ISGAN Project

Annex 3

BENEFIT & COST ANALYSES AND TOOLKITS

AJOU UNIVERSITY

March 2014

This report is submitted to:

International Smart Grid Association Network (ISGAN)

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Introduction and Executive Summary

The scope of ISGAN's Annex 3 is the development of methods and tools for the evaluation of the costs and benefits of smart grid projects, and for the preliminary assessment of the level of smartness of present electricity systems. The objective of this Annex is to develop a global framework and related analyses that can identify, define, and quantify in a standardized way the benefits that can be realized from the demonstration and deployment of smart grids technologies and related practices in electricity systems. To meet the required objective of this Annex, a program of work is designed. The program of work includes three tasks

Task 1: Assess Current Network Maturity Models and Tools available
- Subtask 1.1: Collecting and comparing maturity frameworks and tools
- Subtask 1.2: Trial application of two network maturity analysis tool and results discussion
- Subtask 1.3: Guidelines for the development of a new ISGAN simplified maturity analysis tool

Task 2: Assess Current Benefit-Cost Analytical Methodologies and Tools
- Subtask 2.1: Collecting and comparing benefit-costs frameworks and tools
- Subtask 2.2: Assessing policy and regulatory considerations for smart grid

Task 3: Develop Toolkits to Evaluate Benefit-Costs at the Technology or Sub-system Level
- Subtask 3.1: Trial application of the DOE benefit-cost analysis computational tool and results discussion
- Subtask 3.2: Guidelines for the development of a new ISGAN benefit-cost analysis tool

In the previous report, initial discussions following the tasks specified above are carried out. For Task I, the report goes through several maturity frameworks available, especially those of Software Engineering Institute (SEI) and Katholieke Universiteit Leuven (KUL). The SEI has developed a management tool that can be used to measure the current state of a smart grid project, then help the utility to identify the target and build proper strategies to reach it. The tool, Smart Grid Maturity Model (SGMM), utilizes a set of surveys called Smart Grid Compass. By filling out the surveys, a utility can expect to assess the maturity level of its smart grid project, that is outlined using the SGMM Matrix. The Matrix has two dimensions: eight domains of smart grid (ranging from Grid Operations to Value Chain Integration) and six levels of maturity (Default up to Pioneering). The drawback of this tool is the undocumented scoring method of the surveys once a result is obtained. Full assistance of an SGMM Navigator is required for the utility to understand and analyze the SGMM output. Meanwhile, the KUL references[1] introduce the characteristics, categories and key performance indicators of a smart electricity grid. It must be noted that the works of KUL are comparable to the characteristics of smart grid by EPRI (2010) and DOE (2009). The previous report also points out the comparison.

This report would discuss the progress made in Task I since then. During the period of the second year project, a national experts meeting of Annex 3 was held in Brussels, Belgium. One of the focus on that meeting is the design and dissemination of a questionnaire specifically made for ISGAN members. The leader of Italian team, Prof. Delfanti, came with a draft and the whole members discussed, and modified

[1] The main references of smart grid assessment by KUL are the papers written by Benjamin Dupont and Ronnie Belmans, both professors at Department of Electrical Engineering, KUL

the questionnaire--some questions are eliminated, words are changed, some points are added. The meeting agreed that the questionnaire would be applied to the smart grid projects of ISGAN's members and the results would be discussed. Finalized questionnaire compiled by Prof. Delfanti is attached at the Appendix of this report. In addition to that, another questionnaire called Smart Grid Investment Quotient (IQ) is discussed in this paper. Developed by Smart Grid Research Consortium (SGRC), it is a scorecard that can be used to score the effectiveness and efficiencies of smart grid investment--with 100 as the "best practice."

For the last year report's Task II, several studies on Benefit and Cost Analysis (BCA) are surveyed. The domestic case of BCA (Lee, 2011) is analyzed, too. A simple table summarizing the differences in benefits between several papers is provided. The McKinsey's BCA approach was one of the main candidates for the base of ISGAN's toolkit, although the pricing problem prevented it to happen. For the policy and regulations survey, some reports are discussed. Adding to that, smart grid cases around the world are summarized from the policy perspective.

In this report, an extensive update of the BCA survey is provided. It starts with various frameworks related to BCA, which include Frontier Economics and the Smart Grid Forum (SGF) in UK, Smart Grid Investment Model (SGIM) of SGRC, IMPLAN Model, McKinsey Tool, and general overviews of EPRI's methodology to BCA and its subsequent developments by DOE and JRC. After that, several BCA applications to country-specific or states cases are summarized. Some of the surveyed countries are Czech Republic, Netherland, Lithuania, Denmark, and USA states. For the comparison purpose, the summary for each case is carried out following some key points: background of the smart grid project, the methodology or toolkits used, the scope of the project (location, period, technologies), the list and definition of benefits and costs, and deliverables (results, recommendations, policy and regulations).

A different approach was taken for the previous year report. The discussions on EPRI, JRC, and DOE frameworks are allocated in Task III. In the end, a comparison table between the three is provided. The focus of Task III was the Smart Grid Computational Tool (SGCT), a BCA toolkit that is developed by US DOE, which is based on EPRI's methodology. The SGCT is an excel based program that utilizes macro and Visual Basic for Application (VBA) for automation. How the program derives benefits from smart grid assets (using several linkage matrixes) and their monetization formula, how the costs are represented, and the examination of the program's codes and sheets are discussed thoroughly.

The main topic for this report's Task III is not only the analysis of the current available frameworks and toolkits, but also the plan and initial research for the development of a new ISGAN BCA tool. In addition to the extensive coverage of BCA frameworks and applications from Task II, Task III also examines the update to the EPRI methodology. In the new and more detailed reports (EPRI 2011, 2012b), the steps proposed for assessing a smart grid project is expanded from simply 10 steps to 24 steps. Both reports, though, haven't deliberated the full steps, yet. For the development of smart grid BCA toolkit, a standalone program based on Object Oriented Programming (OOP) is considered. Two possible approaches are: revising and upgrading the currently available excel-based SGCT and developing from another type of software that simulates the grid system. The planned work's division and timeline are also provided.

Task I: Assess Current Network Maturity Model and Tools Available

Subtask 1.1: Collecting and comparing maturity frameworks and tools
Subtask 1.2: Trial application of two network maturity analysis tools and results discussion
Subtask 1.3: Guidelines for the development of a new ISGAN simplified maturity analysis tool & Current Problems Identified

I.1 Questionnaire of ISGAN'S Annex 3

On July 2nd-3rd, 2012, the national experts meeting for Annex 3 of ISGAN was conducted in Brussels, Belgium. In total, there are representatives from five countries (Italy, Korea, Sweden, Switzerland, USA) and JRC that present on that meeting. One of the main focus on that meeting is the discussion of the questionnaire of smart grid maturity measurement that could be disseminated to member countries. The draft of the questionnaire has been prepared by the leading Italian team to be criticized and reshaped by the national experts. The other agendas for that meeting is the preparation for the executive meetings of ISGAN and the other two tasks of the ISGAN Annex 3.

From the discussion, a new and updated survey has been produced. This survey would be disseminated by the member countries and gathered by the Annex 3 team to evaluate its effectiveness to measure the smartness of smart grid.

In the case of Korea, the survey would be disseminated to the sole power utility, Korean Power Company (KEPCO). Hopefully, the output of this questionnaire could generally outline the progress of smart grid issues in Korea in comparison with other countries' cases. It must be noted that since most of the questions prepared in this questionnaire is in form of percentage and Yes or No type, it is possible to have a comparison between smart grid cases and projects without having a referencing problem. For the purpose of conveying the result of this questionnaire, the meeting has decided to use the radar graph with six characteristics of smart grid on each axis. Graph below shows the example of the main result from the survey:

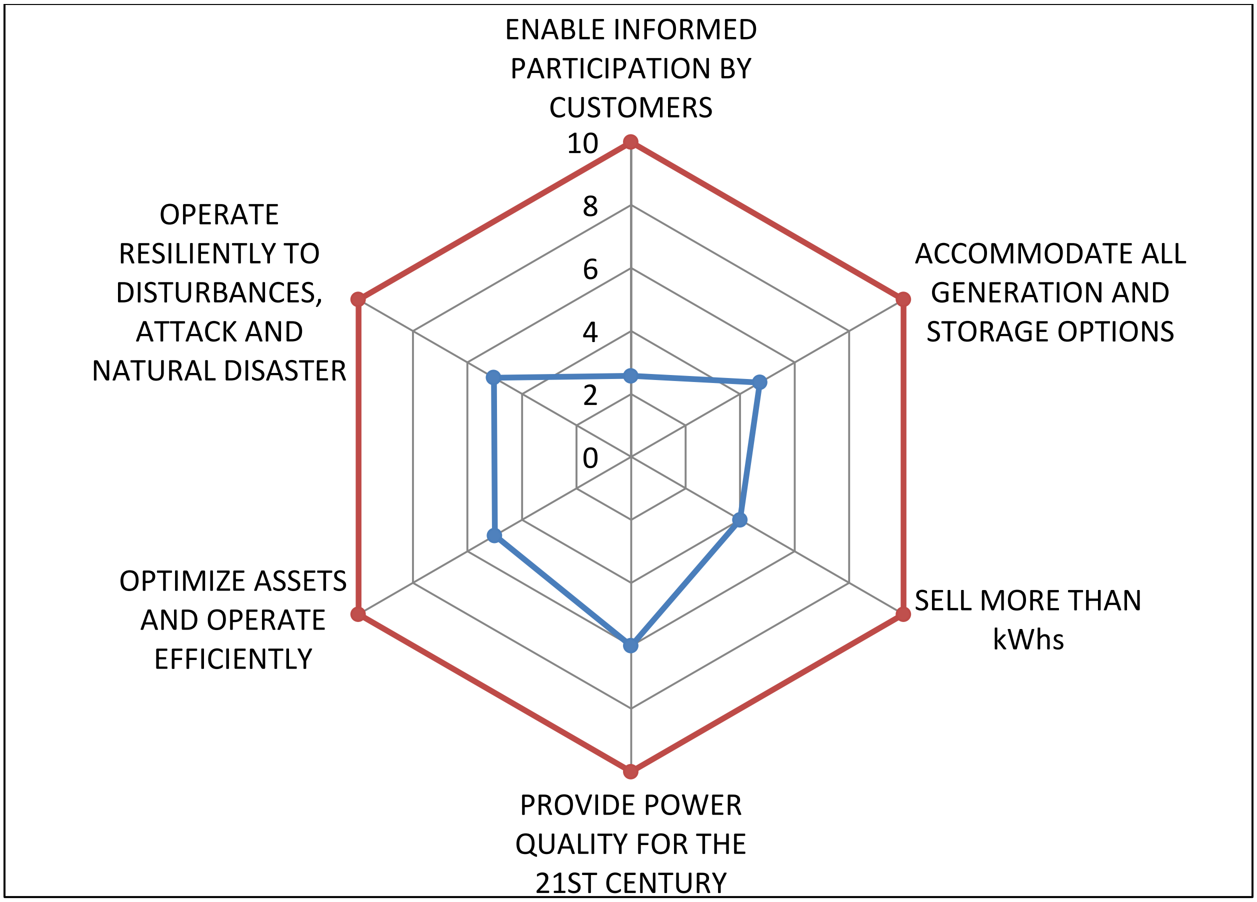

Figure 1 Example of Multi-criterion Output from the Questionnaire Prepared by ISGAN Annex 3

The questionnaire has two parts: preface and the survey itself. In the preface, the general information of the utility taking the survey is gathered. Basic information such as customers number, loads served, HV/MV lines, and the status of transmission and distribution grid would be needed. The questionnaire part is divided into six criteria of smart grid: Enabled informed participation by consumers, Operate resiliently to disturbances, attack and natural disaster, Optimize assets and operate efficiently, Provide power quality for the 21st century, Sell more than kWHs, and Accommodate generation and storage options. Additional criterion (not shown in above figure) is funding and investments for smart solutions. Each of the criteria would have several questions to be answered.

