Smart investment on the smart grid: A proposed framework

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1. Overview:

The global investment necessary to upgrade the existing power grids and make them smarter is significant, calculated by existing studies, as is the expected return on the investment. Already demonstration projects have proven partially this assessment, but the step from pilot projects, test-beds [36], living-labs, demonstration projects, etc, to initiatives without public funding and valued as conventional investments by utilities has not been extensively implemented.
This paper presents actual tools and model initiatives for the implementation of the smart grid and proposes a framework for defining a smart grid roadmap, mainly for utilities. Additional to the economical sustainability and initiative prioritization, the model for smart grid investments must take into account the social [15] and environmental benefits [34]. All these proposed features are discussed in detail in the paper as part of the research.

Keywords: smart grid investment, Power systems planning, smart grid roadmap, smart grid business case

2. Methods:

The method for the research has been to revise the existing Smart Grid assessment systems and business case models for implementation maps in order to propose a comprehensive integrated model that can allow the evolution to the future grid [40]

2.1 Initiatives, models and tools

Initiatives to implement smart grids have been and are incentivized by governments [14][17][18][23] and also promoted by utilities as pilots, research[43] and development tools [16] [21]. Examples of these projects can be found internationally [44], for the US, in [19], and for the EU in [20]

Models have been created by consulting companies and research centres to guide smart grid strategy definition such as the Principal Characteristic Maturity Model [5], or the Smart Grid Maturity Model [7] as well as interoperability models [24][22].
A review of these systems is done in [45] and while the research highlighted that each system is influenced by the region and technological focus of the region where it was created, a general model could be integrated. Additionally, as the smart grid allows new products and systems, business cases for new applications and businesses [25] are difficult to include and require regular updating on any model.

The scheme for the methodology of [5] is shown on figure 1. This model starts with the vision for smart grid implementation, evaluates the actual state and analyzes the business case for the list of solutions that fill the gaps.
A computational model has also been created by the DOE to evaluate demonstration projects [2] Moreover, some companies have developed their smart grid roadmap and are publicly available [26][27] serving as a guide for other utilities.

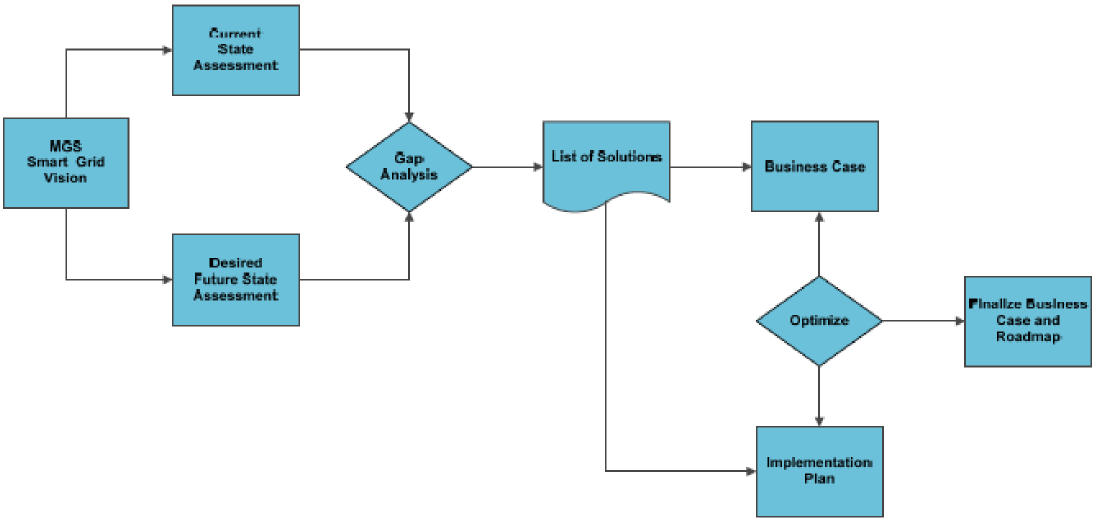

Fig 1. NETL Smartgrid business case methodology [5]

Business cases and experiences are also useful for utilities, as a mean to share experience, best practices and lessons learnt [8], accelerating the global implementation of smart grid technologies.

