Assessing Smart Grid Benefits and Impacts:
EU and U.S. Initiatives

Joint Report EC JRC – US DOE

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1 BACKGROUND

In the last few years, initiatives on Smart Grids have been growing in number and scope on both sides of the Atlantic. A variety of projects has been deployed throughout Europe and US with different aims and results. Substantial public and private investments have been committed to research and development (R&D), demonstration and deployment activities. At this stage, there is a need to evaluate the outcome of implemented projects and share experiences and lessons learned. Effective project assessment and knowledge sharing is instrumental to prioritize policy initiatives, unlock market investment potentials and instil trust and understanding in consumers.

The scope of this document is to find common ground between EU and US assessment approaches on Smart Grid projects. First of all, we need to make sure we understand each other’s language. We need to assess correspondences among definitions, terminology and methodological approaches, in order to clarify commonalities and differences. Secondly, we need to strengthen cooperation on assessment frameworks and on sharing data collection experiences, project results and lessons learned.

This joint work is carried out in the framework of the EU-US Energy Council[1], which intends to deepen the transatlantic dialogue on strategic energy issues such as policies to move towards low carbon energy sources while strengthening the on-going scientific collaboration on energy technologies.

In this context, a first meeting among EU and US experts on Smart Grid Assessment framework was held on the 6th of December 2010 in Albuquerque, where a set of cooperation items was identified. The outcome of the first meeting has resulted in an interim version of this document which has then served as basis of discussion for a second meeting, which was held on the 7th of November 2011 in Washington (the list of participants is reported in ANNEX VIII).

The outcomes of the meeting have been incorporated in this final report, which provides a framework for EU-US cooperation on Smart Grid assessment methodologies and highlights a number of open issues for further common work.

1.1 What is a Smart Grid?

Smart Grids can be described as an upgraded electricity network enabling two-way information and power exchange between suppliers and consumers, thanks to the pervasive incorporation of intelligent communication monitoring and management systems.

EU and US smart grid experts share similar views on the main components and functions of the Smart Grid (the Smart Grid definitions proposed in Europe and USA are reported in box 1).

[1] http://www.eeas.europa.eu/us/sum11_09/docs/energy_en.pdf

The US National Institute of Standards and Technology (NIST) [NIST 2010] has proposed a Conceptual Model to represent the building blocks of an end-to-end Smart Grid system, from Generation to (and from) Customers, and exploring the interrelation between these Smart Grid segments. The European Commission (EC) Smart Grid Task Force[2] is currently using the NIST model as a basis for the definition of a Smart Grid reference architecture, which is being used for the Analysis of Standardization gaps, cyber-security threats and options for future market models in Europe. As reported in figure 1, to fit the European context, the EC Smart Grid Task Force (in particular the Expert Group working on standardization[3]) has extended the NIST model by including the Distributed Energy Resources domain (in blue in the picture).

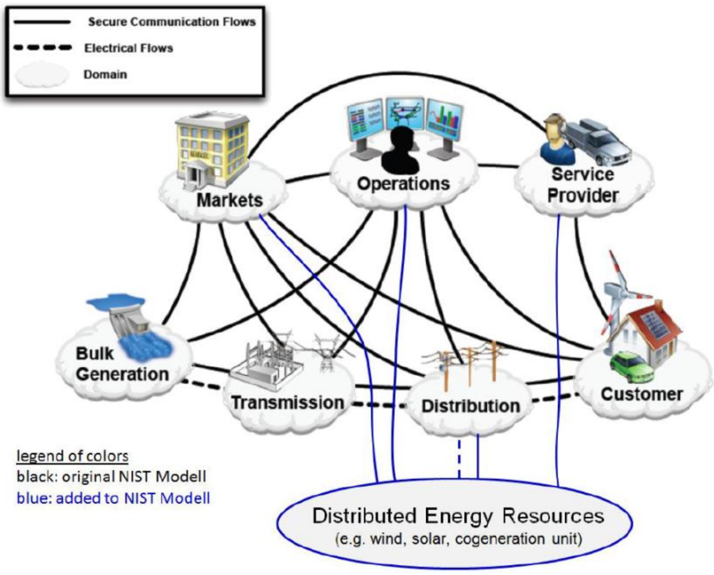


Figure 1 – Original NIST Smart Grid conceptual model and adaptation to the EU context (in blue)

[2] The EC Smart Grid Task Force is chaired by the European Commission and includes all relevant European Smart Grid stakeholders, ranging from utilities to manufacturers and consumers associations. Its mission is to advise the Commission on policy and regulatory frameworks at European level for successful implementation of Smart Grids.

[3] http://ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm

Box 1. Smart Grid definition

EU - A Smart Grid is "an electricity network that can intelligently integrate the behaviour and actions of all users connected to it- generators, consumers and those that do both- in order to efficiently ensure sustainable, economic and secure electricity supply" [EC Task Force for Smart Grids, 2010a]

US - A Smart Grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources [US DOE, 2009a]

It should be noted that Smart Grid can be defined in multiple ways including by its technologies, its functionality, and its benefits. Smart grid can impact all aspects of the electric power system from generation to transmission to distribution to consumer, and can impact power delivery, communications, and marketplace.

European Union

According to [EC Task Force for Smart Grids, 2010a], a Smart Grid is "an electricity network that can intelligently integrate the behaviour and actions of all users connected to it- generators, consumers and those that do both- in order to efficiently ensure sustainable, economic and secure electricity supply".

This definition stresses that Smart Grid deployment should be user-centric and output-focused (the Smart Grid is a means to an end not an end in itself). The ultimate goal is to set up a Smart Electricity System, which encompasses both the grid and the users connected to it (distributed generators, Electric Vehicles, Smart Homes etc.) and provides reliable and sustainable electricity services (demand response, VPP, dispatching, integration of RES etc.).

Policy drivers EU

The overarching policy objective for the deployment of Smart Grids is to provide a more sustainable, efficient and secure electricity supply to consumers.

To this end, it is acknowledged that Smart Grids are instrumental in the transition to a low-carbon economy, facilitating demand-side efficiency, increasing the shares of renewables and distributed generation, and enabling electrification of transport. In this area, key policy drivers for the implementation of the Smart Grids are the 2020 EU targets [EC, 2007b]:

√ Cutting greenhouse gases by 20%.

√ Reducing energy consumption by 20% through increased energy efficiency.

√ Meeting 20% of the EU's energy needs from renewable sources.

Another important policy driver is the set-up of an internal European energy market. Smart Grids are considered as a key enabler to strengthen cross-border energy transactions, support retail competition and open the market to new services and players in the interest of consumers.

USA

The definition of Smart Grid is based on the description found in Title XIII, Section 1301 of the Energy Independence and Security Act of 2007. This description states that it is the policy of the United States to support the modernization of the nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:

(1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.

(2) Dynamic optimization of grid operations and resources, with full cyber-security.

(3) Deployment and integration of distributed resources and generation, including renewable resources.

(4) Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.

(5) Deployment of `smart' technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.

(6) Integration of `smart' appliances and consumer devices.

(7) Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.

(8) Provision to consumers of timely information and control options.

(9) Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.

(10) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

Policy drivers USA

The principal policy objective for implementation of Smart Grids is to provide affordable, reliable, secure and sustainable supply of electric power in the United States. To achieve these objectives, the electric power system will require a major transformation aimed at building a self-healing grid to improve reliability and integration of distributed energy resources and consumer assets to improve operational efficiency. This transformation will create economic development opportunities, reduce peak load and consumption, improve operational efficiency, improve reliability and resilience of electric service, enable distributed energy resources including renewable energy, and reduce carbon dioxide emissions. To assist with the transformation, DOE has set interim 2020 targets for its R&D program to reduce SAIDI distribution outages by 20%, reduce outage time for critical loads by 98%, and reduce peak loads by 20%.

The DOE Office of Electricity Delivery and Energy Reliability 2010 strategic plan and its smart grid R&D plan supports the Secretary of Energy's goals of building a competitive, low-carbon economy and secure America's energy future, as well as the President's targets of 80% of America's electricity from clean sources by 2035 and 1 million electric vehicles on U.S. roads by 2015.

1.2 Overview of the Smart Grid landscape

Country/ Region	Forecasted Smart Grid investments (€/$)	Funding for Smart Grids development (€/$)	Number of Smart meters deployed and/or planned
European Union	€56 billion by 2020 [Pike Research, 2011]* *(estimated Smart Grids investments)*	€184 million (FP6 and FP7 European funding for projects in the JRC catalogue [EC, 2011b]) About €200 million from European Recovery Fund, ERDF, EERA. National funding: n/a	Over 40 million already installed [EC, 2011b] 240 million by 2020 [Pike Research, 2011]
USA	$338 (€238) to 476 (€334) billion by 2030 [EPRI 2011]** *(estimated investments for implementation of fully functional smart grid)*	$9.6 (€-) billion in 2009 (US Recovery act; includes Federal and private sector funding)	8 million in 2011 [Smartmeters.com, 2011] 60 million by 2020 [Smartmeters.com, 2011]

** Other estimates (http://setis.ec.europa.eu/newsroom-items-folder/electricity-grids, June 2011), referring to the upgrade of transmission and distribution grids (not only Smart Grids) forecast a required investment of €500 billion by 2030, where distribution accounts for 75% and transmission for 25%.*
*** Other estimates exist including one from the Brattle Group indicating investments of $880 billion (2008)*

Table I Forecasted Smart Grids investments in Europe and USA

European Union

According to the inventory of Smart Grid projects [EC, 2011b] performed in 2011 by the Joint Research Centre (JRC), the European Commission's in-house Science service, the level of investments in Smart Grid projects amount to around €5.5 billion.

A recent report by Pike Research [Pike Research, 2011] forecasts that during the period from 2010 to 2020, cumulative European investment in Smart Grid technologies will reach €56.5 billion, with transmission counting for 37% of the total amount.

According to the International Energy Agency (IEA), Europe requires investments of €1.5 trillion over 2007-2030 to renew the electrical system from generation to transmission and distribution [IEA, 2008]. This figure includes investments for Smart Grid implementation and for maintaining and expanding the current electricity system.

USA

A recent report from the Electric Power Research Institute on "Estimating the Costs and Benefits of the Smart Grid" [EPRI, 2011] indicates that between $338 and $476 billion will be needed to fully implement Smart Grid in the United States. These costs are in addition to investments needed to maintain the existing system and meet electric load growth. The annual investment needed for Smart Grid is between $17 and $24 billion over the next 20 years. Costs allocated for transmission and substations are between 19 and 24% of total costs, while costs allocated for distribution are between 69 and 71 % and costs for consumer systems are between 7 and 10%.
The costs include the infrastructure to integrate distributed energy resources and consumer systems, but do not include generation costs, cost of transmission expansion to access renewables and meet load growth, and cost of consumer's smart appliances and devices.

1.3 Inventory of Smart Grid projects and initiatives

Mapping of Smart Grid projects are on-going both in Europe and in the USA (see box 2).
Table II reports the project categories that have been defined in the JRC mapping (http://ses.jrc.ec.europa.eu) and in the DOE-sponsored mapping carried out by the Virginia Tech Smart Grid Clearinghouse (www.sgiclearinghouse.org/AboutSGIC).

Box 2 – Inventory of Smart Grid project - Summary

European Union

July 2011 inventory**: 219 projects**; total budget over **€5 billions** [EC, 2011b]

USA

99 Smart Grid Investment Grants (SGIG), total budget **$9.6 billion** (federal portion about $3.4 billion) [US DOE, 2009b]

32 Smart Grid Demonstration Projects (SGDP) and 9 Renewable and Distributed Systems Integration (RDSI) Projects. SGDP (**$1.6 billion** (federal portion about $620 million); RDSI ($195 million)

	European Union (JRC mapping [EC 2011b])	**USA (ARRA Smart Grid program)**
Smart Grid project categories	Smart Network Management	Advanced Metering Infrastructure
	Integration of DER	Electric Transmission Systems
	Integration of large scale RES	Electric Distribution Systems
	Aggregation (Demand Response, VPP)	Integrated and crosscutting Systems
	Smart Customer and Smart Home	Customer Systems
	Electric Vehicles and Vehicle2Grid applications	Storage Demonstration
	Other (please specify)	Equipment Manufacturing
		Regional Demonstration

Table II Categories for the classification of Smart Grid projects in Europe and in the USA

European Union

In the study "Smart Grid projects in Europe: lessons learned and current developments" [EC, 2011b], the JRC has presented a review of 219 Smart Grid projects Europe-wide. The total budget of the collected projects (over €5 billion) shows that significant efforts have already been undertaken, but that we are just at the beginning of the Smart Grid transition.

Smart Grid projects are not uniformly distributed across Europe, with few countries standing out in terms of investments (figures 2 and 3). Most of the projects and investments are located in EU15

Member States, while EU12 Member States still lag behind[4]. About 27% of the projects collected in the catalogue fall in the Smart Meters category; these projects involve the installation of more than 40 million devices for a total investment of around €3 billion. Estimates forecast about 240 million smart meters to be installed by 2020 [Pike Research, 2011].

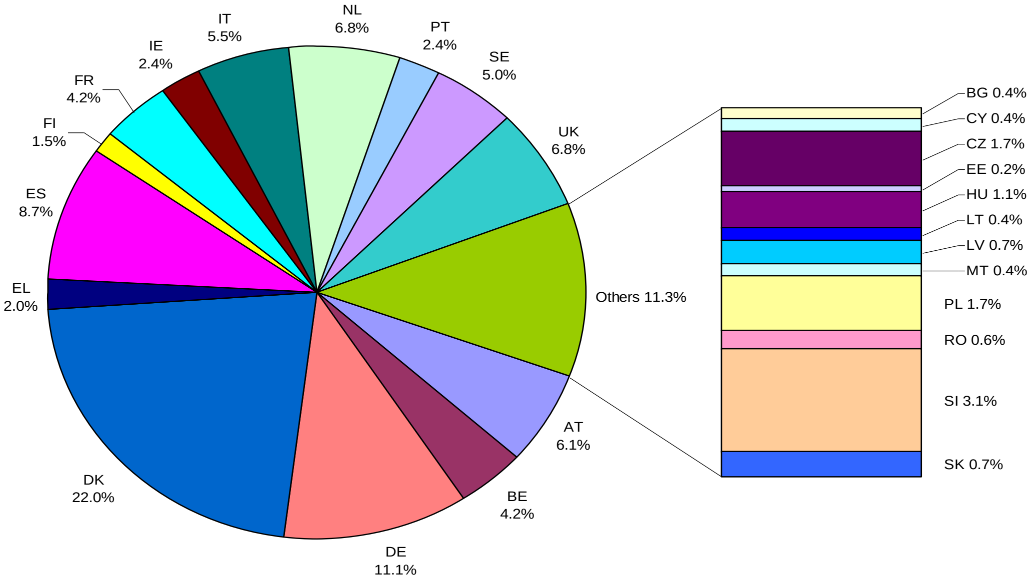


Figure 2. Distribution of projects between EU15 and EU12 Countries

[4] **EU15 Member States**: EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom

EU12 Member States: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia

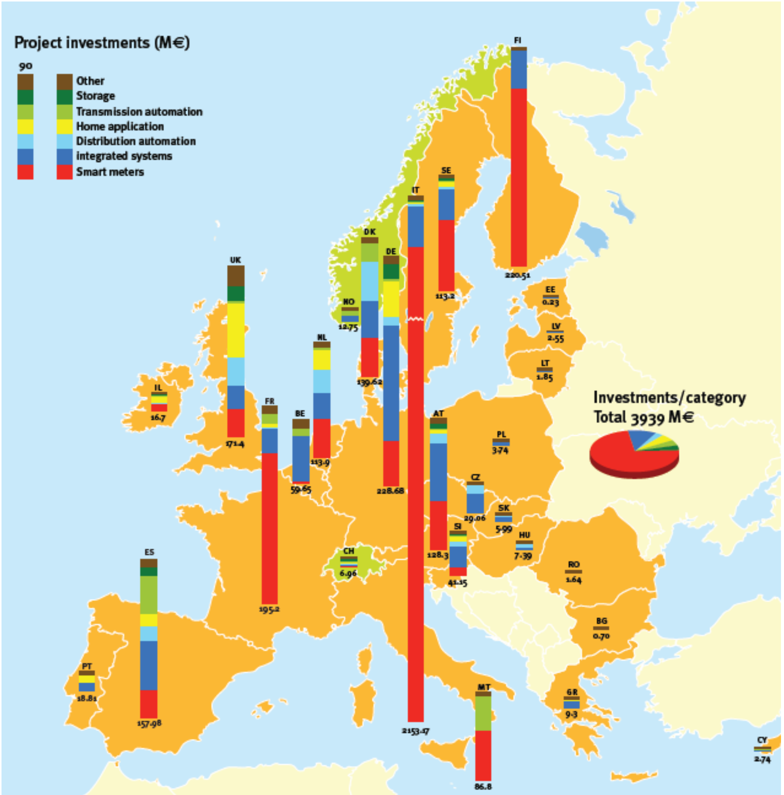


Figure 3 - Geographical distribution of investments and project categories

Deployment projects (mainly smart meter roll-outs) cover the lion's share of investment commitments- about 56% of the total- while R&D and demonstration projects account for a much smaller share of the total budget (figures 4 and 5). Most R&D and demonstration projects are small to medium size (on average €4.4 million for R&D projects and about €12 million for demonstration projects), suggesting the need to invest in larger scale demonstration projects to gain a better knowledge of the functioning and impacts of some innovative solutions and to validate results to a broader extent. It was assumed a threshold of 15M€ to define "large scale" projects.

