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Overview of Activities and Players in Smart Grids

Electricity System Development: A focus on Smart Grids

The purpose of this short paper is to provide a brief overview of smart grids and its role in the development of electricity systems. This will be accomplished by defining smart grids, highlighting the major drivers for deployment, outlining the range of actors that need to be engaged and a vision for electricity system development. The paper closes by presenting some possible future work that could be carried by UNECE to both engage with the global smart grid dialogue and serve member countries.

What are smart grids?

The development of a "smart grid" is an evolutionary process that happens over time, and not in a single step. Often the deployment of smart grid technologies is referred to as "smartening the grid" or "modernizing the electricity system". From a starting point of an existing grid, or a construction of new networks (or extensions of networks), the deployment of smart grid technologies is not a goal in itself – but rather an enabler to the provision of secure, reliable, clean, economic electricity required by end users. There are numerous definitions that seek to describe smart grids (Table 1).

Table 1. Selection of Smart Grid definitions

Author	Definition
IEA	A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts will maximising system reliability, resilience and stability. [1]
EC	Smart grids are energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand accordingly. When coupled with smart metering systems, smart grids reach consumers and suppliers by providing information on real-time consumption. With smart meters, consumers can adapt – in time and volume - their energy usage to different energy prices throughout the day, saving money on their energy bills by consuming more energy in lower price periods. Smart grids can also help to better integrate renewable energy. While the sun doesn't shine all the time and the wind doesn't always blow, combining information on energy demand with weather forecasts can allow grid operators to better plan the integration of renewable energy into the grid and balance their networks. Smart grids also open up

[1] International Energy Agency Smart Grid Roadmap: https://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf

	the possibility for consumers who produce their own energy to respond to prices and sell excess to the grid.[2]
USA OE	"Smart grid" generally refers to a class of technology that people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers -- mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' homes and offices.[3]
IEC	The general understanding is that the Smart Grid is the concept of modernizing the electric grid. The Smart Grid comprises everything related to the electric system in between any point of generation and any point of consumption. Through the addition of Smart Grid technologies the grid becomes more flexible, interactive and is able to provide real time feedback. A smart grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. A Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to: facilitate the connection and operation of generators of all sizes and technologies; allow consumers to play a part in optimizing the operation of the system; provide consumers with greater information and choice of supply; significantly reduce the environmental impact of the whole electricity supply system; deliver enhanced levels of reliability and security of supply.[4]
JSCA	In the context of Smart Communities, smart grids promote the greater use of renewable and unused energy and local generation of heat energy for local consumption contribute to the improvement of energy self-sufficiency rates and reduction of CO_2 emissions. Smart grids provide stable power supply and optimize overall grid operations from power generation to the end user.[5]

Definitions can also reflect national or regional electricity system development needs. For example, in China initial emphasis was placed on the "Strong Smart Grid", reflecting technology development and infrastructure needs in transmission networks. In May 2009, the State Grid Corporation of China (SGCC) officially launched the study and construction of the "Strong Smart Grid" system, to be completed by 2020, noting that this has not precluded efforts by China in distribution technologies. The years 2011 to 2015 mark the construction stage, when rollout of Ultra High Voltage links will be accelerated and urban and rural distribution networks built out.[6]

Even with five different definitions presented not all views are reflected, but the above do provide reasonable consistency. The definitions above do not show any glaring errors or incorrect information, but rather different ways of articulating the development the electricity system.

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[2] European Commission: http://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters

[3] USA Office of Electricity Delivery & Energy Reliability: http://energy.gov/oe/services/technology-development/smart-grid

[4] International Electrotechnical Commission www.iec.ch/smartgrid/background/explained.htm

[5] Japan Smart Community Alliance: www.smart-japan.org/english/index.html

[6] http://smartgrid.ieee.org/july-2011/99-chinas-approach-to-the-smart-grid

Therefore to summarize the definition of a smart grid the principal smart grid functional characteristics are:

- Self-healing from power disturbance events
- Enabling active participation by consumers in demand response
- Operating resiliently against physical and cyber attack
- Providing power quality for 21st century needs
- Accommodating all generation and storage options
- Enabling new products, services, and markets
- Optimizing assets and operating efficiently

A smart grid uses digital technology to improve reliability, resiliency, flexibility, and efficiency (both economic and energy) of the electric delivery system. The strategy to achieve this vision hinges upon activities that directly address the technical, business, and institutional challenges to realizing a smarter grid.[7]

These overall explanations of the smartening of electricity systems can be carried out at a city, national or regional scale, and can also be brought to the level of mini or micro-grids (Box 1). All electricity systems can be improved or optimised, but what is key is to determine what key drivers are motivating investments and then to choose investments that can yield the most value for stakeholders.