2.2 Proposal for a framework

With the use of a maturity model self-assessment, complemented with the specific characteristics of the utility (business environment, regulatory, market, strategy definition, budget, etc.) and applying an evolving business case calculation, an integrated tool for utilities can be created. This framework would assess the utility's smart grid situation, and propose a road map for implementation, detailed with investment initiatives prioritized by sustainability benefits (economical, social and environmental) and strategic imperatives, accelerating implementation as suggested in [4]. Compared to actual calculation models [2], this tool's input is not the smart grid project but the characteristics of the utility and the smart grid implementation plan is the output and it complements the benefit approach and a strategic perspective.

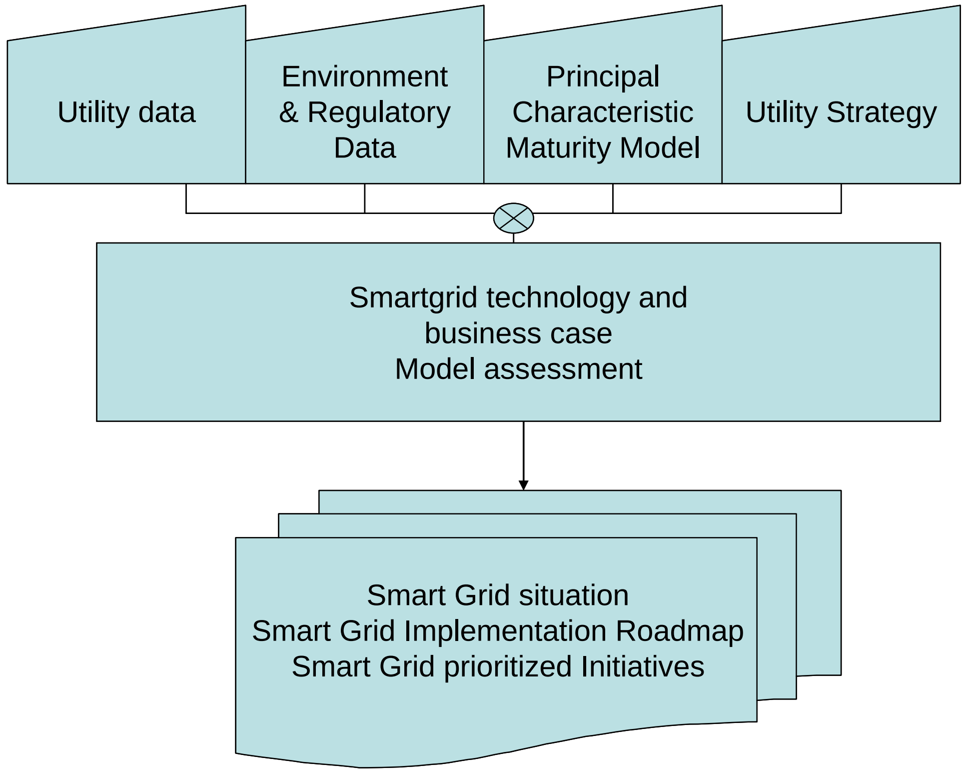

Fig. 2. Proposed model definition

The approach to smart grid implementation using the proposed model may be more holistic, and compress existing proposals [5]. It allows a further analysis on specific areas or initiatives, but facilitates a summarized situation and proposal for initiatives.

2.3 Model description

Utility Data has to include the areas in which the utility is operating, such as generation, transmission [10], distribution [28] [41] [32], retail and/or energy services, where the transformation to a smart grid applies [9][11][12]. All action plans and available technologies apply to the different levels of the sector.

The data required includes the following:

- Category of the company, areas of operation
- Network data:
- Km lines
- Yearly Power delivered
- Number of substations and type
- Number of secondary distribution centers
- Number of meters and smart meters
- % of technical losses
- % of non technical losses
- SAIDI
- SAIFI
- Generation data:

- Power plants owned by the company
- Existing power plants in the network
- Installed capacity
- Yearly generated power
- Peak demand
- Peak/valley ratio
- Customer data:
- Number of customers
- Average consumption
- % of EV vehicles
- Employees
- Capital available for smart grid implementation
- Required return on investment

Environment and regulatory conditions reflect the boundaries and conditions in which the utility develops its operations. For example, FIT [29], can affect the power generation decisions to great extent.
The input in this category includes the following data:

- Mandatory implementation for smart meters and conditions
- CO_2 emission restrictions and CO_2 price
- Cost of interruptions and outages (fines)
- Mandatory renewable %
- Renewable FIT support
- Allowed Autoconsumption and net-metering

The Principal Characteristic and Maturity Model, similar to [7], collects the data in terms of smartgrid data from the utility, as a starting point for the model, as a self assessment of the situation. The user has to assess the situation of the different areas:

- Strategic approach to smart grid implementation
- Existing plans for implementation
- Existing technologies in service from the smart grid technology list explained further on, and utilization
- Competencies and training on smart grid technology
- Organizational perspective on smart grids
- Company IT infrastructure

The Utility Strategy, has to be defined through the prioritization of the values and benefits the smartgrid technologies can offer, linked to the utilities mission, vision [14] and business strategy.
Smartgrid values are defined as follows selected from previous studies [35][38][42] as well as smart grid definitions by many stakeholders:

- Efficiency
- Reliability
- Security
- Quality

- Profit
- Optimization
- Innovation
- Environmental sustainability
- Social responsibility
- Customer involvement/participation

The prioritization of these values implies the prioritization of the technologies associated with these values. And the utility strategy can be defined using the following types:

- Growth
- Low-cost
- Differentiation - Competitive advantage
- Diversification
- Segmentation
- Restructuring
- Operational excellence
- Product leadership
- Customer intimacy-service
- Innovation

The model allows the utility scoring on the different values and strategies to be used as variables for technology prioritization.

The Smartgrid Technology and business case model assessment, utilizing the data from the previous inputs (as variables) calculates the impacts for all the different smartgrid technologies based on previous studies [1][2][5].
The technologies the model considers at the actual state are the following, classified in categories of customer, retail/energy services, distribution, transmission and generation.
Compared to [2], this model proposes an additional link to the strategy and values, as mentioned above, so the scheme of functions per technology and associated benefits is also linked to those. The benefits are also categorized in the three sustainability categories (social, environmental, economical) as in figure 3.

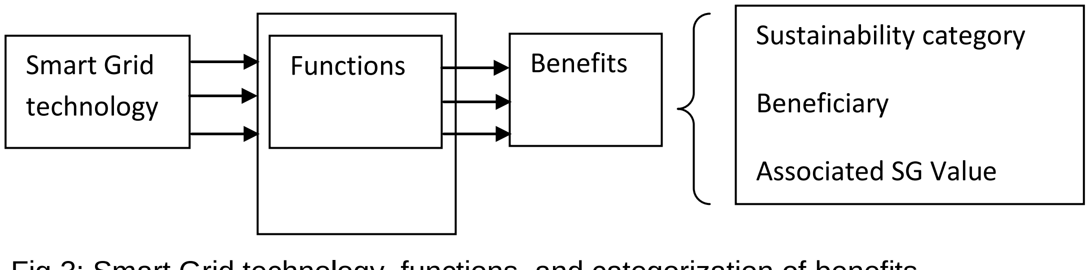

Fig 3: Smart Grid technology, functions, and categorization of benefits

Social benefits is a category that has not been considered widely, although energy security and reliability can be considered also social benefits. Other social benefits that this model proposes to include are:

- Accessibility, as more control and information on power consumption increases the social accessibility (for example with remote control on the electrical appliances)
- Linked to control and information, the empowerment of customers is also a social benefit, increasing the knowledge and the decision capability of the society
- Lower energy theft is as well as an economical benefit, a social benefit, reducing the free riders and increasing justice
- Emission reduction is linked to social health increase, not only from power plants but also from vehicle pipe emissions in the case of cities.
- Sound emissions reduction (from ICE vehicles to EVs) is also socially sustainable, related to comfort and health
- Job creation is not only an economical benefit, but also social, specially of the jobs created, as those related to smart grid technologies are of high value
- Extending the right of society to generate its own electricity (with micro generation and net-metering for example) is a social benefit. The use of these smart grid technologies with renewable energy sources in remote areas reducing energy costs, yields a social impact as it facilitates access to electricity

The difficulty is to monetize these benefits in order to compare costs and benefits of all technologies including them.

3. Results

3.1 Value assessment:

First result from the research is the need for a simple value and strategy based selection of applicable technologies and functionalities of interest for the stakeholder. This method allows a first orientation of the technologies and functionalities to study, more aligned with the ultimate strategy and goals of the companies to design the business transition [31]. The selection is subjective to the stakeholder.
The following table shows the matrix relation between the functions and benefit sustainability category. The prioritizing of the values and strategic objectives results in the alignment of smart grid functions with the stakeholders goals.