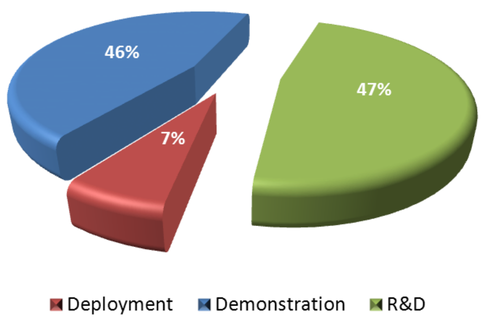


Figure 4 Investments along the stages of the innovation chain

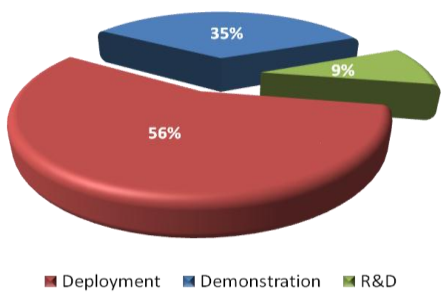


Figure 5 Projects along the stages of the innovation chain

The JRC inventory is carried out on an on-going basis and new snapshots of the Smart Grid landscape will be periodically published (see chapter 3).

USA

Major Smart Grid projects funded through the U.S. Department of Energy include 99 Smart Grid Investment Grants (SGIG), 32 Smart Grid Demonstration Projects (SGDP) and 9 Renewable and Distributed Systems Integration (RDSI) Projects [US DOE, 2009b].

The SGIG program consists of 99 projects across the country. The total project value is about $9.6 billion; the federal portion is about $3.4 billion. Projects are grouped according the following categories (figure 6): advanced metering infrastructure, customer systems, electric system distribution, electric transmission systems, equipment manufacturing, integrated and/or cross-cutting systems. Figure 7 and 8 show the geographical distribution of SGIG projects and SGDP projects respectively.

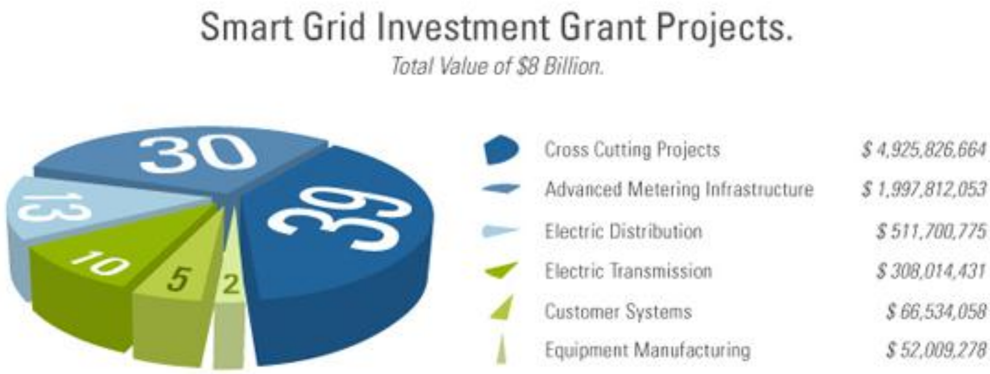


Figure 6 – Smart Grid investment grants per project category

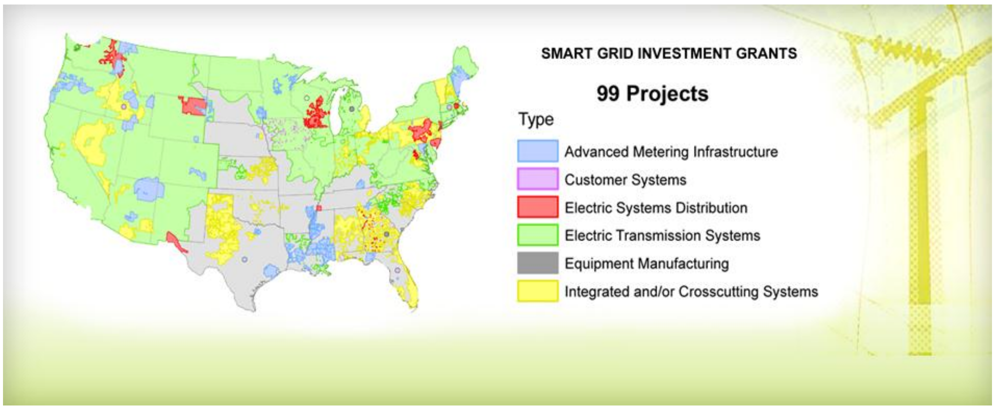


Figure 7 – Geographical distribution of Smart Grid investment grants per project category

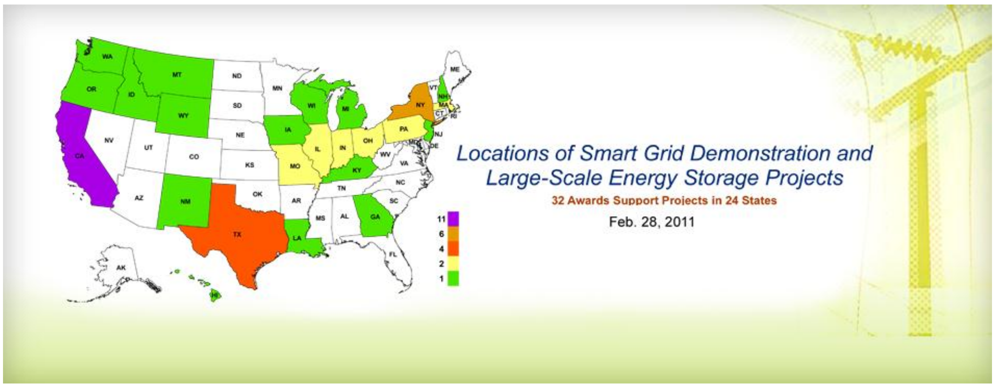


Figure 8 – Geographical distribution of Smart Grid Demonstration Projects

It is important to note that while the DOE ARRA projects are a significant first step in building out the smart grid in the U.S., they represent only a few percent of the total build-out needed to create a nationwide smart grid.

It should be noted that the Electric Power Research Institute is sponsoring 11 smart grid demonstration projects in the United States and three foreign demonstrations in Ireland, France, and Canada.

1.4 On-going standardization efforts

European Union

There is a large consensus on the need of European technical standards for Smart Grids. Common pan-European approach to Smart Grid technology solutions will enable a pan-European market and world-wide expansion.
Standards are an ideal instrument to achieve a number of objectives such as [CEN-CENELEC-ETSI, 2011]:

- seamless interoperability,
- harmonized data models,
- compact set of protocols,
- communication and information exchange,
- improved security of supply in the context of critical infrastructure,
- robust information security, data protection and privacy adequate safety of new products and systems in the smart grid

In March 2009, the Commission issued mandates to the European Standardization Organizations (ESOs), namely CEN, CENELEC and ETSI, for standardization of smart meters.[5] In June 2010 ESOs initiated development of standards for charging[6] electric vehicles. Recently, the Commission launched a mandate for Smart Grids[7] aimed at developing standards facilitating the implementation of different high-level Smart Grid services and functionalities defined by the Task Force[8] [EC Task Force for Smart Grids 2010a, 2010b, 2010c]. The identification of standard gaps is performed through a Smart Grid reference architecture, which identifies the different subsystems composing the Smart Grid and represents the functional information data flows among them. The reference architecture for Smart Grids in Europe and a first set of standards is expected to be issued by the end of 2012.

Some important work has already been carried out. A report on "Standards for Smart Grids" [CEN-CENELEC-ETSI, 2011] has been issued in May 2011. The European Commission has also created a Smart Grids Reference Group (now working within the framework of the Smart Grid Task Force) to monitor implementation of the work program established with a view to ensure timely adoption of the standards [EC 2011a]. Reports summarizing the work of the Smart grid reference Group are expected by the end of 2012.

Besides the technical specifications, the mandate for Smart Grids also contains elements related to data protection and data privacy, which is a key issue for the deployment and acceptance of Smart Grids [EC Task Force Expert Group 2010b; EC 2012c].

USA

The Energy Independence and Security Act of 2007 gave the National Institute of Standards and Technology (NIST) the primary responsibility of ensuring the interoperability of Smart Grid devices and system. More specifically, NIST, an agency of the U.S. Department of Commerce, is to

5 M441 on 12 March 2009, available at http://www.cen.eu/cen/Sectors/Sectors/Measurement/Pages/default.aspx

6 M468 on 29 June 2010, available at: http://ec.europa.eu/enterprise/standards_policy/mandates/database/index.cfm?fuseaction=search.detail&id=450#

7 M490 on 1 March2011 – Standardization Mandate to European Standardisation Organisations (ESOs) to support European Smart Grid deployment

8 The EC Smart Grid Task Force (including representatives from all Smart Grid stakeholders) has been launched by the European Commission in 2009 to advice the Commission on policy and regulatory directions at European level and to coordinate the first steps towards the implementation of Smart Grids under the provision of the Third Energy Package.

coordinate the development of a framework of protocols and standards for information management that, taken together, will achieve Smart Grid interoperability. DOE has provided NIST with $10 million in Recovery Act funds to carry out this responsibility.

NIST created the Smart Grid Interoperability Panel (SGIP) to help coordinate development of Smart Grid standards. SGIP is a consensus-based group of more than 675 public and private organizations. In July, 2011, the Smart Grid Interoperability Panel published the first six entries of its new Catalogue of Standards, a technical document now available as a guide for all involved with Smart Grid-related technology.

The catalogue is a "knowledge base" for the industry including regulators and is not intended to be requirements or mandates. The new standards cover:

- **Internet protocol.** This will allow devices connected to the smart grid to exchange information.
- **Energy usage information.** This will allow consumers to know how much energy usage costs at any given time.
- **Vehicle charging stations.** This will ensure that electric vehicles can be connected to power outlets.
- **Communication use cases** between plug-in vehicles and the grid. This will help ensure that electric vehicles (which draw heavy power loads) won't stress the grid too much.
- **Smart meter upgrades.** This will cover replacing traditional electric meters, as well as guidelines for assessing standards for wireless communication devices needed for grid communication. Grid-connected wireless devices can be less tolerant of delays or signal interruption than, say, cell phones.

NIST notes that these standards cover five of the 19 Priority Action Plans named by grid experts as the issues that must be addressed first in order for the smart grid to function.
The Catalogue itself is available at http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SGIPCoSStandardsInformationLibrary

2 SMART GRID ASSESSMENT FRAMEWORK

The Smart Grid is an enabler for an end, not an end itself. The implementation of a Smart Grid is useful to achieve strategic policy goals, such as the smooth integration of renewable energy sources, a more secure and sustainable electricity supply, full inclusion of consumers in the electricity market.

On the other hand, Smart Grid implementation should be market-driven. Market forces need to be mobilized within the boundaries of energy policy goals to provide the required massive investments over the next decades. In this perspective, an estimation of costs, benefits and beneficiaries is necessary to reduce business risks and unlock private investments.

Steering the Smart Grid transition is a challenging, long-term task, which requires balancing energy policy goals and market profitability.

In this perspective, a first approach in Smart Grid assessment is to evaluate to what extent Smart Grid projects are contributing to progresses toward the "ideal Smart Grid" and its expected outcomes (e.g. sustainability, efficiency, consumer inclusion), which are directly linked with the policy goals that have triggered the Smart Grid transition. Assessment initiatives in EU and US have therefore defined different sets of performance indicators to measure the impact of Smart Grid projects and their contribution to the goals behind the Smart Grid implementation (sections 2.1 and 2.2). This first approach is conducted via the definition of suitable metrics and key performance indicators (KPI).

A second complementary approach is to assess the profitability of Smart Grid solutions and investments through a cost-benefit analysis. In section 2.3 we will introduce on-going initiatives in Europe and US.

ASSESSING THE IMPACT OF SMART GRIDS

European Union

In Europe, two main assessment frameworks based on key performance indicators (KPIs) have been introduced.

The EC Task Force for Smart grids [EC Task Force for Smart Grids 2010a, 2010c] has introduced the characteristics of the ideal Smart Grids (services) and the outcomes of the implementation of the ideal Smart Grid (benefits). A measure of the contribution of projects to the ideal Smart Grid is quantified in terms of benefits, via a set of KPIs. More details are reported in section 2.1.

The European Electricity Grid Initiative [EEGI, 2010] has followed a different approach. It has divided the ideal Smart Grid system into thematic areas (clusters) and is currently mapping Smart Grid projects into clusters (more details in section 2.2). A set of KPIs are being discussed to assess the contribution of projects to progresses at the level of each thematic area (e.g. Smart customers) and at the system level [EEGI, 2010].

Some overlapping exists between the approaches of the EC Task Force and of the EEGI. Both approaches first define the characteristics of the ideal Smart Grids - in terms of services (EC Task Force) or in terms of critical thematic areas of the Smart Grid system (EEGI) - and then define KPIs to measure outcomes and progresses, achieved through the implementation of Smart Grid projects.

USA

Similarly to what has been done in the EC Task Force, the DOE has defined the ideal characteristics of the Smart Grid and a set of metrics to measure progresses toward the ideal Smart Grids [US DOE, 2009a]: build metrics that describe attributes that are built in support of a Smart Grid (e.g. percentage of substations using automation) and value (or impact) metrics that describe the value that may derive from achieving a Smart Grid (e.g. percentage of energy consumed to generate electricity that is not lost). (e.g., quantity of electricity delivered to consumer compared to electricity generated expressed as a percentage).

The characteristics of the ideal Smart Grids and the build and value metrics reflect the expected outcomes of the Smart Grid and the corresponding policy goals (see ANNEX II and III).

Coherently with this approach, the DOE has also defined a framework to evaluate the individual Smart Grid projects [US DOE 2009b, 2010]. Therefore, at project level, a set of build metrics and impact metrics have been defined, which are used to quantify for each project what has been implemented on the field (e.g. number of Smart Meters deployed) and the impact that have derived (e.g. Identification of electricity theft).

COST-BENEFIT ANALYSIS

The implementation of the Smart Grid should be market-driven. Another necessary approach in Smart Grid assessment is therefore to assess the costs, the benefits and the beneficiaries of different Smart Grid solutions. The DOE and EPRI have defined a comprehensive methodology for cost benefit analysis of Smart Grid projects [EPRI, 2010] and are now in the process of testing it on real case studies. In Europe, the European Commission has adapted and expanded the DOE/EPRI methodology to fit the European context [EC 2012a, EC 2012b]. A brief summary of Smart Grid assessment approaches is reported in box 3.

Box 3 – Smart Grid assessment framework

Assessing the impacts of Smart Grids

How much are we progressing toward the ideal Smart Grids? (section 2.1)

Definition of the characteristics and the outcomes of the ideal Smart Grid

EU – Services and benefits/KPIs

USA – Characteristics and build/value metrics

What has been built? What is the impact of Smart Grid projects and programs? (section 2.2)

Mapping and monitoring the implementation of Smart Grid projects and programs

Evaluation of the impact of Smart Grid projects and programs

EU – EEGI Smart Grid model and project mapping; 3 level KPIs

USA – Build and impact metrics of the Smart Grid Implementation Grant (SGIG)

Cost-benefit analysis (section 2.3)

What are the (monetary) costs and benefits of Smart Grid solutions? Who are the beneficiaries?