I.2 Smart Grid Investment Quotient

The Smart Grid Investment Quotient is another form of smart grid smartness measurement method developed by Smart Grid Research Consortium (SGRC). In a white paper (Jackson, 2011), it is mentioned that "The Smart Grid IQ or Investment Quotient is a scorecard composed of six categories with category scores that total to a maximum IQ score of 100."

The smart grid IQ, though, only scores the investment planning process and not the actual costs and benefits of the smart grid. In a sense, this is similar to the other smartness or maturity measurement methods of smart grid--a qualitative assessment of smart grid, not a quantitative one. Basically, if a smart grid project gets a high score in this measurement, it indicates that the project applies--as described in the white paper (Jackson, 2001)--*a "best practice" or "best strategy" with respect to smart grid investment analysis designed to identify appropriate technology, software and program investments with maximum return on those investments*.

The scorecard or questionnaire reflects the SGRCs viewpoint of a “best practice” investment analysis coupled with “typical” weights for two problems considered by utilities. It is possible to have different perspectives between utilities, thus some users may want to adjust these two problems in the scorecard. The problems, which can be subjective, are financial benefits of reliability and environmental benefits. Even so, the modifications should be limited since the scorecard is not designed to evaluate the BCA of these items (quantitatively), but only assisting the financial planning process.

Another point to be considered is that "the scorecard is designed to reflect current, past or future investment analysis." Therefore, in a case where utility does not have an investment analysis or planning capability yet, the characteristics of the expected approach can be used.

Similar to the questionnaire prepared by the ISGAN Annex 3, this scorecard would also be disseminated to KEPCO.

I.3 Preliminary Survey Result (KEPCO)

The first result from the preliminary survey by KEPCO experts is a radar diagram of multi-criterion output. For each criteria of smart grid, a rating is calculated by averaging the scores from the questions within that specific criteria. For question with percentage rate as an answer, the answer itself would serve as the score. Meanwhile for question with either Yes or No as an answer, the value of 100 and 0 is assigned. If there is a question that could not get scored properly using the methods explained beforehand, it would not be included in the calculation.

It must be noted, though, that not all questions are answered by KEPCO[2]. For these cases, there are two options that could be taken. First is giving a zero score. Second is excluding the question from the average calculation process. In this report, the second option is taken. As can be seen in the figure below, KEPCO as the sole power company in Korea manages to get smart grid ratings that range from 48.2 (the highest rate) for "Operate resiliently to disturbances, attack, and natural disaster" to 5.0 (the lowest rate) for "Provide power quality for the 21st century." Averaging the whole ratings, KEPCO has a rate of 28.64 for its smart grid maturity.

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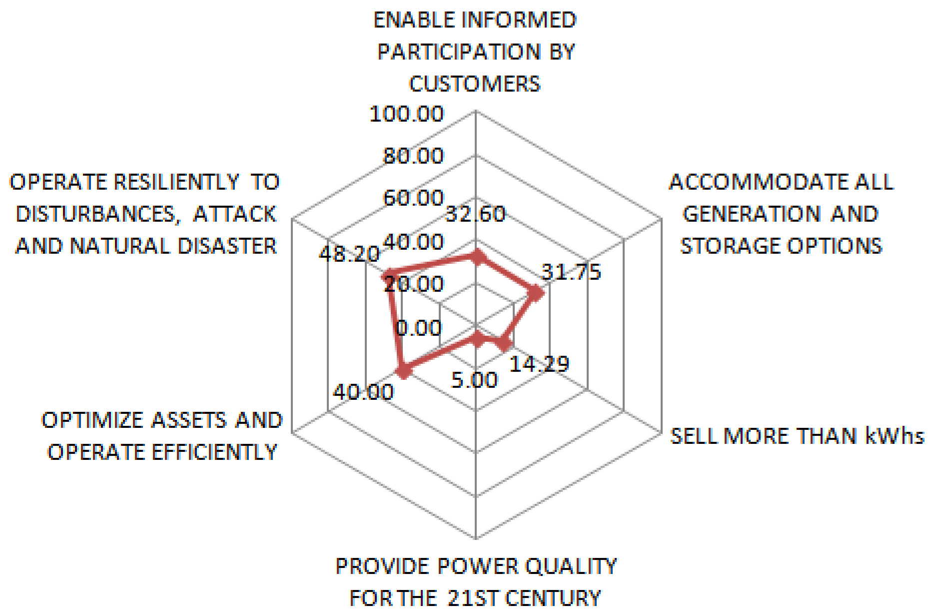

Figure 2 Multi-Criterion Output from the Preliminary Survey by KEPCO

The second result is the Smart Grid Investment Quotient (SGIQ) of SGRC. Table below is the summary of the result. The score column shows the total points given by the KEPCO for the questions within a category. The max column shows the maximum points that could be acquired within a category. Finally, the last column shows the relative score (in a percentage) the KEPCO gets within a certain criteria. It is shown that KEPCO scores the highest for "AMI/DA Investment/Planning Scope" criteria with 100% and the lowest for "Ease of Use/User Interface/Results Presentation" criteria with 0%. Although the score range is quite steep, the total point/score for KEPCO's SGIQ is 71.

Table 1 SGIQ Result from the Preliminary Survey by KEPCO

No	Category	Point	Max	Score (%)
I	AMI/DA Investment/Planning Scope	27	27	100.00
II	Customer Engagement* Investment/Planning Scope	15	20	75.00
III	Other Financial Items	10	12	83.33
IV	Other Utility Customer Detail	7	10	70.00
V	Investment Analysis Quantitative Framework	12	23	52.17
VI	Ease of Use/User Interface/ Results Presentation	0	8	0.00
	Total	71	100	71.00

Task II: Assess Current Benefit-Cost Analytical Methodologies and Tools

Subtask 2.1: Collecting and comparing benefit-cost frameworks and tools
Subtask 2.2: Assessing policy and regulatory considerations for smart grid

II.1 Smart Grid BCA Frameworks

There are several frameworks of Smart Grid's Benefit and Cost Analysis available in the literature. This section specifically summarizes and analyzes those frameworks.

The case of Smart Grid Forum (SGF) in UK is deliberated, combing through the rapid progress they've made for the last few years. It is noted that the five workstreams are similar to that of ISGAN. Adding the summaries of meeting minutes, these discussions can be beneficial for the ISGAN project as a whole. To develop a BCA, they cooperate with Frontier Economics, utilizing real options model. A simple review of the model is shown and the general methodology and idea of the model developed by Frontier Economics are discussed.

The idea of real options as a way of internalizing sensitivity analysis to the BCA could complement the known frameworks that stem from the EPRI's Methodology. Have dealt with them extensively in the previous report, a glimpse of the relationship and comparison between those of EPRI, DOE, and JRC are examined in this report. The proposed McKinsey framework is reviewed, too.

Another model that deals with smart grid's business case analysis is the Smart Grid Investment Model (SGIM). It started with a project with several utilities. Then, the developed and applied model is proposed to the public use through Smart Grid Research Consortium (SGRC). The model used excel base program to run estimate of end-use hourly load for 20-years period before calculating the avoided costs (benefits).

Last framework discussed is IMPLAN (IMpacts for PLANning), that is used for U.S. DOE to analyze the effectiveness of its American Recovery and Reinvestment Act (ARRA) 2009. In this report's case, the smart grid related discussion--through Smart Grid Investment Grant (SGIG)--would be the main focus.

II.1.1 Smart Grid Forum (SGF) of UK

According to SGF (1 May, 2011), The Smart Grid Forum (SGF) aims to bring together key opinion formers, experts and stakeholders in the development of GB smart grids to provide strategic input to help shape Ofgem[3] and DECC[4]'s thinking and leadership in this area. It should also help provide the network companies with a common focus in addressing future networks challenges and provide drive and direction for the development of smart grids.

To achieve this aim, SGF drives policy change by:

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[3] The Office of Gas and Electricity Markets
[4] The Department of Energy and Climate Change

- ✓ Developing a common understanding of the value that smart grids can deliver,
- ✓ Identifying barriers to network companies adopting smart grid solutions, and
- ✓ Putting smart grids in the context of wider policy developments.

The Forum thus, will provide a common basis of understanding and disseminate learning to

- ✓ assist government and Ofgem to identify the priorities and focus their work in creating an enabling framework for smart grid development, and work that has an impact on smart grids;
- ✓ help industry or other stakeholders to identify activities that they need to prioritize and to help identify work that might be best delivered jointly; and
- ✓ help network companies better understand future developments in the industry that they need to be preparing for.

For this purpose, the Forum will publish the notes of its meetings and any reports/studies that it carries out or commissions from other parties. Material from the reports/studies will be made available to GEMA and DECC. The group can establish sub-groups to address specific issues and any such groups will adopt an open approach consistent with the operation of the Forum while participation in any sub-groups will be flexible and needs driven.

There are several meetings (11) that have been conducted by the SGF. This subsection would shortly summarize the chronology and main results of those meetings

- ➢ **DECC/Ofgem SMART GRID FORUM 1st Meeting, 11th April 2011, Ofgem, 9 Millbank, London**

5 workstreams are identified as follows:

- ✓ Work Stream 1 “Assumptions and Scenarios”
- ✓ Work Stream 2 “Evaluation Framework”
- ✓ Work Stream 3 “The Ideal Network”
- ✓ Work Stream 4 “Closing doors”
- ✓ Work Stream 5 “ways of working”

Each workstream (WS) is defined as follows:

WS1: Assumptions and scenarios - This work stream will look to take the different low carbon pathways work already carried out by DECC and, in conjunction with the relevant policy teams that focus on electric vehicles, distributed generation and heat, ‘convert’ these into a set of assumptions and scenarios designed to act as a guideline for the network companies. These assumptions and scenarios will be in the form of demand forecasts - the term demand here being used in the widest sense to include all devices that are likely to require network connection. It is proposed that data will be generated for 2020 and 2030. It will be vital that this work is linked to the work on the Evaluation Framework.

