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Smart electric grid

Strategy and roadmap

2015-2019

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InnoEnergy is supported by the EIT,
a body of the European Union

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1. Market challenges and business drivers

The need for a smarter electrical grid has been addressed in many documents and by many organizations. Not the least with-in the EU communities there are several initiatives to support the development of a smarter electrical system and electric storage. At the same time, there have been some concerns raised about the business feasibility of the proposed solutions. Clearly in some areas there is a strong need for smarter solutions such as in grids where the penetration of renewables is very high.

Business Drivers

The drivers for a smarter energy system can be summarized as a major change in the generation patterns as well as the change in the usage patterns of electricity. In addition, since a marjority of the grid business is regulated, several business drivers are coupled more or less directly within the regulatory and policy domains. This includes the development of grid codes putting for example new requirements in the interaction between distribution and transmission grids. In the market domain, the development towards a unified European market for electricity is an additional driver requiring more interconnections but also more tools for handling cross-border power flows. Finally, an important driver is the development of multi-modal energy systems where the optimization of energy flows in different carriers is opening new possibilities. Some of these drivers are further elaborated below.

Interaction between Transmission & Distribution

With more active consumers and also with increasing production in the distribution grids, there is both a possibility but also a need for more control in the distribution level of the power system. The development of ENTSO-E grid codes is opening up areas of new requirements on DSOs including the necessity to control voltages and active and reactive power flows to a much larger degree than is currently the case. It can be foreseen that these new requirements will lead to needs for new technologies and solutions for control and automation of the distribution systems which was previously limited to transmission level grids.

European Electricity market development

The continuous development of the European Electricity market implies more cross-border flows in order to better utilize the availability of production with varying levels of controllability. Here, a range of key technologies will be needed to manage the integrated grid that results, these range from HVDC transmission systems and grids to Flexible AC Transmission solutions and control and communication systems that allow real-time control of such very large systems. At the market and system operator level, new tools are needed for congestion management and forecasting of load flows in order to allow for clearing of the market

Integration of renewables

Allow integration of renewable generation both at centralized and decentralized locations.

- The energy system must be able to manage the variability in renewable generation by storage or sharing of remote resources by improved transmission.

- The energy system must be flexible enough to accept decentralized generation at all voltage levels in the system.
- Prepare the grid for new ways of using electricity

- Increase the security of supply in the European Energy System
  - This means allowing much higher penetration of European domestic generation
  - Create a more fault tolerant electric grid

Customer empowerment

An additional aspect of the European Electricity market is at the consumer end; the political will to empower the customer to enable him/her to make informed choices about their energy (electricity) consumption. This specific area requires careful treatment, since it is not obvious which technology and service providers that can gain the trust of the consumer. There are several examples of Smart grid solutions aiming to empower the consumer that have been launched by utilities which did not reach their goals- In short, the idea of empowering the customers is to

- By allowing local generation
- By introducing market designs that allow customers to act on market signals

The estimated total market for Smart Grids is significant but the estimations vary quite a lot based on what definition that is used. Much estimation is based only looking at the IT part and neglecting the fact that the largest investments actually will be in grid hardware and software. But it is important to note that the ICT and Service part are enabling technologies and thus instrumental for the implementation. This graph gives a good illustration of the total market estimation for Smart Grids:

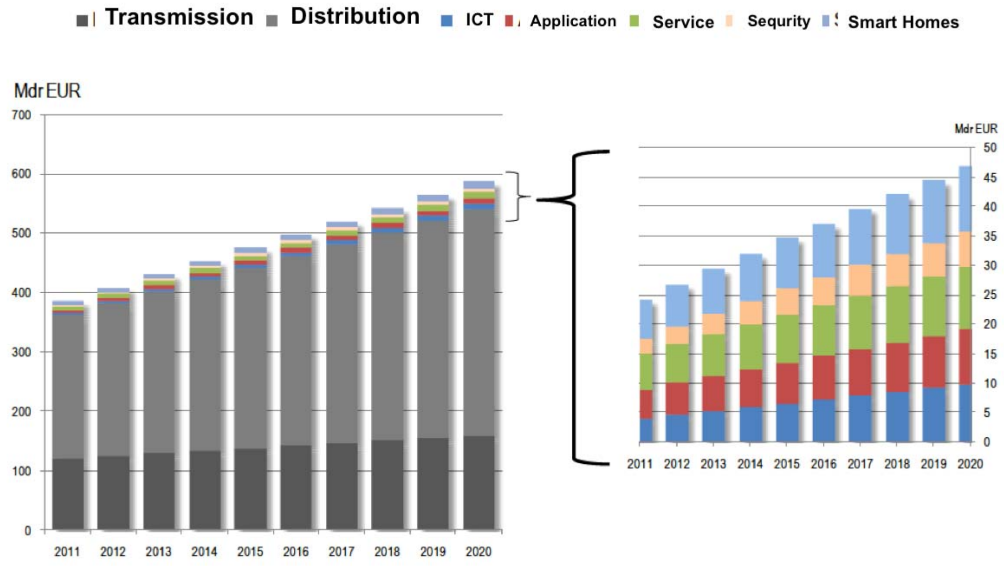


Figure 2: Total Global Smart Grid Market; Source: IEA, EU, Peak Research, Blue Institute.

Smart Grid markets evolution and penetration is related to the introduction and roll out of Smart Meters. Looking at the Smart Meter rollout status will then give a good measure of the geographic and national status of the Smart Grid market.

It should be pointed out that one overall goal with Smart Grids and Storage is to make cost efficient overall solutions. By investing in these technologies, other investments can be deferred or reduced.

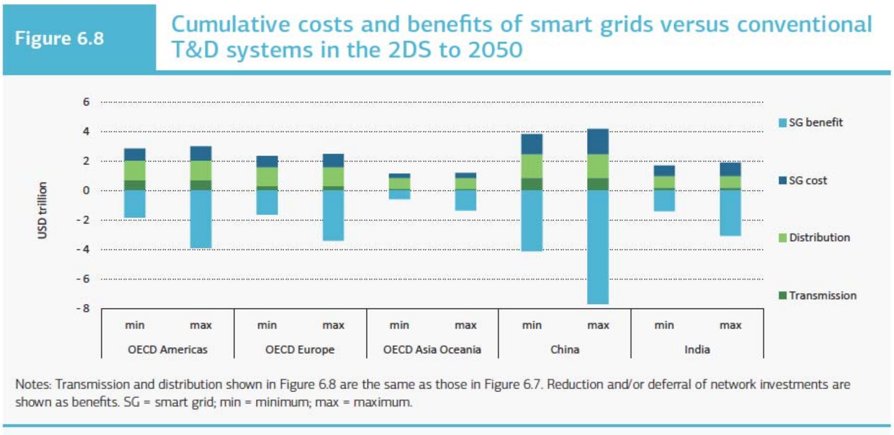


Figure 4: Cumulative Costs and benefits of Smart Grids vs conventional T&D system; Source: IEA Energy Technology Perspectives 2012

Market Challenges

Key challenges for deployment for Smart Grids solutions are:

- *Lack of stakeholder engagement, including that of end-users uncertain of the value of the new services as well as the challenge of sharing costs and benefits of investments that lead to difficulties in getting stakeholder commitment.*

- *Lack of standards that limit the interoperability of the system solutions needed, both across technical and business domains.*

- *Lack of regulatory and policy support, including the lack of incentive schemes to support investment by grid operators but also varying schemes for subsidizing storage, electric vehicles and other technical solutions. These are not necessary challenges, but certainly important to shape the investment landscape.*

- *Lack of funds, some of the investments are very long term and must be valued against existing solutions. In parts of Europe the economic climate may not be favorable for such investments due to lack of available financing.*

It is necessary to appreciate that the asset of the European electricity grid represents enormous values and that it is not possible to expect an immediate replacement of the assets. It is also necessary to understand that the normal investment cycle of the grid is at least 40 years. It will rather be a gradual upgrade into a smarter system that we would like to speed up by our projects. One example would be the implementation of smart meters with in some EU countries (e.g. Sweden, Italy). But regulations must also support the functionality of the new system for instance regulation supporting hourly pricing which is already in place in Sweden and planned in several others.

2. Technologies to address those challenges

The challenges outlined in the preceding section require that, apart from utilizing traditional technologies, regulatory regimes and standards will need to be adopted. In addition entirely new solutions are needed. To address these areas from a technology point of view, the Thematic Area Smart Grids and Storage have been grouped in 5 areas that will be merged in the three subtopics in the roadmap.

