

Power to the People!

European Perspectives on the Future of Electric Distribution

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THE ELECTRICITY DISTRIBUTION BUSINESS IN Europe is made up of more than 2,400 companies that serve 260 million connected customers, operate 10 million km of power lines, distribute 2,700 TWh a year, and directly employ more than 240,000 people. This is a very diverse business, varying in the number and size of its operational areas, the number of their customers, and the characteristics of the various networks, as well as their ownership structures. Despite this diversity, European distribution system operators (DSOs) generally provide a very high level of reliability and quality of supply to their customers.

An elevated level of harmonization across Europe has been achieved in some fields of the power sector as a series of legally binding texts from the European Union (EU) has created a single regulatory framework in the 28 member states, prompting the unbundling of the sector and the implementation of retail markets. There is no common European energy policy, however. Each member state



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Implementing smart grids is central to the transition to a low-carbon economy, and DSOs are key players in this transition.

defines its own provisions regarding, for instance, support for renewable energy.

In most European countries, intermittent generation is developing very quickly, leading to a total current installed capacity of 106 GW of wind and 70 GW of PV in Europe. The vast majority of these plants are connected to distribution networks. Together with the development of active demand and electric vehicles, this will lead to a deep transformation of the role of DSOs.

Active Distribution System Management

With the EU well on its way to meeting a 20% target for renewable energy sources (RESs) in total energy consumption by 2020, the share of electricity supply from RESs is on the rise. A large proportion of these resources, including intermittent solar and wind, will be connected to low- and medium-voltage distribution networks. In fact, Germany, Ireland, and Spain are already experiencing a high penetration of such generation. In addition to this, e-mobility, local storage, and demand response will all affect the distribution grids heavily. The operation of this future system will become more complex since significant power will flow not only from the power system to the customer but also from the customer to the power system. Problems like excessive voltage variations and bottlenecks will occur more frequently. Technical limits will be breached, requiring additional investments in network reinforcement and in more sophisticated protective relaying and control systems.

Today's distribution networks are designed to meet peak loads. The current "fit-and-forget" approach implies that all issues are resolved up front, at the planning stage; the shift to more decentralized power production and new applications, however, means that this approach alone is not cost-effective. Peak demand occurs for only a limited number of hours per year, and the utilization rate is declining. In addition, the priority grid connection and access granted to RESs contributes to inefficiencies in grid development. Decentralized generation, flexible loads, and storage offer the potential for greater flexibility within the grid, but the current approach to grid design means that this potential cannot be used.

The European DSOs believe in promoting active system management, which could optimize the distribution network by allowing greater interaction among the key network processes—planning, connection and access, and operation—which take place within different time frames. Greater flexibility, on both the supply side and the demand side, will represent a key tool in this respect. While traditional

network reinforcement will remain important, such flexibility would help optimize the use of the existing network and thereby minimize distribution grid extensions. To make this paradigm change happen, the active involvement of customers is a must. In addition, DSOs need to play a more active role, and their networks must evolve facilitated by the right tools to allow them to comply with their fundamental tasks of maintaining reliability of supply and quality of service.

In November 2012, EDSO for Smart Grids (EDSO) listed the key elements of active distribution system management:

- ✓ **A variety of network planning and access options that would reduce the need for investment:** Long-term network planning would let DSOs prevent bottlenecks in the most cost-effective way. To this end, coordination among all relevant actors, particularly transmission system operators (TSOs) and DSOs, will be important. New types of network access could also help reduce network investments. Variable network access contracts could be one such option. In addition, alternatives involving close-to-real-time operation should also be investigated.
- ✓ **An adequately designed connection requirement for distributed generation (DG):** DG resources must fulfill certain technical criteria without which they cannot be properly integrated into the network: they must be able to resist voltage dips and prevent islanding. Separate metering for production and consumption should be provided.
- ✓ **A new role of services in distribution grid operation:** DSOs should be able to obtain flexibility from DG resources and consumers to solve grid constraints. This could result in new market mechanisms: so-called *flexibility platforms*. To manage the operation of distribution systems, basic system conditions should be defined, as is the practice for transmission networks today. A "traffic-light" scheme could be used to select the actions appropriate for various system conditions. Under normal "green light" conditions, DSOs would operate using market procedures. In insecure "yellow light" states, the DSO would use a set of market-based procedures to incentivize grid users to adapt production and/or consumption to the grid situation. Finally, in well-defined emergency "red light" conditions, the DSO should be able to undertake direct load management or emergency DG curtailment after the contracted options have been exhausted. The increasing share of DG and flexible

A key objective of European DSOs is to make sure that the new solutions that will be implemented are designed to benefit *all* customers.

load connected to the distribution grid brings the need for well-structured and well-organized information exchange mechanisms in distribution grids. The relationship and interaction between the DSO and the TSO should be further investigated. With increasing DG penetration, voltage problems are becoming more frequent. These require local solutions, as reactive power cannot be transported over long distances. Such problems should, therefore, be managed by DSOs, which should be allowed to explore all local options with a view to choosing the most efficient one. Such an approach calls for user participation.

✓ **Technical tools that let DSOs become real “system operators”:** The success of the above-mentioned active system management tools will depend on the ability of DSOs to actively monitor their grids, particularly at the medium- and low-voltage levels. Today’s DSOs do not have systems installed that can acquire much in the way of data from DG resources; this data gap is especially severe in the case of small-scale DG resources. As the share of distributed energy resources (DERs) expands, DSOs will need monitoring simulation, control strategies, and advanced protection systems that let them supervise and control power flows and voltage in their medium-voltage (MV) and low-voltage (LV) networks.

In this context, European DSOs see five key tasks for decision makers:

- 1) Member states and national regulators must properly implement existing EU legislation, namely, the second and third energy packages and the new energy efficiency directive.
- 2) Member states and national regulators must create an adequate regulatory framework that allows network solutions that go beyond the traditional approach of “investing in copper.”
- 3) The European Commission (EC), Agency for the Cooperation of Energy Regulators (ACER), and ENTSO-E, when drafting EU-wide network codes, must take into account lessons learned from relevant smart grid demonstration projects and already implemented solutions.
- 4) The EC, ACER, and the European Network of Transmission System Operators for Electricity (ENTSO-E) must design operational rules and facilitate the procurement of flexibility from the market.

- 5) The EC, ACER, and member states must adapt DER grid connection and access rules so as to meet the need for flexibility.

Smart Meters

In most EU member states, the installation of smart meters will be the responsibility of DSOs. As part of the physical grid infrastructure, the meters fall under the grid operator’s domain, making DSOs best suited to manage them.

The rise of smart metering systems in Europe today has been fostered by EU legislation. This includes the third energy package and other legislative instruments such as the energy services directive, the directive regarding the energy performance of buildings, and the energy efficiency directive. In detailed provisions on intelligent metering systems, these documents demand that end customers be provided with individual meters that accurately reflect consumption and provide information regarding actual time of use. Furthermore, they stress the adoption of smart meters as tools for both enhancing competition on retail markets and fostering energy efficiency.

The different European countries are at various stages of smart metering deployment. For instance, full deployment has already been completed in Italy and Sweden while mass rollout is ongoing in Finland and Spain and has been decided on but not yet implemented in France and the United Kingdom.

