictly speaking.

Another example of scope definition problem concerns smart meters. Regulatory regimes do not always state explicitly if grid operators can recoup smart meter investment. Eurelectric has shown that in many European countries[29], the possibility to recover the cost associated with the smart meters and their deployment is not guaranteed.

All players of the electricity value chain stand to benefit from the emergence of smart grids but investment costs will for a large part fall onto grid operators. At the same time, if investment costs were to fall only on the players that stand to benefit most from the introduction of smart solutions (i.e. renewable project developers and owners, end-users, ESCOs, etc.), it is highly probable that this would act as a strong deterrent to smart grid investments.

Because smart grids technologies will be embedded into existing regulated networks, it will be very difficult to allocate smart grid costs and benefits to individual projects or market players (e.g. renewable energy developers and producers, ESCOs, end-users). Most of the benefits of smart grids will come from the fact that they increase synergies between the various components and players of electricity networks. As a consequence, it is almost impossible to assess the incremental value of specific smart grid investments.

29 Czech Republic, Denmark, France, Germany, Netherlands, Norway, Poland, Portugal, Slovakia

Investments in smart grids should lead to lower future system costs but not necessarily to lower costs for DSOs as they may not be able or in the position to recover all the benefits from the investment they have carried out (positive externalities or spillover effects).

The benefits of smart grid are also likely to be long term, diffused and reach their full potential only once a certain critical mass has been attained (threshold effects). The lumpiness of network investments is further complicated by the fact that smart grid issues are multifaceted and cross-sectoral. They impact energy supply and demand, unbundling and grid regulation, market design, support schemes in favour of renewables, distributed generation, demand response, R&D policies, etc. This complexity is probably best handled through output regulation than input regulation.

4.3 Regulatory needs for the implementation of smart grids

Having said that flexibility will have to increase in order to overcome the surge of volatility in our future electricity grid, we must identify regulatory needs that will help to make this transition. Having more flexibility on the grid will result from different conditions. These conditions are discussed below:

4.3.1 Data protection and security

Care must be taken to protect personal data and security. The EU Directive on the protection of personal data (95/46/EC) and the e-privacy Directive (2002/58/EC) set very clear requirements on who has access to different categories of such information and how it is processed. This also covers the specific aspects of smart grids.

Recently, the Commission made recommendations in which it is said[30] "the aim of the Commission's Recommendation is to ensure the highest level of protection of personal data and security for individuals and grid operators. The Commission is recommending a "security and data protection by design" approach whereby data protection and security features are built into smart metering systems before they are rolled out. "

Data collection should be limited to the minimum necessary and, as much as possible, data should be rendered anonymous so that the individual is no longer identifiable. Finally, the Commission plans to develop a data protection impact assessment template and present it by the end of the year.

4.3.2 The smart metering functionalities

In order to develop new demand response solutions, smart metering will have an important role to play. In a communication published in March 2012[31], the Commission has identified several functionalities for the smart metering, and regulators will have to make sure they are well taken into account. Those functionalities are:

- frequent updates of the readings provided directly to the consumer. Being able to follow their actual electricity consumption in real time gives consumers strong incentives to save energy and money.

[30] "Commission recommendation on preparations for the roll-out of smart metering systems", European Commission, March 2012.

[31] "Commission recommendation on preparations for the roll-out of smart metering systems", European Commission March 2012.

- storage of data. The customers should be able to retrieve information on their past consumption patterns to help them better understand their actual energy consumption and make decisions on future energy use.

- remote reading of meters by the operator that are frequent enough to help network planning.

- enabling advanced tariff structures and remote tariff control. This will allow consumers respond to the variation of prices in real time.

4.3.3 Develop common European standards

Many experts confirm the urgent need to adopt European standards for Smart Grids. Standards concern primarily the technology itself. For instance, this harmonisation will allow users to use the same charger for a range of electric vehicles and ensure that such chargers can be connected and operated throughout the EU.

But standards concern also the service provided to customers. For instance, energy regulators may define performance indicators for which grid companies are rewarded or penalised depending on their ability to reach the target or not (high quality of electricity, few outages…). Performance indicators should be quantifiable and verifiable in an objective manner.

Based on a communication made by the EC[32], a mandate has been issued to the European standardisation organisations CEN, CENELEC and ETSI (ESOs) to establish European standards for the interoperability of smart utility meters, involving communication protocols and additional functionalities, such as assuring interoperability between systems to provide secure communication with consumer's interfaces and improve the consumer's awareness to adapt its actual consumption. The ESOSs were to provide European standards for communication in March 2010, but the deliverables are accumulating delay. The first deliverables for European standards for smart meters are expected by the end of 2012.

Furthermore, the Commission continue reviewing European standardisation policy by following up its White Paper 'Modernising ICT standardisation in the EU — The way forward' as well as the global standardisation developments.

4.3.4 Regulation models and incentives to invest in innovative grid technologies

Both cost-based and incentive regulation models are primarily destined to achieve cost-efficiency and are not designed to promote innovative investments, high levels of R&D or even high quality targets. Performance-based or incentive regulation is generally designed so as to ensure that investment and operational costs are kept under control and network tariffs the lowest possible given the necessity to guarantee power quality as well as grid stability and integrity. They provide very strong incentives to lower costs through better investment spending discipline and operational efficiency. There is a risk to see grid companies keep to traditional approaches well understood and recognised by regulators and postpone investments in innovative technologies.

[32] "Smart Grids: from innovation to deployment", European Commission, April 2011.

In the mid and long term, this regulatory approach can have adverse effects on the quality of electricity. Maintaining a high quality of service will become increasingly difficult as the grid ages and the share of intermittent renewable energies increases.

Innovation and quality are not the only limitations that incentive regulation faces. Both yardstick and cap regimes rely on successive regulatory periods of limited length[33]. This can lead to the apparition of a "time-inconsistency" problem. Grid investments being highly capital-intensive, capital expenditures can only be recovered over a long period of time. Whether smart of not, grid investments have sunk costs characteristics and are highly sensitive to regulatory risks or uncertainties[34]. Because of this time-inconsistency problem, network companies, which need to secure future profits, will not invest without the assurance that they will be able to recover their costs well beyond the current regulatory period.

A specific case of time-inconstancy is the CAPEX-time shift problem. In some incentive regulation schemes, there can be a lag between the moment the investment is made and the moment it is recognised leading to delayed cash flows and a lower than expected rate-of-return. According to Eurelectric, this problem has for instance not been remedied yet in Germany and the Netherlands.

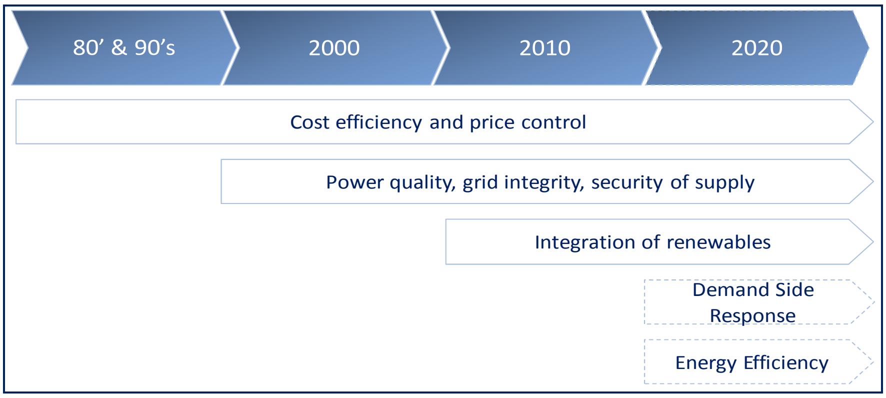

Figure 4.4Evolution of regulation objectives over time

Source: Enerdata

It is widely considered that traditional cost-based and incentive regulation models fail to provide adequate incentives for innovative grid investments. As a result, grid companies tend to under-invest and may be reluctant to deploy smart grid technologies that represent immediate costs and uncertain as well as distant returns. Regulatory uncertainty, instability and inadequacy are major obstacles to innovative investment.

Regulators need to develop a number of complementary regulation techniques or schemes to overcome the limitations of price or revenue controls and make sure that cost-efficiency is not reached at the expense of system integrity, service quality or innovation.

[33] Typically 3 to 5 years

[34] For a discussion of the time-inconsistency problem, see Dieter Helm

4.4 The costs associated with smart grids

4.4.1 Smart grid investments imply new and additional costs for grid operators

New developments on the supply and demand side will have a profound impact not only on the way electric grids and systems are managed but also on total system costs. Investments required for the transition from passive networks to actively managed "smart" grids are significant if difficult to assess precisely. In any case, overall grid investment costs will be on the rise as shown conceptually in the following chart.