Final report : Spring 2012 (coincident with and part of DECC’s vision paper)

WS2 : Evaluation Framework - The framework will be designed to dovetail with the outputs from WS1. It is intended to deliver a spreadsheet model that will enable smart grid investments to be assessed on a comparative basis with BAU solutions. It is expected that the model will be able to recognize that different value streams will become important in different timeframes. It should therefore help us understand the key variables that have the greatest effect on the value of specific smart grid functionalities. The model will be able to provide inputs to the business planning processes of the network companies.

This WS will also consider the key value drivers for a smarter network. It will test the thesis that the facilitation of demand side management (in particular related to the reduction of generation capacity but also system balancing and managing network constraints) could be the highest value smart grid application, albeit not strictly a network issue. The work on this already carried out should be developed further to better understand/evaluate this value stream.

Final report - following 4th SGF meeting, February 2012. Spreadsheet model to be made freely available to the network companies.

WS3 : The Ideal Network - It is proposed that the scope should initially be limited to the distribution network up to 132kV and that the time horizon should be [2030]. Ideally, this work should be based on the outputs of WS1 but the network design should not be constrained by the system existing today. It is recognised that, regardless of cost, the solution delivered may not have a credible transition path from today's networks. However, the exercise may generate specific development opportunities that are able to be incorporated in actual plans.

Final report - end February, 2012

WS4 : Closing Doors - To review current electricity supply chain developments, particularly the smart meter implementation program, to assess their impact on the development of smart grids.

WS5 : Ways of Working - A number of practical issues were identified at the first SGF meeting relating to the operation of the SGF. They included:

- ✓ Horizon scanning - how can we efficiently track smart grid developments internationally?
- ✓ Knowledge dissemination - how can we do this most effectively?
- ✓ Role & profile of the SGF - what outreach activities would be of value?

- **DECC/Ofgem SMART GRID FORUM, 2nd Meeting, 20th July 2011, BIS Conference Centre**

In addition to the discussions on WS1 to WS5, ENSG update (working group) by Paul Hawker (DECC), European Update by Gareth Evans (Ofgem) DECC's heat strategy by Aaron Gould (DECC), Smart Grids GB by Petter Allison (British Gas) were given.

- **DECC/Ofgem SMART GRID FORUM, 3rd Meeting, 20th October, 2011, Ofgem, 9 Millbank, Westminster**

Especially, Sarah Deasley (SD) and Claire Thornhill (CT) presented the work that Frontier is doing on behalf of WS2. Discussion around the table was positive. Model is based on CBA using real options approach with two stage decision trees. (refer to slide 12 of presentation material of Frontier Economics (20 October 2011)).

- **DECC/Ofgem SMART GRID FORUM, 4th Meeting, 18th January 2012, Ofgem, 9 Millbank, Westminster**

Frontier Economics (March 2012) is delivered. In addition,WS1,2,3,5 with Smart Meter Implementation Update are given.

- **DECC/Ofgem SMART GRID FORUM, 5th Meeting, 3rd May 2012, BIS Conference Centre, 1 Victoria Street**

WS5 is noted as "Knowledge management" in this meeting.

Members are informed that the Smart Grid Evaluation Framework had now been published and that the accompanying modelling tool would soon be available from Ofgem. The work had established a common Framework to evaluate the costs and benefits of smart grids. Two important conclusions that arose from the work were that smart solutions could save consumers between ￡10 to ￡ 20 billion up to 2050, and the downside of investing early (i.e. during ED1) is an order of magnitude less than this. However, he stressed the preliminary nature of these results and that the work of WS3 will provide a more robust view of the potential costs and benefits.

- **DECC/Ofgem SMART GRID FORUM, 6th Meeting, 24th July 2012, BIS Conference Centre, 1 Victoria Street**

WS 3 model and report are presented with an overview of the project including the objectives and the context. The model includes regional variation and allows DNOs[5] to adapt it to the characteristics of their license area.

WS6 is first discussed at this SGF. For WS6, the cost recovery for addressing power quality is revisited. Key conclusions of the work stream thus far include that supply security standard should be amended and that changes in the regulatory framework are needed to ensure notification of Low Carbon Technology (LCT) and consistency around charging. The issue of charging domestic customers for resolving power quality is put on agenda at next SGF meeting.
For RIIO-ED1[6], work coming out of the SGF is said to be used in its development and the WS3 model is to prove useful in establishing a common framework to assess investment.

- **DECC/Ofgem SMART GRID FORUM, 7th Meeting, 23rd October 2012, BIS Conference Centre, 1 Victoria Street**

WS6 is named as the Commercial and Regulation workstream at this meeting. Terms of references for WS6 are discussed that the list of potential wider system work areas, including the lack of commercial enablers to support smart grid solutions where DNOs needed to interact with third parties, should be scoped out to provide greater detail.

Smart Grid Commercial and regulatory barriers report is introduced as the WS6 phase 1 report.

WS5 Update is given under the name of “development and launch of the knowledge portal”.

SGF next steps are discussed to maintain strategic direction by capturing the ideas for potential future Smart Grid Forum work.

- **DECC/Ofgem SMART GRID FORUM, 8th Meeting, 22nd January 2013, Ofgem, 9 Millbank, Westminster**

“SGF Year 3 Priorities” paper is introduced with 5 explicit recommendations for that purpose:

- ✓ **Recommendation 1** – The SGF should continue to act as the industry/stakeholder group to assist/advise DECC and Ofgem on smart grid issues and in particular, identify barriers to its delivery, subject to an annual review of the SGF’s aims and objectives.
- ✓ **Recommendation 2** – The SGF’s focus should now extend beyond the current price control process, ED1 (i.e. beyond 2015).

[5] Distribution Network Operators

[6] RIIO-ED1 is the first electricity distribution price control review to reflect Ofgem’s new regulatory framework: RIIO. It will be set for an eight-year period from 1 April 2015 to 31 March 2023

- ✓ **Recommendation 3** –DECC and Ofgem, with input from interested SGF members, should develop a common view on the proposed refresh of the Smart Grid Routemap including timing and resourcing.
- ✓ **Recommendation 4** –It is proposed that WS6 should develop a program of work informed by the paper at Annex 4 and with a focus on the future roles and responsibilities of parties in the value chain and their relationships with each other and consumers.
- ✓ **Recommendation 5** – If the SGF agrees this area warrants further consideration, Ofgem will lead an ad hoc group to develop a proposal for work on system operation issues. This group will take account of the potential future work of the IET and bring a proposal to the SGF as to how it should engage in this area.
- ✓ **Recommendation 6** – It is proposed that a more structured approach to monitoring/tracking other smart grid areas (including those set out in paragraphs 2.13 to 2.15)[7] should be established.
- ✓ **Recommendation 7** – The SGF should review the work of the existing work streams so that they form a coherent body of work consistent with delivering our smart grid ambitions (see 1.6)[8] and any other agreed deliverables.

All the recommendations seem to have been accepted with minor revision. And follow-up action plans are discussed.

- **DECC/Ofgem SMART GRID FORUM, 9th Meeting, 25th April 2013, BIS Conference Centre, 1 Victoria Street**

OLEV strategy is explained - the Office of Low Emission Vehicles (OLEV) is a cross Government team based in DfT, combining policy, funding streams and staff from DfT, BIS and DECC. The last Government Spending Review announced provision of over £400 million to support OLEV's work to 2015.
Three new projects are proposed for SGF Year 3 Program.

- ✓ A project to refresh of the "Smart Grid Vision and Routemap".
- ✓ A revised scope of WS6 is introduced to carry out an assessment of the options for the development of smart grids, particularly in terms of how customers will engage with smart grids. It will also help to define the necessary roles of industry parties and the relationships between them.
- ✓ Terms of reference for the "Distribution Grid 2030" project which will aim to validate the technical viability of smart distribution network scenarios for GB in 2030 in a whole system (transmission & distribution) context is proposed.

[7] This is not identifiable since the full report of "SGF Year 3 Priorities" paper is not open public.
[8] The same as above.

- **DECC/Ofgem SMART GRID FORUM, 10th Meeting, 30th July 2013, Ofgem, 9 Millbank, Westminster**

WS7 is first shown in this meeting minutes and more detail is noted to be outlined to the SGF at the October meeting.

Also, WS8, Vision and Routemap (V&R),is first noted here and is noted to be presented to the SGF October 2013 meeting for endorsement with a view to publish in November.

- **DECC/Ofgem SMART GRID FORUM, 11th Meeting, 22nd October 2013, BIS Conference Centre, 1 Victoria Street**

For WS8, Vision and Routemap, a high level draft of the Vision & Routemap (V&R) document prepared by the Smart Grid Forum V&R working group is presented and drafting of final document is discussed Discussion on V&R scope whether to cover the entire energy system or to focus only on distribution network.

Recent activities on BEAMA[9] for SME participation, WS4,5, 6 & 7 and European issues are updated. DECC solar strategy is discussed with the expected release of fuller PV strategy document in the Spring 2014. Horizon 2020, the European Commission's research and development funding program is expected to launch a call for proposals on 11th December 2013.

Current Workstreams Identified from above are:

- ✓ Work Stream 1 "Assumptions and Scenarios"
- ✓ Work Stream 2 "Evaluation Framework"
- ✓ Work Stream 3 "The Ideal Network"
- ✓ Work Stream 4 "Closing doors"
- ✓ Work Stream 5 "Knowledge management" or development and launch of the knowledge portal
- ✓ Work Stream 6 "assessment of the options for the development of smart grids"
- ✓ Work Stream 7 It is not clear from meeting minutes, but it is likely an extension of WS5.
- ✓ Work Stream 8 "Vision and Routemap"

It is found that SGF is very actively conducting its own work maintaining its forum meeting every three months with tight schedule for defined deliverables. Although it currently focuses on electricity sector, heat, EV and other sector activities are closely monitored within the group so that the Forum can extend its work scope as the current work progresses.

[9] BEAMA is the independent expert knowledge base and forum for the electrotechnical industry for the UK and across Europe.

For BCA analysis, WS2 of evaluation framework seems to have been successfully accomplished. SGF meeting minutes of 4th, 5th and 6th already declares that. Following the presentation and draft report by Frontier Economics (March 2011, October 2011), Frontier Economics submitted the result of analysis as Frontier Economics (November 2011). The developed too is based on real options methodology which accounts the probability of salvaging option in each of the decision tree within the period of the project life. It is noted to be circulated within UK utilities.

II.1.2 BCA analysis of Smart Grid by Frontier Economics

- **A Simple Review of Real Options**

Real options valuation or real options analysis, applies option valuation techniques to capital budgeting decisions. It is named "real" options since it deals with real physical assets instead of financial assets in valuation process. Suppose the current asset value, exercise price, volatility of project value, leakage and risk free rate of return denoted as S, X, σ, δ and r_f, respectively,

$$c = Se^{-\sigma T}\Phi(d_1) - Xe^{-r_f T}\Phi(d_2)$$

where $\Phi(.)$ indicates cumulative standard normal distribution function and

$$d_1 = \frac{ln(S/X) + (r_f - \delta)T}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2}$$

$$d_2 = d_1 - \sigma\sqrt{T}\ .$$

This single option value calculation gives a single number as an answer and would not work if any conditions change.