Box 1. Smart grids in micro-grids and mini-grids

Micro- and mini-grids can greatly benefits from the deployment of smart grids. Since the effects of variability (on both supply and demand side) can be felt more acutely due to a smaller base of both generation units and loads, system management to ensure quality and reliably can be very important. Additionally, many such systems depend on higher priced fuels for fossil based generation, and therefore the use of renewables as well as electricity storage can more easily be deployed in a cost effective manner.

Based on this – managing the demand side in a way to reduce variability, or enabling loads to operate in a flexible manner that supports variable renewable generation, as well as managing advanced storage technology are natural uses for smart grid technologies.

TO BE EXPANDED

Smart Grid Deployment Drivers

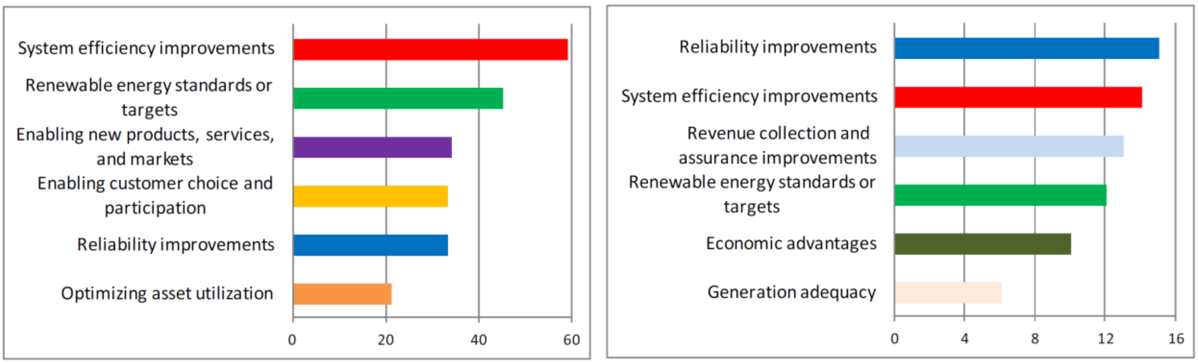
Determining which technologies are best suited to deploy in specific electricity systems requires an understanding of the current status of a given system, as well as anticipated future needs. Assuming quality data is collected and available, assessing the status is relatively straight forward, but does require expert assessment. Future needs can be more difficult, where demand is driven not only by the economic development of the country, but also on how energy efficiency, transport systems and

[7] http://energy.gov/oe/services/technology-development/smart-grid

industrial activity are planned. The motivating drivers can be crudely categorised across developed and developing economies. Using such labels demonstrates a number of common elements, but also shows varying emphasis (Figure 1).

Figure 1. Top-6 Ranked Smart Grid Technology Motivating Drivers based on country surveys

Developed Economies (left); Developing Economies (right)



Note: the rating system indicates the cumulative rating of survey respondents for each smart grid driver. Source: ISGAN, Smart Grid drivers and technologies by country, economies and continent, International Smart Grid Action Network, 2014 Edition

Common in the top six of each economy type are: system efficiency improvements, reliability improvements and renewable energy standards or targets, but each are placed at different levels of priority. Differences between the two economy types include

- for developed countries:
  - customer choice and participation;
  - new products/services/markets) and optimizing asset utilization.
- For developing countries:
  - economic advantages;
  - revenue collection and
  - the role of smart grids to support generation adequacy.