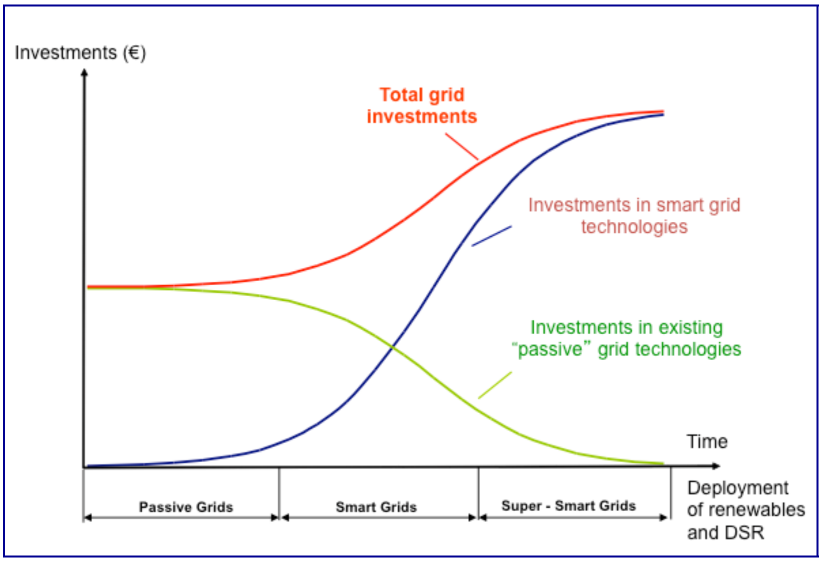

Figure 4.5, Impact of the transition from passive to smart grids on total grid investments

Source: Adapted from (Hans Auer, 2009)

However, it is important to understand that because networks will have to evolve anyhow in order to cope with the coming challenges, smart grid investments are neither a substitute nor fully additive to conventional grid investments (replacement, extensions).

Networks will have to become smarter and at the same time retain high levels of security, quality, reliability and availability. Future investment costs therefore comprise both "conventional" and "smart" components.

Besides traditional network upgrades, new investments will be required to make grids smarter and more flexible. New technologies and costs associated with the emergence of smart grids include:

- Smart meters
- New electro-technical devices (sensors)
- IT and communication infrastructure: hardware equipment and software for grid management and operation
- Additional and extended computational capacity to deal with increase data flows (e.g. real time metering and billing)
- Complementary components such as storage facilities

One key issue is that if networks do not become smarter, their upgrade that is made necessary by intermittency and DSR will become more costly. Overall, the modernisation of electricity grids is expected to bring net benefits.

One should not forget that grid operators would not be the only players to support the cost of new smart grid (e.g. new consumer equipment, upgraded appliances, monitoring devices, software, etc.). Also, new transaction and administrative costs will arise that will concern all players of the electricity value chain. New standards, norms, procedures and contracts will have to be implemented and enforced.

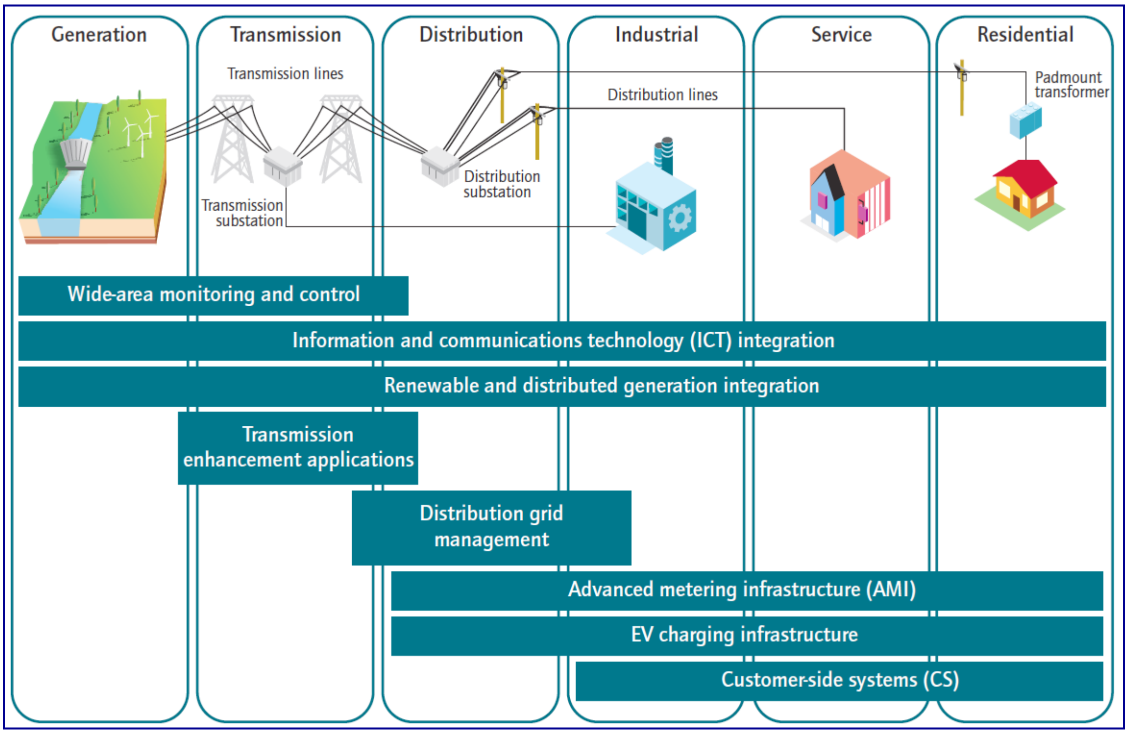

Figure 4.6 Main smart grid technology areas

Source: (IEA, 2011)

4.4.2 Evaluating the costs and benefits of smart grids

To our knowledge, no detailed cost-benefit analysis of smart grids has been carried out at the European level so far. But a major progress is expected from the work currently on-going by JRC on Smart Electricity Systems. A first methodological document has been issued by this institute[35] in 2012 while the full report is about to be published.

In its 2010 World Energy Outlook, the International Energy Agency estimated that total investment needs in the European distribution network would amount to 480 billion Euros by 2035.

It is extremely difficult to provide an estimate of smart grid investments costs. Benefits are equally hard to assess. Key issues with cost assessments of smart grids include:

- The absence of a clear definition of the scope of smart grid investments

[35] "Guidelines for cost-benefit analysis of smart metering deployment", JRC Scientific and Policy Report, 2012.

- Smart grids will keep evolving as new technologies become available
- Smart grids are highly evolutive and their future shape is largely unknown
- Smart grid technologies are still in their infancy and their performance and longevity remains uncertain

On the other hand, the cost of ICT tends to decrease faster than the cost of conventional grid technologies. Regulators and grid operators are used to network asset life of several decades (30 to 50 years). In contrast, ICT equipment has a much shorter life (5 to 15 years). Replacement costs of network equipment mixing the two types of technology (conventional and "smart") need to be assessed carefully.

Moreover, the technology used for telecommunications to support smart grids may conduct to very different costs. For instance, a less expensive communication mechanism is proposed where devices shave peaks by shifting their loads in reaction to grid frequency. Grid frequency could be used to communicate load information without the need of an additional telecommunication network.

The only comprehensive attempt to evaluate smart grid investments costs and benefits was carried out by the US-based Electric Power Research Institute (EPRI) in 2011[36]. The EPRI study makes a detailed assessment of the cost of all the various smart grids components for the entire US electricity network. Costs include the infrastructure to integrate distributed energy resources and costs to achieve full customer connectivity. They exclude the cost of generation, the cost of transmission expansion to add renewables and to meet load growth. They exclude some (but not all) customer costs for smart-grid ready appliances and devices. The list of smart grid technology elements taken into account by the EPRI for its cost estimate is given in the table below.

[36] "Estimating the costs and benefits of the smart Grid: A preliminary estimate of the investment requirements and the resultant benefits of a fully functioning smart grid". Technical Paper. EPRI, 2011.

Transmission Systems and Substations	Distribution	Customers
• Transmission line sensors including dynamic thermal circuit rating • Storage for bulk transmission wholesale services • FACTS devices and HVDC terminals • Short circuit current limiters • Communications infrastructure to support transmission lines and substations • Core substation infrastructure for IT • Cyber-security • Intelligent electronic devices Phasor measurement technology for wide area monitoring • Enterprise back-office system, including GIS, outage management and distribution management	• Communications between all digital devices on the distribution system • including to feeders for AMI and distributed smart circuits • Distribution automation • Distribution feeder circuit automation o Intelligent reclosers and relays at the head end and along feeders o Power electronics, including distribution short circuit current limiters o Voltage and VAR control on feeders • Intelligent universal transformers • Advanced metering infrastructure (AMI) • Local controllers in buildings, on microgrids, or on distribution systems for • local area networks	• Integrated inverter for PV adoption • Consumer EMS portal and panel • In-home displays • Grid-ready appliances and devices • Vehicle-to-grid two-way power converters • Residential storage for back-up • Industrial and commercial storage for power quality • Commercial building automation

Table 4.1 Cost components for the smart grid

Source: (EPRI 2011)

Although the US electricity system is approximately 20% larger than the EU 27 network[37], the EPRI provides an interesting point of comparison and a good proxy for what smart grids might cost in Europe. In total, the cumulated investment costs required to enable a fully functioning smart grid in the US is estimated between $ 334 billion and $ 476 billion over the next 20-years.