Quantification of costs, benefits and beneficiaries of Smart Grid projects and extrapolation of results to wider-scale replication. Sensitivity analysis of critical parameters of Smart Grid projects.

EU – CBA guidelines based on the EPRI methodology [EC 2012a, 2012b]

USA – DOE/EPRI methodology [EPRI, 2010] or alternative approach from project accepted by DOE.

2.1 How much are we progressing toward the ideal Smart Grid?

Both the Department of Energy and the European Commission have defined the characteristics of the ideal Smart Grids and defined metrics to measure progresses and outcomes resulting from the implementation of Smart Grid projects (see box 4)

The ideal Smart Grid has been defined in terms of characteristics in the US and in terms of services in the European Union (see table III). Built/Value metrics in the USA and Benefits/KPIs in Europe are used to measure progresses toward the ideal Smart Grid. For sake of clarity, some of the metrics are reported in table IV. The complete list of metrics is reported in annex III.

	European Union (Services)	**USA (Characteristics)**
Smart Grid services/characteristics	Enabling the network to integrate users with new requirements	Accommodate all generation and storage options
	Enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management	Enable active participation by customers
	Improving market functioning and customer service	Enable new products, services, and markets
	Enhancing efficiency in day-to-day grid operation	Optimize asset utilization and operate efficiently
	Enabling better planning of future network investment	
	Ensuring network security, system control and quality of supply	Operate resiliently to disturbances, attacks and natural disasters
		Provide the power quality for the range of needs

Table III –- Smart Grid services and characteristics to define the ideal Smart Grid

	European Union (Benefit/Key Performance indicator)	USA (Build and Value metrics)
Some Metrics to measure progress toward the ideal Smart Grids and the corresponding outcomes	**Enhanced Consumer awareness and participation in the market by new players/** Demand side participation in electricity markets and in energy efficiency measures	**Dynamic Pricing** -Fraction of customers and total load served by real-time pricing and Time of Use tariffs
	Adequate capacity of transmission and distribution grids for collecting and bringing electricity to consumers / Hosting capacity for distributed energy resources in distribution grids	**Load Participation Based on Grid Conditions** -Fraction of load served by interruptible tariffs, direct load control, and consumer load control with incentives
	Satisfactory levels of security and quality of supply/Share of electrical energy produced by renewable sources	**Grid-Connected Distributed Generation (renewable and non-renewable) and Storage** - Percentage of distributed generation and storage
	Enhanced efficiency and better service in electricity supply and grid operation/Level of losses in transmission and in distribution networks (absolute or percentage)[9]. Storage induces losses too, but also active flow control increases losses.	**Generation and T&D Efficiencies** - Electrical losses in transmission and distribution system expressed as a percentage of electricity generated
	Satisfactory levels of security and quality of supply Voltage quality performance of electricity grids (e.g. voltage dips, voltage and frequency deviations)	**T&D System Reliability** - SAIDI, SAIFI, MAIFI
	Create a market mechanism for new energy services such as energy efficiency or energy consulting for customers/Effective consumer complaint handling and redress. This includes clear lines of responsibility should things go wrong	**Power Quality** - Percentage of Customers complaints related to power quality issues, excluding outages

Table IV – Some Metrics to measure progress toward the ideal Smart Grids and the corresponding outcomes

[9] In case of comparison, the level of losses should be corrected by structural parameters (e.g. by the presence of distributed generation in distribution grids and its production pattern). Moreover a possibly conflicting character of e.g. aiming at higher network elements' utilization (loading) vs. higher losses, should be considered accordingly.

Box 4. Measuring progresses toward the ideal Smart Grid

European Union

Ideal Smart Grids defined in terms of Smart Grid **Services and Functionalities** (ANNEX II)

Definition of the outcome of the ideal Smart Grid in terms of **Benefits** (ANNEX III)

Metrics to measure progresses and outcomes: **54 Key Performance Indicators** (ANNEX III)

USA

Ideal Smart Grids defined in terms of Smart Grid **Characteristics** (ANNEX II)

Metrics to measure overall progresses and outcomes: **20 Build/Value metrics** (ANNEX III)

European Union

The Smart Grid Services represent the characteristics of the "ideal" smart grid (see annex II for more details). For each service (e.g. Enhancing efficiency in day-to-day grid operation), a number of corresponding Smart Grid functionalities have been defined (e.g. Automated fault identification/grid reconfiguration, reducing outage times). Progresses along these characteristics are directly linked with progresses toward the policy goals and the expected outcomes the ideal smart grid is an enabler for.

The Smart Grid Benefits (see annex III) represent the outcomes of the implementation of the ideal Smart Grid (the term benefit will be used with a different meaning in the context of the cost-benefit analysis, see section 2.3).

Smart Grid services and benefits are very much linked to the EU policy goals that are driving the Smart Grid deployment (sustainability, competitiveness and security of supply). They can therefore be considered as useful indicators to evaluate the contribution of projects toward the achievement of these policy goals.

Key performance indicators (KPI) represent a type of Measure of Performance to evaluate progress toward strategic goals. In the context of the EC Task Force for Smart Grids, strategic goals are (1) progress toward the deployment of Smart Grid Services, (2) progress toward the achievement of Smart Grid Benefits.

The set of benefits and KPIs proposed by the EC Task Force for Smart Grids are reported in annex III.

The assessment framework proposed by [EC Task Force for Smart Grids, 2010c] is based on a merit deployment matrix (see ANNEX IV), where benefits and corresponding KPIs are reported in the rows, whereas functionalities (which are univocally linked to a service) are reported on the columns:

		Functionality j
Benefit	KPI^i_1	0-1
	KPI^i_2	0-1
	KPI^i_3	0-1
	…	…

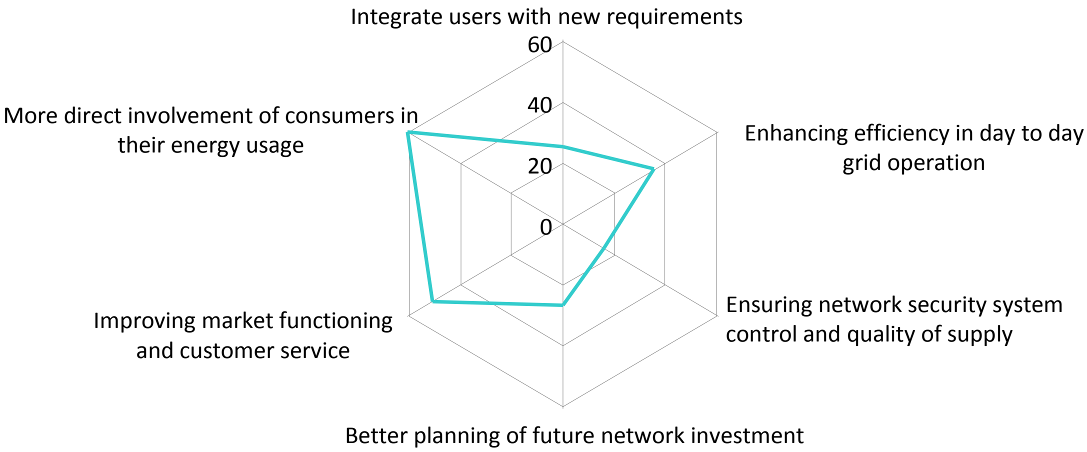
Table V –-Merit deployment matrix to assess services and benefits

For each project, the matrix is filled in two main steps:

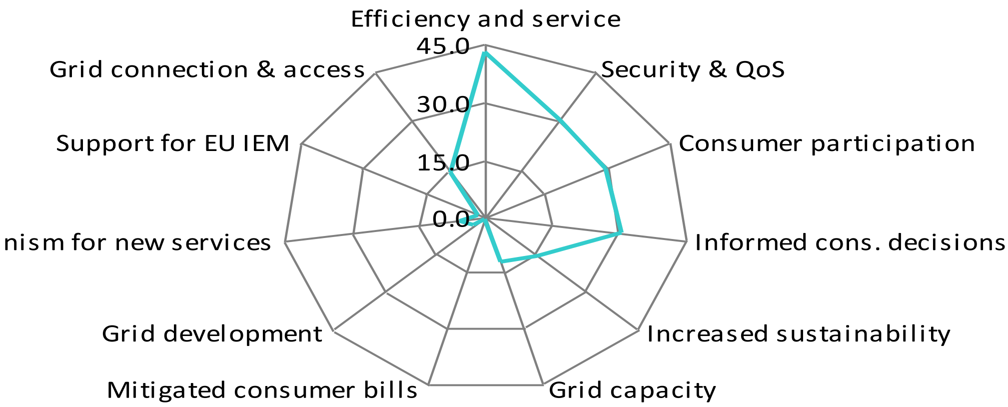
a) Identify links benefits/KPI and functionalities. Select the corresponding cell.
b) For each cell, explain how the link between benefits/KPI and functionalities is achieved in the project. Assign a weight (in the range 0-1) to quantify how strong and relevant the link is.

By summing up the cells along the columns, it is possible to assess the impact of the projects in terms of functionalities, whereas by summing up the cells along the rows, it is possible to assess the impact of the project in terms of benefits. The use of the Task Force assessment framework is a possible approach to qualitatively capture the deployment merit of the project in a more systematic way.

When adding up all columns and rows of the whole deployment matrix (not reported here for the sake of brevity), the graphs in figures 9 can be obtained. The areas spanned in the service/functionality and benefit planes represent the deployment merit of the project: the larger the area in the graph, the higher the project impact.



(a)



(b)

Figure 9- Project impact across services (a) and benefits(b)

The approach presented in figure 9 allows a qualitative evaluation of the impact of a project. It is also necessary to actually calculate the KPIs for a quantitative assessment of the impact of the project. Presently, within the Smart Grid Task Force, the JRC is working to test the KPIs proposed in ANNEX III on case studies, to come up with a list of calculation formulas, necessary data to be collected, guidelines to choose parameters and set assumptions.

The proposed approach is currently used at project level. More work is still needed to generalize it in order to assess the overall status and progress of Smart Grid deployment in Europe.

USA

At a high-level, DOE has described Smart Grid as exhibiting the six principal **characteristics** or functions reported in table III and detailed more extensively in annex II.

The US Department of Energy together with relevant stakeholders has identified a set of metrics for measuring progress toward implementation of Smart Grid technologies, practices and services, and thus toward the ideal Smart Grid possessing the six principal characteristics [US DOE, 2009a].

Two metrics have been identified: **Build Metrics** that describe attributes that are built in support of a Smart Grid and **Value Metrics** that describe the value that may derive from achieving a Smart Grid (see table IV and annex III). It should be noted that "value metrics" and "impact metrics" are used interchangeably in various DOE documents.

Table VI shows a map of how the 20 metrics support the 6 characteristics. The table indicates the characteristics where a metric is emphasized as "emphasis." The other characteristic cells where a metric plays an important role are indicated by "mention."

It is worth stressing that in Europe KPIs for the assessment of Smart Grids does not include Build-type metrics (e.g. Percentage of coverage of Smart Meters) but only Value-type metrics (e.g. Percentage of consumers on time of use pricing). The European approach focuses primarily on the Smart Grid outcomes, in line with the vision that a Smart Grid is a means to an end, not an end in itself [ERGEG, 2010].

	Metric Name	Enables Informed Participation by Customers	Accommodates All Generation & Storage Options	Enables New Products, Services, & Markets	Provides Power Quality for the Range of Needs	Optimizes Asset Utilization & Efficient Operation	Operates Resiliently to Disturbances, Attacks, & Natural Disasters
1	Dynamic Pricing (Build)	Emphasis	Mention	Mention			Mention
2	Real-Time Data Sharing (Build)					Mention	Emphasis
3	DER Interconnection (Build)	Mention	Emphasis	Mention			
4	Regulatory Policy (Build)			Emphasis			
5	Load Participation (Build)	Emphasis			Mention	Mention	Mention
6	Microgrids (Build)		Mention	Mention	Emphasis		
7	DG & Storage (Build)	Mention	Emphasis	Mention	Mention	Mention	Mention

8	Electric Vehicles (Build)	Mention	Mention	Emphasis			Mention
9	Grid-responsive Load (Build)	Mention	Mention	Mention	Mention		Emphasis
10	T&D Reliability (value)						Emphasis
11	T&D Automation (Build)				Mention	Emphasis	Mention
12	Advanced Meters (Build)	Emphasis	Mention	Mention			Mention
13	Advanced Sensors (Build)					Mention	Emphasis
14	Capacity Factors (value)					Emphasis	
15	Generation, T&D Efficiency (value)					Emphasis	
16	Dynamic Line Rating (Build)					Emphasis	Mention
17	Power Quality (value)			Mention	Emphasis		
18	Cyber Security (Build)						Emphasis
19	Open Architecture/Stds (Build)			Emphasis			
20	Venture Capital (value)			Emphasis			

Table VI –- Map of metrics to Smart Grid Characteristics

Moreover, as Smart Grid is built in the U.S., it will be important to collect information on the economic, reliability, environmental, and security benefits made possible by Smart Grid. Every two years, DOE prepares a Report to Congress on the status of Smart Grid deployment in the United States, and documents its impact. The report documents the number of Smart Grid technologies and systems and associated applications deployed in the U.S. since the last report [US DOE, 2012]. To the extent that analyses and results are available, the report documents impacts of the Smart Grid deployments including cost, reliability, power quality, environmental, security, safety, and other benefits. Many resources are used to collect this information, most notably SmartGrid.gov for ARRA projects and the Smart Grid Information Clearinghouse website (see chapter 3 for more details).

2.2 What has been built? What is the impact of Smart Grid projects?

Box 5. Measuring progresses in Smart Grid implementation programs

European Union

Goal: measuring progresses and resulting outcomes of EEGI implementation plan

- KPIs to measure progresses of the whole EEGI (1st level KPIs)
- KPIs to measure progresses in clusters of projects (2nd level KPIs)
- KPIs to measure progresses of individual projects (3rd level KPIs)

USA

Goal: measuring progresses and the resulting outcomes of DOE funded Smart Grid projects

Metrics to measure what has been built**: Build Metrics** [US DoE 2009b, 2010]

Metrics to measure outcome: **Impact Metrics** [US DoE 2009b, 2010]

In this section, we will consider the assessment framework of two important Smart Grid programs: the European Electricity Grid Initiative (Europe) and the American Recovery and Reinvestment Act Smart Grid program (USA).

The European Electricity Grid Initiative (EEGI) proposes a nine year European research, development and demonstration program to be initiated by grid operators to develop a Smart Grid for Europe by 2030 [EEGI, 2010].

The Smart Grid Investment Grant (SGIG) program is an electric grid modernization initiative funded through the American Recovery and Reinvestment Act of 2009 and focuses on the first large-scale buildout of smart grid in the US. The Smart Grid Demonstration Program is also funded through ARRA, and focuses on demonstrating the full complement of smart grid benefits and business case for smart grid investments.

In both the EU and US cases, an assessment framework has been defined, which aims at identifying in which area of the Smart Grid the project has taken place and at assessing the outcome of the implementation.

European Union

Assessing what has been implemented

The EEGI has defined a Smart Grid model identifying the critical building blocks of the Smart Grid system [EEGI, 2010]. The Smart Grid system has been divided into 5 different levels (see figure 10). Each level is then sub-divided into clusters (e.g. Smart customers, Smart Energy Management, Pan European Grid architecture) and each cluster is further sub-divided into functional project areas (e.g. active demand response, tools for pan-European network observability). Overall the EEGI Smart Grid model consists of 14 functional project areas at the transmission level, 12 functional project areas at the distribution level and 5 functional project areas at the interface of transmission and distribution (more details can be found in [EEGI, 2010])

In this framework, a mapping is in on-going to link European Smart Grid projects to clusters. Annex V reports the list of the clusters at distribution and transmission level. The provision of data by project coordinators is done on a voluntary basis.

The first step in the EEGI assessment framework is the labeling of suitable projects with an EEGI stamp. The labeling process consists in evaluating which projects suit the scope of the EEGI and in which area of the Smart Grid model they fit. A labeling procedure has been proposed but there are not yet officially labeled "EEGI projects". EEGI labeled projects will then be mapped into the different functional areas of the EEGI model.

Assessing the impact of Smart Grid projects and programs

For the evaluation of the impact of the EEGI program to advance the Smart Grid concept, three different set of KPIs have been envisioned (see figure 10). The level-3 KPIs assess the individual EEGI projects and are defined directly by individual project coordinators. The definition of project KPIs is still on-going and no proposals have been presented as yet.