SYSTEM

The electrical energy system is facing a number of emerging technologies. These have to be integrated into the existing power transmission system in a "smart" way to alleviate the changes the grid is exposed to. Examples of future aspects influencing the European grid are the increased use of variable power sources like wind- (onshore or offshore) and solar energy where the generation sources move far away from load centers; the difficulty to expand the system with Over-Head transmission lines and the tentative change into electrical vehicles. HVDC systems can offer a more cost efficient underground alternative in sensitive areas as well as adding new levels of controllability to the existing system. These aspects of the power system constitutes a number of challenges for the power system development,

ICT

Optimal design of robust, secure, interoperable and scalable ICT solutions that enable active distribution networks and facilitate new models for customer involvement will be an absolute necessity in the future Smart Grid. From the utility perspective, ICT solutions tightly integrating with the primary equipment is a core component in an active distribution system. These ICT solutions enable cost-efficient advanced control and automation of distribution grids with high levels of renewable energy sources and active consumers.

Smart Components

Innovative power and system components with advanced control and monitoring will pave the way towards an optimal transmission and distribution grid. This field includes the ability to extend the operating limits of components, increasing the robustness, safety, and reliability of the components, environmentally benign designs, and components with reduced losses and good energy quality.

STORAGE

Energy storage is a vital component in the development of an intelligent grid for electricity when integration of large amounts of intermittent renewable energy increases. The storage is needed to bridge the increasing non-deterministic relation between supply and demand. The Smart Grids concept also includes generation by distributed energy resources, which affects the size and type of storage needed. Summarized there is a need for low cost large, medium and small energy storage systems

MATERIALS

Smart Grids of the future is essentially about optimal usage and utilization of system components from small semiconductor to intercontinental transmission cables and system. All of these components can gain significant performance improvements through new innovative material for isolation, magnetics, conduction, contacts etc.

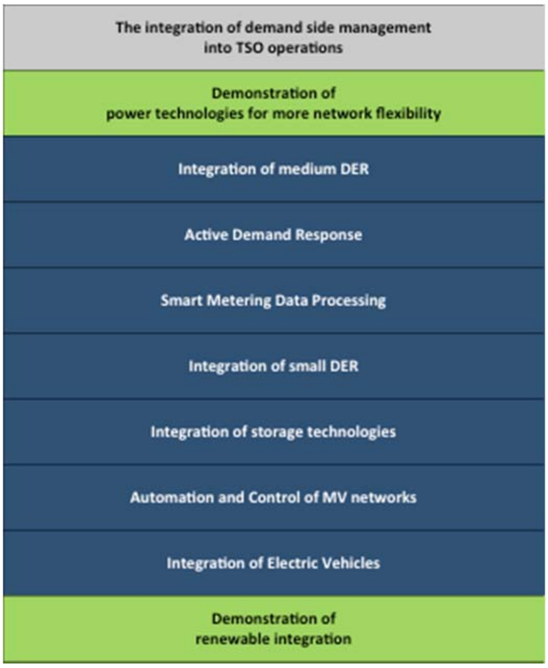
3. Roadmap: Overview

In the process to develop a roadmap for future projects a discussion with other colocations and our industrial partners we have identified examples of projects that could be a part of the roadmap with inputs from the roadmaps of other key organizations in Europe for example The European Electricity Grid Initiative (EEGI). EEGI is one of the European Industrial Initiatives under the Strategic Energy Technology Plan (SET-Plan) that proposes a 9-year European research, development and demonstration program to accelerate innovation and the development of the electricity networks of the future in Europe.

The projects have been prioritized from a number of key criteria. The criteria selection has been:

- Shortest Time to market (for the technology involved)
- Highest impact in: Energy cost decrease, Increase of operability, decrease of GHG effects
- Leadership and competence of InnoEnergy partners in the said topic and technology
- Declared InnoEnergy industry interest and commitment
- Foreseeable regulatory impact
- Required investment to develop the innovations
- Cross impact in several applications

The priority matrix has then been analyzed using different weighting factors. An example of project ideas based on expected impact is below:



The prioritized project ideas have then been clustered in three main areas:

- Smart Distribution Networks
- Smart Transmission Networks
- Storage as a tool for network flexibility

The existing projects have been merged into this profile and new areas have been identified as priority areas based on the described mapping.

A very important input to the roadmap is the needs identified by our key partners. The other input for the thematic strategy has thus been roadmaps from our existing partners. One example of a Smart Grids roadmap including maturity is described below with anticipated time to reach maturity developed by one of our key partners. However it is essential to recognize that the necessary Smart Grids applications are highly dependent on the market where the implementation is made.

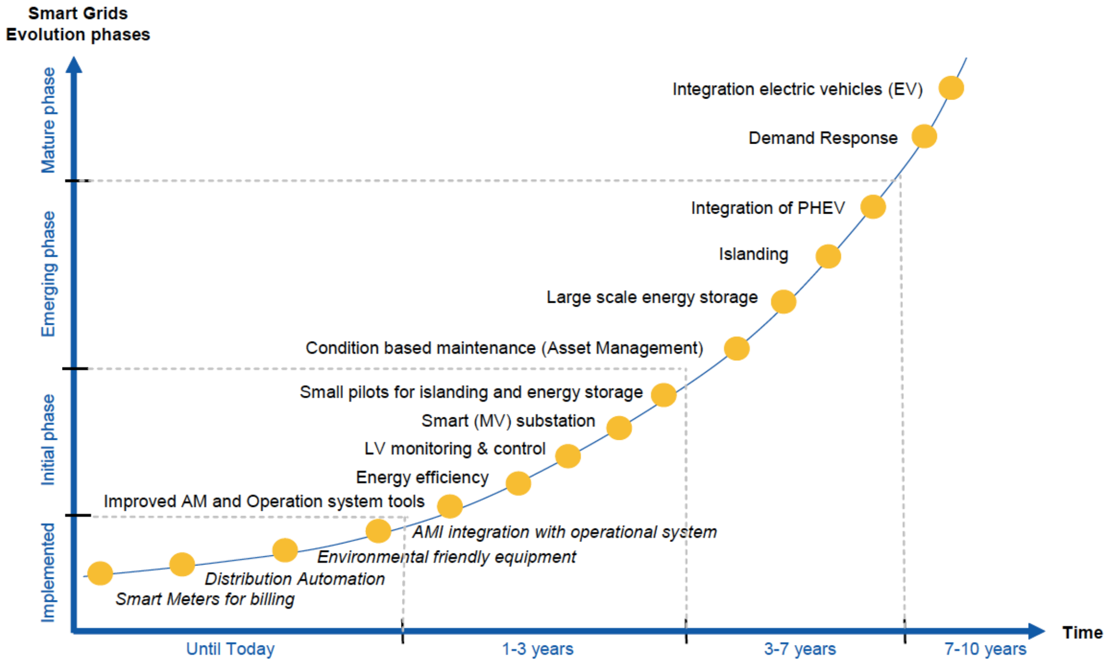


Figure 5: Smart Grid Roadmap with maturity stages; Source: Smart Grid Gotland Project Prestudy

4. Roadmap:

Based on the technology areas presented in chapter 2, the roadmap consists of four areas:

1. Smart Distribution Networks
2. Smart Transmission Networks
3. Storage as a Tool for Network Flexibility
4. Materials for Smart Grid components

Evaluation of economic impact

In the area of Smart Grids, an economical evaluation is very complex since the benefits needs to be looked upon from an overall system point of view. This has also been recognized by the EU Commission that has initiated the development of a document “Guidelines for Conducting a cost-benefit analysis of Smart Grids projects; Report EUR 25246 ”. The intention is to use these guidelines for an evaluation of proposed projects on a case by case basis. To illustrate the nature of this evaluation an example of the value chain is given below:

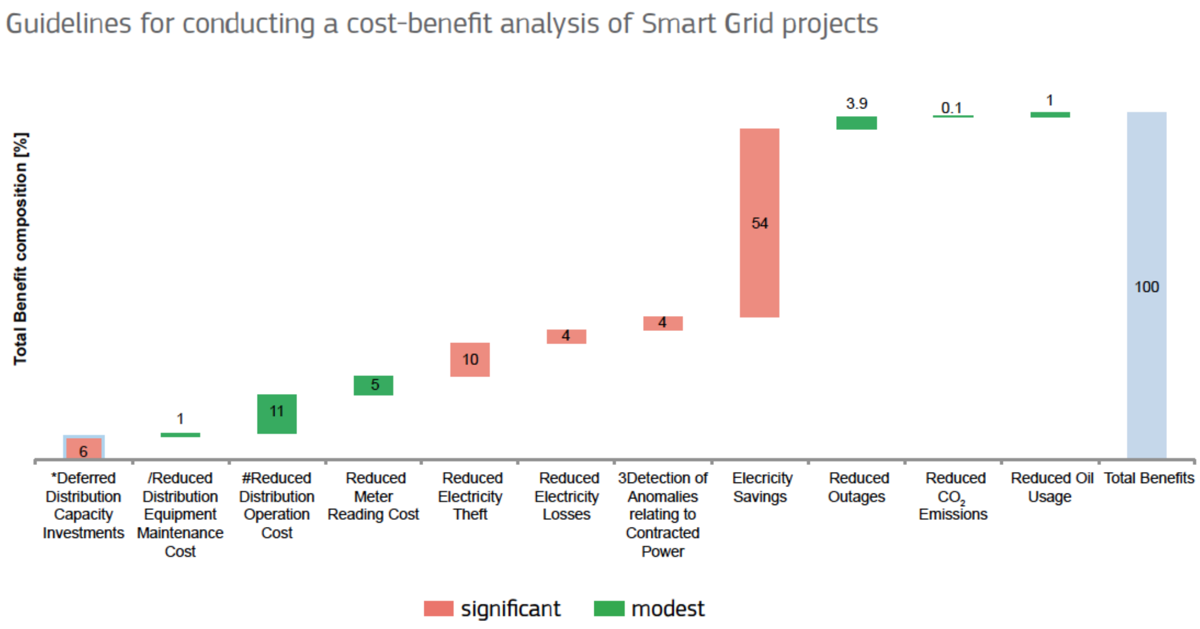


Figure 6: Example of possible benefits breakdown (%) with indication of uncertainty levels;

Source: JRC Report - Guidelines for conducting a cost-benefit analysis of Smart Grid projects

The chart gives a good illustration how economic impact can be both direct and indirect. An evaluation of the overall benefits is thus very important but this is also an illustration of the challenge to link the investment to benefits since the investor and beneficiary can be different entities.

4.1. Smart Distribution Networks

There is a rapid introduction of RES a large amount of the new generation capacity on the local level affecting the distribution grid. This requires further development of technologies to upgrade present distribution system by implementing new Smart Grids technologies and provide improved system support for advancements in the grid. Smart Grids solutions in the distribution grid will benefit entire electrical system and provide the most cost efficient solution.

A tangible effect from a Smart Grids is an overall increased efficiency of the electricity distribution system, which contributes to the EU 2020 target on energy efficiency. Several components deployed in the regional and local grid, automated and monitored remotely by interacting IT systems, will be used to optimize the distribution system. The optimized distribution system reduces transfer losses in the grid since power flows will be shared in a more optimal manor, peak loads will be reduced and voltage levels will be controlled. Further, in the optimized distribution system faults will be detected, and the number of as well as the lengths of the outages will be reduced. The effects of such improvements are:

- Reduction of maintenance cost for the distribution system operator (DSO);
- Optimized use of existing grid infrastructure;

- Higher power quality and lower number and shorter duration of outages;
- Enhanced customer understanding of electricity consumption by communicating and visualizing consumption meter data.

The Quantifiable impacts of projects in the Smart Distribution Networks Topic include (but are not limited to):

- *Increased hosting capacity*
- *% Reduction of curtailment*
- *Reduction in number of events of overvoltage*
- *Reduction in number of events of exceeding thermal limits*
- *Reduced SAIFI*
- *Reduced SAIDI*
- *% of load shifted*
- *% reduction in customer complaints.*

The impacts of the project shall be justified using the methods proposed in Guidelines for Conducting a cost-benefit analysis of Smart Grids projects; Report EUR 25246. This implies determining the baseline of the studied parameter before the introduction of new technology – the Business as Usual Scenario and compare with the I&T – Innovation & Technology scenario.

4.1.1 Timeline with Subtopics

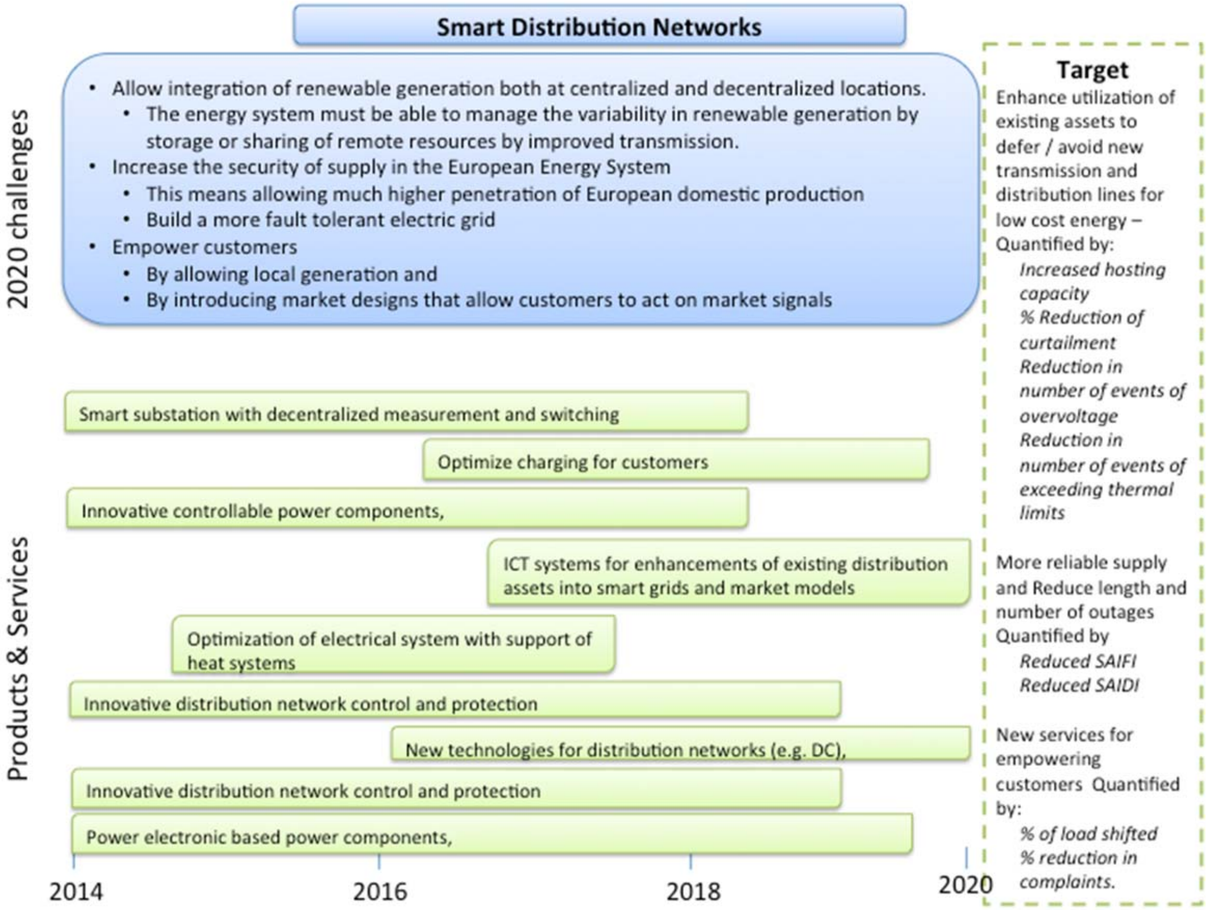


Figure 7: Smart Distribution Networks Roadmap timeline

- 4.1.2 Details per technology/product/service/application selected:**Smart substation with decentralized measurement and switching**: The smart substation includes the decentralization of switches and disconnectors, facilitating the measurement and automated management of the loads, quality and voltage of the electricity in the regional grid. The smart substation devices will decrease the cost of maintenance, as well as indicating outages with more precision, thereby reducing the length and number of outages. Vital elements for the implementation are standardization that can provide interoperability.

- **Innovative controllable power components:** Power components used in power supply, transmission and distribution of electrical energy to disseminate intelligence and controllability of the grid. Examples are active filters, distributed compensation, voltage control equipment …

- **ICT systems for enhancements of existing distribution assets into Smart Grids and market models:** The overall goal is optimal design of ICT systems that enable control of active distribution systems with retained or increased levels of reliability as well as enabling energy-user empowerment. One important example is applications based on smart meter information e.g. outage management system, low voltage monitoring or planning support

- **Optimization of electrical system with support of heat systems:** Load shaving for heating and boilers, is expected be the major part affecting the total cost for electricity. Existing heat loads, such as water boilers, heating systems, heat pumps will make it possible to control with minor changes, allowing for load shifting to periods with low energy costs.