Smart meters provide new advantages for customers and contribute to energy savings. They improve daily service in that invoices can be based on actual consumption and a majority of operations can be performed remotely in less than 24 hours without the presence of the customers. They contribute to the transition to a low-carbon economy by allowing access to information about power consumption, which makes it possible for customers to monitor and reduce their consumption.

Smart meters also let market players design and provide new, innovative services. Moreover, smart meters greatly contribute to optimizing network management. They allow:

- ✓ better fault identification and localization on MV and LV networks, ensuring faster interventions and reduced outage duration
- ✓ detailed monitoring of power quality, which reduces the number of customer complaints and provides faster solutions to problems
- ✓ increased capacity to act remotely on the power networks and in particular to manage peak-shaving programs

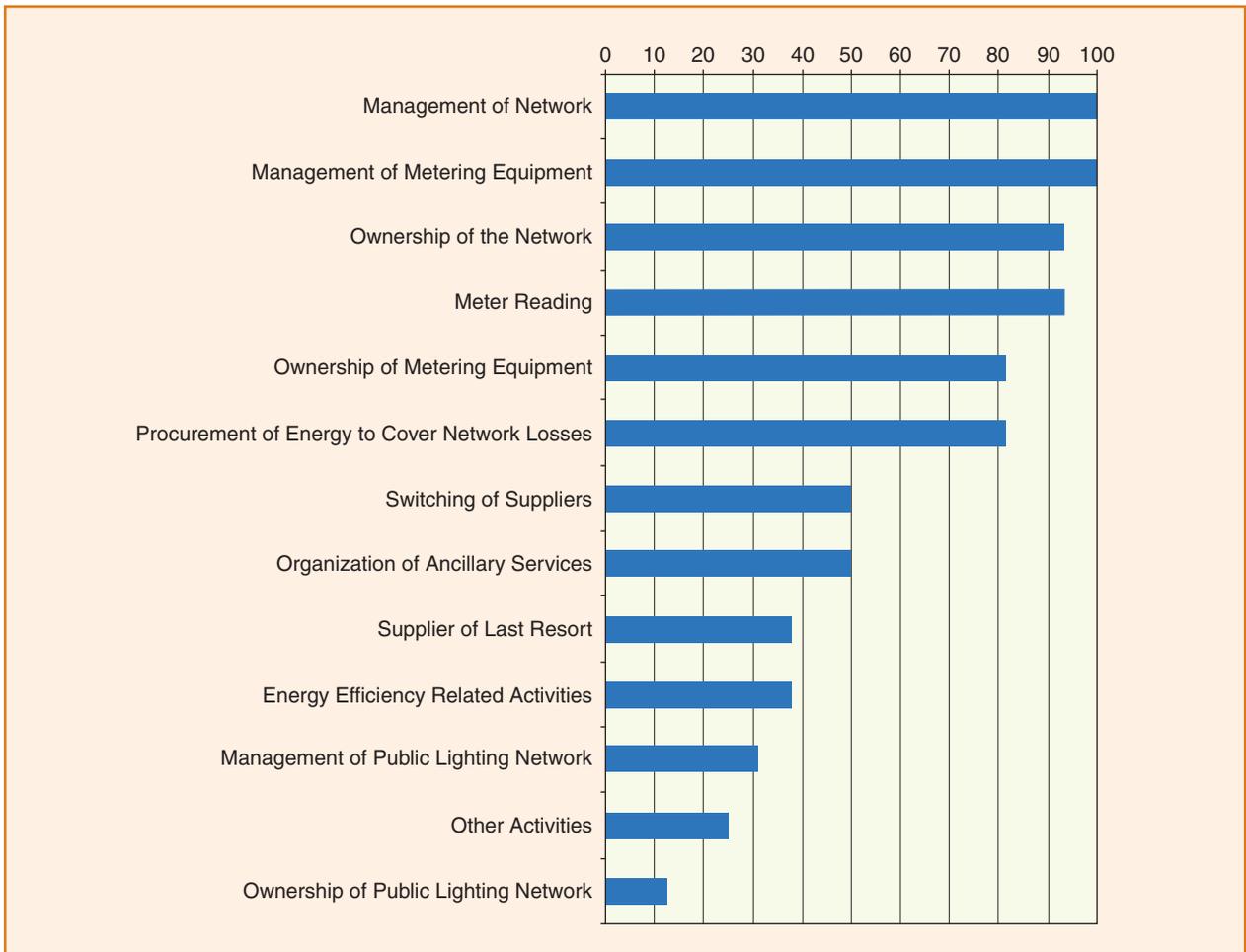


figure 1. The current EU DSO roles and responsibilities today (percentage of European DSOs participating in the survey). For countries where network owners (e.g., local authorities) delegate not only network operation management but also the realization of network investments (capex) to the DSO or DSOs, the graph treats the DSOs as owning the network. The same applies for ownership of metering equipment.

- ✓ implementation of new tools that can forecast network constraints
- ✓ better observation and control capabilities to manage the voltage level and facilitate renewable generation and electric vehicle charging station integration into the networks.

In sum, smart meters are key tools for the deployment of smart grids, and the new data stream they will produce will need to be managed in a cost-efficient and secure way.

Smart Metering and Data Management

Most DSOs own the metering assets and in most countries are responsible for meter reading, estimating consumption, and validating metering data (see Figure 1). Meters also allow them to be informed as quickly as possible about outages and power quality issues. DSOs are also responsible for the rollout of smart meters in most countries and thus represent a key facilitator of this new downstream market.

In all countries where DSOs are in charge of metering, they are best positioned to handle the metering data. It is the most

practical, convenient (in terms of keeping errors to a minimum) and economically efficient solution. DSOs need to have access to all of the relevant data in a timely manner to perform their mission of ensuring the safe and efficient operation of the distribution system. Of course, third-party access, whenever necessary or authorized by the client, must be guaranteed.

The DSO in charge of handling metering data (the so-called DSO as a Market Facilitator Model) has the following advantages:

- ✓ The DSO has responsibility over the full distribution network and encourages the integration of the consumer in the most effective and economical way to maintain the integrity, safety, and service level of the network while ensuring overall energy efficiency.
- ✓ With this model, there is a single responsible entity that ensures the provision of well-defined market facilitation services, guaranteeing accountability and transparency.
- ✓ Today's processes (e.g., a change of supplier) may be left intact or can evolve with the general market

model, so that it is not necessary to change IT systems and processes to adapt to a completely new structure and chains of information or data flows.

- ✓ The DSO is used to dealing with new technologies and is the entity most interested in implementing them in the grid to improve service quality and reduce costs.

The DSO, as an entity that is directly and physically linked to the customer base, also has a key role to play in tomorrow's energy system. Limiting the tasks and responsibilities of the DSOs in this respect would have a strong negative impact on the future development of the European energy market. By allocating well-regulated additional tasks and responsibilities to DSOs, the development of the internal energy market will be accelerated, since DSOs, by providing market facilitation and data services, enable this in a logical and evolutionary way.