One can be surprised by this amount. Indeed, the smart meter is a component of the smart grid and certainly Italy has not the same size as the United States, but the project Telegestore in Italy cost only € 2.1 billion. In fact, it seems that the amount for the US covers all the investments needed for the network. We also know that for years, US has under-invested in its electricity grid, and now some catch up investments need to be done. In conclusion, the figure given by EPRI might be overestimated for Europe.

The EPRI also estimated that the benefits of the smart grid over the next 20 years would amount to between $ 1,294 billion and $ 2,028 billion. The benefit-to-cost ratio ranges between 2.7 and 6.1 (Figure 4.7).

[37] In terms of electricity generated

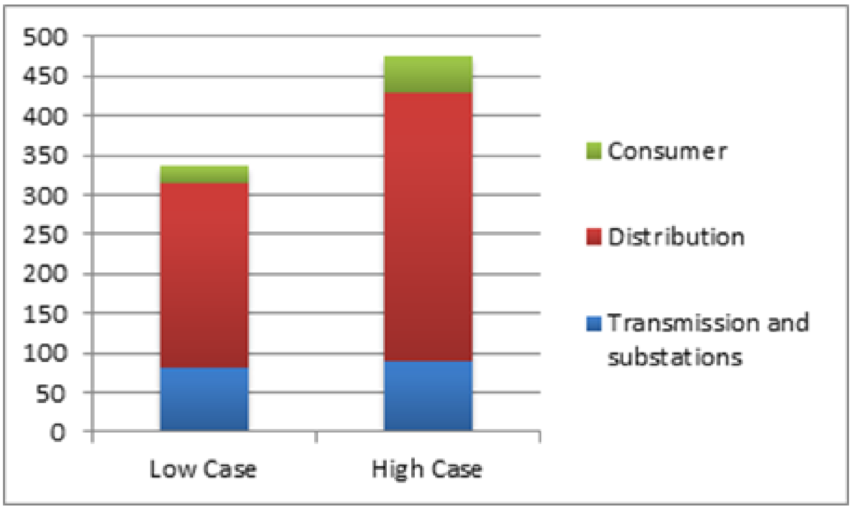

Figure 4.7, Estimated costs over the next 20 years for implementing a US smart grid (Billion $)

Source: (EPRI 2011)

It is clear from the EPRI analysis that most of the costs will be borne by distribution grid operators (approximately 70%). Transmission grid operators will bear between 20 and 25% of the costs and end-users less than 10%.

The EPRI has also calculated the estimated impact of smart grid investments on the US customer's electricity bill. Again, because most of the costs are expected to concern the distribution part of the grid, most of the cost will fall onto residential and commercial customers. Their bill is expected to increase by an average of 8.4% to 12.8%. Industrial users should not be significantly impacted (Figure 4.8).

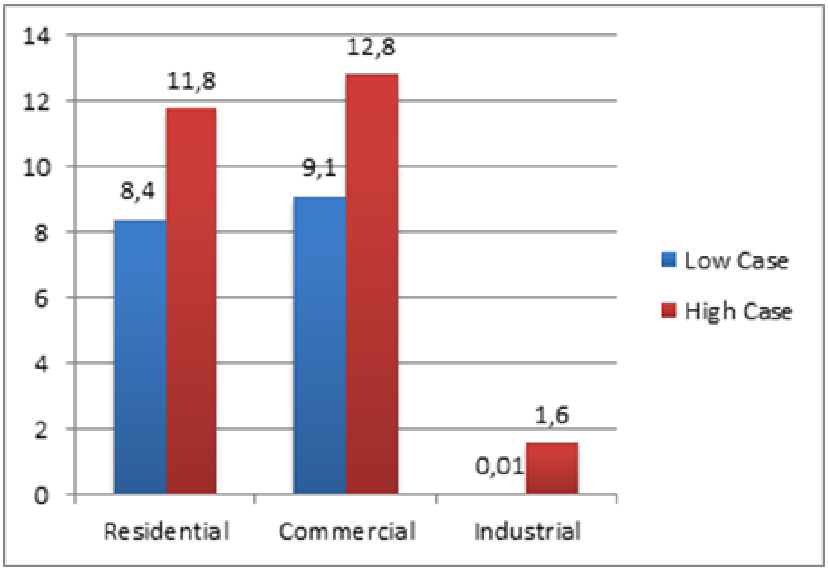

Figure 4.8, Smart grid cost to consumers: % annual increase in monthly bill (10-year depreciation)

Source: (EPRI 2011)

4.5 Overview of best regulatory practices and recommendations for a successful deployment of smart grids

A number of recent initiatives at such as Eurelectric's or the ERGEG's have proposed guidelines and recommendations to adapt or transform existing regulatory regimes so as to make them more favourable to smart grid projects. We also present the Ofgem's RPI-X@20 review of regulation and its recommendations

4.5.1 European Regulators Group for Electricity and Gas (ERGEG)

In 2009, the ERGEG[38] launched a European wide public consultation about how smart grids can be encouraged and how they can best benefit network users and other stakeholders in the European electricity supply system. The consultation also analysed the drivers and regulatory issues related to the deployment of smart grids. ERGEG's conclusions have been published in June 2010 in a "position paper on smart grids". The main conclusions and recommendations from this consultation are presented in the box below.

[38] The ERGEG is composed of EU Member States' gas and electricity regulatory authorities and acts as the advisory body to the European Commission on internal energy market issues. Its creation follows the decision 2003/796/EC.

Box 3, ERGEG's recommendations

Recommendation 1: to ensure, as appropriate, a long-term stable regulatory framework and reasonable rate of return for cost-efficient grid investments

Recommendation 2: to consider and further analyse decoupling between grid operators' profits and the volumes of electricity they deliver, taking into account the introduction of performance indicators and performance-based incentive regulation

Recommendation 3: to pursue regulation of outputs as a mechanism to ensure value for money paid by network users and to investigate metrics for the quantification of the most important output effects and benefits at national level

Recommendation 4: to promote mechanisms favouring an improved consumer awareness of their electricity use and market opportunities through actions of suppliers and other market participants and an improved engagement of network operators with their network users

Recommendation 5: to encourage the deployment of smart grid solutions, where they are a cost-efficient alternative for existing solutions, and as a first step in this direction, to find ways of incentivising network companies to pursue innovative solutions where this can be considered beneficial from the viewpoint of the society

Recommendation 6: to evaluate the breakdown of costs and benefits of possible demonstration projects for each network stakeholder and to take decisions or give advice to decision-makers based on societal cost-benefit assessment which take into account costs and benefits for each stakeholder and for the society as a whole

Recommendation 7: to ensure dissemination of the results and lessons learned from the demonstration projects in case they are (co-)financed by additional grid tariffs or from public funds to all interested parties, including other network operators, market participants, etc.

Recommendation 8: to participate in 'smart grids' discussions and cooperation activities among stakeholders and especially to consider an active cooperation with European and national standardisation organisations, grid operators and manufacturers, for example on open protocols and standards for information management and data exchange, in order to achieve interoperability of smart grid devices and systems

Recommendation 9: to clarify the difference between regulated grid activities and market opportunities for new services under a competitive regime (e.g. aggregation of resources, EV recharging) instead to carefully monitor the possible presence of cross-subsidies between network activities by TSOs or DSOs and market-based activities

Recommendation 10: to continue exchange of expertise at European level, in order to learn as soon as possible from best regulatory practices

Source: (ERGEG, 2010)

4.5.2 UK's RPI-X@20 review of regulation and recommendations

Ofgem's RPI-X@20[39] is a detailed review of the British energy network regulation. It is certainly the most comprehensive review of grid regulations launched so far in Europe. It is also the most explicit with regards to the promotion of R&D in electricity and gas grid activities.

The objective of the RPI-X@20 review was to consult stakeholders in order to define how best regulate energy grid companies in a new context of sustainability and low carbon objectives. The result of this consultation is the RIIO[40] model (see Box 4) that the Ofgem will use for future price controls.

Very few European countries have launched concrete initiatives to promote R&D at the distribution level. The UK is an exception as it has launched several programmes: the Innovation Funding Incentive (IFI), the Low Carbon Networks Fund and an Innovation Stimulus package, which is part of RIIO, model (see box below).

The UK introduced the Innovation Funding Incentive (IFI) as part of the electricity distribution price control for the 2005- 2010 period. Ofgem presents the IFI as a response to the consistent decline in investment in R&D by DSOs since 1990. The IFI grants an allowance for innovation that can reach 0.5% of the grid company's turnover. The IFI also permits DSOs to pass through to customers up to 80% of the cost of eligible IFI projects. These projects concern activities focussed on the technical aspects of network design, operation and maintenance.