Figure 1 yields valuable insights, but it is import to acknowledge that they drivers are still aggregated greatly across countries represented by survey respondents. Choices for the development of a specific electricity system must be made through an analysis that determines needs based on a long term plan that includes social, economic and environmental factors in the given city, region or country. Additionally to what technologies are deployed, it is important to determine which technologies should be deployed as a cluster and in what order in order to get the most benefit for a given investment in the shortest amount of time.

Smart Grid Technologies

There is a very broad range of smart grids technologies. Some of those are commonly applied in many systems today (e.g.: smart meters, SCADA and FACTS) and some are still in development or early deployment stages (e.g.: PMU, and V2G technologies). Transmission systems are typically “smarter” today compared to distribution systems. This is mainly due to the typical scale of transmission systems relative to the respective number of nodes that are managed. Currently transmission systems make up only about 10% of total network length[8], connecting few, but large customers or generators or interconnecting regional electricity systems. An additional reason for the smartness of transmission systems is that the operators at the transmission level typically have been given the responsibility to ensure reliable operation of the entire electricity system. In order fulfil this task adequate management technologies must be deployed on the system.

Comparatively distribution networks make up about 90% of total electricity system network length and a very large share (based on the number of connections) of electrical demand and smaller scale generation (both renewable and conventional generation) is connected to distribution networks.[9] In the planning for distribution networks customer demand is often estimated based on historical trends. Electricity infrastructure is dimensioned to ensure high levels of reliability under the worst case scenarios – often referred to as “fit and forget[10]”. While these approaches have often resulted in high levels of reliability in many countries, existing systems may be over designed or may not be fit for increased demand (e.g.: high penetrations of electric vehicle charging infrastructure in urban centers) or impacts of increased distributed generation deployments (e.g.: reverse flows from high penetrations of PV generation in rural networks).

Smart grids can be a significant tool used to optimise electricity systems by monitoring and managing electricity flows from generation to demand, but it is essential understand the breadth of technologies across the entire electricity system (Table 2). Some of the technologies shown are specific to electricity systems, some cross over into other energy systems and others still are common information and communication technology (ICT).

Table 2. Smart Grid Technologies

Technology area	*Hardware*	*Systems and software*	*Network deployment*
Wide area monitoring and control	Phasor measurement units (PMU) and other sensor equipment.	Supervisory control and data acquisition (SCADA), wide-area monitoring systems (WAMS), wide-area adaptive protection, control and automation (WAAPCA) and wide-area situational awareness (WASA).	Transmission
Information and communication technology integration	Communication equipment (power line carrier, WiMAX, LTE, RF mesh network, cellular), routers, relays, switches gateway, computers (servers).	Enterprise resource planning so_ ware, customer information system.	Transmission and distribution

[8] ABS (ABS Energy Research) (2010), Global Transmission and Distribution Report 2010, ABS Energy Research, London.
[9] Smart Grids for Distribution Networks How to Guide, IEA, 2015
[10] “Fit and forget” refers to the typical approach used to plan and build distribution systems. In this approach distribution systems are dimensioned based on learned (historical) demand patterns, after which they are not regularly monitored to determine whether they are either under- or over-designed. Fit and forget approaches make it difficult to anticipate or manage impacts from generation or demand that diverge substantially from historical patterns.

Renewable, distributed and conventional generation integration	Power conditioning equipment for bulk power and grid support, communication and control hardware for generation and enabling storage technology.	Energy management system (EMS) Distribution management system (DMS), SCADA, geographic Information system (GIS).	Transmission and distribution
Transmission enhancement	Superconductors, FACTS, HVDC.	Network stability analysis, automatic recovery systems	Transmission
Distribution grid management	Automated re-closers, switches and capacitors, remote-controlled distributed generation and storage, transformer sensors, wire and cable sensors.	GIS, DMS, outage management system (OMS), workforce management system (WMS).	Distribution
Advanced metering infrastructure	Smart meter, in-home displays, servers, relays.	Meter data management system (MDMS).	Distribution and (transmission)
Electric transportation charging	Charging infrastructure, batteries, inverters.	Energy billing, smart charging grid-to vehicle (G2V) and discharging vehicle to-grid (V2G) methodologies.	Distribution
Customer-side systems	Smart appliances, routers, in-home display, building automation systems, thermal accumulators, smart thermostat.	Energy dashboards, energy management systems, energy applications for smart phones and tablets.	Distribution and (transmission)
Notes: Where transmission is noted in parentheses, it indicates that the given technology plays a minor role in transmission systems. Information and communication technologies are increasingly found in T&D networks and tend to cross all technology areas; FACTS = Flexible alternating current transmission system; HVDC = high voltage direct current.			