Having an "independent and neutral" agent manage the data from the distribution network-customer frontier, instead of the DSO, should be considered cautiously. The possible benefits identified for all stakeholders when implementing a smart grid depend on the correct management of the data from all the frontier points of the distribution network, including smart meters. Beyond the adoption of a market model, many purely operational processes that are the responsibility of the DSO will rely heavily on the availability and reliability of the critical smart grid and metering data.

Regarding the data owned by the customers or the users of the grid, the main principle that should be followed is the need to obtain permission from the customers to manage, use, and create value from this information. This is a standard public service responsibility that already exists within a regulatory framework applicable to all European countries, regardless of their specific situations. Regulatory bodies ensure that customers receive service value. This principle also covers the historical functions that come with the operation of the system. Regulated agents are best positioned to act as neutral market facilitators because they can be supervised easily. This should be considered whenever the neutrality of DSOs is placed in question.

Active Demand

Demand-side participation, as European DSOs understand it, consists of two parts: 1) active and engaged consumers (demand response) and 2) measures taken by utilities to ensure an even supply of electricity by smoothing out peaks (demand-side management). Together, these components will bring benefits to consumers, suppliers, and distributors alike.

The demand for electricity is predicted to increase up to 2020 and beyond, as consumers make ever greater use of electric and plugged-in hybrid vehicles, air- and ground-sourced heat pumps, and air conditioning. The electricity distribution network will have to respond to this challenge, ensuring an even and continuous flow of electricity through demand-side management.

At the same time, the customers' role in the electricity market will increase, paving the way for demand response. Customers will be able to manage and adjust their electricity

consumption in response to real-time information and changing price signals.

Europe's electricity system will need to adjust to these changes in customer behavior. For instance, suppliers will design creative and dynamic feedback programs to provide customers with information that will let them actively manage their consumption. Yet this alone will not change electricity consumption: active demand response will only become possible once customers become more aware of the value of shifting their electricity consumption. By the same token, grid tariffs should reflect actual costs. Retail markets will then be able to deliver attractive products and services based on accurate price signals.

Smart meters are an integral part of getting demand-side participation right. They will increase customers' awareness of their energy consumption, an essential prerequisite if they are to become more active. National regulators should support a rollout of smart meters by clearly defining who should be responsible and how the costs should be recovered.

The shift toward demand-side participation will not be possible without investing in the distribution grid. The regulatory framework should therefore encourage such investments. In addition, a clear and forward-looking market model for smart grids and demand-side participation will be crucial. Such a new market model should set out clear roles and responsibilities for market and system operators. A new set of agreements between suppliers and distributors can ensure better cooperation, allowing customers to benefit from proper market functionality, smooth processes, and a secure and reliable electricity supply.

But customers will only actively participate in tomorrow's retail electricity markets if their privacy and data security are safeguarded and if the system makes all major market processes simpler and easier to understand. As stated in the August 2011 report *EURELECTRIC Views on Demand-Side Participation*, ensuring this should be at the heart of any demand-side participation model.

Decentralized Storage

Electricity storage is one of the flexible solutions to the problem of temporary disparities between supply and demand. Conventional and pumped hydropower already supports the integration of increasing amounts of RESs by providing the necessary flexibility and storage capacity to balance fluctuations. Peak production of intermittent renewable sources that feed into the MV and LV grids will, however, require additional small-scale, grid-connected electricity storage solutions. Such "decentralized" storage can support the development of DG. It can also provide a range of applications and services to DSOs facing challenges such as increasing peak loads and stricter power quality requirements.

Decentralized storage systems could affect the management of the distribution grid in a number of functional areas, including energy management, system services, and the internal business of the DSO, as follows:

The system operators will have to coordinate more on a day-to-day basis to keep the electricity system reliable at affordable costs.

- ✓ Energy management in this sense refers to energy arbitrage, i.e., the decoupling of electricity generation from its instantaneous consumption, a capacity delivered by electricity storage facilities.
- ✓ System services help provide the support that storage can offer in terms of quality of service and security of supply in the electric power system.
- ✓ Finally, for certain special and well-defined applications that cannot be provided by the market, storage devices can be installed as a grid asset that primarily supports the core operational tasks of the grid operator.

Situated within the LV and MV grids or on the customer side of the network, current small-scale storage technologies can provide a large range of functions and capacities to support and optimize the operation of the distribution system. Today, however, there are very few indications and rules that can help guide the integration of decentralized storage into the distribution grid. This creates uncertainty among DSOs and storage providers regarding the necessary agreements between actors as well as storage connection and access rights. For more information, see the July 2012 EURELECTRIC report *Decentralized Storage: Impact on Future Distribution Grids*.

Electric Vehicles

Decarbonization of the transport sector—and particularly, the mass deployment of electric vehicles—will be one of the most important challenges for the decades to come. One-fourth of European carbon dioxide emissions are related to the transport sector, of which 60% is related to passenger transport. Consequently, the deployment of electric vehicles will have a very important impact on European energy objectives for 2020 and beyond.

Widespread e-mobility will dramatically change consumption patterns at the same time that vast amounts of renewable DERs will be integrated into the distribution networks. As stated in the April 2012 EDSO position paper on electric vehicle charging infrastructure, to enable cost-efficient local load management, help the deployment of charging spots, and guarantee open access and support standardization, it is of great importance that this infrastructure be, like any other form of electricity demand, an integral part of the DSOs' network management systems—that is to say, an integral part of the future intelligent network.

In the initial phase, electric vehicles will typically be charged at home, where it is already possible to choose among

several electricity suppliers. In the long term, public charging should also offer the possibility of choosing among suppliers. Since the price of the electricity needed to charge an electric vehicle will only make up a minor part of the total cost of the charging service and since immense investments will be needed to enable a choice of suppliers, the first step should be to enable public charging without focusing on this possibility.

There is a so-called chicken-and-egg dilemma involved with public charging: without charging stations there are no electric vehicles, and without electric vehicles there is no business case for private investors to invest in public charging stations. To 1) not add further hurdles, 2) enable cost-efficient local load management, 3) help the deployment of charging spots, and 4) guarantee open access and support standardization, the DSOs as regulated companies should be allowed to own and manage private charging stations and infrastructure as an extension of their regulated role.

When rolling out the European electric vehicle infrastructure, interoperability is key, allowing all electric vehicles to be charged and to communicate with the electricity grid anywhere in the EU. A common European standard on a single, common plug for public and private charging stations creates a very good basis for such a result. For safety reasons, so-called mode 3 charging as defined in accordance with the IEC 61851 standards will be necessary.

Finally, to make the charging infrastructure an integral part of the future intelligent network, a standardized communication protocol that lets data flow throughout the charging infrastructure, electric vehicles, and the electricity distribution grid is crucial.

How Smart Is a Given Network?

Smart grid solutions will only be considered as alternatives to conventional network reinforcement if investors can compare such investments on a cost-benefit basis. Yet such comparisons remain challenging for two reasons. The first is the rapidly developing and largely untested nature of “smart” solutions. The second is the difficulty of comparing two inherently different types of investment, both of which aim to achieve the same purpose: reinforcing distribution networks so as to increase capacity and improve power quality, supply security, and efficiency.