			Benefits	Benefit sustainability category			Beneficiary						SG Values link										Company strategy link									
Grid Area / Category	Technology/Function	Function description	Benefits	Economic	Environment	Social	TSO	Generation Utilities and IPP	Distribution Utility	Retail/ES utility	Customer	Society	Efficiency	Reliability	Security	Quality	Profit	Optimization	Innovation	Environmental sustainability	Social responsibility	Customer involvement/participation	Growth	Low-cost	Differentiation - Competitive advantage	Diversification	Segmentation	Restructuring	Operational excellence	Product leaders	Customer intimacy-service	Innovation
Customer	Home energy management systems	Visualization of consumption	Consumption reduction		1	1	1		1		1	1	1							1		1	1	1	1						1	1
Customer	Building management systems	Visualization and management of consumptions as well as security	Consumption reduction Comfort & Security	1	1	1			1	1	1	1	1		1	1	1	1	1	1	1		1				1		1	1	1	1
Customer	Demand response devices	Automatization of peak shaving	Consumption reduction, market competitiveness	1	1	1			1	1	1	1		1	1	1	1	1	1		1	1		1		1			1		1	
Customer	Interrumpibility, generation frequency/demand response	Demand response for industrial/commercial users	Grid stabilization	1	1		1		1					1	1		1	1				1		1					1		1	1
Customer	Customer training	Energy efficiency, consumption training	Consumption reduction	1	1	1											1							1	1	1	1				1	1
Customer	Time-of-use pricing	Time-based rates	Consumption reduction					1					1				1			1	1	1		1	1	1	1			1	1	1
Customer	Micro-generation	Net balance, autonsumption	Consumption reduction, loss reduction, emmission reduction, market competitiveness	1	1	1			1		1	1					1					1	1	1		1		1			1	1
Customer	E-vehicle customer adoption	Customer integration of e-vehicle	End user storage peak shaving, valley filling, load balancing, emmission reduction	1	1	1	1	1	1	1	1	1	1				1			1	1	1	1		1	1	1			1	1	
Customer	Statcom, capacitors and filters	Power quality and enhanced cosphi	Power quality and minimized losses	1			1		1		1		1	1		1	1	1		1												
Customer	Drives for motor consumption	Regulation in consumption	Reduced consumption	1	1						1	1	1				1	1		1				1					1			
Tranmission	Substation automation	Communication in substations and between substations for optimum protection	Reduced outages, improved restoration	1			1		1	1				1	1	1		1											1			1
Tranmission	FACTS	Series inductance compensation	Improved capacity, reduced disturbances	1	1		1	1	1			1																	1	1		1
Tranmission	HVDC	HV connection in DC for remote generation and long transmission	Reduced losses, improved reliability, reduced disturbances	1	1	1	1	1	1			1	1	1		1	1	1	1	1			1		1				1	1		1
Tranmission	Bulk energy storage	Storage of electrical energy	Improved reliability, peak shaving	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1						1			1	1		1
Tranmission	WAMS	Monitoring increase operator's situational awareness.	Improved reliability, flexibility	1				1										1	1								1		1	1		1
Transmission	Asset management software	Sensors for monitoring assets	Optimized utilization, maintenance, reduced costs	1	1		1	1	1	1			1	1	1	1	1	1	1	1	1			1			1	1	1	1		1
Distribution System	Smart meter reading	Use of information for business decisions	Decision making, offering						1	1	1	1				1	1	1	1	1	1	1	1		1	1	1		1		1	1
Distribution System	Voltage monitoring	Monitor and maintain voltage levels	Power quality and reduced losses	1	1	1	1		1		1		1	1	1	1		1											1	1		
Distribution System	Flywheels and distributed storage	Stores energy and stabilizes the network	Lower losses, reduction of peak demand, support during failures	1	1	1	1		1			1	1	1	1	1		1		1					1	1			1	1		1
Distribution System	Statcoms	Stabilization of the network	increased reliability and efficiency	1	1	1			1				1	1		1		1	1										1			1
Distribution System	E-vehicle as distribution storage	Stores energy and stabilizes the network	Lower losses, reduction of peak demand, support during failures	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Distribution System	Outage restoration systems	Restoration automation	Reduced outages, security	1	1	1	1	1	1	1	1	1		1	1	1		1	1		1								1	1		1
Distribution System	Advanced protection systems	Protection schemes and bi-directional	Reliability	1		1	1	1	1	1	1	1		1	1	1		1	1		1						1		1	1		1
Distribution System	Distribution DMS	Use of software for Distr operation and automation	Better restoration and monitoring, reduced costs	1					1		1		1	1		1		1					1						1	1		1
Distribution System	Distribution telecontrol	Automatic control and operation	Prevention of damage, Prevention of blackouts, Protection of valuable assets, Security of	1		1			1	1	1	1	1	1		1		1	1						1				1	1		1
Distribution System	GIS supported asset management	Allows active maintenance	Asset optimization reduced maintenance costs	1	1	1			1				1	1	1	1	1	1	1	1			1	1	1			1	1	1		1
Distribution System	Software aided maintenance	Personnel support and maintenance activities tracking	Security to personnel, improved asset managemnt	1		1		1	1		1		1	1	1	1	1	1	1		1		1	1		1		1	1			1
Distribution System	Ship-top-shore connections	Connection of vessels at prot to electrical grid	Efficiency, reduced emmissions	1	1				1	1	1	1				1	1		1	1	1		1		1	1				1		1
Distribution System	Microgrid integration	Allowing islanding	increased reliability and efficiency	1	1	1		1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
Retail/Energy services	Smart meter reading	Use of information for business decisions	Decision making, offering, customer segmentation	1	1	1				1	1	1					1	1	1		1	1	1		1	1	1			1	1	1
Retail/Energy services	Audits and customer consulting	Realizes energy efficiency measures	Reduced consumption,	1	1	1				1	1	1	1			1	1	1	1	1	1	1	1		1	1	1		1	1	1	1
Retail/Energy services	Financing/owning distributed microgeneration	Retail business model for microgeneration technology	Efficient generation, reduced losses, renewable integration	1	1	1			1	1	1	1	1				1	1	1	1	1	1	1			1	1		1	1	1	1
Retail/Energy services	Fle1ible tariffing systems	Customer adopted tariffs	Customer satisfaction	1		1		1		1	1		1				1	1	1		1	1	1	1			1			1	1	1
Retail/Energy services	Advanced billing systems	Automated billing, social psichology for efficiency and personalization	Customer satisfaction, operational cost reduction, efficiency	1		1				1	1	1	1			1	1	1	1		1	1		1	1		1		1	1	1	1
Retail/Energy services	Remote real time info to customers	Customer info realtime and remote	Reduced consumption, customer satisfaction	1	1	1				1	1	1	1			1		1	1		1	1	1							1	1	1
Generation	Virtual Power Plants. Control system for distributed generation	Virtual Power Plants	Allows renewable integration, reducing emmisions	1			1	1	1				1	1				1	1	1			1	1	1	1	1		1			1
Generation	Power plant automation and optimization systems "Smart Generation"	Optimization of power plant operation via control system	Renewable integration, efficiency, reduced maintenance costs	1	1	1		1					1	1	1	1	1	1	1					1				1	1	1		1
Generation	Asset management software	Sensors for monitoring assets	Optimized utilization, maintenance, reduced costs	1	1			1					1	1	1	1	1	1	1					1					1			1
Generation	Market price prediction tools	Software for prediction and generation operation	Better operation and planning	1				1		1						1	1	1					1	1				1	1			1
Generation	Estabilization, integration technologies for generation (Storage, flywheels, FACTS)	Grid compliance and manageability of consumption	Renewable integration, balancing of generation	1	1		1	1		1				1		1	1	1	1	1			1		1	1	1		1	1		1
Generation	Provision of ancilliary services	Provide power services to the TSO	Reliability, power quality, reduced energy price, reduced capacity investment	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1			1		1	1	1		1	1		1