Source: Adapted from IEA Energy Technology Perspectives 2012

Standards

Within each industry, there are groups of experts who come together to discuss, develop, and update standards. These groups are called standards development organizations (SDOs) or standards-setting organizations (SSOs). For the smart grid, there are over 25 SDOs and SSOs involved in updating current standards and developing new standards. These include, for example, IEC, IEEE, IETF, ISO, ITU, NAESB, NEMA, SAE, and many more.[11] Due to the complexity, number and scale of the systems and devices involved in a smarter grid, interoperability between the various systems is key to successful implementation. Research can address interoperability issues while furthering innovation in grid modernization efforts.[12] One of the key organisations carrying out this effort on an international basis is the Smart Grid Interoperability Panel (SGIP). SGIP brings together over 20 industry segments related to smart technologies and deployment and performs a broad range of work to catalogue standards, develop case studies for technology deployment and provide expert advice on testing and certification aspects.

Global Smart Grid Organizations

There are a wide range of organizations around the world that are doing work in the area of smart grids, offering technical and policy advice. Some of these organisations are specifically focused on smart grids and others where smart grids are only a subset of a much broader range of activities. Table 3 is meant to provide a list of the organisations making a substantive contribution to global efforts on smart grids, but is not meant to be an all-inclusive list on a global basis.

[11] http://www.nist.gov/smartgrid/beginnersguide.cfm
[12] Epri: www.epri.com/Our-Work/Pages/Grid-Modernization.aspx

Table 3. Multinational organizations with exclusive or major initiatives in smart grids[13]

Name	Acronym	Geographic Coverage	Sector[14]	Focus
Organizations with exclusive smart grid mandate				
International Smart Grid Action Network[15]	ISGAN	Global with 25 member countries	Government	Technology and policy
Global Smart Grid Federation	GSGF	Global with 18 members	Private Sector	Technology and policy
European Distribution System Operators' Association for Smart Grids	EDSO for Smart Grids	European with 30 DSO members	Utility	Policy
Electricity system and technology organizations with Smart Grid mandates				
European Network of Transmission System Operators for Electricity	ENTSO-E	41 European TSO's	Utility	Policy
GO15. Reliable and Sustainable Power Grids	GO-15	17 Global Power Grid Operators	Utility	Policy
Union of the Electricity Industry - EURELECTRIC	Eurelectric	30 European electricity associations	Utility and Industry association	Policy
21st Century Power Partnership	21 CPP	8 member countries + private sector	Research institute and government	Technology and Policy
Global Sustainable Electricity Partnership	GSEP	12 of the world's largest electricity companies	Utility	Policy and project deployment
The Institute of Electrical and Electronics Engineers	IEEE	395,000 members in 160 countries	Engineering	Research, Policy and Standards

Vision for future electricity systems

The progress towards an overall smart grid vision can best be articulated by a vision of the electricity system of the future. Today's electricity system is largely defined by large scale generation that produces power which flows in one direction to end uses. The electricity system of the future will be defined by the services that electricity can provide, with bi-directional flow of power and information so that generation, distribution and end-users produce or use power while at the same time provide services that can support the operation of the grid (figure 2). The integrated electricity system of the future can provide electricity in an more efficient manner, utilising the grid, generation