When we start with one or several options with times to maturity of less than or equal to T years, T years are divided into a finite number of time periods of length Δt. One method is to accommodate a model with binomial tree with project values at these time periods. In this binomial lattice model, during each period, project value is modeled either to go up with a factor of u or down with a factor of d. If σ is the project's volatility, u, d are calculated as

$$u = e^{\sigma\Delta t} \text{ and } d = 1/u\ .$$

After one time step Δt, the project value can be modeled to have either $S_u = Su$ or $S_d = Sd$. After another one more time step, the project values can be $S_u u = Su^2$ or $S_u d = Sud = S$, $S_d u = Sdu = S$ and $S_d d = Sd^2$. Following diagram shows the binomial tree of project values for all type of cases. A simple expectation of each time node's project value calculation would give us the expected value of project with not flexibility or choice of options.

For the project valuation with the choice of options, options may not be exercised out of the end node time to maximize the valuation. This process can continue for $t = T - \Delta t$ and so on.

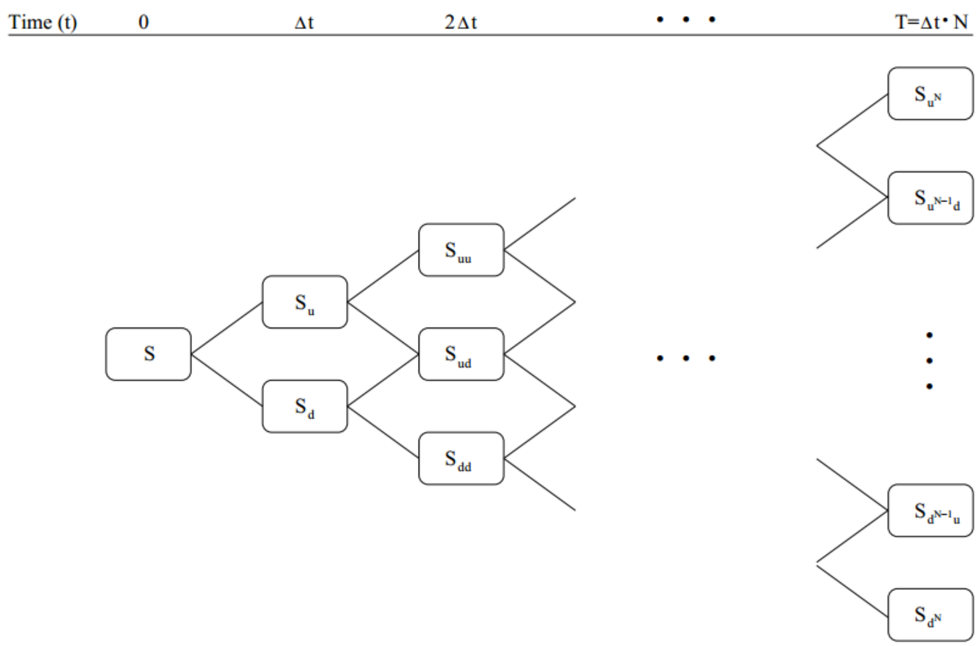

Figure 3 Example of a binomial tree

Another way of modeling project valuation can be utilizing a process accommodating uncertainty such as diffusion process. From above given $u = e^{\sigma\Delta t}$, rephrase that as $u(t) = e^{\sigma dt}$. Then the process of of u which will stochastically determine the value of project can be represented as following dynamics:

$$\frac{du(t)}{u(t)} = \sigma dt \text{ or } du(t) = \sigma u(t) dt$$

Many different types of diffusion process can be modeled for stochastic valuation of the project.

- **Overview of Methodology**

Frontier Economics (Oct. 2011) presets the reason for using real options valuation for BCA as "to avoid lock-in to a particular investment path". For the investment with option values, it presents example cases such as, *investments that can be incrementally augmented in future periods; investments that promote learning, and which may therefore make future investments less costly or more feasible; and investments that entail high upfront costs, but reduce ongoing investment costs.*

Real options-based analysis in the face of uncertainty is chosen to allow the best strategy by factoring in the impact of new information into the analysis at a decision point in the future; and the possibility that the investment strategy can adjust when this new information becomes available.

Following diagram describes the methodology adopted by Frontier Economics for SGF.

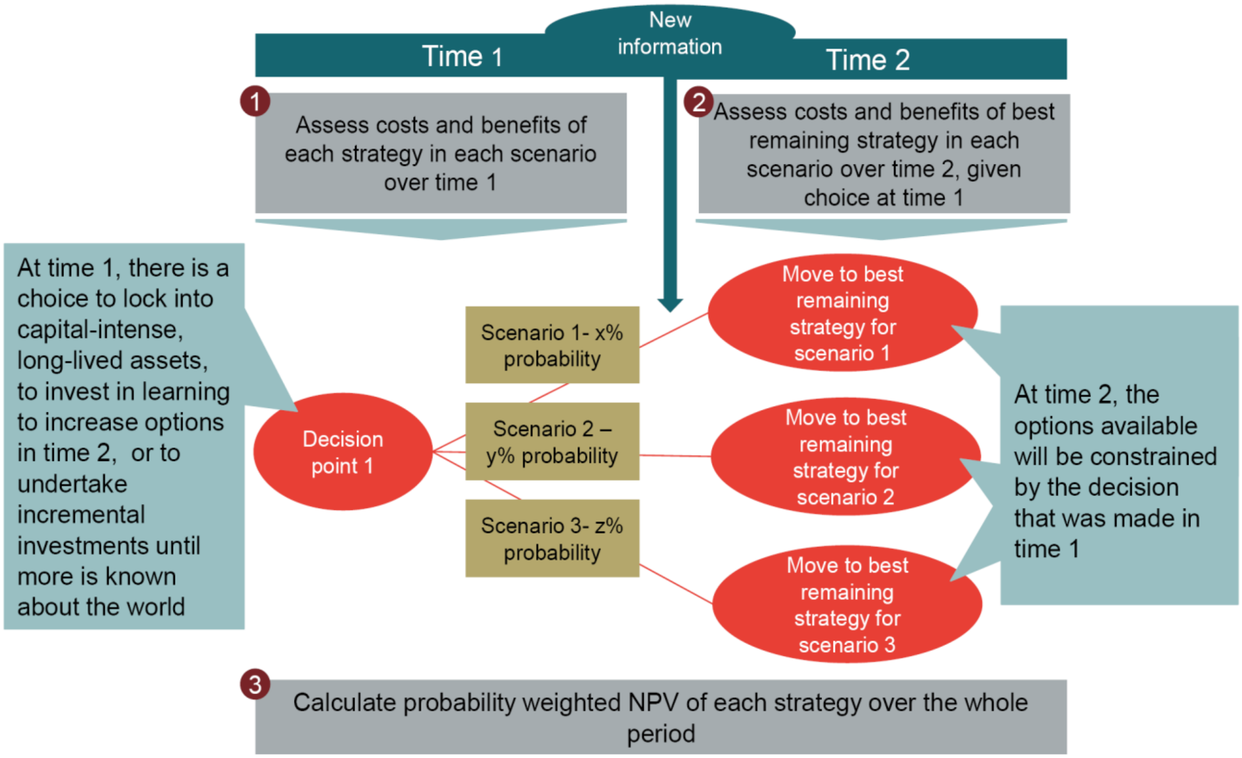

Figure 4 Real Options Valuation Process for SG BCA

Source: Frontier Economics (March 2011)

As the diagram shows, this model adopts two periods (Time 1 and Time 2) for analysis: the first time period from 2012 until 2023, and the second from 2023 out to 2050. The year 2023 is selected considering the fact that Government's *Carbon Plan* sets out scenarios for meeting the UK's 4th carbon budget covering the period from 2023 to 2027[10].

Based on three smart grid investment strategies, Top-Down (Top-down smart grid investment strategy), Incremental (Incremental smart grid investment strategy) and Conventional (Conventional strategy), the best available strategy is tried to be identified for each different scenarios for each of two different Time period. That is, some of the strategies chosen for Time period 1 may or may not be available for Time period 2, since, for example, Top-Down strategy selected for period 1 would prevent other strategies to be adopted for period 2 since it would strand a number as previously invested assets.

[10] DECC (2011)

Table 2 Three Investment Strategies

	Characteristics	Proportion of costs borne upfront	Proportion of costs on an ongoing basis
Top-down smart grid investment strategy	Upfront roll out of control and communications infrastructure. Roll out of smart and conventional technologies when required.	**High** Investment in control and communications infrastructure occurs upfront.	**Low** The upfront investment in control and communications infrastructure means the costs of rolling out additional smart technologies are proportionately lower in this strategy
Incremental smart grid investment strategy	Roll out of smart and conventional technologies, and associated control and communications infrastructure when required.	**Low** No investment in control and communications infrastructure occurs upfront.	**High** The lack of upfront investment in control and communications infrastructure means the costs of rolling out additional smart technologies are proportionately higher in this strategy
Conventional strategy	Roll out of conventional technologies only, when required	**High** Conventional solutions tend to be more capital intense and release more headroom.	**Low** The higher headroom release associated with conventional solutions mean that ongoing costs of this strategy are likely to be proportionately lower

Source: Frontier Economics (Oct. 2011)

The tested scenarios are summarized in the following table, too.

Table 3 Summary of Scenarios

	Electrification of heat and transport	Increase in distributed generation	Increase in intermittent and inflexible generation	Extent to which customers engage with demand response
Scenario 1	Medium transport, high heat (consistent with Scenario 1 of the Government's Carbon Plan)	Medium	Medium	Medium
Scenario 2	Medium transport, high heat (consistent with Scenario 1 of the Government's Carbon Plan)	Medium	Medium	Low
Scenario 3	Low	Low	Low	Medium

Source: Frontier Economics (Oct. 2011)

In this report, it is argued that with limiting time period for analysis to two periods, accounting the different option values associated with different smart grid investment strategies without allowing the evaluation framework to become too complex became possible.

Noting the interdependencies between the functionality of different smart grid technologies will make the costs and benefits of each individual technology be dependent upon among them, this model assesses the costs and benefits of representative smart grid investment packages or strategies, instead of assessing individual smart grid technology in isolation.