Depending on their scope, the individual projects are then linked to the corresponding clusters. The level-2 KPIs then measure progresses in each cluster due to related projects. Progresses in each cluster in turn contribute to the overall impact of the EEGI program, which is captured by the level-1 KPIs (overarching KPIs). As the impact of the EEGI program should be assessed with respect to the pillars of the EU energy strategy (sustainability, security of supply and market integration), the overarching KPIs are being designed accordingly. For sake of clarity, some level-2 KPIs under discussion are reported in TABLE VII.

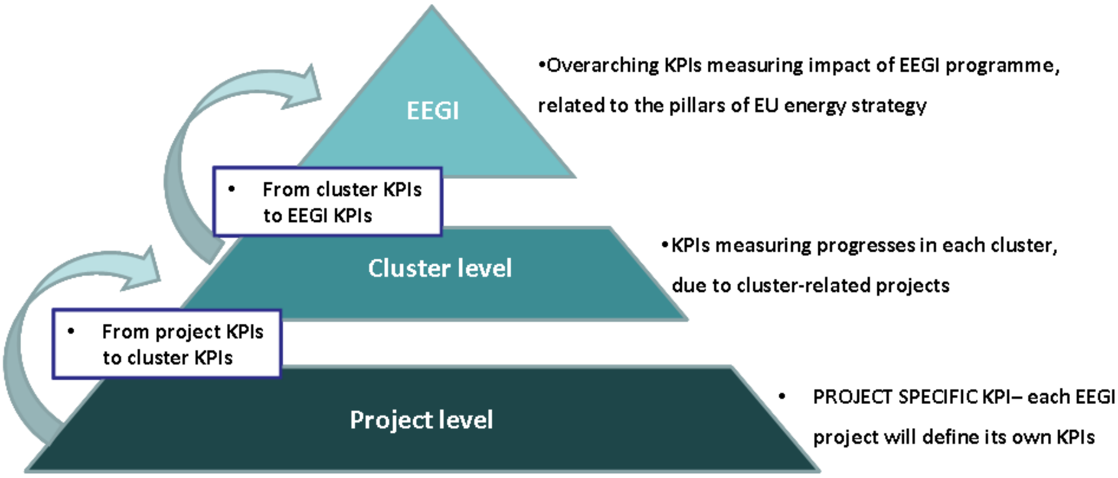


Figure 10 – Smart Grid model defined by the European Electricity Grid Initiative (EEGI)

The most crucial step is to scale-up project results to measure the contribution of projects to progresses in each cluster/functional area and in the Smart Grid system as a whole (see also section 2.4).

Cluster	Associated KPIs
Active Demand	• Percentage Peak load reduction (%) • Percentage reduction in energy consumption (%)
System integration of medium distributed energy resources (DER)	• Increased network hosting capacity for distributed energy resources (DER) in MV distribution networks (%) • Percentage reduction in out of band voltage variations in MV lines, as defined in EN 50160 standard (%) • Percentage reduction in energy not supplied from DER in distribution networks due to improved network conditions (%)

Table VII –-Some KPIs defined to measure progresses in EEGI clusters

USA

The DOE has sponsored the Smart Grid Investment Grants and Smart Grid Demonstration Projects and provided a methodology for the assessment of the program. The methodology aims at assessing what has been built and what has been the outcome. Accordingly, two types of metrics have been defined: build and impact metrics.

Assessing what has been implemented

As briefly shown in section 1.3, the SGIG projects are classified according to six different project categories: advanced metering infrastructure, customer systems, electric system distribution, electric transmission systems, equipment manufacturing, integrated and/or cross-cutting systems.

Build metrics refer to the monetary investments, electricity infrastructure assets, policies and programs, marketplace innovation and jobs that are part of Smart Grid projects (see table VIII).

These Build Metrics represent a portion of the Smart Grid Build Metrics defined in section 2.1, as they are related to the scope of the projects. DOE requests project teams to report on Build Metrics that are funded outside the Smart Grid program. This information is required for subsequent updates of the DOE Smart Grid system report [US DOE, 2009a].

Metric Type	Description
Monetary Investments	Total project costs (DOE plus private cost share) by category and smart grid classification
Electricity Infrastructure Assets	Transmission and distribution equipment and energy resources that, when assembled together, comprise smart grid project equipment
Policies and Programs	Policies and programs that determine the commercial and operational rules for utilities and their customers (e.g. pricing programs)
Job Creation	New jobs created and retained as a result of projects by category and smart grid classification
Marketplace Innovation	New products, services and programs associated with projects by category and smart grid classification

Table VIII –-Build Metric definitions for DOE-sponsored Smart Grid programs

Assessing the impact of Smart Grid projects and programs

Impact metrics refer to Smart Grid capabilities enabled by projects and the measurable impacts of Smart Grid projects that deliver value. They measure how, and to what extent, a smarter grid is affecting grid operations and performance, or how it is enabling customer programs and behaviour changes.

Table IX reports some of the build and impact metrics defined in [US DOE 2009b, 2010].

Build Metrics	Impact Metrics
Number of substation employing advanced sensors, communications, information processing or actuators	Load data and electricity cost by customer class, including tariff
The amount of DG installed as part of the project	Transmission line loads for those lines involved in the project
Number of appliances/devices that can be controlled or receive pricing data	Hourly feeder load (active and reactive) for those feeders involved in the project
Program information by customer class (e.g. real-time pricing)	The new distribution capacity deferred as a result of Smart Grid information or operation
Retail tariff that pays DER owners for electricity produced and exported	Electricity losses of infrastructure within the project scope
Number of services, customers with access, customers adopting	MWh of electricity produced by renewable sources
Number of pricing programs, customers with access, customers participating	MWh of electricity produced by distributed sources

Table IX –-Some metrics defined to measure progresses in DOE-sponsored Smart Grid projects

In its ARRA projects, DOE plans to report results of individual projects for Smart Grid Demonstration Programs (SGDPs) and aggregate results for SGIGs. For both SGDPs and SGIGs, there may be opportunities to analyze and report aggregated results across multiple projects that are aligned with common Smart Grid functions and benefits. Examples would include consumer behaviour studies, peak loading shaving, demand response, conservation affects of home area networks, distribution automation, energy storage, outage management, billing practices, and generation cycling to backfill variable renewables when their generation is not ample to meet load. Figure 11 summarizes the appraisal framework of ARRA programs and projects.

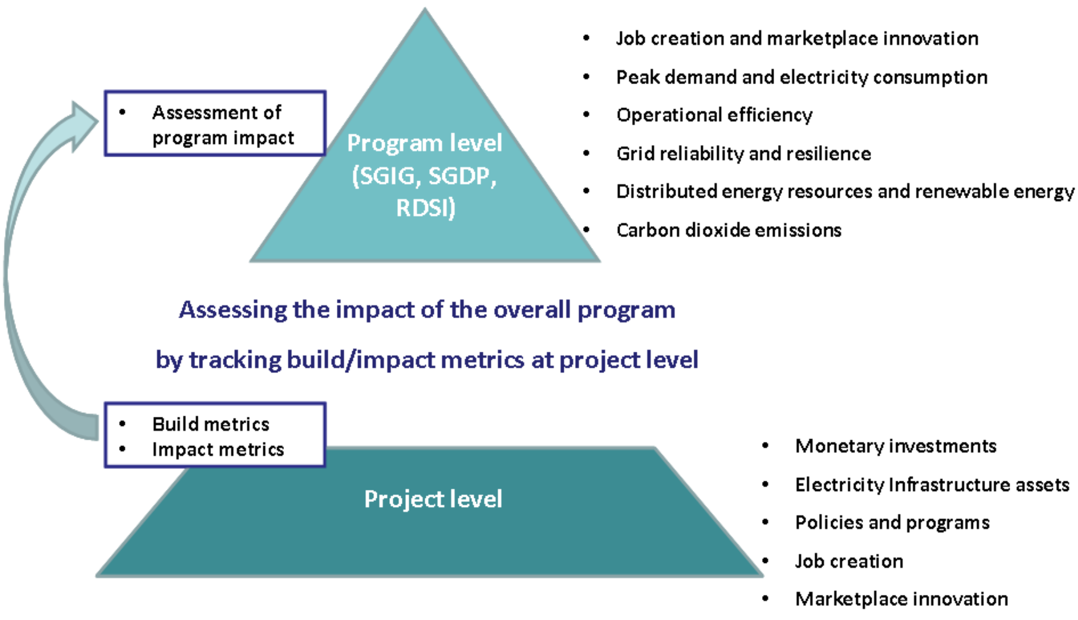


Figure 11- Appraisal of ARRA programs and projects

2.3 Cost-benefit analysis - Which Smart Grid solutions are profitable? For whom?

In 2010, EPRI and the DOE have developed the first comprehensive cost-benefit methodology for Smart Grid projects [EPRI, 2010]. Building on the work by EPRI, the JRC has recently published a set of guidelines for conducting cost-benefit analysis of Smart Grid projects [EC 2012a, 2012b]. More details on CBA initiatives in US and in Europe are reported in box 6.

In the following we will briefly present the EPRI methodology (a summary is in box 7) and illustrate the work currently undergoing in Europe and in the US on cost-benefit analysis.

Box 6. Initiatives on cost benefits analysis

European Union

In 2012, the JRC published guidelines for conducting cost-benefit analysis of smart grid projects and of smart metering deployment [EC 2012a, 2012b]. The proposed assessment framework builds on the EPRI methodology. A European case study (INOVGRID project in Portugal) was used to test and illustrate the proposed approach.

On the basis of the JRC guidelines [EC 2012a, 2012b], the Commission is presently carrying out a benchmarking of the CBAs of national smart metering roll-outs of European Member States. The analysis follows the EC recommendations adopted in March 2012 [EC 2012c], which required Member States to carry out a CBA of their smart metering roll-outs. A benchmarking report is expected in the second half of 213.

USA

√ -Publication of cost-benefit methodology of Smart Grid project [EPRI, 2010]

√ -Computational tool for CBA

√ Computational tool for CBA of energy storage contributions in a smart grid system (draft)

http://www.smartgrid.gov/recovery_act/program_impacts/assessing_benefits

DOE will need to identify with one of its ARRA project recipients or possibly an EPRI project to evaluate use of the Smart Grid computational tool in determining cost and benefits. Criteria for selection of a U.S. project for case study will include timeframe for collection of field data and diversity of smart grid equipment and applications.

Box 7. Cost benefits analysis – DOE/EPRI methodology

Steps

1 Identification of benefits

Definition of assets (e.g. smart meter)

Mapping assets into functions/functionalities (e.g. remote reading)

Mapping functions/functionalities into benefits (e.g. reduced costs for meter reading)

2 Quantification and monetization of benefits

3 Quantification of costs

4 Comparison of costs and benefits

5 Identification of beneficiaries and allocation of benefits

Benefits and beneficiaries The DOE-EPRI cost and benefits methodology [EPRI, 2010] attempts to allocate benefits to the utility, consumers, and society. Not all stakeholders will benefit from the Smart Grid equally, but for Smart Grid to be successful and accepted, all stakeholders should benefit to varying degrees.

Utilities will benefit from Smart Grid through improved operations including more accurate and automated metering and billing, better outage management, reduced electrical losses, better asset utilization, improved maintenance, and improved planning processes. Consumers will benefit through more reliable service, reduced businesses losses, potential bill savings, reduced transportation costs through electric vehicles, and ability to access real-time information with options to control their electrical use. Society will benefit from the Smart Grid by reducing import of crude oil by transportation electrification, improving the security of electricity delivery, and reducing environmental emissions by enabling more renewable energy resources. Smart Grid represents an opportunity to create new domestic jobs for design, construction, operation and maintenance of Smart Grid; for manufacturing Smart Grid components, and for providing Smart Grid services. Smart Grid is a vital component that enables U.S. companies and economy to compete in the global marketplace.

DOE-EPRI assessment framework DOE's metrics and benefits analytical framework will link Smart Grid technologies deployed or leveraged under DOE's Smart Grid projects to up to 25 benefits accrued by three stakeholder groups (i.e., utility/ratepayer, consumer, and society). The cost-benefit analysis weighs the investment costs against project benefits. For this analysis, benefits should represent a concrete value or impact of the projects.

The framework asks several key questions (Fig. 12):

- What is the technology? (i.e., “Assets”)
- What does the technology do? (i.e., “Functions” or “Storage Applications” for energy storage technologies)
- How does it do that? (i.e., “Mechanisms (Impacts)”)
- What goodness results? (i.e., “Benefits”)
- What is the goodness worth? (i.e., “Monetary Value”)

The methodology defines the steps to identify and quantify the benefits of a Smart Grid project. After identifying the assets, it is necessary to map the assets into functions (figure 13). Once the functions have been identified, they are mapped into benefits (figure 14), which are then quantified and monetized and compared with costs.

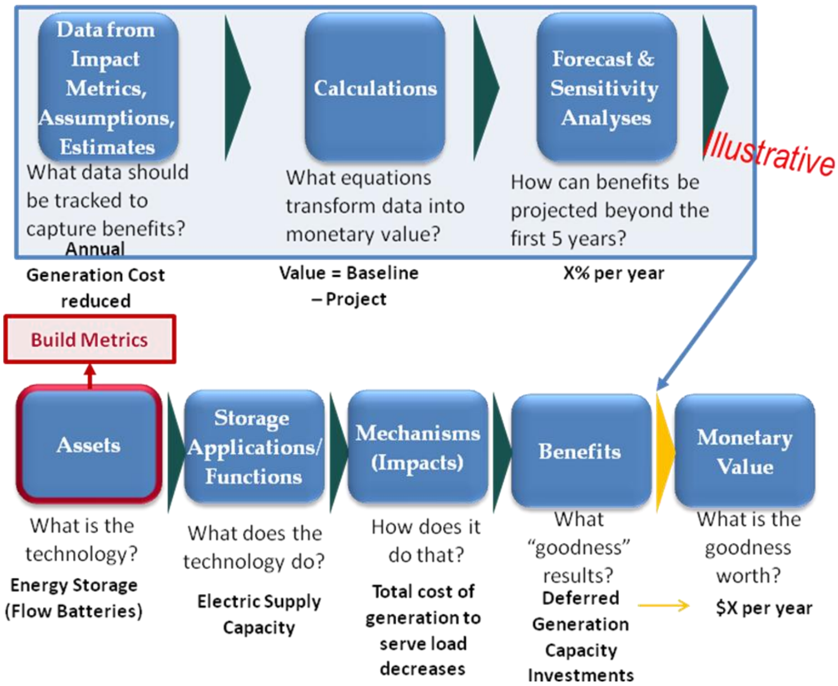


Fig. 12. Smart Grid Metrics and Benefits Analytical Framework

Smart Grid Assets	Functions												
	Fault Current Limiting	Wide Area Monitoring, Visualization, and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder Switching	Automated Islanding and Reconnection	Automated Voltage and VAR Control	Diagnosis & Notification of Equipment Condition	Enhanced Fault Protection	Real-Time Load Measurement & Management	Real-time Load Transfer	Customer Electricity Use Optimization
Advanced Interrupting Switch										•			
AMI/Smart Meters								•			•		•
Controllable/Regulating Inverter							•	•					
Customer EMS/Display/Portal													•
Distribution Automation					•	•	•	•				•	
Distribution Management System			•		•	•	•	•			•	•	
Enhanced Fault Detection Technology										•			
Equipment Health Sensor			•						•				
FACTS Device				•									
Fault Current Limiter	•												
Loading Monitor			•						•			•	
Microgrid Controller							•						
Phase Angle Regulating Transformer				•									
Phasor Measurement Technology		•	•	•	•		•	•		•			
Smart Appliances and Equipment (Customer)													•
Software - Advanced Analysis/Visualization		•	•										
Two-way Communications (high bandwidth)		•			•	•	•	•			•	•	
Vehicle to Grid Charging Station													•
VLI (HTS) Cables				•									

Fig. 13. Smart Grid Assets Mapped to Functions

Benefits			Functions													Energy Resources		
			Fault Current Limiting	Wide Area Monitoring, Visualization, and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder Switching	Automated Islanding and Reconnection	Automated Voltage and VAR Control	Diagnosis & Notification of Equipment Condition	Enhanced Fault Protection	Real-Time Load Measurement & Management	Real-time Load Transfer	Customer Electricity Use Optimization	Distributed Generation	Stationary Electricity Storage	Plug-in Electric Vehicles
Economic	Market Revenue	Arbitrage Revenue															•	
		Capacity Revenue															•	
		Ancillary Services Revenue															•	
	Improved Asset Utilization	Optimized Generator Operation		•													•	•
		Deferred Generation Capacity Investments													•	•	•	•
		Reduced Ancillary Service Cost		•						•			•		•	•	•	•
		Reduced Congestion Cost		•	•	•									•	•	•	•
	T&D Capital Savings	Deferred Transmission Capacity Investments	•	•	•	•									•	•	•	•
		Deferred Distribution Capacity Investments			•								•	•	•	•	•	•
		Reduced Equipment Failures	•		•						•	•						
	T&D O&M Savings	Reduced Distribution Equipment Maintenance Cost									•							
		Reduced Distribution Operations Cost						•		•								
		Reduced Meter Reading Cost											•					
	Theft Reduction	Reduced Electricity Theft											•					
	Energy	Reduced Electricity Losses								•			•	•	•	•	•	
	Electricty Cost Savings	Reduced Electricity Cost													•	•	•	•
Reliability	Power Interruptions	Reduced Sustained Outages					•	•	•		•	•	•			•	•	•
		Reduced Major Outages		•					•				•	•				
		Reduced Restoration Cost					•	•			•	•						
	Power Quality	Reduced Momentary Outages										•					•	
		Reduced Sags and Swells										•					•	
Environmental	Air Emissions	Reduced CO_2 Emissions				•		•		•			•		•	•	•	•
		Reduced SO_x, NO_x, and PM-2.5 Emissions				•		•		•			•		•	•	•	•
Security	Energy Security	Reduced Oil Usage (not monetized)						•			•		•					•
		Reduced Widescale Blackouts		•	•													

Fig. 14. Benefits Mapped to Functions and Energy Resources

European Union

The Directive on the internal markets 2009/72/EC [European Union, 2009] encourages Member States to deploy Smart Grids and smart metering systems (article 3). Such deployment might be subject to long term CBA, as mentioned in the ANNEX I of the Directive.