The OFGEM has also put in place the "Low Carbon Networks Fund". This £500m fund is part of the electricity distribution price control arrangements for the 2010-2015 period and supports projects launched by British distribution network operators to try out new technology, operating and commercial arrangements.

[39] The British RPI-X regulatory regime was about 20 years old at the time of the review

[40] RIIO : Revenue = Innovation + Incentives + Outputs

Box 4, Components of the RIIO model

1 - Objective: The overriding objective of the RIIO model is to encourage energy network companies to:

- Play a full role in the delivery of a sustainable energy sector
- Deliver long-term value for money network services for existing and future consumers

2 - Industry structure: The framework will be implemented under the current industry structure

3 - Enhanced engagement: Stakeholders will be given greater opportunities to influence Ofgem and network company decision making

(4 - Third party modification requests)

5 - Outputs led: At the price control review, Ofgem will set the outputs that network companies are expected to deliver to ensure safe and reliable services, non-discriminatory and timely connection and access terms, customer satisfaction, limited impact on the environment and delivery of social obligations

6 - Ex ante control: Ofgem will set an upfront price control, incorporating a return on the regulatory asset value and inflation indexation. The retail prices index (RPI) will be retained as the inflation index for the fifth transmission price control review

7 - Length of the price control: The price control will be set for eight years, with provision for a mid-period review of the outputs that network companies are required to deliver. Uncertainty mechanism will be implemented where this is consistent with the objectives of the framework and with ensuring network companies can raise required finance in a timely manner and at a reasonable cost to consumers. Ofgem will review the length of the control period at future price control reviews if needed

8 - Proportionate assessment: Ofgem will adopt a transparent and proportionate approach to assessing the price control package, with the intensity and timescale of assessment reflecting the quality of an individual company's business plan and its record for efficient output delivery

9 - Option to give third parties a greater role in delivery: The regulatory tool-kit will include the option to require a company to provide market testing evidence to support its business plan proposals. Ofgem will also have the option to involve third parties in delivery and ownership of large and separable projects, where this is expected to drive innovation, long-term value for money and/or more timely delivery

10 - Incentives: There will be transparent rewards/penalties related to output delivery, including a backstop threat of using Ofgem's existing powers for enforcement action and potential licence revocation for persistent non-delivery. There will be transparent, upfront, symmetric efficiency incentive rates for under- and overspend. Incentives will be calibrated to ensure they provide long-term value for money.

11 - Principles for ensuring efficient delivery is financeable: Ofgem will ensure that efficient delivery of outputs is financeable by committing to published principles for setting a WACC-based allowed return to reflect the cash flow risk of the business over the long term. Financeability will be assessed in the round, including a crosscheck against relevant equity metrics and credit rating ratios. As now, network companies will be expected to manage their business, including capital structure, efficiently to ensure they are financeable

12 - Innovation stimulus package: Ofgem will introduce a time-limited innovation stimulus for electricity (and gas) networks. These will be open to projects at any point in the innovation cycle and to both network companies and third parties for innovation related to delivering the networks required for a low carbon energy sector. The innovation stimulus package will include substantial prize funds to reward network companies and third parties that successfully implement new commercial and charging arrangements to help deliver a sustainable energy sector.

Source: (OFGEM, 2010)

4.5.3 Eurelectric

In 2009, Eurelectric surveyed European DSOs in 16 countries[41] about the adequacy of the regulatory framework for the development of smart grids. Results show that only three countries have the adequate incentives to promote investments in smart grids: the UK, Finland and Slovenia. In other countries, smart grid investments are hampered by low rate-of-return achievability and/or regulatory uncertainty (Figure 4.9).

Rate-of-Return achievability is related to CAPEX time shift problems or issues with the ex-post recognition of some investments carried out in the previous regulatory period. Regulatory stability is related to the regulatory regime's stability over time as well as legal uncertainty i.e. the complexity and opacity of regulatory clauses or benchmarking techniques.

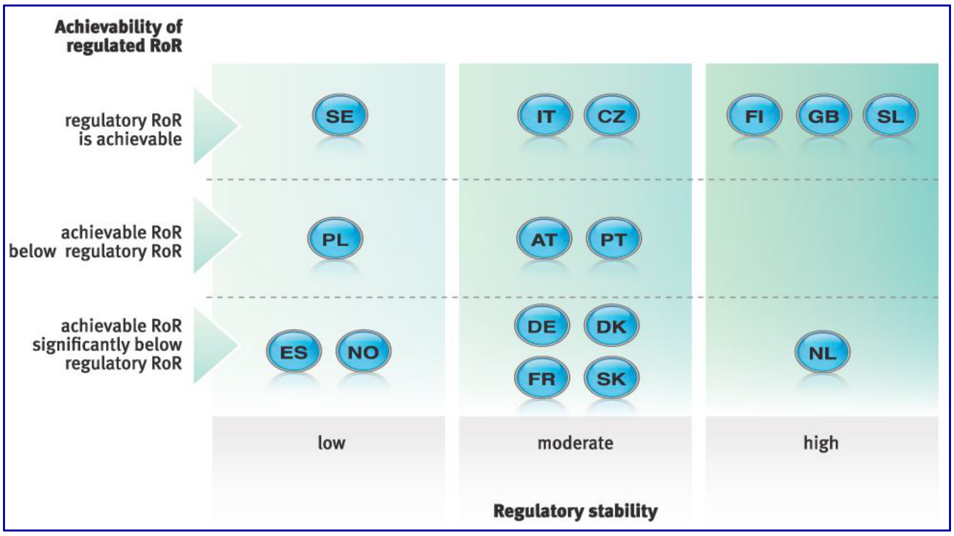

Figure 4.9, Incentives for Smart Grid Investments

Source: EURELECTRIC, 2011

[41] Austria, the Czech Republic, Denmark, Finland, France, Germany, Great Britain, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, and Sweden

Box 5, Summary of Eurelectric's recommendations

1 - Rewarding and Incentivising Capital Expenditures in Smart Grids
- A fair rate of return is an essential requirement for Smart Grid investments
- Smart Grid investments will have a shorter payback period
- For those regulatory models with a capital cost time shift there has to be a compensation implemented
- Investments in the smart-meter roll-out and in the implementation of an ICT infrastructure are needed

2 - Improving the evaluation of Operational Expenditures
- Expenses for research & development and for smart grid pilots should be excluded from the benchmarking

3 - Incentivising innovation and R&D funding
- In the past, innovation has been focussed on how to reduce OPEX
- New technologies (including communication) will need new types of incentives (so far no particular treatment for R&D)

4 - Clarifying roles and responsibilities
- Clear mandates and responsibilities are important for driving Smart Grid investments (including smart metering)

5 - Safeguarding regulatory stability
- Regulatory roadmaps are good practices

6 - The EU should provide additional guidance in order to keep the momentum on smart grids and help stimulate their development

7 - EU financing of large-scale Smart Grids demonstration projects is essential
- Smart grids have not yet been tested on a large scale
- A broad dissemination of results and best practices of Smart Grid demonstration projects is paramount

Source: EURELECTRIC, 2011

5 THE POLICY PERSPECTIVE

This section provides a summary of the current policy perspective for what concerns the development of Smart Grids in Europe, based on the position of the European Commission and of the International Energy Agency.

5.1 The enhancement of the general policy framework with respect the current situation

In line with its strategic energy policy objectives (EC 2011b), the European Commission has drawn up a vision for the deployment of Smart Grids (EC 2006), (EC 2007a), (EC 2011a) which entails a shift from the present electricity network, based on centralized generation and top-down distribution, to a new digitalized grid, increasingly based on a distributed and interconnected architecture. As discussed in the previous chapters, a new grid architecture is a prerequisite for the development and the penetration of:

- distributed local renewable energy sources
- new technological applications (e.g. electric vehicles, demand response);
- optimal management and control practices of the electricity grid (energy savings, reduction of maintenance/ operational/disruption costs)
- an internal energy market (new business models, new market players, consumer inclusion)

Present grid technologies, business models and regulations, as they have been designed and implemented during the 20th century, no longer fit the 21st century, nor do they provide an adequate response to the increasing awareness of the dangers of climate change.

The challenge is to mobilize market forces within the boundaries of energy policy goals to provide the required massive investments over the next decades. According to the EU's energy roadmap for 2050, cumulative grid investments between 2011 and 2050 will range between €1.5 trillion and €2.2 trillion, depending on the amount of support provided to renewable energies. On the other hand, whatever the EU scenario considered, electricity is forecast to nearly double its share of total energy demand, growing from 22% to between 36% and 39%. To meet the EU's 2020 targets, the "Commission's Blueprint for an integrated European energy network" estimates that €140 billion will need to be invested in the electricity grid by the decade's end. Some of this money will go to upgrading existing transmission lines and distribution networks but a major effort is also required to design and implement new business models and regulatory frameworks to combine the various features of Smart Grids within a coherent system and to make the market-driven modernization of the power sector effective. On the other hand, these modernization efforts are likely to remain ineffective if, at the same time, smart grids fail to digitally gather, distribute and act on information about the behaviour of suppliers and consumers in order to improve the efficiency, reliability and cost of electricity services. To "couple broad societal energy goals with a market driven deployment" (V. Giordano, 2011) it is then necessary that DSOs and energy service companies move away from a "paradigm where market profitability is mainly about meeting the rising energy demand and make energy efficiency and conservation a profitable opportunity".