Table 1: Functions, benefits and alignment to values and strategies

3.2 Business cases:

The research of the return on investment through a business case study has been, as mentioned, done on a general perspective. For example [1] calculated the ROI in a factor of 1:2,8-6 benefit to cost ratio, and in [6] the value of the implementation of smartgrids was estimated in 79000 M€. For other researches, focused in a country such as Spain, the ROI was calculated a 1:1,3 cost to benefit ratio by Accenture [46] and 1:2-3,5 by the Boston Consulting Group [39]. The detailed business cases application by application for the functions of the smart grid are not thoroughly analyzed. A selection of the business cases detailed for this model is here presented.

3.2.1 E-vehicle as distribution storage

In order to calculate the business case the input parameters are, the load curve (peak demand Vs valley), the reliability costs (price for unavailability), the GDP of the networked area, the emissions of the power generation, the number of users in the network and vehicles, the mean CO2 emissions per vehicle, and adoption rates for electric vehicles, cost for the installation of new capacity

The main benefits, for the utility, are: losses reduction, reduction of peak demand, reliability (support during outages), increased electricity sales and deferred installation of new capacity. Additional benefits, to users, are the transportation cost reduction, electricity savings if time of usage pricing and bidirectional charge is used, the e-vehicle benefits of noise reduction and emission reduction, as well as societal benefits related to health consequence of the emission reduction.