Built on intensive collaboration between European DSOs and the EC's Joint Research Center (JRC), a new evaluation method was developed in 2012. It was based on an existing methodology developed by the Electric Power Research Institute (EPRI) and was adapted for the smart grid work underway

in Europe. The new method aims to ensure that such evaluation scan be applied consistently across Europe and will adhere to the EU standards currently under development.

The proposed evaluation methodology consists of seven steps. It takes off from the description of a project's goals and eventually results in a direct comparison of costs and benefits. It has been tested on practical examples like the Inovgrid project, an open platform that integrate send users, public standards, and vendors' interoperable solutions led by the Portuguese DSO EDP Distribuição, to refine the methodology for application in Europe.

Network Tariffs

The key mission of DSOs is to deliver reliability and quality of service to their customers. Within the transition to the low-carbon economy, additional network investments will be necessary to maintain the high level of service that European customers expect. Investments by DSOs will account for most future network investments, as their networks need to accommodate an increasing amount of DG, including renewables and other DERs like electric vehicles.

Against this backdrop, the ability of DSOs to carry out such massive investments will be key, and DSOs should be able to collect, through network tariffs, the revenue required to cover the network costs and investments.

Network Tariff Structure

In most countries, network tariffs make up a significant share of a household customer's electricity bill, and they are expected to grow further. Most direct network costs are determined by peak demand (kW) and are largely independent of the actual energy delivered—at least in the short term. Those costs are unlikely to fall with the rise of decentralized generation: the grid must still be designed to cover peak demand when there is no local production.

Today, recovering network costs depends heavily on how much electricity is sold. A EURELECTRIC survey has found that in the majority of countries, network tariffs for households and small businesses are almost entirely based on energy volume (kWh). About 50–70% of the allowed DSO revenue is usually recovered using such volumetric charges. While volumetric tariffs set signals to reduce energy consumption, they do not reflect costs arising from consumption at peak hours.

The newly adopted energy efficiency directive (2012/27/EU) requires the removal of network tariffs that would impede energy efficiency and/or demand response. The European DSOs believe that tariffs encouraging customers to shift their consumption away from peak hours should gain importance. Network tariff structures should incentivize demand response and energy-efficient behavior while providing a stable framework for both customers' bills and DSO revenues (see Figure 2).

Appropriate approaches may include more capacity-based network tariffs, such as two-part network tariffs with a capacity and an energy component or volumetric

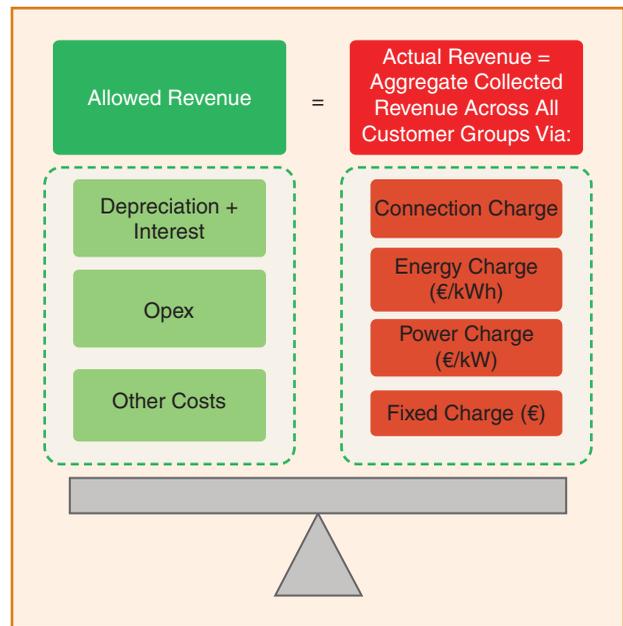


figure 2. The collected revenue should match the allowed revenue.

time-of-use network tariffs with different prices for peak and off-peak energy (see Figure 3). Cross-subsidies between different categories of users should be minimized, ensuring that customers only pay for what they use.

Smart meters will open the door to more cost-reflective tariff structures and demand response. They will allow a differentiation of charges according to customers' impacts on the grid, as DSOs will be able to measure the contribution of domestic consumers to peak load. Different customers' potential and the outcome of the national cost-benefit analysis for the rollout of smart meters should be taken into consideration when designing new tariff structures. For more information, see the May 2013 EURELECTRIC paper *Network Tariff Structure for a Smart Energy System*.

Smart Regulation

Very few DSOs in Europe have strong and appropriate incentives to invest in smart grids. DSO regulation will need to put a stronger focus on the long-term overall benefits of DSO investments rather than narrow, short-term cost optimization and should encourage innovation; research, development, and demonstration (RD&D) expenditures; and the use of new technologies with a new risk-reward balance. Such regulation should focus on the following goals:

- ✓ **Rewarding and incentivizing capital expenditures (capex) for smart grids:** Capex on smart grids in areas where this approach is preferable to a business-as-usual approach is crucial. A fair rate of return is an essential requirement for smart grid investments. (Figure 4 shows the achievability of regulatory rates of return for various European countries.) For those regulatory models with a capital cost time shift, there must also be compensation.

Tariff Type	Possible Effects on Load	Impact on Overall Energy	Impact on Network Costs (Losses Excluded)
Flat Volumetric (€/kWh)		✓	✗ Low
Capacity Based (€/kW)		✓ Medium	
Time-of-Use Volumetric • High €/kWh (Peak Hours) • Low €/kWh (Off-Peak Hours)		✓	✓ High
Two-Part Tariff • Power Component (€/kW) • Energy Component (€/kWh)		Medium to High	

figure 3. The impact of major tariff options on energy consumption and network costs.

- ✓ **Improving the evaluation of operational expenditures (opex):** Expenses for R&D and for smart grid pilots should be excluded from the benchmarking since the efficiency of innovation cannot be easily evaluated.
- ✓ **Incentivizing innovation and R&D funding:** In the last 20 years, innovation has been mainly about how to reduce opex. Today, new technologies—in particular, communication technologies—will need to be tested to determine what works in practice.
- ✓ **Clarifying roles and responsibilities:** Clear mandates and responsibilities are important for driving smart grid

On top of improving the regulatory framework for DSOs, adequate network codes should be approved at the European level. TSOs are in charge of overall system stability; there is a long tradition of cross-border cooperation, and TSOs are closely involved in market design. They are accustomed to managing a system in which a mass of highly predictable and reliable, fully observable, nearly fully controllable generation is provided by a limited number of large facilities operated by industrial experts and directly connected to the transmission network.

But times are changing. Today, a large amount of new generation capacity is being connected to the distribution

investments forward (including smart metering). National regulators should assist in clarifying roles and responsibilities in a smart grid environment.

- ✓ **Safeguarding regulatory stability:** Besides a stable regulatory system, a regulatory roadmap (perhaps to 2020, as exists in Finland) may be a suitable instrument for the enhancement of regulatory stability (see Figure 4).