In 2011, the EC Communication on Smart Grids [EC, 2011a] explicitly stated that the Commission intends to come up with guidelines on the CBA to be used by the Member States to fulfil the provisions in the Annex 1 of Directives 2009/72/EC and 2009/73/EC for the roll-out of smart metering systems. The Communication also stated that the Commission intended to release guidelines for a CBA for the assessment of Smart Grid deployment.

In this context, the JRC has recently published a set of guidelines to perform cost-benefit analysis of Smart Grid projects and of smart metering deployment [EC 2012a, 2012b].

The proposed approach to CBA is composed of three main parts (see figure 15):

- definition of boundary conditions (e.g. demand growth forecast, discount rate, local grid characteristics) and of implementation choices (e.g. roll-out time, chosen functionalities)
- identification of costs and benefits
- sensitivity analysis of the CBA outcome to variations in key variables/parameters

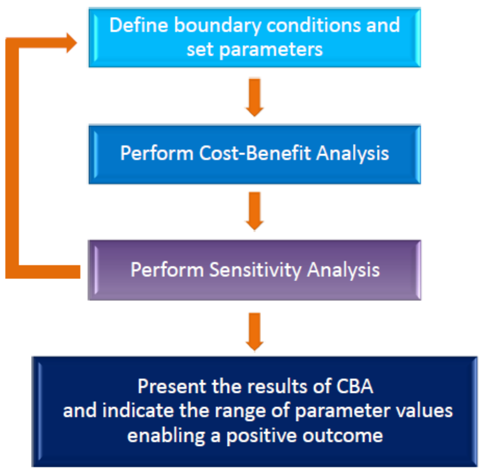


Figure 15 JRC general approach to CBA

For the identification of costs and benefits, the JRC has adapted the EPRI methodology and proposed a number of modifications to fit the European context [EC 2012a, 2012b].

It is worth mentioning that in steps 2 (*Identify the functions*) and 4 (*Map each function onto a standardized set of benefit types*) of the original EPRI methodology [EPRI, 2010], EPRI functions have been replaced by (European) functionalities [EC Task Force for Smart Grids, 2010a]. It is worth stressing that functions and functionalities cannot be directly compared. Functions have a very strong technical dimension (e.g. fault current limiter, Feeder Switching). Functionalities represent more general capabilities of the Smart Grid and do not focus on specific technology. They provide an intuitive description of what the project is about. This may help project coordinators to identify the key capabilities of the projects and hence the resulting benefits. The JRC methodology considers the use of functionalities as a useful tool to assess in which areas of the Smart Grid the project is contributing to and identify benefits and impacts. The mappings of assets on to functionalities and of functionalities on to benefits are reported in figures 16 and 17 respectively.

FUNCTIONALITIES

ASSETS	Integrate users with new requirements				Enhancing efficiency in day-to-day grid operation						Ensuring network security, system control and quality of supply						Better planning of future network investment			Improving market functioning and customer service								More direct involvement of consumers in their energy usage					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
EDP Box	•	•	•	•	•	•	•			•	•	•	•			•	•		•	•		•	•		•	•	•	•	•	•	•		•
HAN Module																						•			•			•		•	•		•
Distribution Transformer Controller (DTC)	•	•	•	•	•	•	•		•	•	•	•	•		•	•	•		•	•	•	•	•					•	•				
DTC Cell Module			•		•																												
DTC Power Quality Module		•	•			•	•	•		•									•														
InovGrid Infrastructure Management	•	•	•	•			•	•	•	•	•	•	•	•	•	•		•	•	•		•	•	•	•	•	•	•	•	•			•
Meter Data Management (MDM)		•		•	•	•	•	•	•	•	•	•	•		•	•	•	•	•		•			•				•	•	•			•
Energy Data Management (EDM)							•		•											•	•			•									
DSO Web Portal	•	•																		•	•	•	•	•	•			•	•	•	•	•	•
Supervision Module		•	•	•	•	•	•	•		•					•			•	•														
Meter Asset Management (MAM)								•										•											•				
Distribution Management System (DMS)		•	•	•	•	•	•	•		•	•	•		•	•				•														

Figure 16: Map each asset on to the functionalities it provides.

FUNCTIONALITIES

BENEFITS	Integrate users with new requirements				Enhancing efficiency in day-to-day grid operation						Ensuring network security, system control and quality of supply						Better planning of future network investment			Improving market functioning and customer service								More direct involvement of consumers in their energy usage					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Optimised Generator Operation																	•																
Deferred Generation Capacity Investments																									•					•			
Reduced Ancillary Service Cost			•			•				•																							
Reduced Congestion Cost																																	
Deferred Transmission Capacity Investments																									•								
Deferred Distribution Capacity Investments						•	•	•								•		•	•		•				•					•			
Reduced Equipment Failures						•	•	•										•	•														
Reduced Distrib. Equipment Mainten. Cost								•										•											•				
Reduced Distribution Operations Cost					•			•																					•				
Reduced Meter Reading Cost																												•	•				
Reduced Electricity Theft									•						•									•				•					
Reduced Electricity Losses			•			•	•	•	•	•		•	•				•		•	•	•			•						•			
Detection of anomalies in Contracted Power							•																										
Reduced Electriciy Cost								•				•										•			•			•	•				
Reduced Sustained Outages			•	•	•			•					•				•			•													
Reduced Major Outages					•									•																			
Reduced Restoration Cost					•	•	•																						•				
Reduced Momentary Outages					•	•	•																						•				
Reduced Sags and Swells						•	•																										
Reduced CO_2 Emissions	•	•				•	•	•	•	•		•					•		•			•	•		•			•	•	•	•	•	
Reduced SOx, NOx, and PM-10 Emissions	•	•				•	•	•	•	•		•					•		•			•	•		•			•	•	•	•	•	
Reduced Oil Usage	•	•				•	•																•					•	•				
Reduced Wide-scale Blackouts																																	

Figure 17: Map each functionality on to a standardised set of benefit types.

In setting up the JRC guidelines for the CBA, the more general target is an economic-oriented CBA of Smart Grid projects, which goes beyond the costs and the benefits incurred by the actor/s carrying out the Smart Grid project. The JRC guidelines ultimately aim at taking a societal perspective in the CBA, considering the project's impact on the entire value chain and on society at large.

The economic analysis takes into account all costs and benefits that can be expressed in monetary terms, considering a societal perspective. In other words, the analysis tries to include all costs and benefits that spill over the Smart Grid project into the electricity system at large (e.g. enabling the future integration of distributed energy resources, impact on electricity prices and tariffs etc.) and into society at large (e.g. environmental costs).

A European Smart Grid project (InovGrid, led by the Portuguese distribution operator EDP Distribuição) has been selected from the JRC Smart Grid project inventory [EC 2011b] and used as a case study to fine-tune and illustrate the proposed assessment framework. To the best of our knowledge, this is the first study to actually test a CBA methodology on a concrete Smart Grid case study.

Cost-Benefit analysis - Social Impact

The proposed CBA approach recognizes that the impact of Smart Grid projects goes beyond what can be captured in monetary terms. Therefore, the overall assessment approach (see figure 18) aims at integrating an economic analysis (monetary appraisal of costs and benefits on behalf of society) and a qualitative impact analysis (non-monetary appraisal of non-quantifiable impacts and externalities, e.g. social impacts, contribution to policy goals).

Due attention is presently paid to the inclusion of an assessment of the social impact into the cost-benefit methodology. In adapting the CBA on European case studies, the JRC is also currently exploring ways to better detail the qualitative analysis on possible social impacts such as employment, safety and compliance of third parties to safety.

Another key point of focus needs to be the adaptation and learning curve of users in their transformation into "smart prosumers" (e.g. compare with the Smart Grid service "More direct involvement of consumers in their energy usage" introduced in section 2.1). One possible idea is to collect anecdotal information from all relevant stakeholders in order to come up with a set of guidelines for Member States for the assessment of social implications of Smart Grid projects.

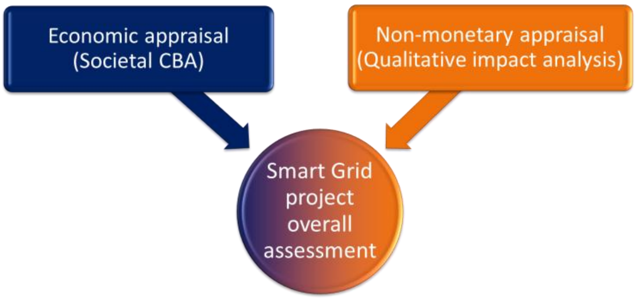


Figure 18 JRC economic assessment framework of Smart Grid projects, including economic and qualitative appraisals

We remark that the "qualitative impact analysis" part of the JRC assessment framework is conceptually similar to step 3 of the original EPRI methodology (*Assess the principal characteristics of the Smart Grid to which the project contributes*) [EPRI, 2010]. This step is intended to measure the smartness of a Smart Grid project and to assess the merit of its deployment (in non-monetary terms).

USA

The US Department of Energy (DOE) is tracking "Assets" via build metrics reporting by projects (see section 2.2), which includes monetary investments (i.e., installed equipment costs), the creation and retention of jobs, and Smart Grid technologies and pricing programs (grouped under the categories of Advanced Metering Infrastructure, Customer Systems, Pricing Programs, Distributed Energy Resources, Distribution, and Transmission).

DOE is tracking "Mechanisms (Impacts)" via impact metrics reporting by projects (see section 2.2), which include metrics that measure how and to what extent the project is affecting grid operations and performance, or how it is enabling customer programs. For example, a project might show a reduction in truck rolls by implementing automated feeder switching. Another project might show a drop in peak demand from a real-time pricing program.

Projects will report both baseline and project and system-level build and impact metrics. Baseline should reflect the parameter values without the DOE Smart Grid Program project, analogous to "business as usual" in a business case analysis. For example, baseline could be established using historical performance data on the feeder(s) or data collected on the feeder(s) during the project prior to the operation of the Smart Grid technologies. Project-level metrics pertain to the project-funded technologies and the impact of those technologies on operations in the demonstration area(s). System-level metrics pertain to technologies that already exist or are being installed in a project separate from the DOE Smart Grid Program, or impacts from project-funded technologies that extend beyond the demonstration area(s) into the broader utility system. For example, a project demonstrates power flow control by installing FACTS devices funded by the DOE Smart Grid Program and using existing phase angle regulating transformers. The project should capture FACTS devices under project-level and phase angle regulating transformers under system-level.

Furthermore, for energy storage-specific projects, DOE will be tracking energy storage applications, which include specific technical considerations such as minimum discharge duration, and the following system performance information:

- System Characteristics—profile of the system such as footprint and energy density
- Data Measurements—storage system measurements and recordings such as battery system state of charge and import/export energy signals
- System Performance Parameters—technical, economic, and environmental health & safety (EHS) performance characteristics that will be measured or calculated during the project such as round-trip efficiency and operating temperature
- Projected Performance Parameters—performance characteristics that will require extrapolating or forecasting based on data collected during the demonstration such as long-term capacity degradation and cycle life

Smart Grid Computational Tool

As mentioned, DOE has identified and mapped key Smart Grid "Assets" to 13 "Functions" that may be enabled by Smart Grid (Fig. 13). The "Functions" and three energy resources have then been mapped to 25 Economic, Reliability, Environmental, and Security "Benefits" (Fig. 14).

In order to quantify these benefits (i.e., "Monetary Value"), DOE has supported the development of a Smart Grid Computational Tool to streamline the evaluation of DOE-funded projects. The tool guides project coordinators to input data and to calculate project performance metrics. DOE encourages project recipients to use the computational tool, but does not mandate it. There is an expectation that recipients will identify ways to improve the computational tool including addition of more algorithms, optional calculation approaches and modifications to existing algorithms. Focus will be on identifying one or more SGDP projects to serve as case studies since the SGDPs typically include more smart grid functionally than the SGIGs.

This tool identifies, organizes, and processes the inputs (e.g., "Assets", "Functions", "Mechanisms (Impacts)", and "Benefits") required to analyze a project. For example, the "Function" of Enhanced Fault Protection can realize a "Benefit" of Reduced Equipment Failures through the following calculation: ($) = Capital Replacement of Failed Equipment ($) * Portion of Failed Equipment Caused by Fault Current or Overloaded Equipment (%). The tool can also perform Net Present Value and sensitivity analyses [NETL 2010, NETL 2011].

The DOE ARRA projects have just begun to use the Smart Grid computational tool to input data to calculate the metrics and benefits of various Smart Grid applications being demonstrated or deployed in the projects. In most cases, the input data for the Smart Grid computational tool will require analysis and conversion of field data to a form that is suitable for input for the computational tool. Two samples of metrics and benefits calculations enabled by the computational tool are included below.

Sample Calculation #1 - Customer Savings from Reduced Sustained Outages

In this sample calculation, the benefit is a reduction in costs to the customer as a result of improved reliability. The metric is reduction of SAIDI from 1.0033 to 0.92 hours per year and the value of the cost reduction is $342,000 per year distributed over one million residential, commercial, and industrial customers.

Algorithm:

**Value ($)** = Σ{ [SAIDI * Total Customers Served within a class (#) * Average Hourly Load Not Served During Outage per Customer by class (kW) * VOS by class ($/kWh)]$_{\text{Baseline}}$ - [SAIDI * Total Customers Served within a class (#) * Average Hourly Load Not Served During Outage per Customer by class (kW) * VOS by class ($/kWh)]$_{\text{Project}}$}

Inputs:

SAIDI (Baseline Value) = 1.0033 hours

SAIDI (Project Value) = 0.92 hours

Total Customers Served within the Residential class = 1,000,000

Total Customers Served within the Commercial class = 10,000

Total Customers Served within the Industrial class = 1,000

Average Hourly Load Not Served During Outage per Customer (Residential) = 1.3 kW

Average Hourly Load Not Served During Outage per Customer (Commercial) = 8.9 kW

Average Hourly Load Not Served During Outage per Customer (Industrial) = 150 kW

Value of Service (VOS) (Residential) = 2.50 $/kWh

VOS (Commercial) = 10.00 $/kWh

VOS (Industrial) = 25.00 $/kWh

Value: $342,000/Year

Sample Calculation #2 - Reduced Meter Reading Cost

In this sample calculation, the benefit to the electric service provider is reduced cost for reading meters and the value is a savings of $17,500,000 per year. The input data is the cost of labor and equipment to take meter readings.