The power losses, in %, are calculated with the simplification shown in (1), where the Lf is the load factor and K a constant. The calculation is done using the load curve power data as load factor, so the losses reduction is estimated comparing the load shifted profile, including increased valley energy.

$$P_l\% = \sum (Lf^2 \times K) = \sum_{1-24} Lf^2 \times K \qquad (1)$$

The reliability benefit for the utility is calculated from the cost of unavailability in power, calculating the stored energy can be used. That means, the avoided cost is equal to the cost of unavailability in power that can be compensated by the power available in e-vehicle storage.

To calculate the cost to the system, the unavailability reduction % from the previous calculation can be used to calculate the production reduction cost for the avoided outages, as part of GDP production for the system.

Concerning the other societal and environmental benefits emission reduction is calculated from the electrical system emissions, depending on the renewable penetration and the mean emission per km of the exiting vehicles. The CO2 has to be given a price tag for the monetization of the environmental benefits [13].

With the calculation of all the benefits, the cost for the integration of storage for the benefit to cost ratio calculation has to be used. The input parameter for cost to the utility is the integration of EV charging and storage into the Distribution Management Software. The investment in vehicles is used also to calculate global cost to benefit, or as the cost to benefit from the user point of view.

In a general case, with values from Spanish distribution, vehicles and other typical conditions, the benefit to cost ratio is above 1:10.

3.2.2 Microgrid business case

In order to calculate the microgrid integration business case the input values are the regulation for autoconsumption, net-metering and islanding, as it has to be permitted, the installed capacity and cost for new centralized power generation, the retail cost for customers and the cost of microgeneration capacity and control system. Microgrids can be considered from the home size [30][37] to community, district or city size.

The benefits are the new central capacity avoidance (special benefit for the utility if the investment on new distributed power generation capacity is done by individual customers, but the co-ownership or financing of these systems avoids reduction of the income as consumption is reduced) loss reduction as the generation is paired with the consumption, the reliability as the microgrids can function isolated, with participation of the distribution company [33], the cost reduction for the consumers, as long as the parity to retail price has been achieved for these technologies as shown in fig 4.

Additional benefits from renewable generation in terms of emission reduction and from democratization of power generation and user education and awareness on power generation and consumption, as well as job creation for the installation and maintenance of these systems. Loss reduction can be calculated using (1) as in the previous business case. The reliability can be calculated from the unavailability of central power generation (interruptions indexes such as SAIDI) that can be compensated with distributed generation and islanding of the microgrids in % reduction times the price for the utility as regulated and the economy interruption in terms of GDP during interruption time.

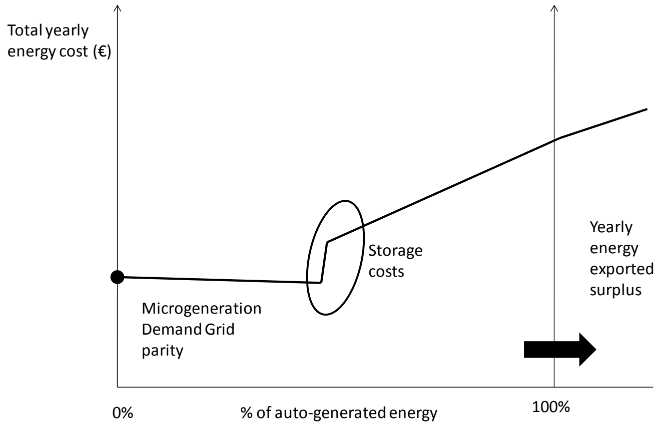

Fig.4: Parity to retail price until storage cost is necessary

A general calculation of the cost to benefit ratio of this functionality is above 1:10. If the microgeneration is installed without additional control and microgrid functionalities, some of the benefits are lost (mainly reliability by islanding) but still the cost to benefit ratio is on the same order of magnitude.