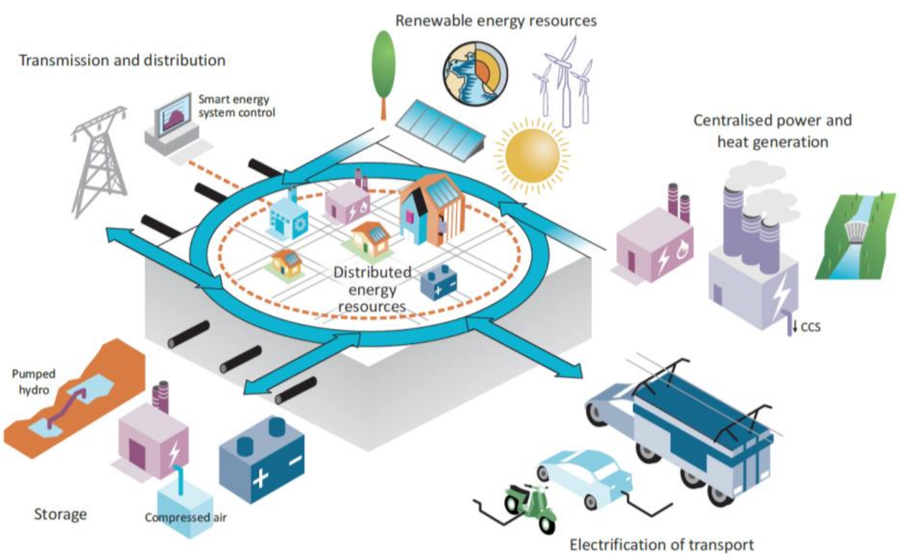
[13] Non-exhaustive list of multi-national organizations with substantive smart grid activities; a more fulsome description is included in Appendix 1.

[14] Primary participation, but not exclusive

[15] ISGAN and GSGF have signed a memorandum of understanding to work together on common goals.

and end-use resources and demonstrated net savings through better asset utilisation. Smart grid technologies will play a huge role in this, but technology on its own will not be sufficient, rather supportive policy and regulation will be essential. By enabling smart grid technology deployment through flexible policy and regulations the learning process needed to find technically and culturally relevant solutions in countries around the world can be accelerated.

Figure 2. An interconnected and integrated electricity system of the future



Source: IEA ETP 2014

Key Message: A sustainable electricity system is a smarter, multidirectional and integrated energy system that requires long-term planning for services delivery

The role of smart grid technologies and the smartening of the grid (or grid modernization) are important for all electricity system globally. Well established and reliable grids can still improve operations and maintenance in incremental steps to maximise asset utilisation. Alternatively, many existing grids in developing and developed countries today have not been well maintained or upgraded, and therefore significant investments are needed. Smart grid technologies can be used to better assess the most urgent needs as well as adapt to changing social and technical requirements, leveraging these opportunities for more optimum electricity system development (such as demand response and electric vehicles). Well planned approaches that consider long term investment horizons and best in class technologies can ensure that investments today do not become the burdens of tomorrow.

Building new infrastructure to provide electricity service to new consumers can offer different challenges, but in some ways can be easier. In provided access to electricity, designs are not encumbered by existing infrastructure and therefore can build systems tailored to meet short term and anticipated long term needs.

One important aspect to consider is that while there is adequate opportunity to learn from other countries and regions (for both modernisation and new build opportunities), there will often be technical, social or regulatory aspects that will require specific solutions. This means that it will be essential to understand the country or region specific context in order to create plans that a best suited.

Concrete next steps for UNECE

There are several opportunities for UNECE to provide meaningful input into the global smart grid dialogue, as well as provide policy advice and guidance to member States. Several proposed actions could be considered by various UNECE Committee on Sustainable Energy Groups of Experts, to be carried out individually or in parallel:

- Survey of member countries (especially focusing on countries not well served by existing smart grid organizations) to determine existing plans for electricity system development and smart grid efforts.
    - Result: Report on findings to assist in the development of a targeted work plan in support of a member State electricity system development.
- Analysis of electricity generation and demand in UNECE sub-regions to determine existing trends, as well as data gaps.
    - Result: Synthesis report and fact sheets on all member States outlining current trends. Regional aggregations could also be used to assess opportunities to establish cross-border electricity system relationships.
- Outline cross-cutting linkages across UNECE Committee on Sustainable Energy Groups of Experts (on Gas, on Renewable Energy, on Cleaner Electricity Production from Fossil Fuels, and on Energy Efficiency) to map out more holistic approach to electricity system analysis for member States
    - Result: Proposed electricity focused work that could be placed under one of the Group of Experts or the creation of a cross-sectoral task force focused on electricity system development.
- Membership of UNECE secretariat in the International Smart Grid Action Network (ISGAN) under formal or observer terms. This would offer representation of the larger UNECE membership (especially Eastern Europe, Caucasus, and Central Asia), alongside UNECE members who are currently members.
    - Result: Access to a significant knowledge base from and direct links to existing ISGAN members. Input from ISGAN members into UNECE member States electricity system planning processes.
- Development of future looking analysis for part of the UNECE membership that does not currently have adequate resources to develop this on its own. Such efforts could be done in collaboration with international organisations such as the IEA, European Commission, ADB or others.
    - Result: Informative analysis that could be used to develop energy systems in ways that could meet sustainability goals.