The TSO-DSO Interface and the Coming European Network Codes

Redefining the TSO-DSO Interface

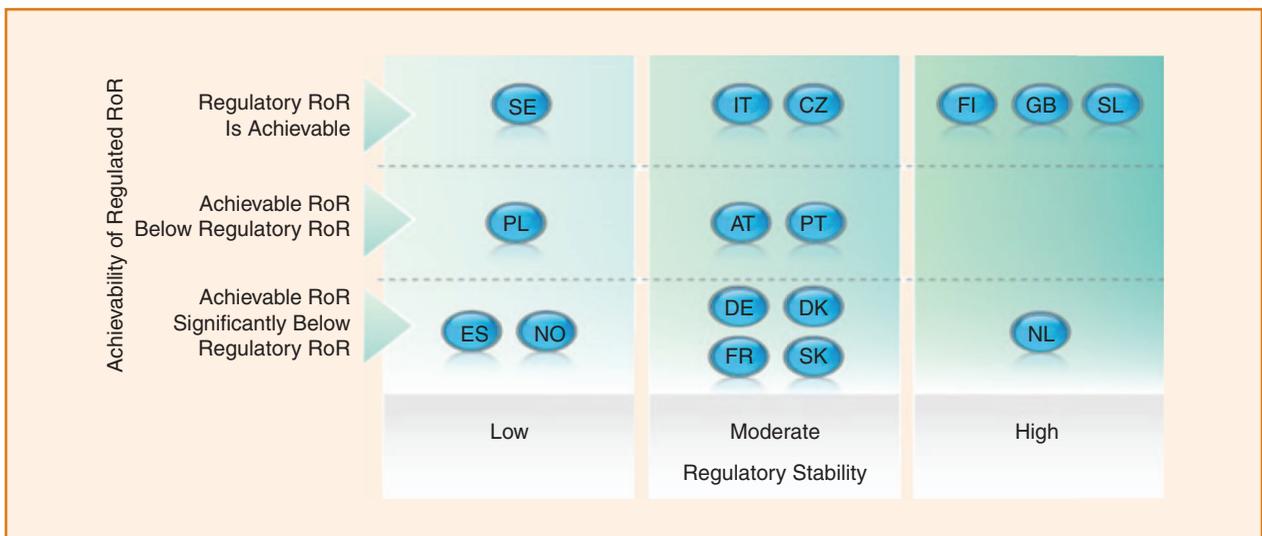


figure 4. The achievability of regulated rate of return (RoR) and regulatory stability for various European countries (source: EURELECTRIC).

networks. A substantial share is only partially observable, controllable, and predictable. This development will be much faster than for transmission-connected assets. In some countries, such subsidized generation with zero marginal costs will probably be overabundant for a significant time period, pushing conventional generation out of the merit order. With demand-side response (DSR) and new appliances such as electric vehicles, consumption will become more flexible and versatile.

In this context, the coordination of all relevant actors, particularly TSOs and DSOs, will be important. In the interest of safeguarding system security, a framework for effectively exchanging operational information among network operators—and between network operators and end customers—should be defined. TSOs should typically rely on DSOs to provide them with the operational information they need from final customers connected to distribution networks. TSOs should not be able to bypass DSOs by attempting to gather this information directly from customers: if safeguarding the operation of the system requires action from these customers, TSOs should transmit these orders via the DSO in question.

In addition, network operators will need more information on the planned actions of the aggregators and independent power producers connected to their networks. The participation of flexibility in TSO balancing markets could create constraints in the distribution grid. Similarly, actions taken by the DSO to solve constraints could have knock-on effects on transmission grids and the system as a whole. The organization of this information exchange needs to be further investigated. The increasing share of DG and flexible loads connected to the distribution grid raises the need for a well-structured and organized information exchange in distribution networks. Knowledge of DG forecasts, schedules, and planned maintenances is key for operating the distribution network in real time and close to real time. Today, European DSOs are often missing this information. In fact, in some cases the TSO receives information from DG resources while bypassing DSOs completely. The most efficient system solutions need to be found. DSOs should be responsible for their networks and are the entities best able to play the role of

facilitators for final customers connected to their networks with respect to the TSOs, so as to support secure and reliable network operation.

European Network Codes

The so-called third energy package empowers the European TSO associations (ENTSO-E and ENTSO-G) to prepare network codes laying down binding, pan-European rules for the electricity and gas markets. ACER provides the over arching framework for ENTSO-E's work as well as "reasoned opinions" on the codes. With coordination by the EC, the codes then go through the "comitology" process, an approval procedure with scrutiny set forth in Article 8 of Regulation 714/2009, and become legally binding (see Figure 5). For more information, see the document *ENTSO-E Network Codes Development Process* (17 February 2012), available at www.entsoe.eu.

As stated in Regulation No. 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity, "The network codes should be developed for cross-border network... and market integration issues, without prejudice to the member states' right to establish national codes which do not affect cross-border trade." The codes are required to cover capacity allocation and congestion management, system operation, grid connection, and network tariffs, taking into account regional situations as appropriate. The EC so far foresees 14 codes. A timeline for this network code development is given in Figure 6. For more information, see the document *ENTSO-E Work Program 2012 Through December 2013* (28 November 2012), available at www.entsoe.eu.

The discussion of the codes has revealed a number of strategic questions about future electric systems. Some of the draft network codes describe solutions as defined by the traditional environment, with TSOs retaining their organizational and supervisory status, albeit with a much reduced influence on the system that they directly operate and develop and on the system's overall performance. In this vision, the DSO appears schematically as a:

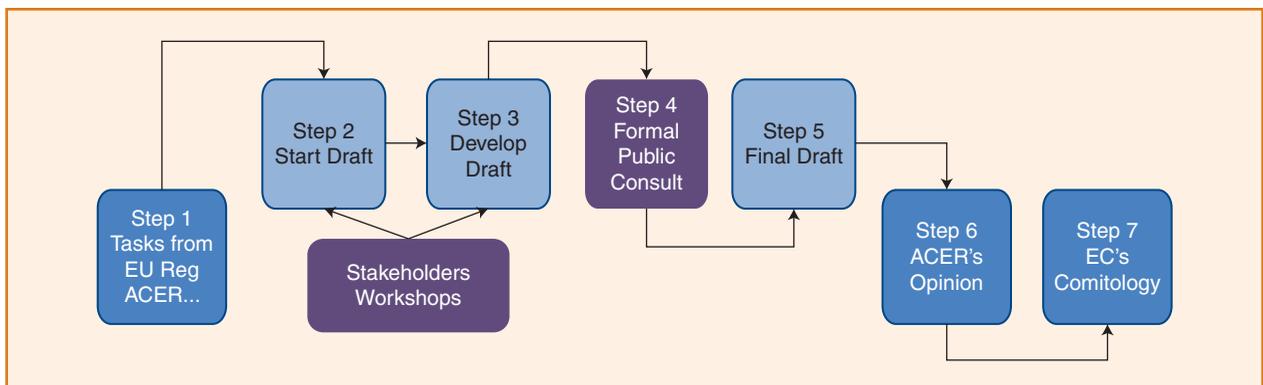
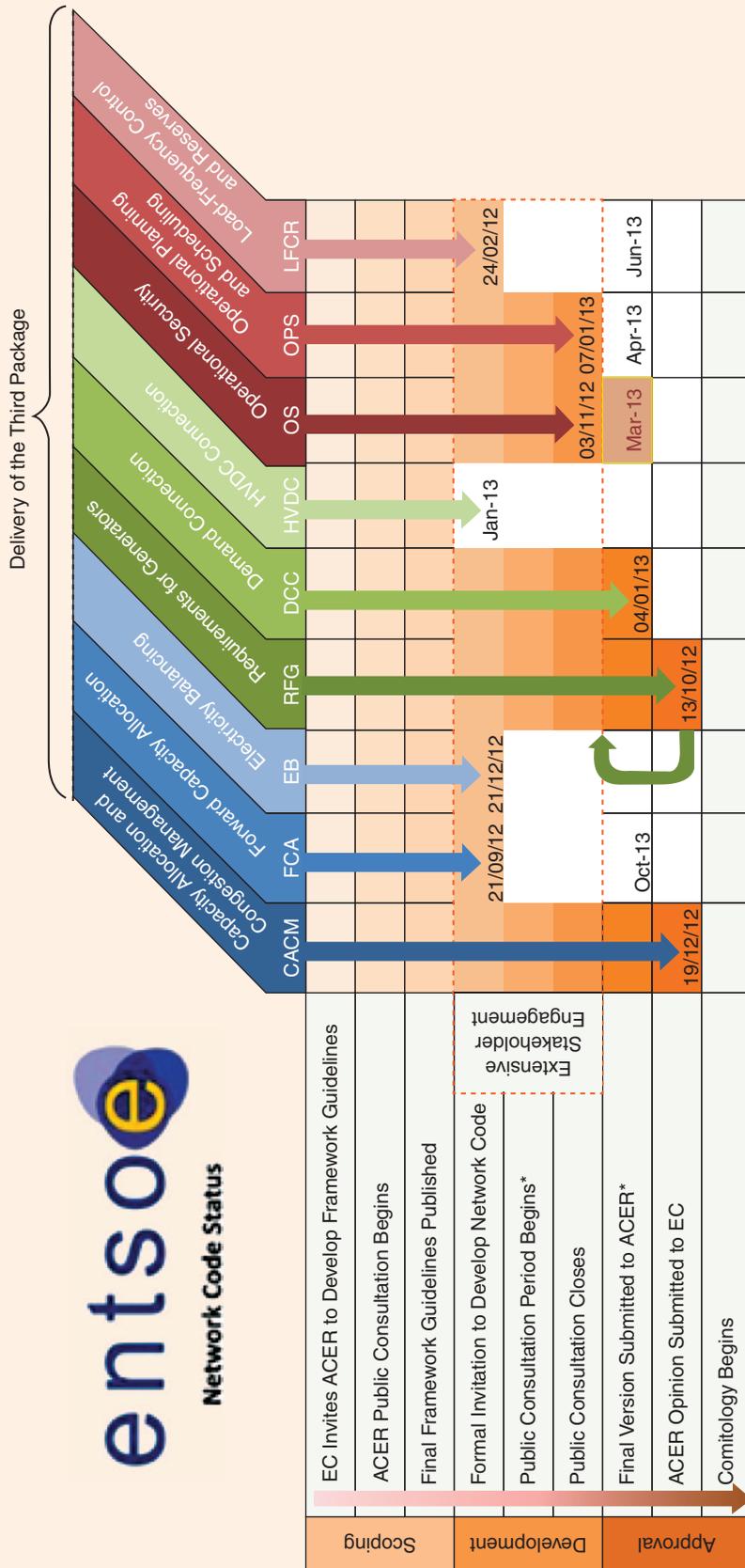


figure 5. The network code development according to the third energy package (source: ENTSO-E).

entsoe

Network Code Status



Disclaimer: The purpose of this chart is to provide overall transparency of ENTSO-E's network code development. All forward-looking dates are provisional until confirmed. Stakeholders will be informed and invited to all confirmed events by means of official communication.

* In accordance with ENTSO-E's Network Code Development Process, an internal re/drafting and approval is done before the launch of the formal public consultation and submission of the code to ACER.

figure 6. The timeline for network code development (source: ENTSO-E).

- ✓ passive technical collector of demand, bearing the burden of managing reactive power by its own means with less support from TSOs than in the past
- ✓ passive compliance data collector and certification watchdog.

This vision is not compatible, however, with the more ambitious vision of DSOs as active local system managers fully in charge of their responsibility area, and it is likewise an obstacle to the deployment of smart grid solutions. It is therefore important that the network codes set safe rules for all grid users and network operators while being flexible enough to provide DSOs with some leeway to adapt to the rapid changes occurring in their networks. Distribution grid peculiarities and the present and future role of DSOs with respect to their network users need to be adequately considered to avoid a scenario in which these codes—designed with the intention of ensuring security of supply, allowing the internal energy market to function, and reaching the EU’s 20/20/20 targets—actually hamper the evolution of the electric system necessary to achieve those goals.

These new developments are not wishful thinking on the part of DSOs, as was shown by a recent JRC study. In fact, DSOs are committed to and investing in smart grid research, development, and demonstration projects all over Europe.

RD&D: The JRC Smart Grid Catalog

The JRC was commissioned to gather data on smart grid projects in the European Economic Area (EEA). The JRC is acting as the key connection point in cataloging data on European smart grid projects, coordinating with (among others) the European Electricity Grid Initiative (EEGI) to gain information. In 2013, the JRC published an update of its smart grid project catalog, listing all ongoing projects in the EU and including both quantitative and qualitative analyses (see Figure 7).

This latest update lists 281 smart grid projects, representing a total investment of €5 billion, and shows that DSOs are front-runners in RD&D (see Figure 8). More specifically, the study reveals that DSOs are:

- ✓ involved in 80% of the smart grid projects listed
- ✓ running 43% of the projects focusing on consumer involvement, putting them in a leading position in this area
- ✓ taking the lead in a total of 115 projects with investment equal to €1 billion (57% of the overall investment in smart grid projects)
- ✓ at the center of smart grid activity, with 80% of the budget allocated to functional areas at the distribution level.

The JRC study also highlights the fact that one of the focus areas in the smart grid projects it looked at is to improve the observability and controllability of the MV- and LV-level