- **Innovative distribution network control and protection:** The protection and control system used in the substations and distributed in the power grid will additionally to functions as fault disconnection and restoration the system will also manage monitoring of power flow and measured load in feeders. The systems are expected to move towards more autonomous operations.

- **New technologies for distribution networks (e.g. DC):** Currently the production is more distribution than previous which requires further development of technologies to upgrade present distribution system by implementing new Smart Grids technologies and provide improved system support for advancements in the grid. Interesting examples are DC distribution grids and solid state transformers.

- **Power electronic based power components:** There is a strong development of power components including both new topographies of convertors and new semiconductors based on new materials such as silicon carbide SIC. This will open up for entirely new components in the distribution grid with higher efficiency.

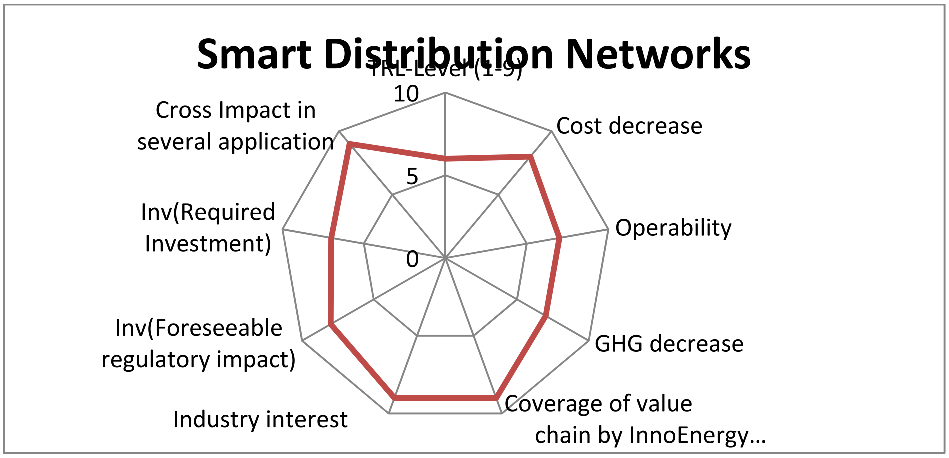
4.1.3 Assessment on “Impactability” of selected topic:

Distribution networks have historically been designed with the following criteria:

- Power flow is always from higher power levels to lower power levels
- No local generation
- No local storage
- Meter readings based on annual or at the most monthly reading
- No direct activation of customers anticipated

In the new energy landscape emerging all these factors are changing:

- Power flow can be bidirectional
- Local generation and storage
- Meter readings and billing based on momentary values or at least hourly
- Direct customer participation anticipated



4.1.4 Industry value chain necessary

The future Smart Grid is the end result of a fundamental topology transformation of the complete energy grid, where both technical system, operation, actors involved (suppliers, utilities, customer) and their way of interaction through new business models will be different vs the traditional network.

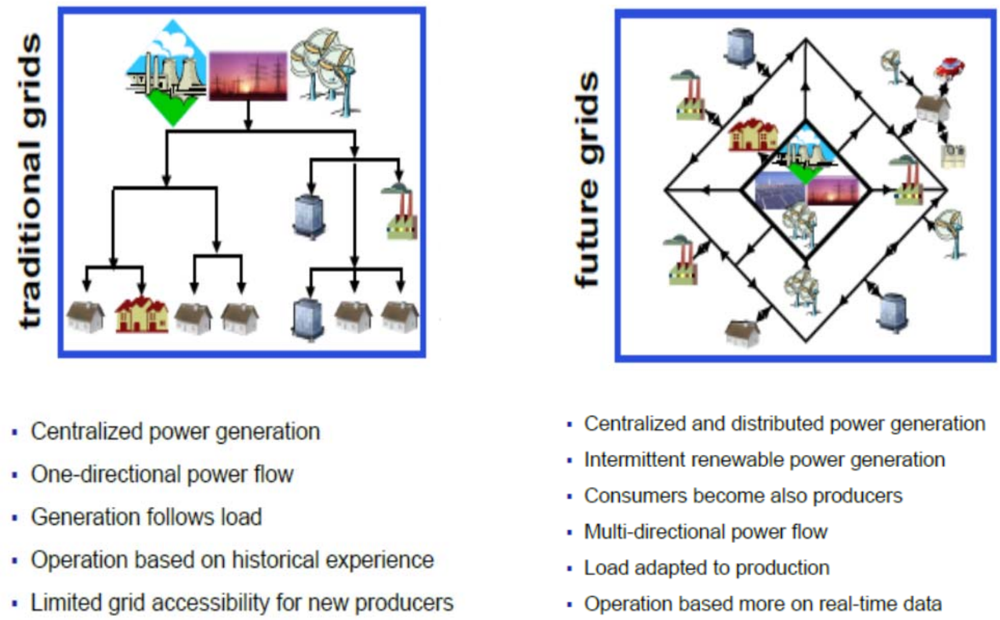


Figure 8, Evolution of the traditional electrical grid to the future Smart Grid. Source: ABB.

This transformation process implies that the value chain of bringing product and services to the Smart Grid market will also change, be dynamic and ultimately end up in a very heterogenic structure with actors form energy industry, telecom and ICT. An illustrating example is given in figure below:

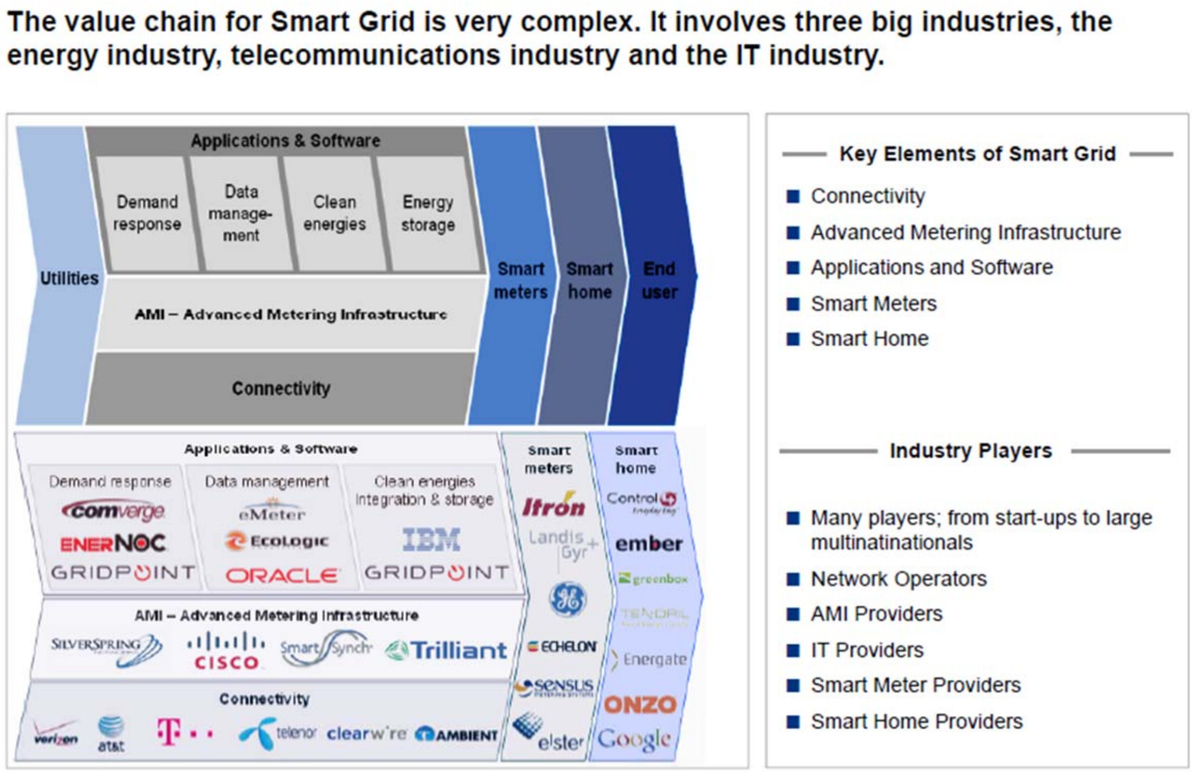


Figure 9. US Smart Grid Value chain. Source: Detecon Consulting USA

To realize the The Smart Distribution Networks roadmap we will be needing industries from

- Utilities (mainly DSOs)
- Power equipment components, system, integrators and service suppliers
- Telecom
- ICT (traditional and Start Ups)

It will be mainly be a B2B type of value chain and today all these categories of industries are represented in the partner base of CC Sweden, and InnoEnergy wide it looks even better. However, still the number of partners today will most likely not be sufficient to execute the whole roadmap as existing partner will engage in projects to various extents.