Algorithm:

Value ($) = $[\text{Meter Operations Cost } (\$)]_{\text{Baseline}}$ - $[\text{Meter Operations Cost } (\$)]_{\text{Project}}$

Inputs:

Meter Operations Costs (Baseline Value) = $22,900,000

Meter Operations Costs (Project Value) = $5,400,000

Value: $17,500,000/Year

Cost-Benefit analysis - Social Impact

In addition to quantifying and monetizing performance of the Smart Grid and impacts to consumers and society, it is important to record observations and reactions to Smart Grid from utility workers (e.g., planners, designers, operators, and maintenance crews), consumers, regulatory commissioners, and other stakeholders. There is a need to understand how Smart Grid has improved or worsened the ability of utility workers to perform their jobs and how Smart Grid has impacted the convenience, comfort, and electricity bills for consumers. In fact, several of the Smart Grid Investment Grant (SGIG) projects have volunteered to participate in consumer behaviour studies on dynamic pricing to better understand how Smart Grid technology, education and dynamic pricing affect consumer behaviour. Often, these observations will reveal unintended consequences of Smart Grid – both good and bad. There is a need to develop a structured approach to solicit, collect, analyze, and disseminate these observations. Examples of structured approaches include surveys and interviews.

In addition to observations of impact to stakeholders, the U.S. is attempting to identify and determine societal impacts of smart grid including conversion of some social benefits to monetary values (e.g., environmental impact, job creation). In addition, there will be societal impacts that are real, but difficult to calculate and monetize, such as public safety, national security, and economic development. These benefits may be identified and collected as anecdotal information.

2.4 Scaling up project results

Both the EU and US need to develop and implement approaches to scale the data and results from individual projects and sets of projects to larger scale. This will require development of methodologies, assumptions, and calculation methods that are grounded in experience and knowledge so that scaling results are credible. These scaling results could be used to business planning and investment strategies regarding the future of electric power systems. Scaling is a good opportunity for EU and US to collaborate in development of approaches.

European Union

KPI framework proposed by the EC Task Force – No discussion as yet on a scaling-up framework based on the merit deployment matrix introduced in section 2.1.

KPI framework proposed by the EEGI - Concerning the scaling up of 2nd level KPIs to 1st level KPIs a systemic approach is foreseen. A European network model will be employed to assess the effective contribution of 2nd level KPIs to first level KPIs at European scale. Discussions are still on-going. One challenge is to define KPIs that capture progresses after R&D/Demo projects of the EEGI program, rather than capturing potential progresses deriving from large scale deployment. It is also under discussion how to ensure the scalability of individual project results to larger areas and the extrapolation of individual project results to different European regions.

Cost Benefit analysis [EC 2012a, 2012b] – At present, there is not an agreed framework to extrapolate results of the CBA of individual projects.

USA

There is still not an agreed approach to take individual project results and use them to estimate benefits if applied to a larger portion of the grid. However, similar to previous grid modelling work, project results might be extrapolated to an appropriate number of similar circuits for which the technologies and results would be applicable. For example, the characteristics could be described for a limited number of transmission and distribution circuits in United States. Project results could then be extrapolated to circuits with similar characteristics to circuits used within the project.

3 MAKING THE MOST OF SMART GRID PROJECT RESULTS: DISSEMINATION AND SHARING

Several initiatives are on-going both in the EU and US to enhance the dissemination and sharing of Smart Grid project results, lessons learned and best practices. Box 8 reports a summary of some of the institutional resources for dissemination and sharing.

Box 8. Smart Grid resources for dissemination and sharing

European Union

JRC Smart Grid project repository: JRC-IET mapping (http://ses.jrc.ec.europa.eu);

This database acts as a single repository of Smart Grid projects in Europe. Updated versions of the database are periodically published to be used by different users.

Smart Grid dissemination platform: www.smartgridsprojects.eu

An interactive map linked to the JRC Smart Grid database has been set-up which provides an overview of the smart grids development in Europe. It contains the most up-to-date information regarding smart grids projects in individual EU member states and at European level.

US

Smart Grid project Repository: Virginia Tech Clearinghouse (http://www.sgiclearinghouse.org/); National Renewable and Energy Laboratory (www.smartgrid.gov)

DOE (http://energy.gov/oe/technology-development/smart-grid)

European Union

The JRC inventory exercise described in section 1.3 has highlighted a number of important learning points about dissemination and sharing of Smart Grid results and experiences.

- √ Caution in sharing quantitative data and lessons learned --As the majority of projects shared information on a voluntary basis, confidentiality of data and reluctance to share unsuccessful results hindered the quantity of the data received. There is a clear role for institutional actors to guarantee confidentiality of data and unbiased analysis.
- √ Lack of a common framework for data sharing and analysis –Carrying out a comprehensive and detailed mapping of Smart Grid projects in Europe proved challenging. The difficulties encountered during the data collection process suggest the need for improvements in data collection/exchange. These include a common structure for data collection in terms of

definitions, terminology and categories and strengthening project repositories at the national and European level.

- √ Fragmentation of initiatives for sharing project results – There is the need to keep track and to coordinate initiatives on Smart Grids and to exchange data and results. On the ground of the positive experience of the Smart Grid project mapping exercise, JRC sees the value of institutional actors to act as reference points for several stakeholders and avoid duplication and fragmentation of initiatives.

Current initiatives

In this context, the goal of the JRC is to set-up an open platform for the collection and dissemination of project information throughout Member States, international organizations and energy players. To this end, the JRC has prepared an on-line form (available at http://ses.jrc.ec.europa.eu) to collect information from Smart Grid project coordinators and expand the inventory of Smart Grid projects (presented in chapter 1) on an on-going basis.

Collected data will be checked for consistency and included in the European Smart Grid project database, which acts as the single repository of European Smart Grid projects. The JRC will then regularly publish an updated version of the database (all financial/economic information will be treated confidentially and only aggregated data will be published) to be used by different users (institutional, industrial etc.) (see figure 19). All users are encouraged to contribute to the mapping exercise.

An instrumental role is played by visualization platforms that map projects across Europe. The JRC, together with the European association of the electricity industry in Europe (EURELECTRIC), has set-up an interactive map of Smart Grids projects to provide the most up-to-date information regarding Smart Grids projects in individual EU member states and at European level (www.smartgridsprojects.eu). However, other players are encouraged to make use of the database to create their own visualization platform or to perform their own tailored analysis.

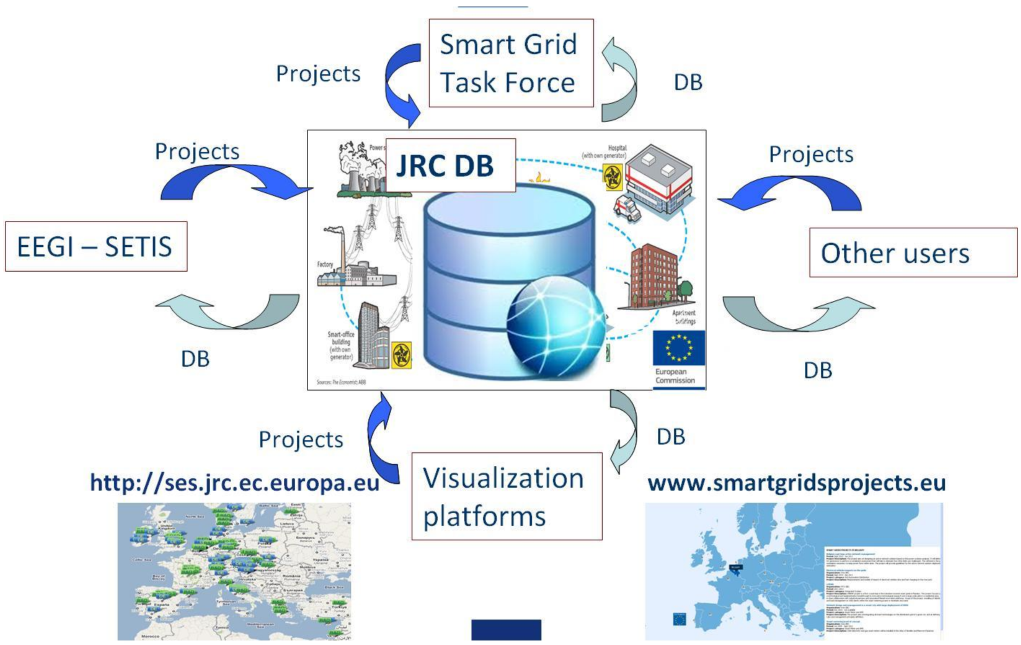


Figure 19 – JRC platform for the collection and dissemination of data and results of Smart Grid projects

As done with INOVGRID project, the JRC sees also a significant added value in selecting Smart Grid projects from the database and using them as case studies for dissemination or for testing Smart Grid assessment methodologies. Work in this area is on-going.

USA

The U.S. has established three primary websites for dissemination of Smart Grid information. The Smart Grid Information Clearinghouse, www.sgiclearinghouse.org, is managed by Virginia Tech Advanced Research Institute with assistance from the IEEE Power & Energy Society and EnerNex Corporation. The objective is to design, populate, manage and maintain a public Smart Grid Information Clearinghouse (SGIC) portal. Contents in the SGIC portal will include demonstration projects, use cases, standards, legislation, policy and regulation, lessons learned and best practices, and advanced topics dealing with research and development. The SGIC database will highlight the rapidly evolving opportunity to use electricity in an environmentally responsible way. It is envisioned that the SGIC portal will be the essential gateway that connects the smart grid community to the relevant sources of information that are currently scattered and distributed on the worldwide web. The portal will also direct its users to other pertinent sources or databases for additional data, case studies, etc. It will serve as a decision support tool for both state and federal regulators in their deliberations for rule-making and evaluating the impact of their investments in the smart grid technologies and software.

The second primary website for Smart Grid information is the Smartgrid.gov, www.smartgrid.gov which is managed by the National Renewable and Energy Laboratory. SmartGrid.gov is a resource for information about the Smart Grid and all Federal government-sponsored Smart Grid projects. It is the primary source for information on smart grid projects funded through the ARRA. The information on SmartGrid.gov helps consumers and stakeholders understand the basics of a Smart Grid and the range of Smart Grid technologies, practices and benefits. Title XIII of the Energy Independence and Security Act of 2007 sets forth the policy of the U.S: "to support the modernization of the nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure." The Act further stipulates initiatives for government programs to undertake in smart grid investments, including coordinated research, development, demonstration, and information outreach efforts.

The third primary website **(http://energy.gov/oe/technology-development/smart-grid)** is the smart grid section of the DOE Office of Electricity Delivery and Energy Reliability website. It includes information on smart grid R&D projects and all smart grid activities and events sponsored by DOE.

There are many challenges to the sharing and dissemination of Smart Grid information including currency of information, consistency of information, avoiding duplication of effort, promotion of key websites, proprietary and confidentiality issues, etc.

In addition to the websites, the US has magazines and newsletters that include many articles on Smart Grid. Examples include Smart Grid Today, Smart Grid News, Energy Central, Intelligent Utility, Utilities Fortnightly, and EnergyBiz among many others.

Role of case studies as dissemination means

DOE and EPRI plan to initiate case studies, lessons learned, and best practices to address key challenges of deploying Smart Grid. Some of the case studies may use field data from the DOE and EPRI Smart Grid demonstration and deployment projects. One purpose of this work is to interpret and summarize results and experiences in a way that is useful to future deployment of Smart Grid. Examples of possible Smart Grid case studies include value of demand response, effectiveness of customer education, and use of field results in development of business cases.

Two types of case studies are evolving from the DOE ARRA projects. The first type involves lessons learned and best practices on approaches to conduct Smart Grid demonstration and deployment projects, and the second type is focused on best practices and lessons learned from the ARRA projects that impact design, operation, and maintenance of the electric power system.

4 EU-US COOPERATION ON SMART GRID ASSESSMENT METHODOLOGIES- SUMMARY AND FUTURE WORK

In the following, we summarize the main discussion points that have been directly or indirectly brought up in the previous chapters and present concrete research questions which have been discussed at the EU-US meeting in November 2011 and will be further tackled in future joint EU-US work on Smart Grid assessment methodologies. Some key highlights are provided in box 10.

Mapping activities

The dissemination of information, results, best practices and lessons learned is of great value to bring together the Smart Grid community and support the Smart Grid transition. There is still a great room for improvement in the systematic collection, organization and dissemination of Smart Grid information. Items of common interest that deserve further discussion include:

√ Coordination of EU and US mapping exercises of Smart Grid projects, also with reference to the ISGAN framework[10]. As much as possible, ensuring consistency in terminology, project classification etc.

√ Harmonization efforts between the reporting templates of JRC and VirginiaTech, and links with the ISGAN mapping (ANNEX I of ISGAN work programme[11]). Definition of a minimum set of common data fields that can be seamlessly shared.

√ Clarify definition of large-scale and small-scale demonstrations

√ Clarify definition of R&D, demonstration and deployment projects

Extrapolation of project results

One of the most critical and complex steps in Smart Grid assessment is to extrapolate project results to infer a wide-scale picture of Smart Grid progress and possible benefits.

It has been agreed that further discussion should focus on possible approaches to scale-up project and meta-analyses result to larger control areas (e.g., a possible approach in the US will be based on typical circuit designs). For the US, examples of larger control areas could be additional customers within the service territory of the electric service provider; extrapolation of results to control areas with similar characteristics as the control area of the project; state-wide deployment based on state rules including amount of renewables, energy efficiency, and emissions; and ISO/RTO regions. For

10 http://www.iea-isgan.org/c/2/27

11 http://www.iea-isgan.org/c/2/27/28

the EU, examples of larger control areas include country-wide based on the country's electric policies and Transmission System Operator regions.

Project assessment

In this report, we have discussed differences and similarities between the European and the US approaches to performance assessment (KPI-based analysis) and cost-benefit analysis. Cooperation within the ISGAN framework (particularly ANNEX III of ISGAN work programme[12]) is also recommended.

Items of common interest that deserve further discussion include:

- √ How to capture non-quantifiable impacts (e.g. social/environmental impacts) and include them in the CBA?
- √ How to measure and analyze social impact? Is the use of anecdotal information (mainly about observations and trends) sufficient?
- √ How to collect and analyze performance feedback [NETL, 2011] from all stakeholders of electric power including, but not limited to, electric service providers, residential consumers, vendors, regulators, academia, research organizations, advocacy groups, and commercial and industrial businesses.
- √ Need to complement CBA with KPI analysis? How to combine them together? Exploration of multi-criteria analysis tools.
- √ Evaluate opportunity to adjust the Smart Grid computation tool (SGCT) to the European context (and possibly Energy storage computational tool-ESCT) to better reflect EU projects, goals, drivers, and metrics and benefits parameters.
- √ Cross-walk EEGI clusters to DOE focus areas (and identify possible correspondences)

Case-studies analysis

A consensus has emerged about the importance of using case studies to perform detailed analysis and to facilitate dissemination of the Smart Grid concept. This work should also take into account the on-going work conducted in ANNEX II of ISGAN work programme[13]. Specific items for further cooperation include:

- √ Evaluate opportunity for parallel case studies on consumer behaviour recognizing differences in drivers, regulations, demand, and supply, and different approaches to involve consumers.

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12 http://www.iea-isgan.org/c/2/27/30

13 http://www.iea-isgan.org/c/2/27/29

- √ Evaluate EU smart grid technology platform as possible approach to capture performance feedback.
- √ Need US projects, possibly from DOE and EPRI, to serve as case study(ies) for metrics and benefits analysis to parallel Inovgrid EDP project from Portugal [EC, 2011b]. Evaluate metrics and benefits methodology, calculations, and results; approach to collect best practices and lessons learned; benefit areas; and revisions to SGCT/ESCT

Other areas of common interest

Additional items of common interest that deserve further discussion include:

- √ Clarify market differences EU-US (unbundled vs bundled market) and highlight how assessment methodologies should reflect these differences
- √ Explore possible cooperation actions between this work on EU/US smart grid assessment framework and ISGAN work scope and annexes, as appropriate.

Box 9. EU and US initiatives - Highlights

The intent of Box 9 is to highlight some common ground where EU and US approaches to determining metrics and benefits of smart grid projects have strong similiarities.

Smart Grid definition

Use of the NIST Smart grid conceptual model as a basis for describing Smart Grid building blocks and use cases.

Strong similarity in the way the features of the ideal Smart Grid are defined (services in the EU, characteristics in the US). Differences lay only in the formulation, but the main expected features and functionality of the Smart Grid are the same.

Mapping of Smart Grid projects

Mapping Smart grid projects and tracking project results is on-going both in EU and US.