5.2 The European Commission regulatory framework

According to the European Commission, five main challenges must be addressed to allow this paradigmatic transformation to take place:

- Consumer engagement at all levels
- Protection, handling and security of data
- Standardisation and interoperability
- Regulatory framework and incentives
- Infrastructure investments and roll out

Policy actions undertaken to date by the European Commission have adopted a rather cautious approach vis-à-vis Member States (encouragement rather than binding measures), and are in fact not sufficient to decisively drive Europe toward the advocated transformation. The main steps taken so far are:

- The Directive on energy efficiency (2006/32/EC, now being deeply reformulated) that encourages Member States to take into account efficiency gains obtained through the widespread use of cost effective technological innovations, for instance electronic metering.
- The 2001/7 Directive (now 2009/28/EC) on the promotion of the use of energy from the renewable, which supports the development of Smart Grids indirectly.
- The 3rd Energy Package's provisions (to be transposed by March 2011) that encourage the long-term modernisation of the European grids across Europe, subject to individual Member State's transposition. In addition, Annex 1 of the new Electricity Directive (2009/72/EC) explicitly encourages Member States to assess the conditions for the rollout of smart meters as a first step towards the implementation of Smart Grids.

The Commission has actually recognized the urgency of the development of an EU-regulatory framework for Smart Grids and its crucial importance in order to "guarantee that existing barriers to the Smart Grid roll-out are addressed at European level as well as that no new barriers to the Smart Grid deployment are created by unilateral actions of the Member States" (EC 2010). The design of such a regulatory framework has been entrusted to a Task Force (set up in November 2009) composed by national data protection supervisory authorities, consumers, suppliers, traders, power exchanges, transmission companies, distribution companies, power equipment manufacturers and ICT providers. The aim of this Task Force has been then to advice the Commission on policy and regulatory directions at European level and to coordinate the first steps towards the implementation of Smart Grids. The main topics on which the Task Force has been asked to advice are:

- Functionalities of Smart Grid and needs for standards.
- Regulatory recommendations for data safety, data handling and data protection
- Regulatory recommendations and roles/responsibilities of actors involved in the Smart Grids deployment

The Commission has then endorsed the information provided by the Task Force on each of these topics and, in its communication to the European Parliament and the European Economic and Social Committee of March 2011 (EC COM[2011]202), it has accordingly identified a series actions and tasks to be implemented in the short term:

Action	Tasks
Smart Grids Standards	With the help of the Task Force, the EC will monitor the implementation of the work programme established in the mandate with the view to ensure timely adoption of the standards. If in the course of 2011 is not sufficient, the EC will intervene to ensure that the deadline is met and the necessary standards are set.
	The EC will also follow the development of ICT standards at the European and international level to facilitate the implementation of Smart Grids
Data Privacy and security of data	The EC will monitor the provisions of national sectoral legislation that might apply to take into account the data protection specificities of Smart Grids
	The ESOs (European Standard Organizations) will develop technical standards for Smart Grids taking the "privacy by design" approach
	The EC will continue bringing together the energy and ICT communities within an expert group to assess the network and information security and resilience of Smart Grids as well as to support related international cooperation
Adjust the existing regulatory framework for Smart Grids	The EC will develop regulatory incentives for the deployment of Smart Grids, for example in the application and revision of Energy Services Directive and/or through the development of a network code or implementing act on tariffs
	The EC will establish guidelines to define a methodology for the smart meter implementation plans of Member States, as well as for their (possible) cost-benefit analyses
	Beyond the targets for smart meters in the Third Package, the EC will request Member States to produce action plans with targets for the implementation of Smart Grids
	Through its role in the Regional Initiatives and its involvement in ENTSO-E, the EC will encourage and promote coordinated action towards the deployment of Smart Grids at European and regional level
Guarantee competitive Smart Grids services to customers	The EC will introduce, through revision of the Energy Services Directive, minimum requirements for the format and content of information provision for customers, and for access to information services and demand management (e.g. in-house control of consumption)
	The EC will monitor the implementation of the Third Package requirements needed to create a transparent and competitive retail market for the development of services (e.g. time-of-use and demand response) based on Smart Grids and metering. If the requirements are not implemented or not effective, the EC may take further actions, possible in its review of the Energy Services Directive
Support innovation and rapid application	During 2011, the EC will propose additional new large-scale demonstration initiatives for rapid Smart Grids deployment, taking into account the needs identified in the EEGI. They will include ways to leverage financing, in line with the Energy Infrastructure Package and as requested by the European Council of 4 February 2011
	The EC will also launch the initiative Smart Cities and Communities in 2011

Source, EC 2011a

Based on the actions thus identified, the European Commission's position on the crucial dimensions of the development of Smart Grids can be illustrated as follows.

Standards

Although the definition of common standards has been identified as crucial at the outset, and therefore considered by the Commission as one of the pillars for the deployment of a Smart Grids system, the delivering of the related norms and communication protocols is currently lagging behind. The European standards organisations (ESOs) were tasked, via a Commission mandate in March 2009 (Mandate M/441) to develop an open architecture for utility meters, then in June 2010 (Mandate M/468) to address the charging of electric vehicles, and finally in March 2011 (Mandate M/490) to develop and update a set of consistent standards to achieve the systems interoperability and facilitate the implementation of the different Smart Grids services and functionalities. Mandate M/490 has thus received more comprehensive and ambitious objectives that include the outcomes of the existing Mandates M/411 and M/468. The fulfilment of this mandate has been entrusted to the European standardization organizations CEN, CENELEC and ETSI42 with the purpose to develop a reference framework to enable ESOs to perform continuous standard enhancement and development in the field of Smart Grids. This framework lies on the following three pillars:

1. A technical reference architecture, which will represent the functional information data flows between the main domains and integrate many systems and subsystems architectures.
2. A set of consistent standards, which will support the information exchange (communication protocols and data models) and the integration of all users into the electric system operation.
3. A sustainable standardization process and collaborative tools to enable stakeholder interactions, to improve the above-mentioned architecture and set of standards, and adapt them to new requirements based on gap analysis, while ensuring the fit to high level system constraints such as interoperability, security, and privacy, etc.

The work started in June 2011 and the first results are expected by the end of 2012. In the meantime the three standardization organizations have published a strategic report (CEN/CENELC/ETSI, 2011) that outlines the standardization requirements for implementing the European vision of smart grids, especially taking into account the initiatives by the Smart Grids Task Force of the European Commission. This paper paves the way to the fulfillment of the Mandate M/490 as it provides an overview of existing standards, current activities, fields of action, international cooperation and strategic recommendations.

It is worth noting that this report outlines a set of recommendations that should serve as the reference guidelines to frame the development of future standards:

- **Use a top down approach: t**he different applications to be deployed over time need to fit together. This can only be assured by strong coordination.
- **Build up a flexible framework of standards:** market business models, players and technical solutions are still changing. A flexible model or architecture must be available to map services and use cases.

[42] CEN is the European Committee for Standardisation, CENELEC the European Committee for Electrotechnical Standardization and ETSI the European Telecommunications Standards Institute

- **Agree on a European set of use cases:** establish a single repository of use cases to systematically identify existing and future standardization needs.
- **Align with international standards:** cooperate with international and relevant national smart grid standardization activities. Base European standards on existing international standards and promote European results to the international level.
- **Don't reinvent the wheel:** reuse existing mature standards whenever appropriate.
- **Adapt the organization and processes for standardization:** smart grids are a system issue rather than a product issue. The CEN/CENELEC/ETSI Joint Working Group will promote this approach in close collaboration and cooperation with the existing TCs and structures.

The Commission is finally promising to monitor more closely the implementation of this mandate by ensuring that the "deadline (end of 2012) is met and the necessary standards are set".

Consumer privacy and security of data

Ultimately, the Commission seeks to develop legal and regulatory regimes to ensure that consumer privacy is respected and, at the same time, that the overall system security enhanced.

For what concerns privacy, the aim is to monitor the production of national legislation that might be relevant, and the extent to which it takes into account the data protection specificities of smart grids. To this end European standards organizations have been asked to develop technical standards for smart grids adopting a so-called 'privacy by design' approach. "Privacy by design" refers to the philosophy and approach of embedding privacy into the design specifications of various technologies. This may be achieved by building the principles of "Fair Information Practices" into the design, operation and management of information processing technologies and systems. This approach originally had information technology as its primary area of application, but it has since expanded its scope to other areas and currently applies to: i), information technology; ii) business practices; and iii) physical design and infrastructures.