3.2.3 Building management systems

The business case for the building management uses the number of consumers, the contracted power, the mean building size and efficiency status. The use of energy certified classification for the buildings enables the calculation of the energy efficiency improvements, and the investment necessary based on the different technologies available for the different consumptions in the buildings.
The benefits are mainly on energy reduction, with the deferred additional central generation investment benefit, and also societal benefits of energy consumption awareness, and accessibility to information. Additional benefits are job creation for the rehabilitation of existing buildings and additional comfort for building users.
Most studies up to date use estimations, as the consumption reduction due to behavior is difficult to assess, as it is in the business case of smart meter information and time of use cases. For example [6] estimates a mean reduction of 15% in emissions from the application of BMS, [46] estimates 21% possible reduction for offices, 10% for retail, 7% for educational buildings and 4% for recreational buildings, with a general cost to benefit 1:3.
In a general applicable figure the benefit to cost ratio is above that figure, when deferred capacity investment is included and value for societal benefits, more close to 1:5.

3.3 General model
The general model will include as many business cases as available, to select the most interesting investments and prioritize the implementation of the smart grid.

The output of the tool is the situational awareness, as well as the next steps to adopt smartgrid technologies.

Smart grid situation reflects the actual assessment for the stakeholder (mainly utilities), and the smartgrid implementation gaps.

Building on this situation, the model is an implementation roadmap, with the main needs and the prioritized areas and initiatives.

4. Conclusion:

As part of the barriers for implementation of smart grids can be solved increasing awareness [3], understanding of the benefits and facilitation implementation tool-kits and models for stakeholders, this paper proposes improving actual models, extending the cost and benefit analysis to a sustainability perspective.

Further improvements will be required, mainly on the business cases used for the model, as prices and lessons learnt from pilots will show updates are necessary on the calculations and assumptions the model has to include.

Results of this model have to be proven on case studies, and will be publicly available to complement the research with the integrated tool.

5. Bibliography:

[1] Estimating the Costs and Benefits of the Smart Grid, A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid, EPRI, 2011 Technical report

[2] Methodological Approach for estimating the benefits and Costs of Smart Grid Demonstration Projects, EPRI, January 2010

[3] Accelerating Smart grid investment, World Economic Forum, Smart Grid Task Force, in partnership with Accenture, 2009

[4] Accelerating successful smart grid pilots, World Economic Forum, Smart Grid Task Force, in partnership with Accenture, 2010

[5] Building a Smart grid Business case, whitepaper by MGS team (actual SGIS), NTEL august 2009

[6] Smart 2020, The Climate Group report for the Global eSustainability Initiative (GeSI)

[7] Smart Grid Maturity Model, Software Engineering Institute, Carnegie Mellon University, 2009-2011, www.sei.cmu.edu/smart grid/

[8] "Sharing Smart Grid Experiences through Performance Feedback", NETL SGIS

March 31, 2011

[9] Getting Smart, Enrique Santacana, Gary Rackliffe, Le Tang, and Xiaoming Feng, IEEE Power and Energy magazine, march/april 2010

[10] Fangxing Li, Wei Qiao, Hongbin Sun, Hui Wan, Jianhui Wang, Yan Xia, Zhao Xu, and Pei Zhang "Smart Transmission Grid: Vision and Framework", , IEEE Trans. on smart grid, vol. 1, no. 2, september 2010

[11] Guest editorial on IEEE transactions on industrial electronics, vol. 58, no. 10, october 2011

[12] Eric M. Lightner and Steven E. Widergren, An Orderly Transition to a Transformed Electricity System, IEEE Trans. on smart grid, VOL. 1, no. 1, pp. 3-10, June 2010

[13] Environmental Benefits of Interoperability: The Road to Maximizing Smart Grid's Environmental Benefit, Prepared for the GridWise™ Architecture Council by E Source, Sep. 2009 Jan. 2010 [Online]. Available: http://www.gridwiseac.org/about/publications

[14] SmartGrids (2006): European SmartGrids technology platform. Vision and strategy for Europe's electricity networks of the future, DG Research, European Commission, Brussels

[15] "Characterizing and Quantifying the Societal Benefits Attributable to Smart

Metering Investments" EPRI, Palo Alto, CA: 2008. 1017006.