This report is focuses on the benefit, cost calculation of three different investment strategies and scenarios. Followings are the cost and benefit considered in their model:

- ✓ Distribution network reinforcement
- ✓ Distribution network interruption costs
- ✓ Distribution network losses
- ✓ Generation costs
- ✓ DSR “inconvenience” costs
- ✓ Transmission network reinforcement

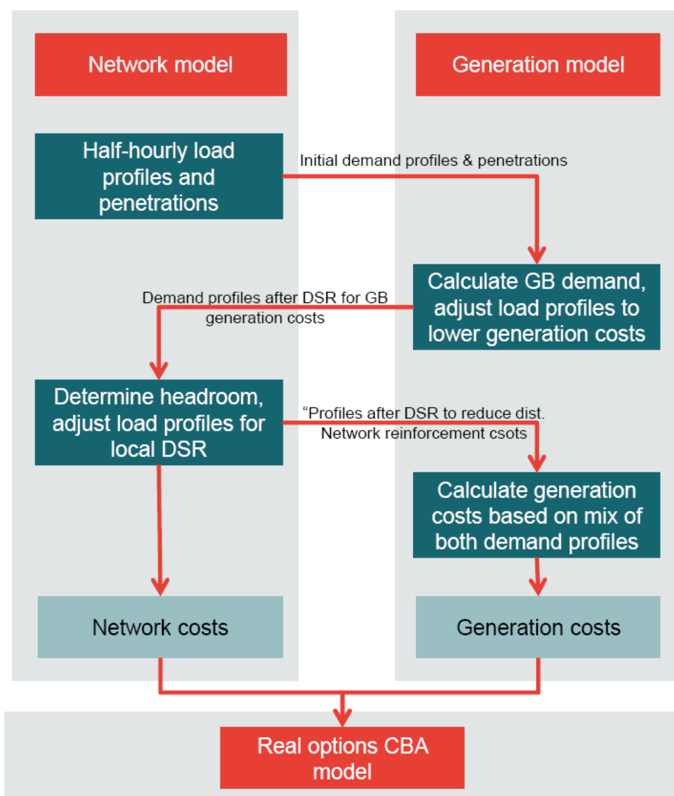

Figure 5 Model Interlinkages Accommodating DSR

Source: Frontier Economics (Oct. 2011)

Above diagram depicts how network model, generation model for proper representation of demand, for intermittent generation facilities such as wind and PV, and Real Options CBA model can be utilized in an interlinked manner.

Simply reviewing the details of model documentation on these aspects would not reveal the modeling details of real options CBA. But this report shows a way to overcome the problems of cost and benefit quantification arising from uncertainty.

II.1.3 Previous Reports: EPRI, DOE, McKinsey, JRC

EPRI (Electric Power Research Institute), in its report titled "Methodological Approach for Estimating the Benefits and Costs of smart Grid Demonstration Projects" (2010), presents a comprehensive framework for the estimation of the benefits and costs of Smart Grid projects and the step-by-step approach needed to conduct the analysis. The framework proposed in this report then utilized by other institutions to develop their own framework, methodology, and toolkits for Benefit and Cost Analysis (BCA) of a Smart Grid project.

In the EPRI Methodological Approach, one of the focus is the concept of benefit. The term "benefit" is defined as an impact (of a Smart Grid project) that has value to a firm, a household, or society in general. To measure the size of benefits, quantification is needed. In addition, the quantified benefits should be expressed in monetary so that it can be compared with others. To estimate the benefit, as well as the cost, there are three dimensional framework that must be analyzed upon, as shown in figure below.

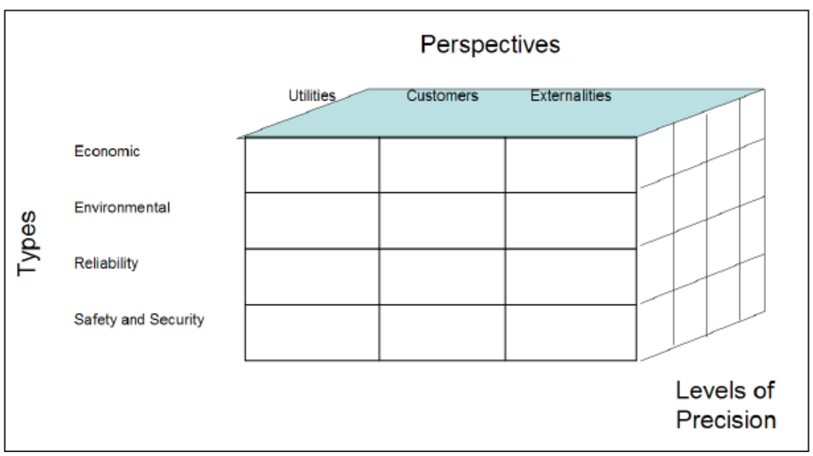

Figure 6 The Three Dimensions of Benefit and Cost of Smart Grid

Source: EPRI, 2010

The first dimension is the four fundamental categories (types) of benefits, that is economic, environmental, reliability, and safety and security. The second is the different perspectives of the benefits themselves, as seen by three beneficiaries: utilities, customers, and society as a whole. The third dimension, though, is proven to be the most difficult one to tackle: the levels of precision. The only reasonable way of characterizing the general level of precision is to use broad categories such as (EPRI, 2010):

- ✓ Modest level of uncertainty in quantitative estimates and/or in monetization
- ✓ Significant uncertainty in quantitative estimates and/or in how to monetize
- ✓ Highly uncertain
- ✓ Cannot be quantified

The approach taken by the EPRI report to estimate the benefit and cost of smart grid can be categorized into three parts: Characterization of the Project, Estimation of the Benefits, and Comparison of Costs to Benefits. As explained before, it can be seen that the focus of this framework is the benefit estimation, for it can be proven difficult and sometimes not straightforward enough. Based on the three parts approach, the full steps of BCA proposed by the report is as follow:

1. Review the project's technologies/elements and goals
2. Identify the Smart Grid functions which each project element could provide
3. Assess the Smart Grid Principal Characteristics that are reflected in the project
4. Map each function onto a standardized set of benefit categories
5. Define the project baseline and how it is to be estimated
6. Identify and obtain the data needed to estimate the baseline and to calculate each benefit
7. Calculate quantitative estimates of the benefits
8. Use economic conversion factors to estimate the benefits' monetary value
9. Estimate the relevant costs
10. Compare costs to benefits

As explained by steps 2, 3 and 4 above, a set of matrixes is needed to map the element of project to smart grid functions that is further is mapped to smart grid benefits. Then, the resulted list of benefits must be monetized so that it can be compared to smart grid costs and get analyzed.

Based on this methodology, the Department of Energy (DOE) of United States developed the Smart Grid Computational Tool (SGCT), a BCA toolkit that is built on the platform of Ms. Excel Macro (Visual Basic Application). Some slight modifications from the EPRI are:

- ✓ SGCT bypasses or simplifies some of the 10 (ten) steps approach of EPRI. For example, there is no detailed characteristic needed in SGCT, only a mapping from assets-functions-mechanisms-benefits is needed.
- ✓ The step of project's baseline definition for benefits calculation is given to the user and the tools will only receive it as an input.
- ✓ The quantified and monetized benefits steps are combined.
- ✓ Addition of several additional analyses in the tools, such as sensitivity analysis.

As mentioned before, one of the focus of EPRI methodology, as well as other BCAs that follow its lead, is the benefit quantification. In the DOE's SGCT, the process of transforming smart grid elements (assets) to the monetized value of benefits is done following this illustration

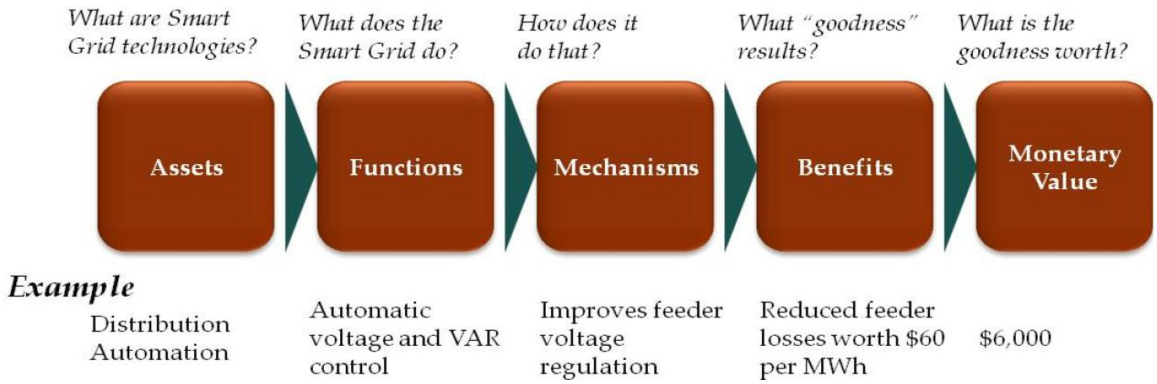

Figure 7 Illustration of the Translation of Smart Grid Assets to Benefit's Monetary Value

Source: Navigant, 2011

The tool already has a list of Smart Grid assets that can be analyzed, which is divided into five categories: Customer Assets, AMI Assets, Distribution Assets, Transmission Assets, and Other Assets. In total, there are 21 possible assets--an increase from the 19 assets in EPRI report--provided by the tool. Then those assets are translated into 15 functions, such as automatic voltage and VAR control. The mechanism is a translator between functions and benefits in this toolkit. Each function would have several possible mechanisms that can be chosen by the user. The toolkit then translates those mechanisms into the benefits of smart grid. Lastly, the user would need to provide the data and values of the smart grid to fill out the parameters and variables needed to monetize those benefits.

European Commission (EC)'s Joint Research Centre (JRC) also developed their own BCA framework as an improvement of the EPRI methodology. The joint effort between Members of EURELECTRIC and JRC resulted in a methodological framework to systematically estimate the different benefits of smart grid projects in seven steps, as follow.

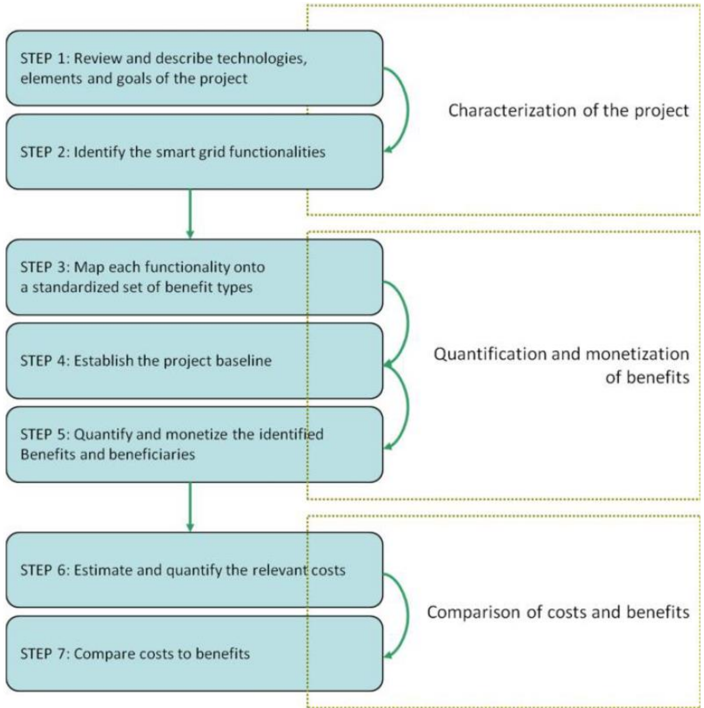

Figure 8 Cost Benefit Analysis Framework of JRC

Source: JRC, 2012b

In some of their reports, JRC outlines the seven steps of this BCA and its application to InovGrid, a smart grid project in Portugal that is used as sample case of this proposed BCA framework. JRC also combines several of its other researches with the basic EPRI methodology. In "Assessing Smart Grid Benefits and Impacts: EU and U.S. Initiatives," (2012), EC JRC and US DOE compares the two frameworks developed by the two institutions. Figure below shows the comparison between the two:

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)

Figure 9 Comparison between EC JRC and US DOE Framework

Source: Giordano (JRC) and Bossart (DOE), 2012

Another framework that was also considered in the ISGAN Executive Committee Meeting[11] for the Annex 3's BCA research is the one from McKinsey and Company. McKinsey already developed a BCA tool and was under trial within ERDF (European Regional Development Fund) and three other European DSOs (Distributed System Operators). The drawback of this proposal is the high cost for hiring McKinsey to do the job of tool development, that is 70000 Euros.