Therefore future investment rounds will be targeted to other industries in these categories. Particularly in the ICT segment we will seek further cooperation with ICT Labs and their partners, and we will also put high emphasize to tie our Start Up companies from our Business Creation Highway into innovation projects.

Products and services targeting end user might have an aspect of B2C, however we foresee that these segment will mainly be addressed through DSOs or in our thematic area Smart Cities. Currently we don't foresee a need for retailer/distributor type of partner in the roadmap.

Another important aspect of the industry value chain is the market introduction process. Introducing new products, services and business models in a Smart Grid is a **slow process**, and it is commonly accepted to do it through joint industrial demonstration sites.

Therefore we will seek partner with access and engagement in such demonstration sites. Smart Grid Gotland and Royal See Port of Stockholm will be addressed first, followed by more on a need basis.

4.1.5 Actions needed to increase "impactability" (Action plan)

To make this happen there are multiple actions required:

- Development of new technologies including hardware and software
- Development of new business models
- New industrial clusters including merging IT and power skills
- New regulation that supports and give incentives for new technologies and business models e.g.
    - Hourly meter reading and billing
    - Prosumer metering
    - Introduction of time of use pricing
- New communication platforms to incentivize customers to adopt the new technologies.
- Drive standardization for communication, protection schemes etc.
- Finding the right partners to engage in demo sites projects such as Smart Grids Gotland and Royal Sea projects.

4.2 Roadmap: Smart Transmission Networks

The necessity for transforming the European Transmission Grid into a "smarter" grid has been identified in the European Network of Transmission System Operators for Electricity (ENTSO-E) R&D Roadmap. ENTSO-E is also the natural driving force to determine the direction for R&D in the Transmission area.

"Smart Grids is central to ENTSO-E's vision for the European transmission system. *Although sometimes misconstrued as being more relevant for distribution than transmission, the Smart Grids will be impossible without the involvement of TSOs. The Smart Grids will enable TSOs to monitor its assets and react in a smart way, and how loads react to price signals as a consequence of variable inputs from RES. TSOs are responsible for building new lines in response to market needs and thus enabling demand response to bid on Europe-wide intraday and balancing markets."*

The Smart Grids will enable the TSO to get a better total system understanding all the way down to the lower voltage levels. It will allow for using balancing resources provided by the local distribution grids or other actors. These resources can be Demand response or virtual power plants.

TSO will benefit from improved maintenance (condition based maintenance)

The main objective contribution for the KIC to the ENTSO-E is to utilize the network of Universities, Manufacturers and new start-up companies to bring to support the development plan and bring in new ideas.

Targets

- Enhance utilization of existing assets to defer / avoid new transmission lines for environmental impact (public resistance for new transmission lines)
- Increased reliable supply
- Improved power market to lower cost
- Avoid catastrophic failures and extend equipment life
- Reduce length and number of outages

The Quantifiable impacts of projects in the Smart Distribution Networks Topic include (but are not limited to):

- *% increase in capacity of existing of power corridors*
- *% reduction of thermal limit events*
- *% increase in cross border trading*
- *% increase in off-shore DER*
- *% decrease in price volatilty*
- *% reduction in number of faults*
- *% reduction in lost load*

The impacts of the project shall be justified using the methods proposed in Guidelines for Conducting a cost-benefit analysis of Smart Grids projects; Report EUR 25246. This implies determining the baseline of the studied parameter before the introduction of new technology – the Business as Usual Scenario and compare with the I&T – Innovation & Technology scenario.

4.2.1 Timeline with subtopics

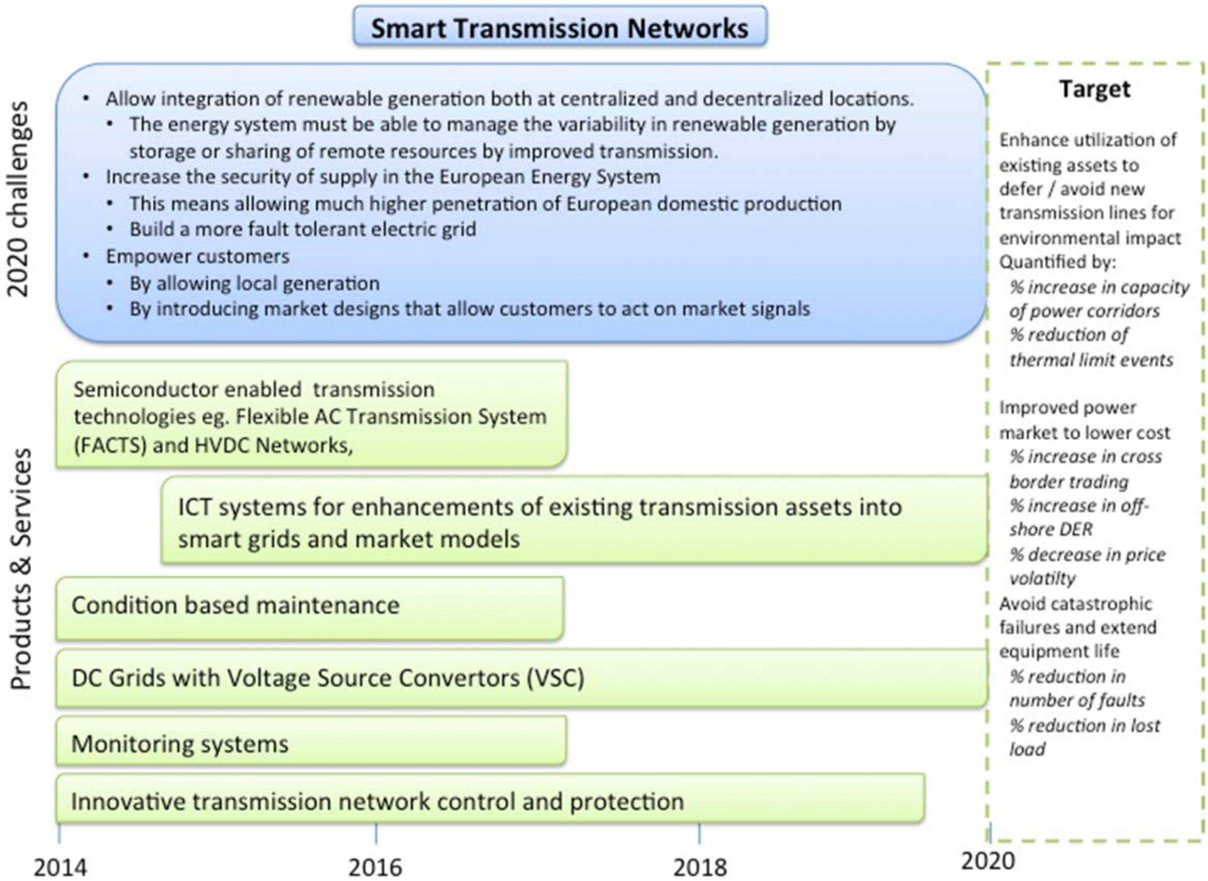


Figure 10: Smart Transmission Networks Roadmap timeline

4.2.2 Details per technology/product/service/application selected:

- **Semiconductor enabled transmission technologies eg. Flexible AC Transmission System (FACTS) and HVDC Networks:**

Smart Grids solutions of today are built with Flexible AC Transmission System (FACTS) and HVDC Convertors. The goal with the program is to develop enhanced functionality, performance and applications with these technologies. Examples of areas to be covered are:

- New or improved software tools to verify the performance if these technologies particular in meshed networks

- Capacity increase in existing or refurbished lines by integration of FACTS devices
- Capacity increase in existing AC lines by stability enhancement from FACTS or HVDC Convertors.
- Capacity increase in lines by converting lines from AC to DC
- HVDC undergrounding technologies including installation, monitoring and maintenance

- **ICT systems for enhancements of existing transmission assets into Smart Grids and market models:**

Existing transmission infrastructure could be given increased performance by adding more sophisticated control systems. New market models could also be required to allow full utilization of infrastructure. Examples of areas to be covered are

  - Development of new market models

- **Condition based maintenance (Asset Management):**
  - Development of software for more efficient maintenance planning
  - Utilization of enhanced information from new monitoring systems to maximize utilization of assets
- **Monitoring systems:**

New monitoring systems could be used to increase the utilization of existing and new transmission assets. Areas to be included are e.g.