The above options have varying resource requirements and timeframes. Some options could be used as scoping elements for longer term and larger initiatives.

Annex 1: Short description of Smart Grid organizations

International Smart Grid Action Network (ISGAN)

ISGAN's vision is to accelerate progress on key aspects of smart grid policy, technology, and related standards through voluntary participation by governments in specific projects and programs. ISGAN will facilitate dynamic knowledge sharing, technical assistance, peer review and, where appropriate, project coordination among participants. ISGAN activities center on those aspects of the smart grid where governments have regulatory authority, expertise, convening power, or other leverage, focusing on five principal areas:

1. Policy standards and regulation; 2. Finance and business models; 3. Technology system development; 4. Workforce skills and knowledge; 5. Users and consumers engagement GSGF

ISGAN facilitates dynamic knowledge sharing, technical assistance, and project coordination, where appropriate. ISGAN participants report periodically on progress and projects to the Ministers of the Clean Energy Ministerial, in addition to satisfying all IEA Implementing Agreement reporting requirements. Membership in ISGAN is voluntary, and currently includes Australia, Austria, Belgium, Canada, China, Denmark, the European Commission, Finland, France, Germany, India, Ireland, Italy, Japan, Korea, Mexico, the Netherlands, Norway, the Russian Federation, Singapore, South Africa, Spain, Sweden, Switzerland and the United States.

Source: www.iea-isgan.org

Global Smart Grid Federation (GSGF)

Over the past several years, various countries have initiated projects and programs to explore the potential of the new generation of information- and communication-based technologies emerging across the power sector. As these efforts matured, formal public-private initiatives were formed. The first, in 2003, was the GridWise Alliance in the United States. It was followed by similar initiatives in the European Union, South Korea, Japan, Australia, Canada, India, and Ireland. Many other countries are in the formative stages of their own initiatives.

The Global Smart Grid Federation was formed to:

- Facilitate the collaboration of national and international Smart Grid nongovernmental organizations and governmental organizations from around the world to conduct and foster research in the application of Smart Grid technologies
- Support rapid implementation of Smart Grid technologies by establishing itself as the global center for competency on Smart Grid technologies and policy issues
- Foster the international exchange of ideas and best practices on energy issues, including reliability, efficiency, security, and climate change
- Create avenues for dialogue and cooperation between the public and private sectors in countries around the world on issues relating to the deployment of Smart Grid technologies.

Each member organization has a seat on the board of directors, which directs all activities of the Global Smart Grid Federation. The bylaws of the organization will be jointly developed and endorsed by the charter members.

Source: www.globalsmartgridfederation.org

European distribution system operators (EDSO) for Smart Grids

EDSO for Smart Grids gathers leading European distribution system operators (DSOs) for electricity, cooperating to bring smart grids from vision to reality in Europe and is focused on guiding EU RD&D, policy and member state regulation to support this development. EDSO for Smart Grids represents 30 leading Distribution System Operators (DSOs) operating in over 17 countries of the European Union and covering up to 70% of European customers.

EDSO is directly involved in a number of EU-funded smart grid projects, under the EU's 7th Framework Programme (FP7), its successor for the period 2014-2020, Horizon 2020, as well as the Intelligent Energy Europe (IEE) programme.

These projects, evolvDSO, GRID+Storage, and FLEXICIENCY involve exercises in:

- Addressing evolving DSO roles
- Demonstrations (real-life and simulations)
- RD&D mapping and prioritisation
- Knowledge-sharing from projects
- Developing and testing market platform for flexibility services

Source: www.edsoforsmartgrids.eu

To be completed for other organizations listed in Table 1