The adoption of such a principle firstly came from the Expert Group 2 (EG2) of the Smart Grids Task Force (Task_Force_EG2, 2011), which recommended to make privacy "a core functionality in the design and architecture of Smart Grid systems and practices," in order to "cover the whole information system of the Grid, from meter to back-office, to support, to the financial department". Enforcement of information coordination and involvement of all the actors including researchers and designers, suppliers, contractors, manufacturers, and final users advocates, is thus necessary and urgent.

The Expert Group actually recognizes that "the classical privacy controls – e.g. anonymisation and access control solutions – have structural limits in providing consumer privacy". Privacy by Design should overcome such limits as it encompasses a variety of elements such as:

i. "Recognition that privacy interests and concerns must be addressed proactively.
ii. Application of core principles expressing universal spheres of privacy protection.

iii. Early mitigation of privacy concerns when developing information technologies and systems, throughout the entire information life cycle —end to end.
iv. Need for qualified privacy leadership and/or professional input.
v. Adoption and integration of privacy-enhancing technologies.
vi. Embedding privacy in a positive-sum (not zero-sum) manner so as to enhance both privacy and system functionality; and
vii. Respect for users' privacy."

In parallel, the Commission, again starting from the Task Force recommendations, will bring together the Energy and ICT communities within a dedicated expert group so as to assess the network and information security and resilience of smart grids. Security is recognized as a critical aspect of the smart grids deployment. The increasing use of ICT-based systems increases the number of entry points and paths that can be exploited by potential adversaries and other unauthorised users, which might even endanger the national and global security (cyber attacks to nuclear sites, intentionally caused blackouts, etc.). On the other hand, grid security is also directly linked to privacy issues, as the increasing volume of customer information collected by IT systems (and transmitted via networks) amounts to a monetary incentive for criminals to attack these systems, potentially leading to the unauthorised disclosure and use of private and sensitive information. At the same time it is well known that any given system is as weak as its weakest component, and in fact, as stated in the EG2 report: " the reliability of most of the current ICT systems and network components and their architectures is far less reliable and fail-safe than power grid components and therefore may introduce a less reliable power supply to the customers."

It is then clear that "securing the smart gird isn't something that any organization could do on its own" and again, as stressed by the Commission, a concerted and cooperative effort by academia, manufacturers, industry leaders, and policy-makers is required to protect the Smart Grids from disturbances and misuse. According to the Task Force the top priorities to be assessed and discussed are:

- <u>Improvement of the electricity companies top management awareness</u>: since these companies have to implement the measures to increase the robustness and resilience of the Smart Grid, their top management needs to be aware of the risk and take appropriate action, e.g. by including cyber issues in policy and in business continuity plans. To this end the Task Force suggests to introduce this awareness concern at a "ministerial top conference on the security and privacy of Smart Grids, with the aim of producing a joint public-private roadmap to secure Smart Grids"
- <u>Develop security-by-design schemes</u>, in order to base the smart meters infrastructure on certificates released by certification authorities, that in turn, should be established prior to the extensive rollout of these devices.
- <u>Updating and consolidation of existing guidelines</u> on certification of products and practices[43], including protocols for vendors and grid maintenance operators

[43] I.e., the NISTIR-7628 guidelines for Smart Grids Cyber Security, the BSI, the international standard body, initiative for common criteria protection files for gateways and security models (https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/SmartMeter/PP?SmartMeter.pdf?__blob=publicationFile), the WIB (The International Instrument Users' Association)Process Control Domain Security Requirements for Vendors

- Taking care of the human factor to provide continuous cyber security training and information facilities to the employees of the electricity companies.

Regulatory framework

Here the aim of the Commission is to promote regulatory incentives that encourage network operators to earn revenue in ways that are not exclusively linked to additional sales but are also based on efficiency gains and lower peak investment needs. In practice this means moving away from a volume-based business model to a quality or efficiency-based one (see also chapter 3).

Regulatory incentives for the deployment of smart grids as along with the development of a network code on tariffs, will be thus included in the forthcoming adaptation of Directive 2006/32/EC on energy services. On top of this, the EU executive will issue guidelines defining a methodology for smart meter implementation plans to be drawn up by member states as well as their (possible) cost-benefit analyses. The Commission will finally request member states to produce action plans with targets for smart grid implementation and to promote greater coordination at regional and EU level.

Competiveness

An additional concern of the Commission is the competitive advantage that smart grids are likely to hold out to distribution system operators (DSOs), who would actually have access to detailed information about consumers' consumption patterns. The Commission therefore intends to introduce, also through a revision of the 2006 Energy Services Directive, minimum requirements for the format and content of information provision for customers as well as for the access to information services and demand management (e.g. in-house control of consumption). The Commission further intends to monitor the implementation of the legal requirements set in the 2009 third energy liberalisation package, which aim at creating a transparent and competitive retail market. If the 2009 energy package requirements are not met then the Commission may, once again, seek redress by proposing a modification of the Energy Services Directive.

Support to innovation

The Commission is envisaging continued support for innovation and uptake of smart grid technology and through the research framework programs (FP5, FP6 and FP7) around €300 million have been allocated to smart grid R&D over the past decade.

It is also worth remembering that in June 2010, a European Electricity Grids Initiative (EEGI) was established under the EU's Strategic Energy Technology (SET) plan. The EEGI estimates the financing needs for smart grid research in ca. €2 billion over the period 2010-2018. Although which part of this effort will come from the EU is not yet clear, the Commission is considering the possibility of using other EU funding instruments, such as the Structural Funds, to offer "tailored" financing solutions, including grants and loans, to support smart grid technologies. The EU executive should further propose additional new large-scale demonstration initiatives for smart grid deployment. There will, too, be proposals on leveraging finance. A further push for smart grids will be also provided by the launch of the EU's Smart Cities and Communities initiative in the forthcoming Horizon 2020 program.

5.3 The International Energy Agency policy perspective

5.3.1 The IEA roadmap

At the global level, the International Energy Agency (IEA, 2011) has elaborated a policy roadmap that, taking into account the challenges here outlined, would make the smart grids deployment effective. The IEA identifies three main lines of action:

- Improving the regulatory schemes and the business models for Generators, TSOs and DSOs.
- Enhancing the consumer oriented policies
- Building consensus on smart grid deployment

In this framework the Agency, supported in this by the Commission, advocates a stronger collaboration between policy makers and the network operators that support smart grids investments and among the operators themselves. The key is "to find the right balance in sharing costs, benefits and risks. The responsibility for achieving this balance lies with regulators and, in some cases, legislators, but must include input from all stakeholders". (IEA, 2011)

The IEA policy roadmap concretely translates into a list of actions and milestones broken down by the main sectors and actors of the electricity system value chain:

Services/Actors	Tasks and Milestones
Power Generation Companies	Develop an evolutionary approach to regulation for changing the generation landscape from existing and conventional assets to more variable and distributed approaches – including both large and small electricity generation. **From 2011 to 2030**
	Develop regulatory mechanisms that encourage business models and markets to enable a wider range of flexibility mechanisms in the electricity system to support increased variable generation penetration. **From 2011 to 2030**
TSOs	Continue to deploy smart grids on the transmission system to increase visibility of operation parameters and reliability. **Ongoing**
	Assess the status of regional transmission systems and consequently future requirements in smart grid technology applications to address existing problems and potentially delay near- and medium-term investments. **From 2011 to 2020**
DSOs	Determine policy approaches that can use smart grids to leverage distribution system investments strategically and optimise benefits. **From 2011 to 2030**
	Promote adoption of real-time energy usage information and pricing that will allow for optimum planning, design and operation of distribution system in co-operation with customers. **Focused effort from 2011 to 2020, ongoing to 2050**
Customers	Collect and codify best practice from smart grid and smart metering pilot projects and increase study of consumer behaviour, use findings to improve pilot projects. **From 2011 to 2020**
	Expand pilots on automated demand response especially in service and residential sectors. **Continue over 2011 to 2050**
	Develop electricity usage tools and pricing practices that incentivise consumers to respond to changes in electricity markets and regulation. **Evolve approaches over time, largely completed by 2030**
	Develop new policies and protection mechanisms to control and regulate privacy, ownership and security issues associated with detailed customer usage behaviour information. **From 2011 to 2020**
	Develop social safety nets for vulnerable customers who are less able to benefit from smart grid pricing structures and are susceptible to remote disconnection functions made possible by smart grids. **From 2011 to 2015**

Source: IEA, 2011

5.3.2 Improve the regulatory schemes and the business models for Generators, TSOs and DSOs.

Generation

As discussed in chapters 1 and 3, the share of intermittent generation sources is expected to strongly increase across EU by 2020 (see Table 1.6 at paragraph 1.4.2.1), even more by 2050, and new business models are needed to guarantee the flexibility required by the deployment of the variable generation while ensuring reliable system operation. On the other hand, IEA stresses that market transparency must increase to allow new actors and third parties to enter and provide conventional or innovative solutions for the achievement of the advocated flexibility. The interactions between well-known and experimented approaches, such as e.g. peaking generation plants, and new ones, such as the demand – response applications, have to be further analysed and demonstrated along with new market and business models refinements. To this end the agency warns that the deployment of smart grids may have a negative impact on some types of generation, especially those currently in use when sudden requests of power must be met. These power assets may thus become redundant as smart grids are deployed because of the shifting of demand profiles. This entails that, "as smart grids will enable increased DR and electricity storage that reduces the need for peaking generation, identification of possibly redundant assets should be carried out at the earliest possible point in smart grid deployment to allow for appropriate planning and cost/benefit analysis".