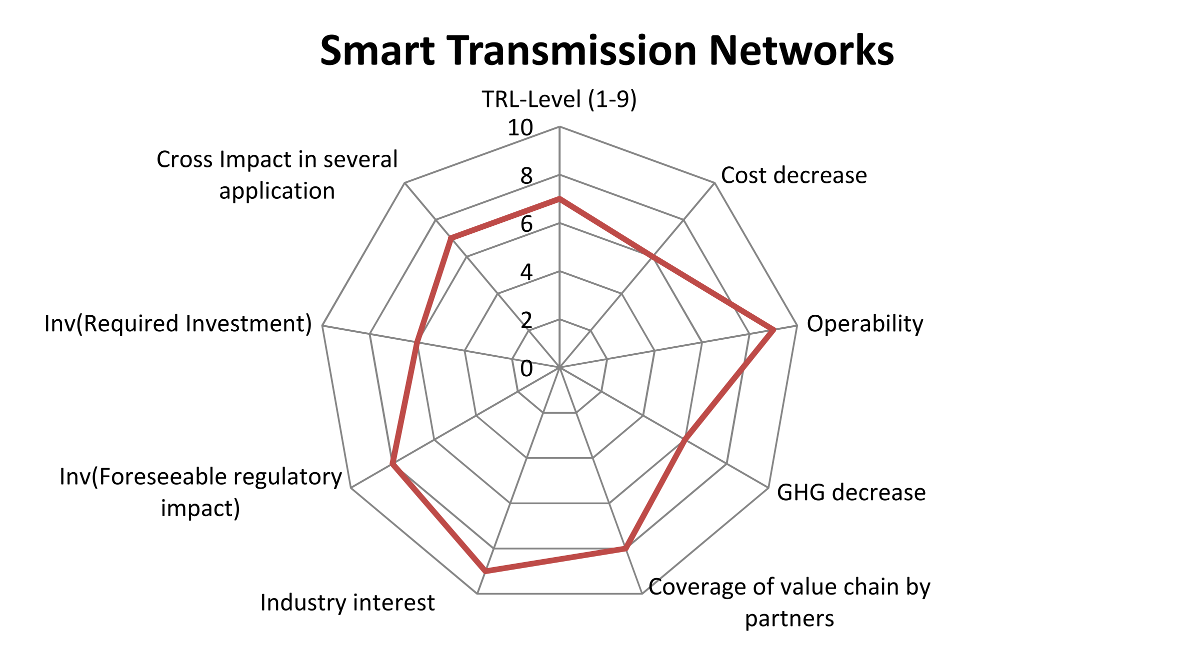
  - New sensors to measure critical quantities affecting transmission capacity such as temperature, wind
  - Load prediction systems
  - Utilizing existing control and protection system for monitoring

- **DC Grids with Voltage Source Convertors (VSC):**

DC systems are today usually built as point-to-point connections. With the new Voltage Source (VSC) technology it is for the first time realistic to start building networks with HVDC convertors. This will include innovative products e.g. in the following areas

  - Development of software for analyzing technical performance DC Grids
  - Development of models for analyzing economical benefits of DC Grids in particular the potential enhancement of existing AC infrastructure by improved dynamic performance.
  - A special application for DC Grids is off-shore grids for interconnections and connection of off-shore wind power. This application requires specially designed control and protection schemes.'
  - DC breakers are just being introduced in conceptual form and will be a key element in the development of DC Grids. This will have implications on standardization, control and protection schemes as well as monitoring equipment.
- **Innovative transmission network control and protection:**
  - Overload calculator
  - Automatic power failure detection and restoration
  - Implement Wide area monitoring for optimizing power flow in the pan-European grid
  - Develop protection and control strategy for optimal distribution of Renewables within Europe based on an overlaying HVDC Grid on the existing HVAC grid.

4.2.3 Assessment on "Impactability" of selected topic:



4.2.4 Industry value chain necessary

Transmission System Operators involvement is crucial to determine the customer needs in the market so that component manufacturers and service companies can deliver the right solutions.

Transmission systems are highly regulated and have very high reliability standards. This requires industrial cooperation including TSOs and manufacturers to establish necessary standards.

In general the industry value chain is similar as described for The Smart Distribution Network roadmap, but with much more weight on traditional big energy industry (no B2C). The InnoEnergy partner base has today these industries, but need to reinforce it on both supplier and customer/user side. It will be further analyzed.

4.2.5 Actions needed to increase "impactability" (Action plan)

To make this happen there are multiple actions required:

- Development of new technologies including hardware and software
- Development of new business models
- New industrial clusters including merging IT and power skills
- New regulation that supports and incentives new technologies and business models e.g.
  - Continue to build cross border electricity markets
  - Encourage cross-border interconnections including supporting
  - Continue to build Pan-European network planning primarily through ENTSO-E to

4.3 Storage as a Tool for Network Flexibility

Electricity storage is identified as a key technology priority in the development of the European power system, in line with the 2020 and 2050 EU energy targets. Power storage has gained high political interest in the light of the development of renewables and distributed generation, as a way to reduce carbon emissions, to improve grid stability and to control the fluctuations of variable resources.

Electricity storage offers the potential of storing electrical energy once generated and to subsequently match supply and demand as required. Storage technologies could therefore relax the grid's matching constraint by decoupling energy production and consumption. Indeed, it could play a variety of roles in firming up RES in different timeframes, i.e. from moment to moment, daily and even seasonally. Such storage options are not only essential to expand renewable energy sources, but also to ensure continuity of supply, increase energy autonomy and mediate against intermittent power production.

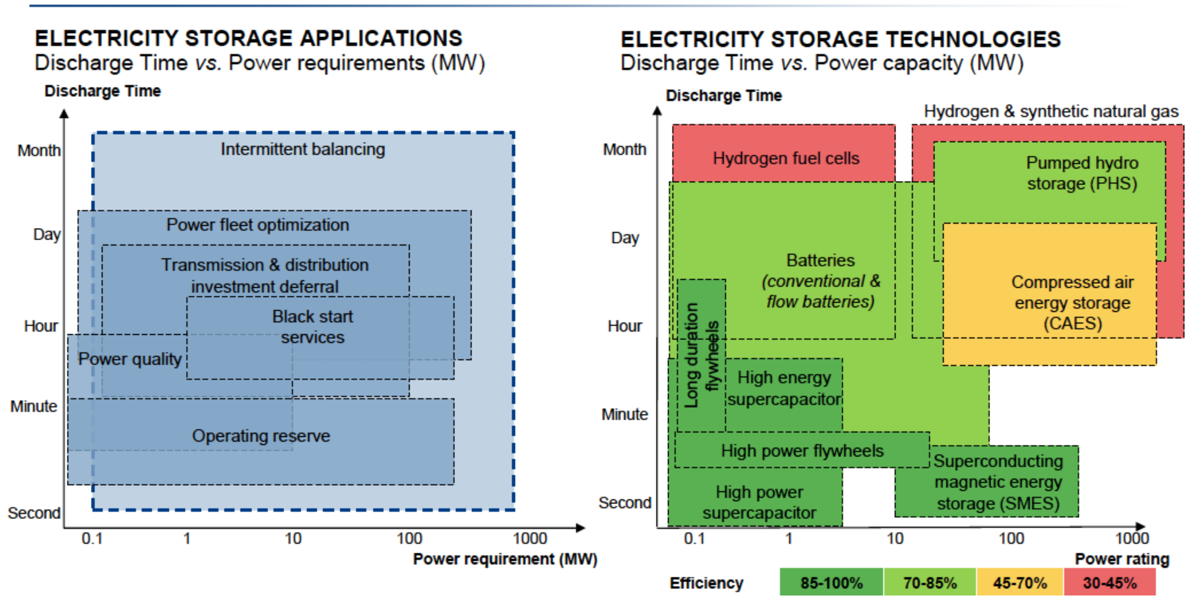


Figure 11: Applications ans technologies for electric storage. ©2013 SBC Energy Institute

Large-scale storage, like water reservoirs and pumped storage plants, are uniquely situated to help integrate intermittent renewables whereas small-scale, grid-connected electricity storage, on the other hand, will open new markets, offer new opportunities and also pose new challenges to the business of distribution grid operators. EV's have also great potential to be used