In their tool, the smart grid elements (applications) are classified into four different groups with different functionalities, that are: AMI, customer application, grid automation, and integration of DG (Distributed Generation) and EV (Electric Vehicle). They also put the smart grid benefits into four major groups: demand shift and savings, longer life of assets, operational improvement, and reliability improvement. These categorizations are different than those proposed by EPRI, but still they share general similarities. In essence, most if not all smart grid benefits is based on the saving, reduced, or avoided costs of normal grid between the baseline and scenario. Figure below shows the groups of benefits proposed by McKinsey

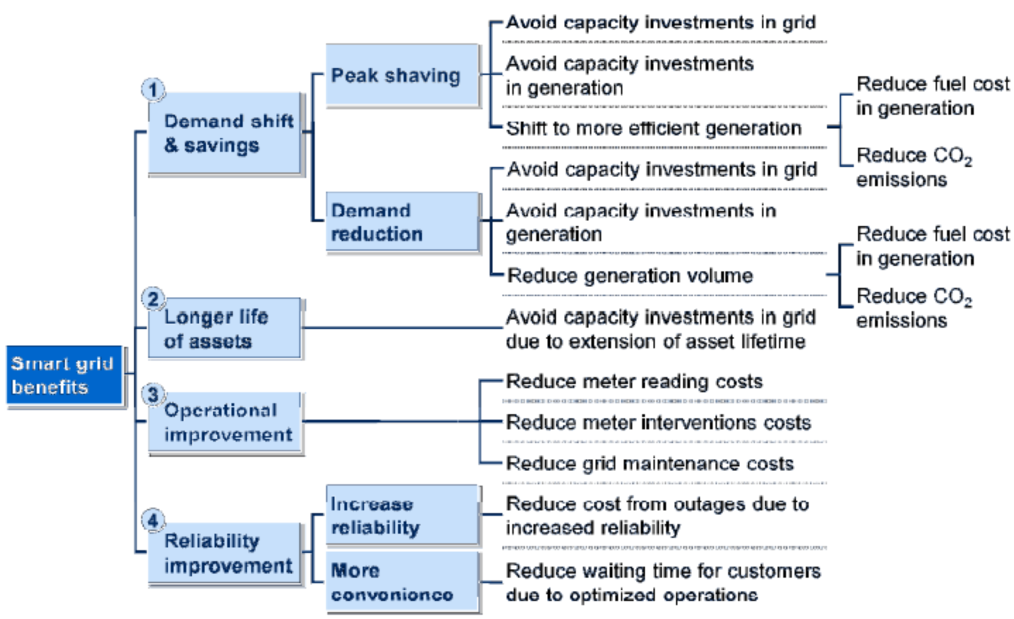

Figure 10 The Four Major Groups of Smart Grid Benefits according to McKinsey

Source: Nigris, 2012

II.1.4 Smart Grid Investment Model (SGIM) of SGRC

The SGRC is a research and consulting firm providing smart grid software and financial analysis with headquarters in Orlando, Florida. It was initiated by Dr. Jerry Jackson at Texas A&M University in 2010, which is an energy economist with experience in energy technology market analysis, financial model

[11] The framework was proposed in the 4th Executive Committee Meeting in Nice, France, September 26th-28th, 2012.

development, and project management. Initially a research project to assist cooperative and municipal utilities with smart grid investment analysis, the SGRC transitioned to an independent research and consulting firm in January 2011. The model itself is completed on December 2011 and available to non-consortium members on February 2012.

The main product of the SGRC is the Smart Grid Investment Model (SGIM). The SGRC has completed smart grid business case analysis for 16 utilities and is currently engaged in four new projects[12]. Each investment analysis project applies the SGIM to provide the most cost-effective and comprehensive smart grid business case analysis available. These utilizations of the model then maintained by the SGRC for future references so that new analysis of smart grid investment can be done more effectively and efficiently.

SGIM utilizes four basic steps to evaluate the benefits and costs of smart grid project, that are:

- ✓ Identify each technology and program that fits within the smart grid purview,
- ✓ Identify benefits of each technology/program including cost savings, operational efficiency and reductions in customer kWh, peak kW and hourly load profiles over the next twenty years,
- ✓ Identify technology, installation, program and management costs based on utility and customer characteristics
- ✓ Compare benefits and costs to determine investment returns.

In general, the steps of SGIM utilization are illustrated in the figure below. Although each utility might have a unique information of load profiles, avoided power costs, and customer characteristics among others, the same quantitative BCA is applicable to all cases. To take into account the utility-specifics, as shown in figure below, combination of utility customer data and member utility data would be used to estimate end-use hourly load model for 20-year horizon. The model then applies various impacts--technology, program, economic and utility--to estimate the avoided costs (benefits)

[12] As mentioned in http://www.smartgridresearchconsortium.org/index.htm, accessed December 27th, 2013

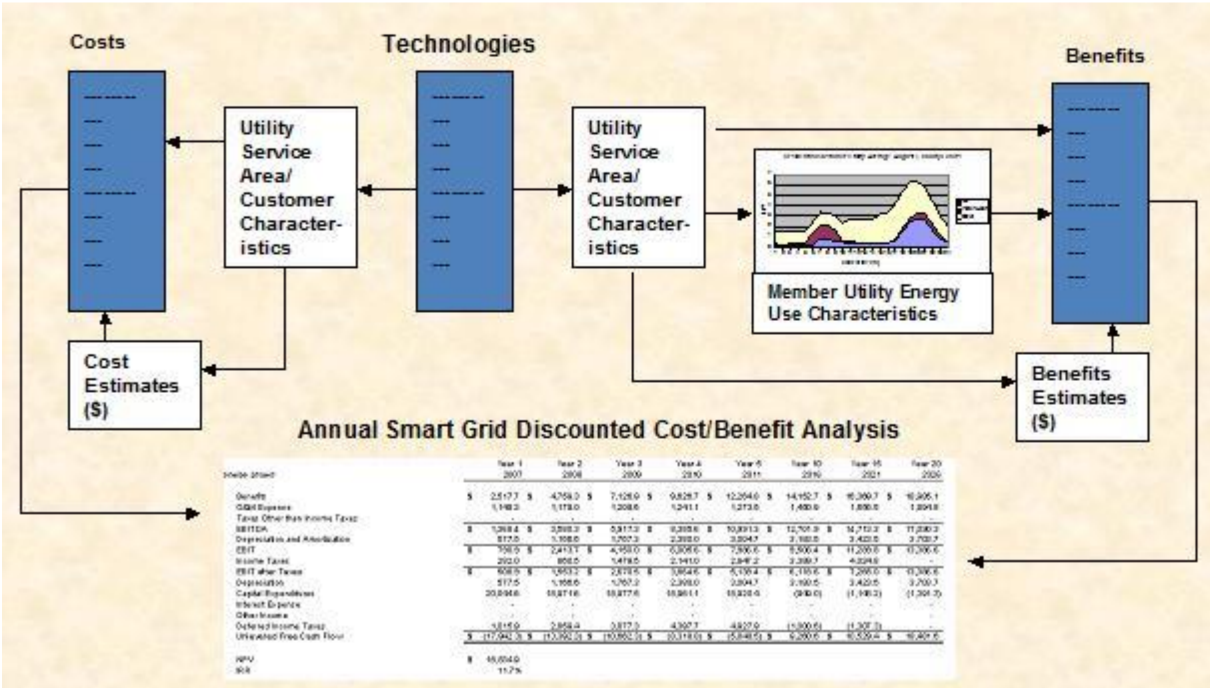

Figure 11 Basic Steps of BCA using SGIM

Source: Jackson, J. (2012)

On the application of the model, SGRC develops an excel based stand alone program for the users inputting various specific data and analyzing the results. The first part of the program is a quantitative characterization of the base case electricity use. This base case would be later used as a reference point to the avoided costs calculation.

Then, a specific worksheet called GATEWAY is used to provide several information: selecting the technologies and/or programs that would be available through the smart grid investments, starting point to input detailed parameters related to the technologies/programs, showing selected summary BCA results (IRR, undiscounted breakeven period, discounted breakeven period, NPV) among others. Figure below shows the screenshot of the GATEWAY worksheet.

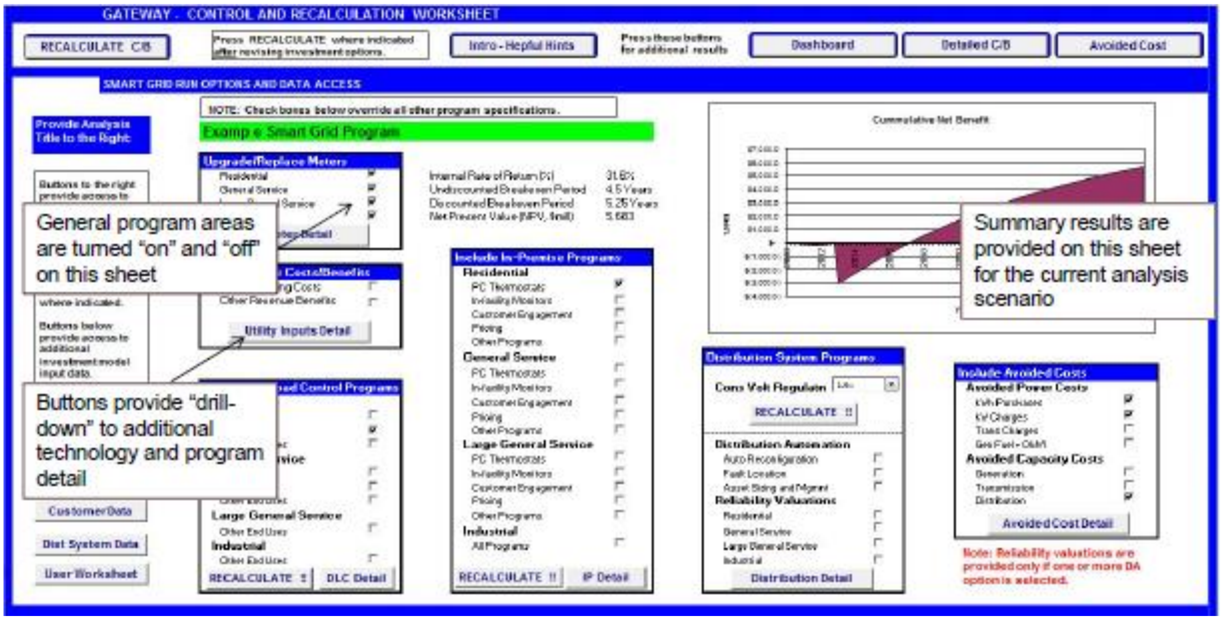

Figure 12 GATEWAY Worksheet of SGIM

Source: Jackson, J. (2012)

The detailed BCA results are presented in the DASHBOARD and other worksheets. The DASHBOARD also provides the user with appropriate buttons to evaluate the parameters applied in the analysis. The users can also modify the parameters that are supplied by the SGIM. Figure below shows the various worksheets of detailed BCA results provided by the SGIM. The SGIM can also be used to work on sensitivity analysis by changing the parameters.