Joint mapping effort will be consolidated within the ISGAN framework, where a common database structure will be used to facilitate the sharing of project results and best practices.

Indicators

Project impact assessment: conceptual similarity between EU *KPIs* and US *outcome metrics.* Sharing lessons learned from the concrete evaluation of these indicators with field data (on-going work both in EU and US) will provide feedback over how to best formulate and calculate the indicators and will facilitate the sharing of project impacts.

Shared priority in EU and US: How to scale and to extrapolate project results? This is clearly an area of future cooperation.

Cost-benefit analysis

Both CBA approaches in EU and US are based on the DOE-EPRI methodology.

In EU, the CBA guidelines have already been applied to concrete case studies. In the US, testing of the CBA methodology on real case studies is also on the agenda.

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ANNEX I – SMART GRID PROJECT CATEGORIES

European Union

In 2011, the JRC used the following categories to group Smart Grid projects [EC 2011b]:

Smart Meter and advanced metering infrastructure

It includes projects which specifically address Smart Meter deployment.

Grid Automation Transmission

Include projects which refer to automation upgrades of the electricity grid (e.g. feeder automation, wide area monitoring etc.), at the transmission level.

Grid Automation Distribution

Include projects which refer to automation upgrades of the electricity grid (e.g. feeder automation, wide area monitoring etc.), at the distribution level.

Integrated System

It includes projects focusing on the integration of different Smart Grid technologies and applications (e.g. smart meter, demand response, grid automation, distributed storage, renewables, etc.).

Home application - Customer Behaviour

It includes projects which address new applications at home or directly involve consumers.

Specific Storage Technology Demonstration

It includes projects which address the potentialities of storage technologies both new and more conventional ones (e.g. hydro, chemical, mechanical).

Based on the feedback received from project coordinators, the JRC has redefined the list of categories for the Smart Grid project inventory. The new project categories are:

- ✓ **Smart Network Management**

  It focuses on the application automation and smart technologies to improve the network management at the distribution and the transmission level.

- ✓ **Integration of large scale RES**
- ✓ **Integration of large scale DER**
- ✓ **Aggregation (demand response, virtual power plant etc.)**
- ✓ **Smart Customer and Smart Home**

  This category is perfectly in line with the previous "Home application – Customer Behaviour"

- ✓ **Electric Vehicles and Vehicle2Grid applications**

USA (SGIG project categories) [US DOE, 2009b]

Equipment Manufacturing

Projects in this topic area produce or purchase smart grid systems, equipment, devices, software, or communications and control systems for modifying existing electric system equipment; building, office, commercial, or industrial equipment; consumer products and appliances; or distributed generation, demand response, or energy storage devices to enable smart grid functions.

Customer Systems

Projects in this topic enable the smart grid functions in buildings, facilities, and appliances and equipment on the customer side of the meter. These projects primarily involve adding smart grid functions to equipment and/or software applications including "smart" appliances and equipment, home area networks, building or facility management systems, distributed energy systems, demand response equipment, load control systems for lowering peak demand, energy storage devices, plug-in electric vehicles, and microgrids.

Advanced Metering Infrastructure

Advanced metering infrastructure (AMI) projects include the installation of smart meters that can facilitate two-way communication between consumers and utilities. Smart meters are able to measure, store, send, and receive real-time digital information concerning electricity use, costs, and prices that can be used to implement a range of customer service initiatives including dynamic pricing, demand response, load management, billing, remote connect/disconnect, outage detection and management, tamper detection, and other programs.

Electric Distribution Systems

Projects in this topic add smart grid functions to local electric distribution systems in retail electricity markets. Projects primarily involve adding smart grid functions to devices, equipment, and/or software applications including substations, transformer banks, feeder lines, pole-top transformers, and customer interconnection and communications systems. Projects in this area involve distribution automation systems; supervisory control and data acquisition (SCADA) systems; distribution monitoring, control, and optimization systems; load control systems for lowering peak demand; and electric distribution applications of distributed generation and energy storage equipment.

Electric Transmission Systems

Projects in this topic area are aimed at adding smart grid functions to the electric transmission systems in bulk power markets that typically involve power delivery over long distances including multi-state regions. Projects primarily involve adding smart grid functions to devices, equipment, and/or software applications such as phasor measurement units, phasor data concentrators, and visualization tools that use phasor or other data; other types of remote sensing, monitoring, data acquisition and retrieval equipment; planning and control room applications; advanced communications and interconnection systems; and retrofit of electric transmission systems with smart grid functions and capabilities.

Integrated and/or Crosscutting Systems

Integrated and/or crosscutting systems add smart grid functions to multiple portions of the electric system or integrating multiple smart grid capabilities. Projects in this topic area involve equipment and/or software applications that cover two or more of the above topic areas such as: AMI and electric distribution systems; customer systems and AMI; or electric transmission systems and electric distribution systems.

Consumer Behavior Studies

DOE is organizing a subset of SGIG projects to conduct statistically rigorous studies of consumer behaviour and demand response. These projects include applications of AMI, dynamic pricing, and enabling technologies such as Web portals, in-home displays, and programmable communicating thermostats. They also include the use of randomized and controlled experimental designs with treatment and control groups. This effort presents an opportunity to advance the electric power industry's understanding of consumer behaviour by addressing unanswered issues and questions with highly rigorous statistical methods.

ANNEX II – SMART GRID SERVICES (EU) and CHARACTERISTICS (US)

European Union

At high level, the EC Smart Grid Task Force has defined the Smart Grid as supporting the following services and corresponding functionalities:

A. Enabling the network to integrate users with new requirements

Outcome: Guarantee the integration of distributed energy resources (both large- and small-scale stochastic renewable generation, heat pumps, electric vehicles and storage) connected to the distribution network.

Provider: DSOs

Primary beneficiaries: Generators, consumers (including mobile consumers), storage owners.

Corresponding functionalities:

1. Facilitate connections at all voltages/locations for any kind of devices
2. Facilitate the use of the grid for the users at all voltages/locations
3. Use of network control systems for network purposes
4. Update network performance data on continuity of supply and voltage quality

B. Enhancing efficiency in day-to-day grid operation

Outcome: Optimise the operation of distribution assets and improve the efficiency of the network through enhanced automation, monitoring, protection and real-time operation. Faster fault identification/resolution will help improve continuity of supply levels.

Better understanding and management of technical and non-technical losses, and optimised asset maintenance activities based on detailed operational information.

Provider: DSOs, metering operators

Primary beneficiaries: Consumers, generators, suppliers, DSOs.

Corresponding functionalities:

5. *Automated fault identification/grid reconfiguration, reducing outage times*
6. Enhance monitoring and control of power flows and voltages
7. Enhance monitoring and observability of grids down to low voltage levels
8. Improve monitoring of network assets
9. Identification of technical and non-technical losses by power flow analysis

10. Frequent information exchange on actual active/reactive generation/consumption

C. Ensuring network security, system control and quality of supply

Outcome: Foster system security through an intelligent and more effective control of distributed energy resources, ancillary backup reserves and other ancillary services. Maximise the capability of the network to manage intermittent generation, without adversely affecting quality of supply parameters.

Provider: DSOs, aggregators, suppliers.

Primary beneficiaries: Generators, consumers, aggregators, DSOs, transmission system operators.

Corresponding functionalities:

11. Allow grid users and aggregators to participate in ancillary services market
12. Operation schemes for voltage/current control
13. Intermittent sources of generation to contribute to system security
14. System security assessment and management of remedies
15. Monitoring of safety, particularly in public areas
16. Solutions for demand response for system security in the required time

D. Better planning of future network investment

Outcome: Collection and use of data to enable more accurate modelling of networks, especially at LV level, also taking into account new grid users, in order to optimise infrastructure requirements and so reduce their environmental impact. Introduction of new methodologies for more 'active' distribution, exploiting active and reactive control capabilities of distributed energy resources.

Provider: DSOs, metering operators.

Primary beneficiaries: Consumers, generators, storage owners.

Corresponding functionalities:

17. Better models of Distributed Generation, storage, flexible loads, ancillary services
18. Improve asset management and replacement strategies
19. Additional information on grid quality and consumption by metering for planning

E. Improving market functioning and customer service

Outcome: Increase the performance and reliability of current market processes through improved data and data flows between market participants, and so enhance customer experience.

Provider: Suppliers (with applications and services providers), power exchange platform providers, DSOs, metering operators.

Primary beneficiaries: Consumers, suppliers, application and service providers.

Corresponding functionalities:

20. Participation of all connected generators in the electricity market
21. Participation of virtual power plants and aggregators in the electricity market
22. Facilitate consumer participation in the electricity market
23. Open platform (grid infrastructure) for EV recharge purposes
24. Improvement to industry systems (for settlement, system balance, scheduling)
25. Support the adoption of intelligent home/facilities automation and smart devices
26. Provide grid users with individual advance notice of planned interruptions
27. Improve customer level reporting in the case of interruptions

F. Enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management

Outcome: Foster greater consumption awareness, taking advantage of smart metering systems and improved customer information in order to allow consumers to modify their behaviour according to price and load signals and related information.

Promote the active participation of all players in the electricity market through demand response programmes and a more effective management of variable and non-programmable generation. Obtain the consequent system benefits: peak reduction, reduced network investments, ability to integrate more intermittent generation.

Provider: Suppliers (with metering operators and DSOs), Energy Service Companies.

Primary beneficiaries: Consumers, generators.

The only primary beneficiary who is present in all services is the consumer. Indeed, consumers will benefit:

- either because these services will contribute to the 20/20/20 targets
- or directly through improvement of quality of supply and other services.

The hypothesis made here is that company efficiency and the benefit of the competitive market will be passed on to consumers – at least partly in the form of tariff or price optimisation, and is dependent on effective regulation and markets.

Corresponding functionalities:

28. Sufficient frequency of meter readings

29. Remote management of meters
30. Consumption/injection data and price signals by different means
31. Improve energy usage information
32. Improve information on energy sources
33. Availability of individual continuity of supply and voltage quality indicators

USA

At a high-level, DOE has described Smart Grid as exhibiting the following seven principal characteristics or functions.

1. Enables Informed Participation by Customers

Consumers become an integral part of the electric power system. They help balance supply and demand and ensure reliability by modifying the way they use and purchase electricity. These modifications come as a result of consumers having choices that motivate different purchasing patterns and behavior. These choices involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives.

2. Accommodates All Generation and Storage Options

A smart grid accommodates not only large, centralized power plants, but also the growing array of distributed energy resources (DER). DER integration will increase rapidly all along the value chain, from suppliers to marketers to customers. Those distributed resources will be diverse and widespread, including renewables, distributed generation and energy storage.

3. Enables New Products, Services, and Markets

Correctly-designed and -operated markets efficiently reveal cost-benefit tradeoffs to consumers by creating an opportunity for competing services to bid. A smart grid accounts for all of the fundamental dynamics of the value/cost relationship. Some of the independent grid variables that must be explicitly managed are energy, capacity, location, time, rate of change, and quality. Markets can play a major role in the management of these variables. Regulators, owners/operators, and consumers need the flexibility to modify the rules of business to suit operating and market conditions.

4. Provides the Power Quality for the Range of Needs

Not all commercial enterprises, and certainly not all residential customers, need the same quality of power. A smart grid supplies varying grades of power and supports variable pricing accordingly. The cost of premium power-quality (PQ) features can be included in the electrical service contract. Advanced control methods monitor essential components, enabling rapid diagnosis and precise solutions to PQ events, such as arise from lightning, switching surges, line faults and harmonic sources. A smart grid also helps buffer the electrical system from irregularities caused by consumer electronic loads.

5. Optimizes Asset Utilization & Operating Efficiency

A smart grid applies the latest technologies to optimize the use of its assets. For example, optimized capacity can be attainable with dynamic ratings, which allow assets to be used at greater loads by continuously sensing and rating their capacities. Maintenance efficiency involves attaining a reliable state of equipment or "optimized condition." This state is attainable with condition-based maintenance, which signals the need for equipment maintenance at precisely the right time. System-control devices can be adjusted to reduce losses and eliminate congestion. Operating efficiency increases when selecting the least-cost energy-delivery system available through these adjustments of system-control devices

6. Operates Resiliently to Disturbances, Attacks, & Natural Disasters

Resiliency refers to the ability of a system to react to events such that problematic elements are isolated while the rest of the system is restored to normal operation. These self-healing actions result in reduced interruption of service to consumers and help service providers better manage the delivery infrastructure. A smart grid responds resiliently to attacks, whether organized by others or the result of natural disasters. These threats include physical attacks and cyber attacks. A smart grid addresses security from the outset, as a requirement for all the elements, and ensures an integrated and balanced approach across the system.

ANNEX III – Key Performance Indicators and metrics

European Union

Benefits and KPIs - The EC Smart Grid Task Force has identified a list of benefits deriving from the implementation of a Smart Grid. Each benefit is expressed via a set of key performance indicators.

#	Benefits and KPIs
	Increased sustainability
1	Quantified reduction of carbon emissions
2	Environmental impact of electricity grid infrastructure
3	Quantified reduction of accidents and risk associated with generation technologies (during mining, production, installations, etc.)
	Adequate capacity of transmission and distribution grids for 'collecting' and bringing electricity to the consumers
4	Hosting capacity for distributed energy resources in distribution grids
5	Allowable maximum injection of power without congestion risks in transmission networks
6	Energy not withdrawn from renewable sources due to congestion and/or security risks
7	An optimised use of capital and assets
	Adequate grid connection and access for all kinds of grid users
8	First connection charges for generators, consumers and those that do both
9	Grid tariffs for generators, consumers and those that do both
10	Methods adopted to calculate charges and tariffs
11	Time to connect a new user
12	Optimisation of new equipment design resulting in best cost/benefit
13	Faster speed of successful innovation against clear standards
	Satisfactory levels of security and quality of supply
14	Ratio of reliably available generation capacity to peak demand
15	Share of electrical energy produced by renewable sources
16	Measured satisfaction of grid users with the 'grid' services they receive
17	Power system stability
18	Duration and frequency of interruptions per customer
19	Voltage quality performance of electricity grids (e.g. voltage dips, voltage and frequency deviations)

Enhanced efficiency and better service in electricity supply and grid operation	
20	Level of losses in transmission and in distribution networks (absolute or percentage).[14] Storage induces losses, but active flow control also increases losses
21	Ratio between minimum and maximum electricity demand within a defined time period (e.g. one day, one week)[15]
22	Percentage utilisation (i.e. average loading) of electricity grid elements
23	Demand-side participation in electricity markets and in energy efficiency measures
24	Availability of network components (related to planned and unplanned maintenance) and its impact on network performances
25	Actual availability of network capacity with respect to its standard value (e.g. net transfer capacity in transmission grids, distributed energy sources (DER) hosting capacity in distribution grids)
Effective support of transnational electricity markets by load flow control to alleviate loop flows and increased interconnection capacities	
26	Ratio between interconnection capacity of one country/region and its electricity demand
27	Exploitation of interconnection capacities (ratio between mono-directional energy transfers and net transfer capacity), particularly related to maximisation of capacities according to the regulation of electricity cross-border exchanges and congestion management guidelines
28	Congestion rents across interconnections
Coordinated grid development through common European, regional and local grid planning to optimise transmission grid infrastructure	
29	Impact of congestion on outcomes and prices of national/regional markets
30	Societal benefit-cost ratio of a proposed infrastructure investment
31	Overall welfare increase, i.e. always running the cheapest generators to supply the actual demand (this is also an indicator for benefit (6) above)
32	Time for licensing/authorisation of a new electricity transmission infrastructure
33	Time for construction (i.e. after authorisation) of a new electricity transmission infrastructure
Enhanced consumer awareness and participation in the market by new players	
34	Demand side participation in electricity markets and in energy efficiency measures

[14] For comparison purposes, the level of losses should be corrected by structural parameters (e.g. by the presence of distributed generation in distribution grids and its production pattern). Moreover, a possible conflict between, for example, aiming for higher utilisation of network elements (loading) and higher losses, should be considered.

[15] For comparison purposes, a structural difference in the indicator should be taken into account due to, for example, electrical heating and weather conditions, shares of industrial and domestic loads.