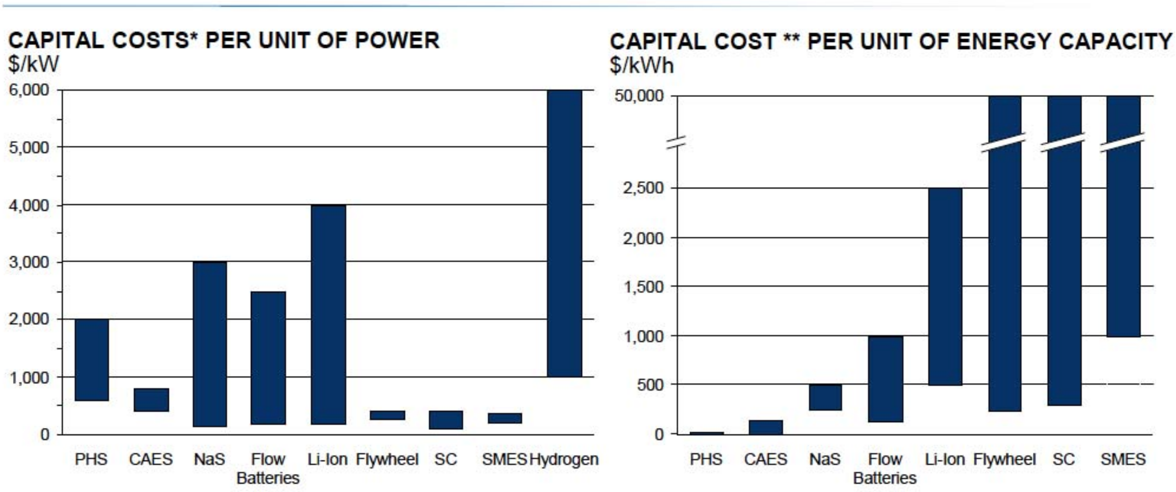


Figure 12: Current Status of Power Storage Technologies; ©2013 SBC Energy Institute

On capital cost it should be mentioned that the EV market appears to drive down costs of Li-Ion batteries very fast. Annual cost reductions of 20 – 30 % are reported and this is expected to make this option much more attractive particularly in the low energy range.

Each storage technology has some inherent limitations that make it practical or economical for only a limited range of applications. Thus we will focus on the technologies that can be used as a tool for the network flexibility on the grid, which shows a prominent value in the market.

The Quantifiable impacts of projects in the Smart Distribution Networks Topic include (but are not limited to):

- *% reduction in DER curtailment*
- *% reduction in over/under voltage events*
- *% reduction in thermal limit events*
- *% redcution in SAIDI*
- *% reduction in SAIFI*

The impacts of the project shall be justified using the methods proposed in Guidelines for Conducting a cost-benefit analysis of Smart Grids projects; Report EUR 25246. This implies determining the baseline of the studied parameter before the introduction of new technology – the Business as Usual Scenario and compare with the I&T – Innovation & Technology scenario.

4.3.1 Timeline with subtopics

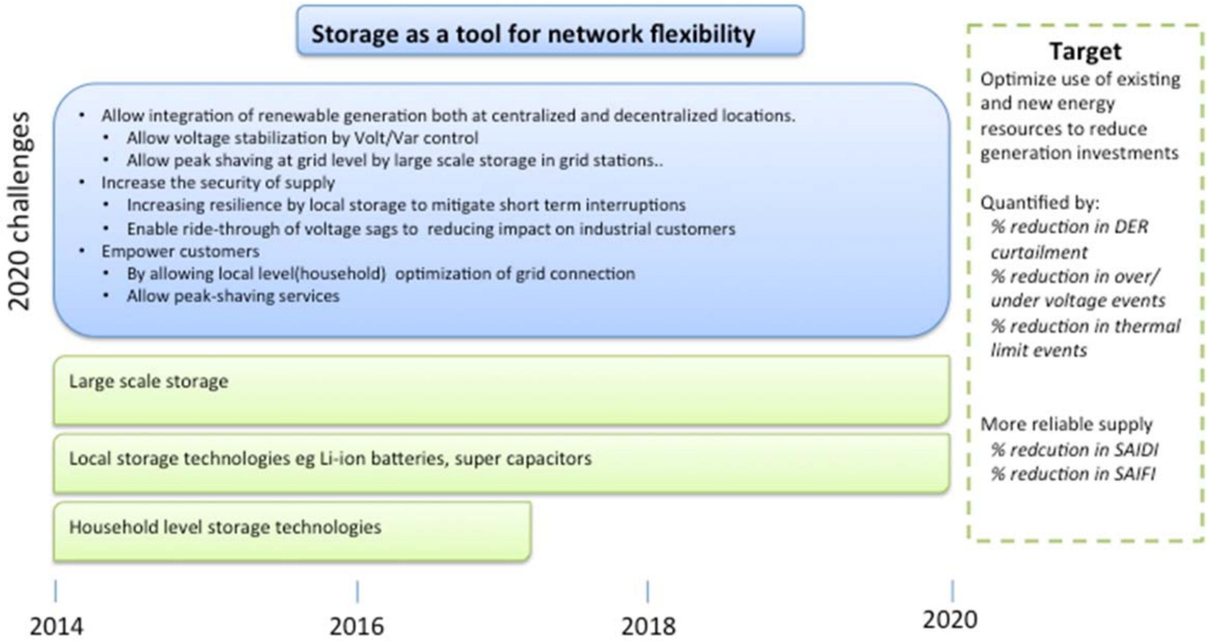


Figure 13: Storage as Tool for Network Stability Roadmap timeline

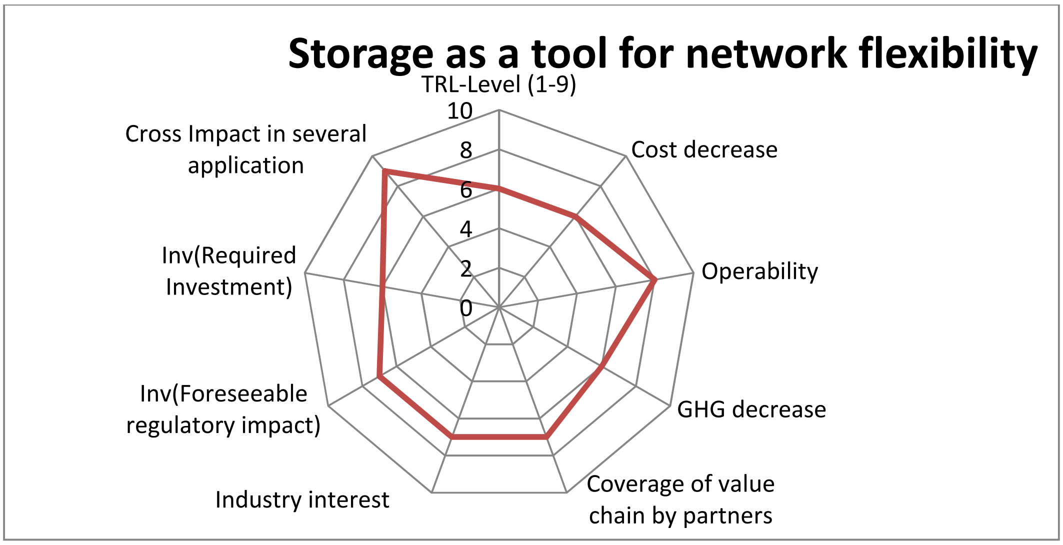
4.3.2 Details per technology/product/service/application selected:

- **Large scale storage:** With a large-scale energy storage facility, the storage can function not only as a voltage control facility and allow for short periods of islanding, but actually act as a power source, allowing for dynamically controlled power to be injected into, or drawn from, the grid.

- **Local storage technologies e.g. Li-ion batteries, super capacitors:** An energy storage facility that is integrated in the distribution system, allowing for voltage control and power quality improvements. Small-scale energy storage allows for short period of islanding, meaning that the storage can allow for an island of the grid to function without any outside input of electricity.

- **Household level storage technologies: Energy storage technologies optimized and packaged to** be sold on the consumer market. The technologies in the area is similar to that for local storage above, but its control system solutions is optmised for cycles together with prosumer level production such as PV including communication solutions for building level automation.

4.3.3 Assessment on "Impactability" of selected topic:



4.3.4 Industry value chain necessary

The electric storage market related to large-scale storage will basically be the same as for distribution systems. Very large scale electric storage on TSO level is less likely but if they are applied they value chain will be the same as for transmission storage.

More local storage even on consumer level are very likely to happen, both in the form of using EV batteries as well as dedicated local electric storage. Here the value chain will be totally different. The traditional utilities may be an actor in the same way they today are actively offering local PV systems and local heat pumps to end customers on household level. But we can also expect that new actors using more traditional channels to and customers as well as new actors acting as aggregators will emerge in this field.