Transmission network

In Europe investment in the smartening of the transmission network is already occurring but new transmission capacity and transborder interconnections are required to reduce or even eliminate congestion and upgrade the aged infrastructures. The challenge for TSOs is to identify technology applications and requirements for additional capacity and interconnection through the assessment of the current status and future requirements at regional level. This assessment should lead to "new technical and regulatory solutions that optimise the operation and planning of existing systems, enabling the deferment of conventional investments that may be hindered by long approval processes or local opposition." To this end the agency warns that these transmission system investments should be timely and adequately allowed by governments to avoid future risks of higher costs and system failure.

Distribution networks

The smartening of distribution networks is the real critical challenge that policy regulators and operators have to face in view of the deployment of the smart grids. Distribution networks have a much higher number of nodes to manage and the ICT interconnections and requirements are also significantly more numerous than those necessary for transmission networks. As described throughout this report, distribution networks connect nearly all electricity customers and will have to manage the power input from distributed and variable sources as well as new loads as the electric vehicles. Moreover market unbundling has deeply changed the ownership and operating arrangements of the distribution value chain. New actors such as electricity retailers, energy services providers and aggregators are entering in the market and new business models and pricing schemes have to be implemented, also building upon the experience gained through pilots and demonstration projects.

In this regard the Agency stresses that these new regulatory, business and market models must share risk and benefits with other stakeholders: with other system operators and generators upstream as well as with end users downstream. "Business models without shared costs and benefits will not be successful. Additional policy and regulation will be needed for DSOs to manage and utilise these relationships to meet system investment needs"

5.3.3 Enhancing the consumers policies

The IEA rightly puts much emphasis on policies that must be devised to address the end users' side of the smart grid transition. In fact it articulates its proposal for the implementation of the smart grids roadmap in five different actions of which the first three are focused on the evaluation of the consumers feedback to the new price policies and to the opportunity to become more proactive in the management of their loads as well as on the need to develop and implement pilot projects to study the consumers attitude and behaviour. The last two actions touch two other critical aspect of this sensitive matter, concerning consumers privacy, data protection and security issues, and the social equity. It is in fact beyond doubt that the interaction between smart electricity technologies and the end users, especially in the residential sector, is one of the critical points requiring the utmost attention at both the political and technical level to ensure the successful the deployment of smart grids.

Analysis of consumers' feedback and pricing policies

For what specifically concerns studies and pilot projects on consumers feedback, the Agency notes that they can be flawed owing to the difficulty in discerning whether the mental frame of respondents and participants is geared on a limited trial period, or rather on a long term and structural change of their relationship with the electricity vendor. According to the past experience this may lead to overestimate or underestimate long-term results. More rigorous research is thus needed to identify a more robust method to deliver feedback. Research in this crucial area should moreover have the following three objectives:

- Identify lessons for policy makers from social science research on consumers feedback analysis, aiming at better understanding consumers acceptance of new pricing policies and real life behaviour with respect enabling technologies (e.g. advanced metering and/or automated demand – response patterns).
- Identify technologies and policies that might better foster sustainable changes in consumers' behaviour.
- Establish a community of practice at EU level to develop analytical tools to evaluate the impact in terms of barriers/benefits of the behavioural changes on the smart grids deployment pace.

In fact, two main factors must be considered in the design of pilot projects:

- the optimal mix between the active involvement of the consumers and the introduction of technologies that automatically adjust loads according to price (or other) signals:
- the pricing policies.

The optimal mix of active involvement and automatic adjustment will depend on the ICT-intensity of the DR scheme and on its performance in terms of privacy and security; on the other hand market segmentation is of the essence as different types of consumers (households, commercials, small industries) have different requirements and different perceptions.

The issue concerning the choice of the most appropriate pricing policies is still totally open. As previously mentioned, the capability to deliver dynamic, real-time pricing signals is an important added value of the smart grids. Actually, recent pilot projects and studies have demonstrated that time-differentiated pricing can reduce peak demand by an average of 15% and, adding information and DR technologies on the consumer side of the meter, such impact could as much as double. Nonetheless the mechanism to transfer this potential benefit to consumers is raising fundamental questions, e.g. whether it should reflect real cost in real time or provide customers with choice, and/or eliminate cross-subsidies.

Price policy types for small consumers are basically three:

- Flat-rate or static pricing for which the unitary price of the electricity is fixed (or possibly changes in accordance with given thresholds of energy consumption) and does not vary throughout the 24 hours. This leads to overcharging during non-peak times and undercharging during peak times, and does not provide customers any incentive to shift their demand to different periods of the day.
- Real-time pricing, based on actual costs of generation, transmission and distribution. Over and undercharging are avoided in this case, but customers might be unable to switch loads during peak times or find automatic DR schemes unacceptable, therefore incurring in higher costs.
- Time of Use (TOU) pricing mechanisms that take advantage of the possibility to predict electricity costs on daily and seasonal basis.

In devising pricing options by combining elements from these three basic schemes, the regulator is faced with delicate questions such as, for example, whether the dynamic pricing should be a default or an optional service; how to tune a price mechanism like the TOU in order to obtain the maximum benefit in terms of demand response and, which communication policies are needed to overcome the inertia and risk aversion of consumers?

A special attention must moreover be devoted to the impact of these new pricing policies on low-income and/or aged families. These may be disadvantaged by their inability to change behaviour and usage patterns as a result of pricing, or may be subject to rate burdens that are not commensurate to the potentially accrued benefits (for example, if the electricity uses of a low-income family are limited to lighting, a refrigerator and few other small appliances, there is no way it can benefit from low night prices).

No clear answers to these questions are available yet, prompting the need for additional research to evaluate how, and to which extent, price differentiated policies can structurally modify consumers’ behaviour.

Consumer protection policies

As previously noted, customer privacy and data protection issues are crucial factors on which consumers and their advocates tend to concentrate their attention. Smart grids and, especially, smart meters might be seen as intrusive devices that generate a large flow of customer sensitive information, possibly transmitted via Internet. Given the limited experience of electricity distribution companies for what concerns the security of massive data flows, this information is likely to be highly vulnerable to criminal attacks. The Smart Grids Task Force, along with other national organisms, are devoting sustained attention to these matters, which may be summarised – in the words of the IEA – through four main policy questions:

- Who owns the customer's data and how its access and use will be regulated?
- Who guarantees privacy and security of customer data?
- Will sale or transfer of customer data be allowed and under what terms?
- Do competing electricity providers have access to customer data on the same terms as the incumbent utility?

6 CONCLUSIONS AND WAY FORWARD

The deployment of smart grids raises a variety of challenges that are directly relevant for policy makers and stakeholders. This chapter summarizes the main findings of the study, the issues still open for further investigation and debate, and presents them in the form of short messages under the five basic headings of Technology, Regulation, Business, Economics and Society.

6.1 Technology

1. Smart Grids rely on a variety of technological advances, many of which have already proven their functional and technical value. More technological innovation is needed and expected (notably in the field of energy storage), but the real key to a successful deployment of smart grids will be the capability to **integrate individual technologies** and devices into a multi-layer, multi-actor service framework.

2. **Information and communication technologies** and systems will play a fundamental role in ensuring the advocated integration. Although technological changes are well on their way in all three layers of smart grid systems (energy technologies, market applications, information and communication) the most decisive progress is expected in the latter.

3. The future of smart grids is heavily dependent upon the trend towards higher levels of self-production and self-consumption of electricity. Current and forthcoming progress in the cost performance of distributed generation from renewables will lead to **grid parity** (whereby the cost of the electricity made available for direct consumption is lower than that of the electricity distributed through the network) in an increasing number of situations, probably before 2020. If present barriers to grid access remain, **off-grid solutions or small-scale, local networks** will become more popular and will require different types of "smart" solutions. As concerns the load-shaping factor of smart grids, substitution trends between electrical and thermal energy for uses such as heating, cooling and hot water need careful analysis, since advanced systems, assisted by renewable energy sources (geothermal, solar, biomass), are becoming increasingly efficient and in a position to compete with traditional fossil fuel sources. This trend could have a strong impact on peak loads in the electricity network in some European regions. Cost-benefit analysis for smart grid deployment should therefore consider alternative or complementary solutions for different climate zones, based on consumption profiles.