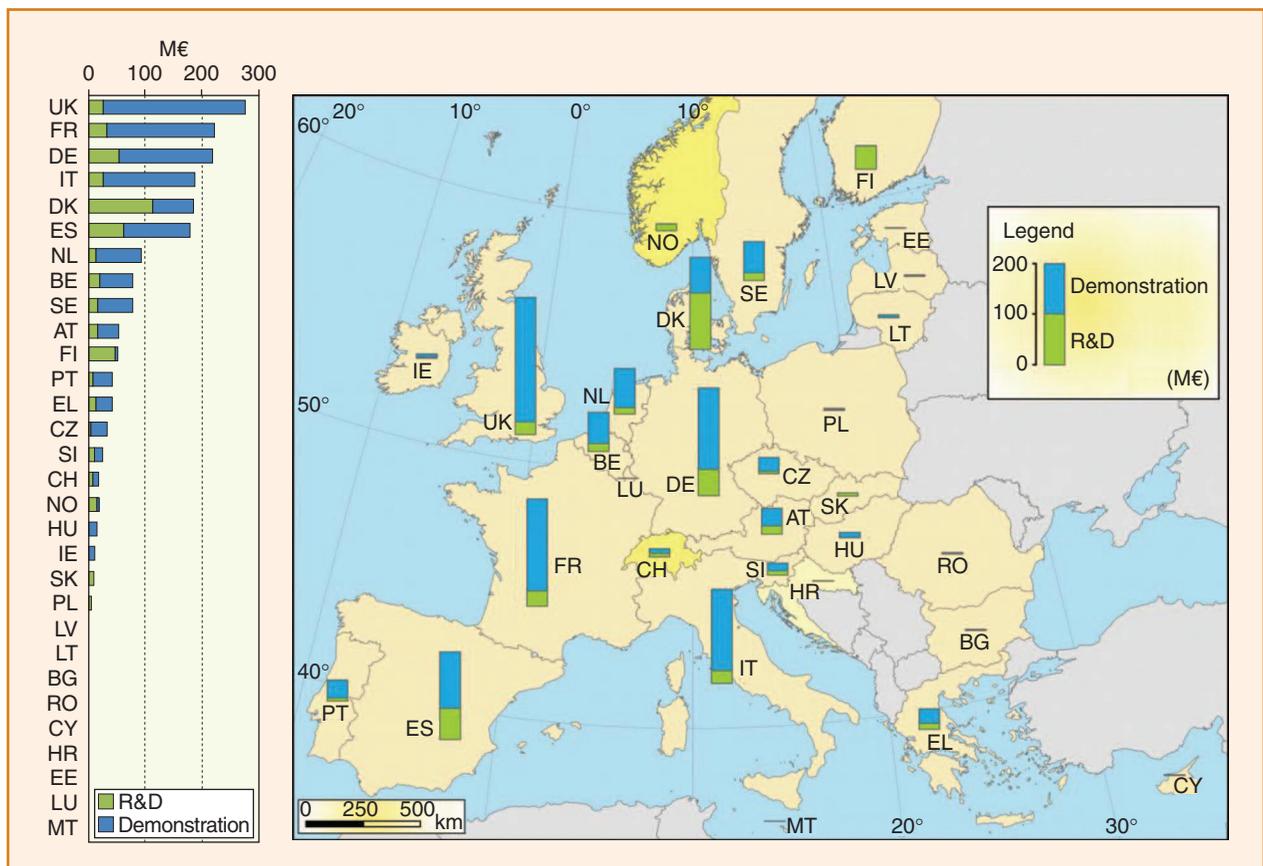


figure 7. Smart grid RD&D projects across Europe (source: JRC).

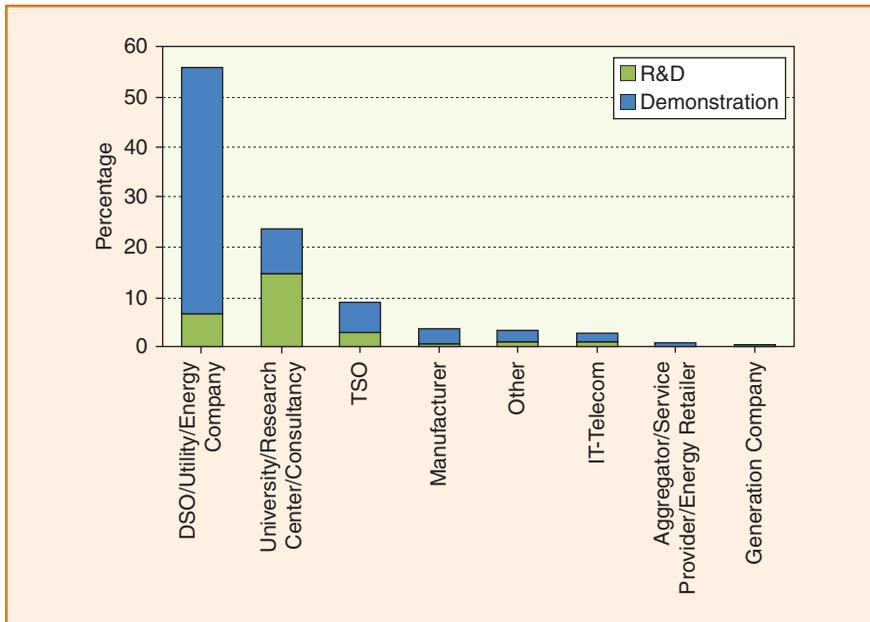


figure 8. The involvement of various actors in smart grid RD&D projects (source: JRC).

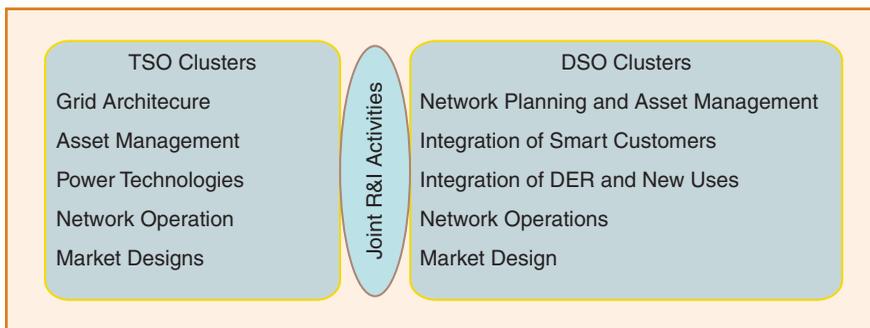


figure 9. Clusters of R&I activities in the EEGI roadmap.

C1	Integration of Smart Customers	D1	Active Demand for Increased Flexibility
		D2	Energy Efficiency from Integration with Smart Homes
C2	Integration of DER and New Uses	D3	DSO Integration of Small DER
		D4	System Integration of Medium DER
		D5	Integration of Storage in Network Management
		D6	Infrastructure to Host EV/PHEV
C3	Network Operations	D7	Monitoring and Control of LV Network
		D8	Automation and Control of MV Network
		D9	Networks Management Tools
		D10	Smart Metering Data Processing
C4	Network Planning and Asset Management	D11	New Planning Approaches for Distribution Networks
		D12	Asset Management
C5	Market Design	D13	Novel Approaches for Market Design Analysis

figure 10. Clusters and objectives in the distribution area of the EEGI roadmap.

networks, as the challenge of DERs must be tackled at the distribution level. The authors note that technical solutions for the integration of DERs are maturing, and the same goes for smart network management at both the TSO and DSO levels. But if the technical obstacles are expected to be overcome soon, the regulatory barriers remain. The uncertainty over roles and responsibilities in new smart grid applications and over the sharing of costs and benefits (and consequently over new business models) discourages companies from investing more in RD&D and from investigating smart grid solutions.

This issue is particularly acute for DSOs, and the heterogeneity of legal frameworks throughout Europe may render the replication and scaling up of technical solutions very difficult from one country to another. To coordinate their research efforts, the DSOs are working together in the EEGI, where they have produced a joint roadmap to help bring smart grids from vision to reality.