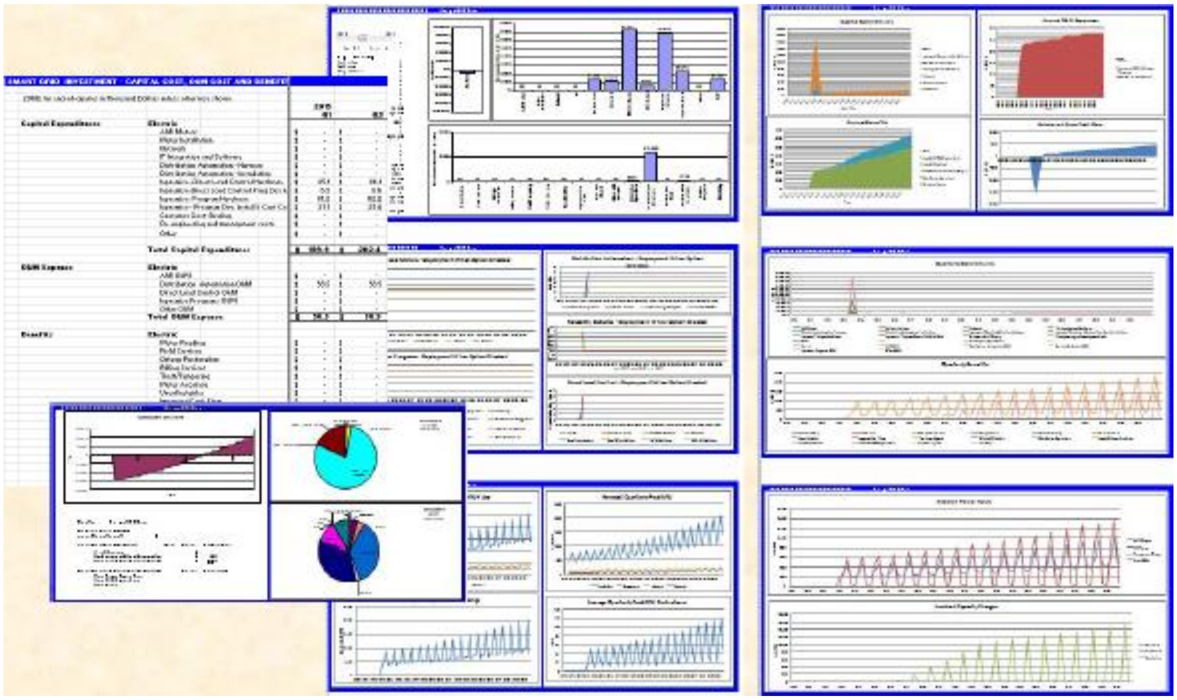

Figure 13 BCA Detailed Results in SGIM

Source: Jackson, J. (2012)

Some of the smart grid applications that can be analyzed by the SGIM are:

- ✓ AMI/Smart Meters
- ✓ Distribution Automation
- ✓ VAR Control
- ✓ Customer Technologies and Programs, such as Programmable Communication Thermostats (PCT), Pricing and Demand Response
- ✓ Communication and IT Application
- ✓ Meter Data Analytics

Although the model could be very good comparison and base for the improved SGCT program, the fact that it is a privatized model (not public) deters the possibility. Also, there is not enough documentation of the model and its utilizations to be based upon.

II.1.5 IMPLAN of ARRA 2009

IMPLAN (IMpacts for PLANning) is a model developed by the Minnesota IMPLAN Group (www.implan.com). Recently released IMPLAN 3.0 version is a regional economic analysis model that offers U.S. data for regional economic models from ZIP Code level to nationwide in the base year 2010.

The IMPLAN model is based on the input-output data from the U.S. National Income and Product Accounts (NIPA) from the Bureau of Economic Analysis. The model includes four Activity Types (Industry Change, Commodity Change, Industry Spending Pattern, and Institution Spending Pattern) which includes 440 economic sectors and two other Activities of Labor Income Change (2 Sectors) and Household Income Change (9 household types sorted by household income) based on the North American Industry Classification System (NAICS).

This model enables to analyze multiple scenarios of the change in activity scale, commodity value, industry sales price, labor income value, household income, and coefficients of industry spending and institution spending patterns on the economic impacts. The results present Study Area Data, Social Accounts (Industry by Commodity based Accounting Matrix, Input-Output Accounts), Industry Accounts (Industry by Industry Accounting Matrix, Input-Output Accounts), and Multipliers. The figure below shows the snapshot of one IMPLAN model result. And it is possible to explore the detailed results on the study area, social accounts, industry accounts and multipliers.

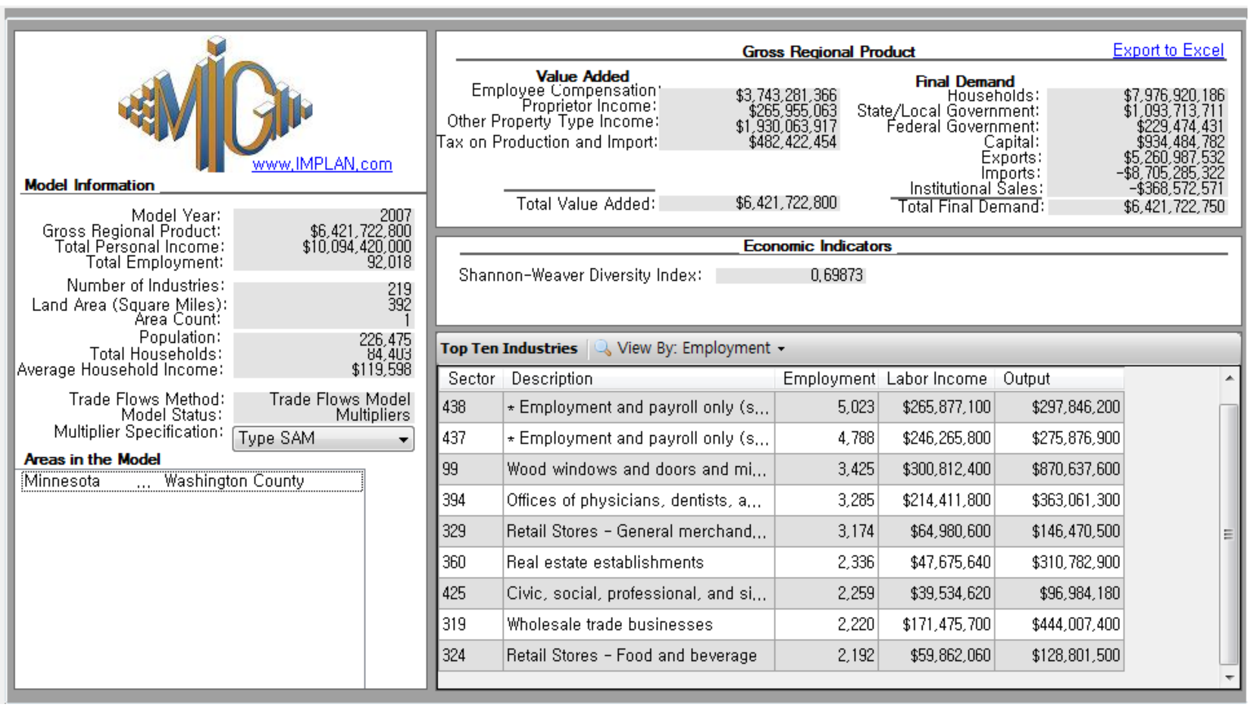

Figure 14 IMPLAN Model Economic Overview

Source: US Department of Energy, Office of Electricity Delivery & Energy Reliability, Economic Impact of Recovery Act Investments in the Smart Grid, April 2013

Once a change in activities or income is injected into a selected regional economy, IMPLAN initiates a multiplier effect and analyze total spending impact of new activity. This economic activity creates new local economic activity, jobs (i.e., the total employment), and tax revenues for federal and state/local governments (i.e., the total fiscal impact).

IMPLAN traces and calculates the multiple rounds of secondary indirect and induced economic impacts throughout the supply chain which remain in the selected region. The regions can be the entire U.S., specific regions within the U.S., or various states. This Smart Grid analysis is conducted for the entire U.S.

The model uses region-specific multipliers to trace and calculate the flow of dollars from the industries that originate the economic activity to supplier industries that generate additional activity (as noted above). These multipliers are thus coefficients that "describe the response of the economy to a stimulus (a change in demand or production)." Figure below illustrates the three types of impacts used in IMPLAN:

- ✓ Direct – represents the economic impacts (e.g., employment or output changes) due to the direct investments, such as payments to companies in Smart Grid 'core' industries.
- ✓ Indirect – represents the economic impacts due to the industry inter-linkages caused by the iteration of industries purchasing from industries, brought about by the changes in final demands (e.g., when a meter manufacturer purchases computer chips from another company).
- ✓ Induced – represents the economic impacts on all local industries due to consumers' consumption expenditures arising from the new household incomes that are generated by the direct and indirect effects of the final demand changes (e.g., a worker purchases new clothing or purchases food in restaurants).