6.2 Regulation

4. The smartening of electricity grids is primarily driven by a combination of economic interests and technical feasibility. Nevertheless, the deployment of smart grids requires a **stable, long-term policy framework to guarantee that the necessary resources are mobilized**: the bulk of grid related investments - including future smart grid investments - are placed under the responsibility of regulated businesses i.e. Transmission System Operators (TSOs) and, even more, Distribution System Operators (DSOs). Regulatory models must therefore provide the right incentives for utilities to invest in smart grid technologies and solutions, failing which the innovation process will inevitably be hampered.

5. On the other hand, Smart Grid-related services and devices that are not part of the regulated network activities such as home automation, small distributed generation, aggregation services, smart appliances and in some instances smart meters will only develop and reach their full potential if the grid can effectively and efficiently integrate them. It follows that ensuring an adequate and supportive regulatory framework for the development of smart grids in the regulated area (the transmission and distribution backbone) is a prerequisite for the **emergence of a healthy smart grid business and market play**.

6. Current regulation models, whether cost-based or incentive-based, primarily aim at achieving cost-efficiency and are not designed to promote innovative investments, high levels of R&D or even high quality targets. In the perspective of smart grid deployment, these models are likely to lead grid companies to keep to traditional approaches and postpone investments in innovative technologies. In turn, this will inevitably produce adverse effects on the quality of electricity as the grid ages and the share of intermittent renewable energies increases. In theory, TSOs and DSOs should have a strong incentive to make their grids smarter to mitigate the impact on costs of renewables and enable demand response. In practice however, the willingness of grid operators to take on these new costs largely depends on the way these costs are allocated and made recoverable by regulatory regimes. The key issue to be addressed by regulation is therefore to **ensure the right balance in the sharing of costs, benefits and risks**.

7. The future deployment of Smart Grids will only be beneficial to all players concerned, and in particular to energy users, if a basic transition occurs **from a "volume-based" to an "efficiency-based" business model**. Incentives from the regulatory framework should therefore encourage the actors to seek benefits from efficiency increases rather than additional sales.

6.3 Business

8. The power system of the future will look fundamentally different from the current one. Through the steady improvement of technology for communication and control combined with higher granularity of energy usage data, new high profit business opportunities will arise. While in the old value chain the customer was not the main focus of utility business, the actively engaged customers of future smart grids require real-time access to dynamic prices information that will influence their consumption. In the long run, this creates a need **for customer participation models supporting energy efficiency and demand response**, including more smart appliances and less of the current bulky regulation rules. A new type of demand response includes price-responding customers and granular energy services to optimize overall energy usage. In addition to highly aware active customers, declining technology costs will increase the growth of demand response markets. Until the transformation is completed, traditional energy efficiency and demand response business models will develop further as profitable intermediate solutions.

9. Due to the existing European market architecture there is an **increased need for aggregation of distributed energy resources** in the short-term. This lowers market entry barriers for small customers, supported by further deployment of smart meters as enabling technology, optimizes balancing distributed energy resources, and decreases overall operating costs. One promising approach aggregates small generation units to virtual power plants, which provides the opportunity for a cost-efficient, secure, and sustainable participation of small units in the power system. To ensure fair benefits to the involved stakeholders, business models have to transform the highly complex market mechanisms into simple transactions for their customers.

10. In the emerging smart grid market a variety of platforms are appearing, that aim at linking several market actors and providing system operation data, with platform owners accruing benefits from the provision of access to different applications. **Market platforms for the aggregation of distributed energy resources** on the supply-side are highly developed whereas additional research is needed on the demand-side. Results from the establishment and operation of market platforms so far indicate a **strong correlation between platform profitability and consumer engagement**.

11. Although it remains to be seen how the new technologies and business ideas make their way to customers and other stakeholders, their potential can already be observed in several research and pilot projects. Smart meters in combination with new smart home appliances stimulate behavioural changes. This positive effect is likely to increase with the further diffusion of advanced appliances and the increased availability of granulated energy usage data, thus triggering a virtuous circle leading to higher demand-side participation. In the short term, the successful development of innovative business models will require that

    - ✓ utilities fully acknowledge the potential benefits of **transforming the formerly limited customer relation into a mutually profitable partnership**
    - ✓ stakeholders are forcefully encouraged to **jointly establish the new technology framework**, with its standards and its real-time economics
    - ✓ policy makers provide **continuing support to smart meter investments**
    - ✓ **fair cost sharing schemes** are devised to exploit the full potential benefits
    - ✓ new business model concepts systematically **involve the customer beyond the meter.**

6.4 Economics

12. Networks will have to evolve anyhow in order to cope with current and emerging challenges, becoming smarter and at the same time retaining high levels of security, quality, reliability and availability. Besides traditional network upgrades, new investments will be required to make grids smarter and more flexible. Altogether, Smart grid investments should therefore be seen neither as a substitute, nor as fully additive to conventional grid investments (replacement, extensions), as **future investment costs include both "conventional" and "smart" components**.

13. Specifically for what concerns the emergence of smart grids, **new technology-related costs** are primarily related to:

    - ✓ Smart meters
    - ✓ New electro-technical devices (sensors)

- ✓ IT and communication infrastructure: hardware equipment and software for grid management and operation
- ✓ Additional and extended computational capacity to deal with increased data flows (e.g. real time metering and billing)
- ✓ Complementary components such as storage facilities.

14. **Assessing the costs and benefits** of smart grids investment poses a series of new challenges, methodological and practical:

- ✓ Regulators and grid operators are used to a network asset life of several decades (30 to 50 years) whereas ICT equipment has a much shorter life (5 to 15 years). **Replacement costs** of network equipment mixing the two types of technology (conventional and "smart") need to be assessed carefully
- ✓ As the timing of energy usage becomes more important than total consumption, the economic valuation of **time-related energy consumption** needs to be carried out
- ✓ Indirect, **macroeconomic effects** of smart grids deployment may turn out to be more important than the direct effects at the microeconomic level. They should therefore be carefully assessed and accordingly included in cost benefit analyses

15. Estimates of the overall amount of investment required for the large-scale deployment of smart grids in Europe have been made, varying at times considerably with the scope and objective of the assessment. In any instance, there is an increasing recognition of the need to explicitly include users/customers and society at large in cost benefit exercises. Typically, profitability calculations for smart grids do not take into account investments that customers have to make into enabling technologies beyond the meter, nor cost-benefit analysis for generation assets. On the other hand, if it is demonstrated that smart grids contribute significantly to improving security of supply, the argument for **"socializing" investment costs** for this purpose is strong – if they are lower than the costs of power outages. Considering that not only the DSOs, but also generators, appliance makers and the automobile industry will eventually benefit from smart grid deployment, a fully fledged **appraisal of external costs and benefits of smart grids** is needed, to provide evidence for both the design of the regulatory framework and of the corresponding instruments (incentives, optimal sharing of burdens) and in order to ensure the full and equitable recovery of social costs (e.g. through internalization of negative externalities).

6.5 Society

16. As repeatedly stressed, **customers are at the centre of the transition towards smart grids**, which will only take place if users shift from the traditional passive mode to an actively participating role. For this to happen several basic conditions must be met, notably including:

- ✓ Visible and credible monetary savings (at least 10%)
- ✓ Ease of use of home automation system and other enabling technologies
- ✓ Retained control over own consumption

17. In order for smart grids to actually deliver benefits to the customer, utilities must drastically change their communication behaviour and engage in reciprocal actions. **Information and communication campaigns** are absolutely necessary to ensure an adequate level of customer motivation, and to overcome a number of currently **widespread misconceptions** such as e.g. the over estimation of the impacts of smart meters (both positive and negative).

18. Privacy issues, and the (real and perceived) intrusiveness of enabling devices such as smart meters and home automation systems are a much-voiced concern of citizens and users groups. Furthermore, data security is intrinsically threatened by the manifold multiplication of data flows. But legal concerns related to privacy and security do not only affect customers, but are in fact shared by utilities, which fear potential liabilities that may arise from data transfer and management, including responsibilities for data accuracy, availability, security, timeliness, and authority to access and transfer such data – as well as the costs associated with managing such a large amount of data. Third parties, on the other hand, see the access to consumer data as generating potential market opportunities. Here again a two pronged approach is required, combining a legal and regulatory framework that safeguards the basic privacy rights and principles, with a cooperative approach between service suppliers and customers that should guarantee not only transparency, but, most importantly, the empowerment of customers, if only through the provision of "opt out" alternatives.

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This document is the final report of the STOA study 'Smart grids/Energy grids - The techno-scientific developments of smart grids and the related political, societal and economic implications'.

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This is a publication of the
Directorate for Impact Assessment and European Added Value
Directorate General for Internal Policies, European Parliament

PE 488.797
CAT BA-32-12-537-EN-C
DOI 10.2861/98028
ISBN 978-92-823-4017-2