RD&D: The EEGI Road Map

There is a great need to take action now if a cost-efficient transition to a sustainable and competitive energy future is to be possible; it requires testing new innovative solutions and sharing knowledge throughout Europe. Cofunded, large-scale demonstration projects in real-life conditions with consumer engagement are therefore absolutely necessary.

For this reason, the EEGI, a nine-year research and demonstration program for the acceleration of innovation and the development of the electricity networks of the future, is playing a crucial role in the development of the new sustainable and competitive energy system. The EEGI's objectives are to:

- ✓ transmit and distribute up to 35% of electricity from

DSOs are committed to and investing in smart grid research, development, and demonstration projects all over Europe.

dispersed and concentrated renewable sources by 2020 in preparation for the planned decarbonization of electricity production by 2050

- ✓ integrate national networks into a market-based, truly pan-European network to guarantee a high-quality electricity supply to all customers and engage them as active participants in energy efficiency
- ✓ anticipate new developments, such as the electrification of transport
- ✓ substantially reduce capital and operational expenditures for the operation of the networks while fulfilling the objectives of a high quality, low-carbon, pan-European, and market-based electricity system.

The first EEGI roadmap, for the period 2010–2018, and the first implementation plan for 2010–2012 were prepared by ENTSO-E and EDSO’s EDSO for Smart Grids association in close collaboration with the EC, the European Regulators Group for Electricity and Gas (ERGEG), and other relevant stakeholders. They were approved by the EC and the member states in June 2010.

An updated edition, the EEGI 2013–2022 roadmap, was designed to cover new research, innovation, and knowledge needs in response to the climate change challenges Europe will face beyond 2020 (chiefly, achieving a low-carbon economy by 2050) and to address new areas such as asset management, market design, methods for scaling up and replication, and tools to accelerate the deployment of successful research and innovation. The impacts expected from these new activities are, in short, further optimized capital investment and intensified operational expenditure so as to increase network capacity. These developments will pave the way for a fully decarbonized, pan-European electricity system by 2050 with vast amounts of renewable electricity generation. They will also support the sharing of new knowledge to speed up replication activities based on the most promising results from throughout Europe. The EEGI’s DSO and TSO implementation plans have also been updated based on the new roadmap, summarizing priorities for projects to be launched in the period 2014–2016.

The basis for the roadmap was the dramatic change to the entire energy value chain that is resulting from ambitious European energy policy objectives, as laid out throughout this article. The whole electricity system

optimization process is therefore changing and requires networks to become smarter and stronger, favoring centralized and decentralized storage and allowing bidirectional power flows while maintaining system reliability. In parallel, new financial instruments must be studied to send incentive signals for generation investments as well as demand so as to optimize the entire electric system. Cost-effective network solutions are expected to become operational as early as 2015 from the ongoing EEGI research and innovation (R&I) activities.

The system operators—the TSOs and DSOs—will have to coordinate more on a day-to-day basis to keep the electricity system reliable at affordable costs. This paradigm shift triggers the need to increase the level of flexibility in the electricity networks, as follows:

- ✓ The system will move from a “supply follows load” model to a “load follows supply” model, allowing more flexibility to react to changing electricity generation levels.
- ✓ The system will need to deal with increased challenges arising from real-time balancing by introducing new flexible means exploiting RESs, DERs, active demand, storage, and so on.
- ✓ Aggregators representing small and possibly medium-sized consumers and producers will lean on more active distribution networks to better integrate local supply and load.
- ✓ The future control structure of the whole electricity system will become more complex and will require increased interaction among operators; system operators will interact directly with connected users as well as through aggregators of individual consumers, DERs, and distributed storage.

TSOs and DSOs are regulated companies for which the value chain of services involves similar skills used in similar

Cluster	Name	Functional Objective	Full Names of Functional Objectives
TD	Joint TSO/DSO Activities	TD1	Increased Observability of the Distribution System for Transmission Network Management and Control
		TD2	The Integration of Demand-Side Management at DSO Level into TSO Operations
		TD3	Ancillary Services Provided Through DSOs
		TD4	Improved Defense and Restoration Plan
		TD5	Methodologies for Scaling Up and Replicating

figure 11. Objectives in the joint TSO-DSO area of the EEGI roadmap.

On top of improving the regulatory framework for DSOs, adequate network codes should be approved at the European level.

activities, even though their specific legal obligations may differ from member state to member state. Their innovation activities cover the full value chain of activities performed by system operators and can be grouped into five clusters plus a joint activities area, as shown in Figure 9.

In the distribution area, the five clusters can be divided into 13 functional objectives for the nine-year period covered by the road map, as shown in Figure 10.

The joint area between transmission and distribution can be divided into five functional objectives, as shown in Figure 11.

The budgets for these functional objectives involving distribution are shown in Table 1.

table 1. The budgets for functional objectives involving distribution (in millions of euros).

Objective	Amount
Integration of smart customers	240
Integration of DERs and new users	330
Network operations	400
Network planning and asset management	100
Market design	20
Joint TSO-DSO R&I activities	250

table 2. The areas prioritized in the 2014–2016 DSO implementation plan.

Year	Code	Description
2014	TD2	Demand-side management DSO-TSO
	D12	Asset management
	D10	Smart metering data processing
	TD5	Methodologies for scaling up and replication
	D5	Integration of storage in network management
2015	D3	Integration of small DERs
	TD4	Defense and restoration plan
	D2	Energy efficiency with smart homes
	D7	LV monitoring and control
2016:	TD1	Increased DSO observability for enhanced TSO management and control
	D9	Network management tools
	D8	MV automation and control
	D13	Market design

For the implementation of the roadmap, three-year implementation plans are defined. The prioritized areas in the 2014–2016 DSO implementation plan are shown in Table 2.

Definitions of the functional objective, the implementation plan, and further information can be found online at <http://www.gridplus.eu/eegi>.

Conclusions

Implementing smart grids is central to the transition to a low-carbon economy, and DSOs are key players in this transition. A far-reaching change—one could say a revolution—in power systems is indeed ongoing; designing and implementing smart grids is not an option but an absolute necessity. If we do not do it, or if we do it too slowly, we will face major problems.

To prepare, European DSOs are massively investing in R&D and demonstration projects in cooperation with the information communications technology (ICT) industry, acquiring the knowledge and skills needed to adapt and lead.

Smart grids have the potential to benefit the whole value chain, but the market model must be defined. Whatever the preferred model, DSOs will have a key role to play as market enablers. DSOs will be responsible for setting up the playing field for retailers and aggregators so that it works for the benefit of customers. DSOs will increasingly act as local system operators. Well-organized active distribution system management will make it possible to reduce the investments needed to host renewable energy sources and electric vehicle charging stations and will guarantee security and quality of supply.

Enhancing the “smartness” of distribution grids is not free of charge. It will require significant capex on the DSO side, while the benefits from those investments will accrue throughout the entire value chain. The development of business models, with the strong support of policy makers and regulators, is necessary to ensure that all parties share the risks, costs, and benefits of smart grids. Bringing smart grids from vision to reality will only happen if smart regulation is introduced.

Last but not least, a key objective of European DSOs is to make sure that the new solutions that will be implemented are designed to benefit *all* customers.

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