Further, except for hydro and CAES storage, new storage devices being developed (batteries, flywheels, SMES etc) are relatively small units which need to be mass produced and integrated in an application. Today the partner base of InnoEnergy is missing manufactures of these devices in order to have a complete value chain for the roadmap. Most relevant in the short run is to find a battery manufacturer, which today is missing. This will be prioritized.

4.3.5 Actions needed to increase "impactability" (Action plan)

- Development of new technologies including hardware and software
- Development of new business models
- Find optimal solutions considering complementary technologies such as heat storage
- New regulation that supports and incentives new technologies and business models e.g.
- Find a battery manufacturer to join battery innovation projects

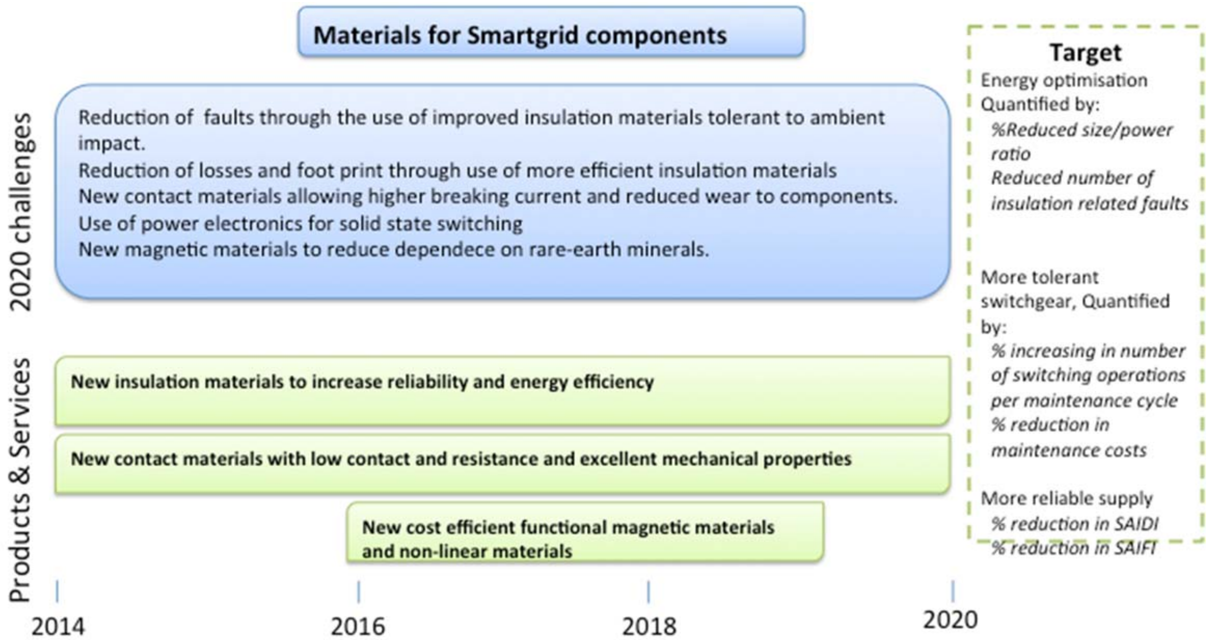
4.4 Materials for Smartgrid components

The increased flexibility of the smart grid implies more use and wear and tear on electric power components such as switchgear, transformers and disconnectors. In addition, the increased loading of components which is implied with more efficient use of already installed assets will lead to higher losses - assuming component characteristics remain unchanged. To reduce losses, beyond what is possible through operational actions such as voltage control, the most promising approach is improved materials that enable lower losses in power electronic converters, transformers, and switchgear.

The evaluation of business value of the actions in this topic is not similar to those of the three previous sub-topics. The impacts of the new materials on component development actually impact not the grid user, but instead the immediate business value of the new material is actually impact the equipment and component vendors business. The material's impact may be difficult to judge in isolation. However, to to allow similarity in comparison between projects in this topic with the other topics, it is suggested that the impact of the material be judged through the entire value chain including the utiliy and end user.

- The quantification of targets within the topic includes but is not limited to:
- *%Reduced size/power ratio*
- *Reduced number of insulation related faults*
- *% increasing in number of switching operations per maintenance cycle*
- *% reduction in maintenance costs*
- *% reduction in SAIDI*
- *% reduction in SAIFI*

4.4.1 Timeline with subtopics



4.4.2 Details per technology/product/service/application selected:

New insulation materials to increase reliability and energy efficiency

More efficient isolation material will increase the utilization of many components. One example is the possibility to increase capacity of power cables and thereby save CAPEX for underground and subsea transmission. All high voltage equipment could potentially be built more compact.

New contact materials with low contact and resistance and excellent mechanical properties
Lower cost and longer lifetime of breakers, including reduction of maintenance costs and reduced risk of faults.

New cost efficient functional magnetic materials and non-linear materials
More efficient and lower cost in transformation equipment. Could reduce the dependence of rare materials for magnetic applications including transformers and electric drives.

4.4.4 Industry value chain necessary

The materials area requires a value chain from material over to power system component, focused on High voltage applications such as insulation for cables and switchgear but also materials for semi conductor applications and plastics for cables.

Project in the area requires customer involvement as component developers. The development of materials is an applied field, based on basic research within the applied branches of chemistry and physics. The life-time of product development from a new technology based on a new material to new products is longer than that of the other topics, and due consideration must be given to this in assessment of projects.

In addition to a component manufacturer acting as customer, project in the field require participation of partners with strong laboratory resources in conjunction with material knowledge.

4.4.5 Actions needed to increase "impactability" (Action plan)

An overall important action needed is to bring materials researchers in contact with the customer. This may involve a larger share of prototyping projects in which new – yet untested – materials can be evaluated or power applications.

A Annexes:

A.1 Dropped topics vs v0

The following topics have been dropped from the V1 roadmap. The reason is the lack of projects in the area and the judgement that there remain several years until the EV fleets will such scale that V2G solutions are economically feasible.

- **EV Batteries as a tool to store excess production:** Electric Vehicle cars, have in common the batteries, which provide storage capability. The storage can be charged when intermittent generation output is high, and discharged depending on market prices, wind availability, grid status or other factor, thereby providing large-scale energy storage. Further the grid infrastructure needs to be optimized if fast charging is introduced since the capacity of today's LV network might not be sufficient.

- **EV Batteries as a tool to V2G (Vehicle to grid):** A more advanced model of using the batteries in electric vehicles is the system integration, meaning that the vehicles respond to demand and supply conditions. Charging is steered to periods of low output, but system integration includes that the batteries also can deliver electricity to the grid during peak hours.

A.2 List of participants in the WG

The following organizations have contributed to the preparation of Smart Grids and Electric Storage Strategy and Roadmap by attending the meeting and workshops as well as reflection their feedbacks on several occasions

- *AGH CC Poland+, academia*
- *ABB, CC Sweden, industry*
- *Elforsk, CC Sweden, industry*
- *Ericsson, CC Sweden, industry*
- *INPG, CC Alps Valleys, academia*
- *IREC, CC Iberia, research center*
- *KTH, CC Sweden, academia*
- *KU Leuven, CC Benelux, academia*
- *Power Circle, CC Sweden, industry*
- *TU/e, CC Benelux, academia*
- *UPC, CC Iberia, academia*
- *Vattenfall, CC Sweden, industry*
- *CC Sweden*
- *CC Benelux*
- *CC Alps Valleys*

References

The reports and documents below has been utilized during the preparation of roadmap

- *ENTSOE - R&D Plan "European Grid Towards 2020 Challenges and Beyond"*
- *EC - Smart Grid: from innovation to deployment*
- *Eurelectric - Smart Grids and Networks of the Future*
- *EEGI - Roadmap and Implementation Plan*
- *JRC - Smart Grids projects in Europe Report: Lessons Learned and Current Developments*
- *ETP Smart Grids - Strategic Research Agenda 2035*
- *ETP Smart Grids - Strategic Deployment Document*
- *Smart Grids Gotland Project - Pre-study*
- *International Energy Agency - Smart Grids Technology Roadmap*
- *JRC -2011 Technology Map*
- *SG EraNet - Smart Grids Initiatives in Europe*
- *JRC - International Strategies on Energy Storage An outlook of European Union's strategy*
- *European Parliament - Outlook of Energy Storage Technologies*
- *IEA - ECES Strategic Plan 2011-1015*
- *JRC - Power Storage options to integrate renewables*
- *IEA Energy Technology Perspectives 2012*
- Guidelines for Conducting a cost-benefit analysis of Smart Grids projects; Report EUR 25246

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InnoEnergy is supported by the EIT,
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