35	Percentage of consumers on (opt-in) time-of-use/critical peak/real-time dynamic pricing
36	Measured modifications of electricity consumption patterns after new (opt-in) pricing schemes
37	Percentage of users available to behave as interruptible load
38	Percentage of load demand participating in market-like schemes for demand flexibility
39	Percentage participation of users connected to lower voltage levels to ancillary services
Enable consumers to make informed decisions related to their energy to meet the EU Energy Efficiency targets	
40	Base-to-peak load ratio
41	Relation between power demand and market price for electricity
42	Consumers can comprehend their actual energy consumption and receive, understand and act on free information they need/ask for
43	Consumers are able to access their historic energy consumption information for free in a format that enables them to make like-for-like comparisons with deals available on the market
44	Ability to participate in relevant energy market to purchase and/or sell electricity
45	Coherent link is established between the energy prices and consumer behaviour
Create a market mechanism for new energy services such as energy efficiency or energy consulting for customers	
46	'Simple' and/or automated changes to consumers' energy consumption in reply to demand/response signals are enabled
47	Data ownership is clearly defined and data processes in place to allow for service providers to be active with customer consent
48	Physical grid-related data are available in an accessible form
49	Transparency of physical connection authorisation, requirements and charges
50	Effective consumer complaint handling and redress. This includes clear lines of responsibility should things go wrong
Consumer bills are either reduced or upward pressure on them is mitigated	
51	Transparent, robust processes to assess whether the benefits of implementation exceed the costs in each area where roll-out is considered, and a commitment to act on the findings by all the involved parties
52	Regulatory mechanisms that ensure that these benefits are appropriately reflected in consumer bills and do not simply result in windfall profits for the industry
53	New smart tariffs (energy prices) that deliver tangible benefits to consumers or society in a progressive way
54	Market design is compatible with the way consumers use the grid

USA

Build metrics/Value Metrics - In [US DOE, 2009a], a set of build and value metrics are proposed to assess the nationwide progress of the Smart Grid implementation in the US.

#	Metric Title	Type
	Area, Regional and National coordination regime	
1	**Dynamic Pricing**: fraction of customers and total load served by RTP, CPP, and TOU tariffs	build
2	**Real-time System Operations Data Sharing**: Total SCADA points shared and fraction of phasor measurement points shared.	build
3	**Distributed-Resource Interconnection Policy**: percentage of utilities with standard distributed-resource interconnection policies and commonality of such policies across utilities.	build
4	**Policy/Regulatory Progress**: weighted-average percentage of smart grid investment recovered through rates (respondents' input weighted based on total customer share).	build
	Distributed Energy Resources	
5	**Load Participation Based on Grid Conditions**: fraction of load served by interruptible tariffs, direct load control, and consumer load control with incentives.	build
6	**Load Served by Microgrids**: the percentage total grid summer capacity.	build
7	**Grid-Connected Distributed Generation (renewable and non-renewable) and Storage**: percentage of distributed generation and storage.	build
8	**EVs and PHEVs**: percentage shares of on-road, light-duty vehicles comprising of EVs and PHEVs.	build
9	**Grid-Responsive Non-Generating Demand-Side Equipment**: total load served by smart, grid-responsive equipment.	build
	Delivery (T&D) Infrastructure	
10	**T&D System Reliability**: SAIDI, SAIFI, MAIFI.	value
11	**T&D Automation**: percentage of substations using automation.	build
12	**Advanced Meters**: percentage of total demand served by advanced metered (AMI) customers	build
13	**Advanced System Measurement**: percentage of substations possessing advanced measurement technology.	build

14	**Capacity Factors**: yearly average and peak-generation capacity factor	value
15	**Generation and T&D Efficiencies**: percentage of energy consumed to generate electricity that is not lost.	value
16	**Dynamic Line Ratings**: percentage miles of transmission circuits being operated under dynamic line ratings.	build
17	**Power Quality**: percentage of customer complaints related to power quality issues, excluding outages.	value
	Information networks and finance	
18	**Cyber Security**: percent of total generation capacity under companies in compliance with the NERC Critical Infrastructure Protection standards.	build
19	**Open Architecture/Standards**: Interoperability Maturity Level – the weighted average maturity level of interoperability realized among electricity system stakeholders	build
20	**Venture Capital**: total annual venture-capital funding of smart-grid startups located in the U.S.	value

ANNEX IV- Merit deployment matrices

European Union

Map of Benefits-KPIs to Smart Grid Services - The EC Task Force for Smart Grids has defined the following merit deployment matrix to link the Smart Grid services with the corresponding outcomes (benefits) for individual Smart Grid projects [EC Task Force for Smart Grids, 2010c].

		Services and functionalities (Annex II)			
		Functionality 1	…	Functionality 33	Total sum: rows
Benefits and key performance indicators (Annex III)	KPI 1				Sum row 1
	…				
	KPI 54				Sum row 54
	Total sum: columns	Sum column 1	…	Sum column 33	

USA

Map of build/value metrics to Smart Grid characteristics - In [US DOE, 2009a], the following link between Smart Grid characteristics and build/value metrics is proposed.

	Metric Name	Enables Informed Participation by Customers	Accom-modates All Generation & Storage Options	Enables New Products, Services, & Markets	Provides Power Quality for the Range of Needs	Optimizes Asset Utilization & Efficient Operation	Operates Resiliently to Disturbances, Attacks, & Natural Disasters
1	Dynamic Pricing (Build)	Emphasis	Mention	Mention			Mention
2	Real-Time Data Sharing (Build)					Mention	Emphasis
3	DER Interconnection (Build)	Mention	Emphasis	Mention			
4	Regulatory Policy (Build)			Emphasis			

5	Load Participation (Build)	Emphasis			Mention	Mention	Mention
6	Microgrids (Build)		Mention	Mention	Emphasis		
7	DG & Storage (Build)	Mention	Emphasis	Mention	Mention	Mention	Mention
8	Electric Vehicles (Build)	Mention	Mention	Emphasis			Mention
9	Grid-responsive Load (Build)	Mention	Mention	Mention	Mention		Emphasis
10	T&D Reliability (value)						Emphasis
11	T&D Automation (Build)				Mention	Emphasis	Mention
12	Advanced Meters (Build)	Emphasis	Mention	Mention			Mention
13	Advanced Sensors (Build)					Mention	Emphasis
14	Capacity Factors (value)					Emphasis	
15	Generation, T&D Efficiency (value)					Emphasis	
16	Dynamic Line Rating (Build)					Emphasis	Mention
17	Power Quality (value)			Mention	Emphasis		
18	Cyber Security (Build)						Emphasis
19	Open Architecture/Stds (Build)			Emphasis			
20	Venture Capital (value)			Emphasis			

ANNEX V Smart Grid programs

In the following we report the clusters of the European Electricity Grid initiative (EEGI) and the focus areas of the Smart Grid implementation Grant (SGIG).

European Union

EEGI (European Electricity Grid Initiative) [EEGI, 2010]

Clusters- distribution level
Smart customers (e.g. Active Demand Response, Energy Efficiency with Smart Homes)
Smart energy management (e.g. Metering infrastructure, Smart metering data processing)
Smart integration (e.g. DSO integration of small DER, Infrastructure to host EV/PHEV)
Smart distribution network (e.g. Monitoring and control of LV/MV network, Integrated communication solution)
Coordination activities between distribution and transmission networks (e.g. Increased observability of the electric system for network management and control, Integration of demand side management in TSO operations, Ancillary services provided by DSOs)
Clusters - transmission level
Pan-European Grid T1 Architectures(R&D) (e.g. tools to analyze the pan European network expansion options)
Power Technologies (Demonstration) (e.g. Demonstration of renewable integration, Demonstrations of Power technologies for more network flexibility)
Network management and control (R&D) (e.g. Tools for a Pan European network observability and reliability assessment, Tools for coordinated operations with stability margin evaluation)
New market design options (R&D) (e.g. Tools for Pan European balancing markets, Advanced tools for congestion management, Tools for renewable market, Integration, Tools to study market integration of active demand)
Pan-European Grid Architectures(R&D) (e.g. Innovative approaches to improve the public acceptance of overhead lines)

USA

FOCUS AREAS

AMI & Customer Systems

A1- Peak Demand and Electricity Usage

A2 -Meter Operations and Maintenance Cost savings

Distribution Systems

D1 - Distribution System Reliability

D2 - Distribution System Energy Efficiency Improvements related to ‘Line Losses’

Transmission

T1 – Transmission Reliability and Applications of Synchrophasor Technology

Consumer Behaviour

CB1- Understand the Impact of AMI and Time-based Rate Programs on Consumer Behaviour

ANNEX VI List of Benefits for Cost-Benefit analysis [EPRI, 2010]

Optimized Generator Operation

Better forecasting and monitoring of load and grid performance would enable grid operators to dispatch a more efficient mix of generation that could be optimized to reduce cost.

Reduced Generation Capacity Investments

Utilities and grid operators ensure that generation capacity can serve the maximum amount of load that planning and operations forecasts indicate. The trouble is, this capacity is only required for very short periods each year, when demand peaks. Reducing peak demand and flattening the load curve should reduce the generation capacity required to service load, and lead to cheaper electricity for customers.

Reduced Ancillary Service Cost

Ancillary services including spinning reserve and frequency regulation could be reduced if generators could more closely follow load Ancillary services are necessary to ensure the reliable and efficient operation of the grid. The level of ancillary services required at any point in time is determined by the grid operator and/or energy market rules. The functions that provide this benefit reduce ancillary cost through improving the information available to grid operators.

Reduced Congestion Cost

Transmission congestion is a phenomenon that occurs in electric power markets. It happens when scheduled market transactions (generation and load) result in power flow over a transmission element that exceeds the available capacity for that element. Since grid operators must ensure that physical overloads do not occur, they will dispatch generation so as to prevent them. The functions that provide this benefit either provide lower cost energy or allow the grid operator to manage the flow of electricity around constrained interfaces.

Deferred Transmission Capacity Investments

Reducing the load and stress on transmission elements increases asset utilization and reduces the potential need for upgrades. Closer monitoring, rerouting power flow, and reducing fault current could enable utilities to defer upgrades on lines and transformers.

Deferred Distribution Capacity Investments

As with transmission lines, closer monitoring and load management on distribution feeders could potentially extending the time before upgrades or capacity additions are required.

Reduced Equipment Failures

Reducing mechanical stresses on equipment increases service life and reduces the probability of premature failure.

Reduced Distribution Equipment Maintenance Cost

The cost of sending technicians into the field to check equipment condition is high. Moreover, to ensure that they maintain equipment sufficiently, and identify failure precursors, some utilities may conduct equipment testing and maintenance more often than is necessary. Online diagnosis and reporting of equipment condition would reduce or eliminate the need to send people out to check equipment.

Reduced Distribution Operations Cost

Automated or remote controlled operation of capacitor banks and feeder switches eliminates the need to send a line worker or crew to the switch location in order to operate it. This reduces the cost associated with the field service worker(s) and service vehicle.

Reduced Meter Reading Cost

Automated Meter Reading (AMR) equipment eliminates the need to send someone to each location to read the meter manually.

Reduced Electricity Theft

Smart meters can typically detect tampering. Moreover, a meter data management system can analyze customer usage to identify patterns that could indicate diversion.

Reduced Electricity Losses

The functions listed help manage peak feeder loads, locate electricity production closer to the load and ensure that customer voltages remain within service tolerances, while minimizing the amount of reactive power provided. These improve the power factor, and reduce line losses for a given load served.

Reduced Electricity Cost

The functions listed could help alter customer usage patterns (demand response with price signals or direct load control), or help reduce the cost of electricity during peak times through either production (DG) or storage.

Reduced Sustained Outages

Reduces the likelihood that there will be an outage, and allows the system to be reconfigured on the fly to help in restoring service to as many customers as possible. A sustained outage is one lasting > 5 minutes, excluding major outages and wide-scale outages (defined below). The benefit to consumers is based on the value of service (VOS).

Reduced Major Outages

A major outage is defined using the beta method, per IEEE Std 1366-2003 (IEEE Power Engineering Society 2004). The functions listed can isolate portions of the system that include distributed generation so that customers will be served by the distributed generation until the utility can restore service to the area. Only the customers in the island, (i.e., < 5,000 customers) or smaller experience reduced outage time from this improved reliability.

Reduced Restoration Cost

The functions that provide these benefits cause fewer outages, which result in fewer restoration costs. These costs can include line crew labor/material/equipment, support services such as logistics, call centers, media relations, and other professional staff time and material associated with service restoration.

Reduced Momentary Outages

By locating faults or adding electricity storage, momentary outages could be reduced or eliminated. Moreover, fewer customers on the same or adjacent distribution feeders would experience the momentary interruptions associated with reclosing. Momentary outages last <5 min in duration. The benefit to consumers is based on the value of service.

Reduced Sags and Swells

Locating high impedance faults more quickly and precisely, and adding electricity storage, functions will reduce the frequency and severity of the voltage fluctuations that they can cause. Moreover, fewer customers on the same or adjacent distribution feeders would experience the voltage fluctuation caused by the fault.

Reduced CO2 Emissions

Functions that provide this benefit can improve performance in many aspects for end-users. These improvements translate into a reduction in CO2 emissions produced by fossil-based electricity generators.

Reduced SOx, NOx, and PM-10 Emissions

Functions that provide these benefits can improve performance in many aspects for end-users. These improvements translate into a reduction in SOx, NOx, and PM-10 emissions produced by fossil-based electricity generators

Reduced Oil Usage (not monetized)

The functions that provide this benefit eliminate the need to send a line worker or crew to the switch location in order to operate it. This reduces the fuel consumed by a service vehicle or line truck. For PEV, the electrical energy used by PEVs displaces the equivalent amount of oil.

Reduced Wide-scale Blackouts

The functions listed will give grid operators a better picture of the bulk power system, and allow them to better coordinate resources and operations between regions. This will reduce the probability of wide-scale regional blackouts.

ANNEX VII — JRC COST BENEFIT ANALYSIS - MODIFICATIONS TO THE ORIGINAL EPRI METHODOLOGY

The CBA methodology proposed in [EC 2012a, 2012b] is based on the EPRI methodology. By concretely testing the EPRI methodology on a real case study, modifications to fit the European context have been proposed:

- Step 3 (*Assess the principal characteristics of the Smart Grid to which the project contributes*) of the EPRI methodology [EPRI, 2010] has been skipped. This step is intended to measure the smartness of a Smart Grid project and the merit of its deployment. In this study, the merit deployment analysis is based on the assessment framework proposed in [EC Task Force for Smart Grids 2010c] and is proposed as a complement to the CBA (see Chapter 4).
- In steps 2 (*Identify the functions*) and 4 (*Map each function onto a standardised set of benefit types*) [EPRI, 2010], functions have been replaced by (European) functionalities [EC Task Force for Smart Grids, 2010a], in order to limit the set of new categories and definitions. It is worth mentioning that functions and functionalities cannot be directly compared. Functions have a very strong technical dimension (e.g. fault current limiter, feeder switching). Functionalities represent more general capabilities of the Smart Grid and do not focus on specific technology. They provide an intuitive description of what the project is about. This may help project coordinators to identify the key capabilities of the projects and hence the resulting benefits. We think that the use of functionalities is a useful tool for assessing which areas of the Smart Grid the project is contributing to and for identifying benefits and impacts.
- Steps 6, 7, 8 (*Identification of benefits, quantification of benefits and monetisation of benefits*) have been grouped together. They are considered as sub-steps of the single step 'Quantification of benefits'.

ANNEX VIII -LIST OF PARTICIPANTS "2ND EU-US WORKSHOP ON SMART GRID ASSESSMENT METHODOLOGIES", WASHINGTON DC, 7TH OF NOVEMBER 2011

US side

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Abstract

The scope of this document is to find common ground between EU and US assessment approaches on Smart Grid projects. First of all, we need to make sure we understand each other's language. We need to assess correspondences among definitions, terminology and methodological approaches, in order to clarify commonalities and differences. Secondly, we need to strengthen cooperation on assessment frameworks and on sharing data collection experiences, project results and lessons learned.

The report provides a comparison of EU and US initiatives on a number of themes related to Smart Grid assessment methodologies: Smart Grid definition and conceptual framework, mapping and classification of Smart Grid projects, project impact assessment based on performance indicators, cost-benefit analysis, sharing and dissemination of project results and lessons learned.

This joint work is carried out in the framework of the EU-US Energy Council, which intends to deepen the transatlantic dialogue on strategic energy issues such as policies to move towards low carbon energy sources while strengthening the on-going scientific collaboration on energy technologies.

In this context, two meetings among EU and US Smart Grid experts were held in December 2010 and November 2011 to discuss Smart Grid Assessment initiatives in EU and US. The outcomes of the two meetings form the core of this report, which also is intended as a framework for further EU-US cooperation on Smart Grid assessment methodologies.

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