[16] Hassan Farhangi, The path of the smartgrid, IEEE power & energy magazine, pp. 18-28, January/February 2010

[17] "Smart grids Energy independence and security act" & Smart Grid Demonstration Program (SGDP)

[18] www.smartgrid.or.kr Korean Smart Grid Institute, Smart Grid Roadmap

[19] www.sgiclearinghouse.org/ProjectMap

[20] ses.jrc.ec.europa.eu, mapping of European smart grid projects, Research and Demonstration

[21] Vincenzo Giordano, Flavia Gangale, Gianluca Fulli (JRC-IE) Manuel Sánchez Jiménez (DG ENER), Smart Grid projects in Europe: lessons learned and current developments

[22] A Smart Grid Interoperability Maturity Model Rating System Predicting "Plug and Play" Integration Probability, James Mater (Quality logic) & Rik Drummond (GridWise)

[23] ISGAN, International Smart Grid Action Network, www.cleanenergyministerial.org

[24] NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0, United States National Institute of Standards and Technology Jan. 2010.

[25] Smart Grid Principal Characteristic Enables New Products, Services, and Markets DOE/NETL, 2010/1401 February 4, 2010

[26] "Smart Grid Strategy and Roadmap," Southern California Edison, 2010.

www.sce.com/smartgrid,

[27] “FirstEnergy Smart Grid Modernization Initiative,” available at www.smartgrid.gov

[28] Mohsen Simab, and Mahmoud-Reza Haghifam, Using Integrated Model to Assess the Efficiency of Electric Distribution Companies, IEEE Trans. on power systems, vol. 25, no. 4, november 2010

[29] Steven Wong, Kankar Bhattacharya, Senior Member, IEEE, and J. David Fuller

Long-Term Effects of Feed-In Tariffs and Carbon Taxes on Distribution Systems, IEEE Trans. on power systems, vol. 25, no. 3, august 2010

[30]Albert Molderink, Vincent Bakker, Maurice G. C. Bosman,

Johann L. Hurink, and Gerard J. M. Smit, “Management and Control of Domestic Smart Grid Technology”, IEEE Trans. on smart grid, VOL. 1, NO. 2, SEPTEMBER 2010 109

[31] G. T. Heydt, “The Next Generation of Power Distribution Systems “, IEEE Trans on smart grid, vol. 1, no. 3, december 2010

[32] Antonio Marcos Cossi, Rubén Romero, and José Roberto Sanches Mantovani , “Planning and Projects of Secondary Electric Power Distribution Systems”, IEEE Trans on power systems, vol. 24, no. 3, august 2009

[33] Sumit Paudyal, Claudio A. Cañizares, and Kankar Bhattacharya, “Optimal Operation of Distribution Feeders in Smart Grids”, IEEE Trans on industrial electronics, vol. 58, no. 10, october 2011

[34] “A novel structure for smart grid Oriented to low-carbon energy”,

Hengsong wang, qi huang, School of Automation Engineering, University of Electricity Science and Technology of China, Chengdu, 610054, China

IEEE Conference on SG Technologies

[35]Santiago Grijalva, Muhammad Umer Tariq, “Prosumer-Based Smart Grid Architecture Enables a Flat, Sustainable Electricity Industry”, , IEEE, IEEE Conference on SG technologies

[36]Ning Lu, Pengwei Du, Patrick Paulson, Frank L. Greitzer, Xinxin Guo, and Mark Hadley , “The Development of a Smart Distribution Grid Testbed for Integrated Information Management Systems”, The second Conference on Innovative Smart Grid Technologies (ISGT 2011)

[37] Francesco Benzi, Norma Anglani, Ezio Bassi, and Lucia Frosini, “Electricity Smart Meters Interfacing the Households”, IEEE Trans on industrial electronics, vol. 58, no. 10, october 2011

[38] “The Smart Grid: An Introduction”, United States Department of Energy, Office of Electricity Delivery and Energy Reliability, Jan. 2010 [Online].

[39] BCG and Futured, “Development of Smart Grids in Spain”, Nov 2012

[40] Ali Ipakchi and Farrokh Albuyeh, “Grid of the Future, Are we ready for the smart grid?” 1540-52 IEEE power & energy magazine 7977/09 IEEE march/april 2009

[41] D. Moore and D. McDonnell, “Smart grid vision meets distribution utility reality,” Elect. Light Power, pp. 1–6, Mar. 2007.

[42] EPRI’s IntelliGridSM Initiative, http://intelligrid.epri.com.

[43] GridWise Architecture Council, http://www.gridwiseeac.org.

[44] http://www.globalsmartgridfederation.org/

[45] Qiang Suna et al., “Review of Smart Grid Comprehensive Assessment Systems” ICSGCE 2011: 27–30 September 2011, Chengdu, China

[46] Accenture for the Spanish club of excellence in sustainability, “Spain 20.20, TICs y sostenibilidad”, 2012