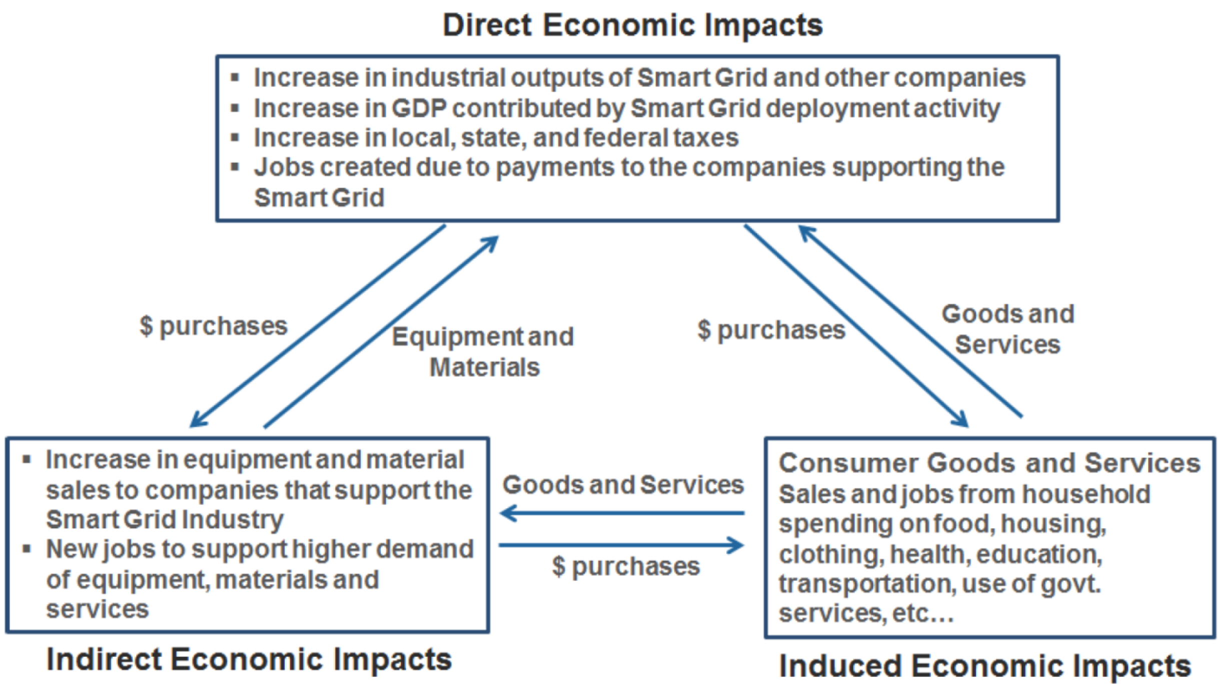

Figure 15 Schematic of IMPLAN Model: Economic Impact Analysis of Smart Grid ARRA Funding

Source: US Department of Energy, Office of Electricity Delivery & Energy Reliability, Economic Impact of Recovery Act Investments in the Smart Grid, April 2013

The total impact is simply the sum of the direct and the multiple rounds of secondary indirect and the multiple rounds of secondary indirect and induced impacts that remains in the region (the entire U.S. in this case). IMPLAN then uses this total impact to calculate subsequent impacts such as total jobs created and tax impacts. This methodology, and the use of IMPLAN, is well-established and consistent with numerous other studies of national policy.

II.2 Application of BCA: Country-specific and Others

II.2.1 Czech Republic

- **Background**

The primary goal of this article is applied and proven on a specific case of electricity accumulation in the environment of Czech Republic. This analysis is based on presumption that each impact (regardless of the fact that influences directly the customer or other market participant) represents finally benefit or cost for customer. This idea is based on the fact that the customer is the final market participant who pays for not only market, but also regulated part of electricity price.

- **The Methodology and/or Toolkits Used for BCA**

There are things that considering to calculation of differences between today's system and future energy industry system incorporating the SG concept.

- ***Economic Effectiveness***

This study's methodology is represented by common Net Present Value (NPV) theory.

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t}$$

It proposes to calculate balance between futures discounted costs and benefits. NPV is net present value of some investment, CF_t is cash flow in some year t , r is discount (time value of money) and T is lifetime of particular investment.

This article provides an environment of SG system as below. The development and outputs of the SG system are characterized by their inputs.

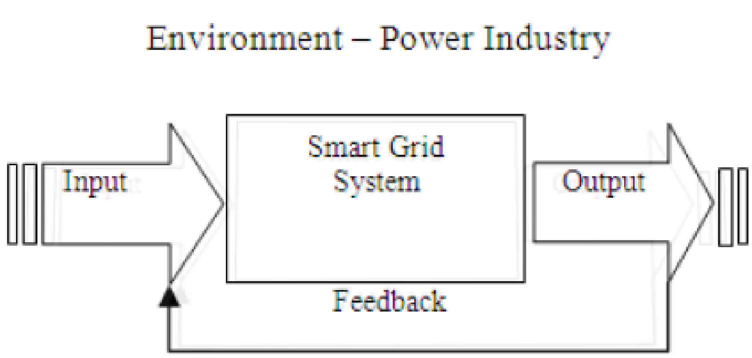

Figure 16 System in the first resolution

Source: Adamec, M. (2011)

✧ *Transformation of Inputs*

Every system transforms inputs into outputs.

$$O(t) = T\left[I(t), S(t)\right]$$

O represents vector of outputs/responses of the system, I represents vector of inputs, S represents vector of State variables and operator T represents transformation process. Vector of state variables characterizes the system and represents borders for the process of transformation which is represented by operator T .

✧ *Valuation of Particular Costs and Benefits*

The systematic approach identifies necessary inputs, outputs and aspects of the system environment and feedback aspects. This cost benefit analysis from the consumer's point of view as follow:

$$\sum_{t=0}^{T} \frac{I_t}{(1+r)^t} + \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t}$$

I_t is particular kind of investment cost, C_t is particular kind of operational cost, B_t represents particular benefit including cost avoidance, r represents discount and T lifetime of SG infrastructure.

- **The scope of smart grid project (Location, Project Period & Technologies deployed)**

They have chosen common household house (with approx. 10 flats) in the Czech Republic. This case study would suppose smart usage of electricity accumulation, which is one of most visible benefit.

- **The list and definition of benefits (Outputs/Responses from SG System)**

They have to incorporate 3 types of economic benefits:

- ✓ Load leveling effect is based on feature of battery to hold the consumption as a reliable source of electricity. This effect leads to the crowding out of consuming peak load electricity consumed with the electricity produced in PV plant.
- ✓ Time shifting effect is based on the accumulating surplus power during peak of the PV plant production (the excess of PV plant production above the consumption) and supporting the delivery of electricity accumulated during the decrease of the PV plant production bellow level of consumption.
- ✓ Off-peak time shifting effect is marginal activity based on accumulating of off-peak load and shifting this energy to peak load hours. Due to our conservative approach we consider this effect only marginally and don´t support speculative aim to benefit mainly from spread between peak load and off-peak load.

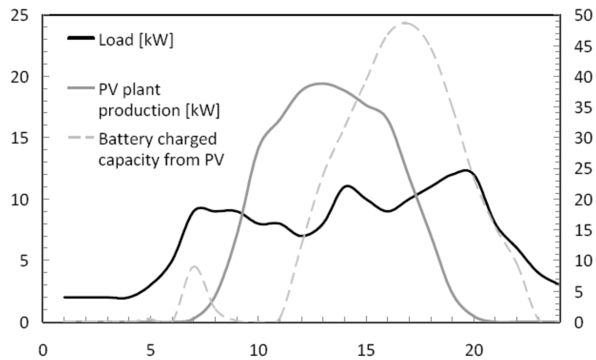

Figure 17 Battery charging during 1st and 4th quarter utilizing PV.

Source: Adamec, M. (2011)

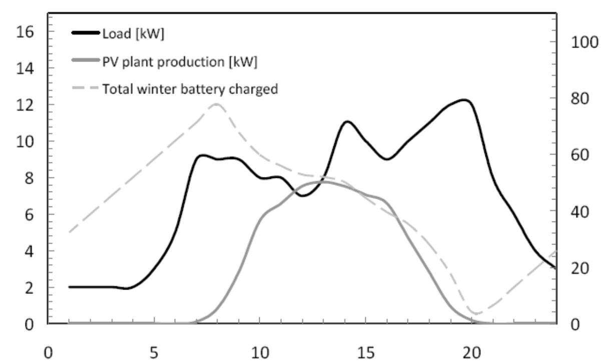

Figure 18 Battery charging during 2nd and 3rd quarter utilizing both PV and off peak charging

Source: Adamec, M. (2011)

- **The list and definition of costs:**
  - ✓ Threshold investment into SG infrastructure: The largest value of investment will be spent on Advanced Metering Management (AMM) devices development, installation.
  - ✓ Interim investment into state of the art maintenance of SG system
  - ✓ Investment into foundation of marketing communication and market share possession
  - ✓ Capital costs that originate from selected methods of financing : Capital costs connected with financing of AMM devices implementation
  - ✓ Maintenance costs of AMM devices CM: Means replacement of spare parts, costs for repairs, long term service costs, wear and tear etc
- **Deliverables**
  - ***Results***

Table 1 and 2 represent the evaluation of economic benefits divided to two periods, summer characterized by evaluation of peak production of PV plant and winter characterized by higher consumption and lower production of electricity.

Table 4 Benefits (summer 2Q and 3Q) per 1 year

Description	Profit(€/MWh)	Cycles	Profit (€/year)
Load leveling (to enable supply for own consumption)+crowding out of peak consumption	23	4000 (180per year)	623,98
Time shifting of reduced electricity from PV plant	9		77,65
Off-peak time shifting	14		22,68

Source: Adamec, M. (2011)

Table 5 Benefits (winter 1Q and 4Q) per 1 year

Description	Profit(€/MWh)	Cycles	Profit (€/year)
Load leveling (to enable supply for own consumption)+crowding out of peak consumption	23	4000 (180per year)	623,98
Time shifting of reduced electricity from PV plant	Not available due to higher consumption (load) than PV plant production		
Off-peak time shifting	14	4000 (180per year)	22,68

Source: Adamec, M. (2011)

Table 3 shows us result of valuation of the SG system with the implemented smart-metering and accumulation. They were working with the reasonable discount rate of 8% due to non-extremely risk connected with the investing to the accumulation and devices responsible for smart behaving of the unit. The negative result of net present value indicates a non-effective solution of an investment.

Table 6 Total economic analysis

NPV for 20 y lifetime		Category	Result [EUR]
Annuity	9,81815	Income 1Y	1 094,85
Lifetime	20	Outlay year 0 (investment)	11 664,00
Discount	8%	NPV	- 914,57

Source: Adamec, M. (2011)

- **Policy and Regulatory**

The SG implementation will grow with increasing amount of decentralized RES-E. Under this condition the spread between low and high price will be much higher than today and will lead to reasonable accumulation and mainly to smart grid concept implementation. Low price would occur during maximal generation in RES-E and vice versa.

II.2.2 Denmark

- **Background**

Denmark has ambitious political climate and energy targets for the next ten years to reduce CO_2 emissions in non-ETS sectors by 20 per cent, to increase the share of renewable energy in electricity generation to 30 per cent, to that in the transport sector to 10 per cent, and to improve energy efficiency. On the supply side, there will be a significant expansion of Danish wind power generation capacity so that in 2025 wind turbines are expected to generate up to 50 per cent of annual Danish electricity consumption. On the demand side, electricity will be increasingly utilized in the heat and transport sectors through the increased use of electric heat pumps as well as electric and plug-in hybrid vehicles. Overall, these targets create a need for reinforcing and expanding the power system.

It is noted that this discussion is summarized from the joint report of Energinet.dk and Danish Energy Association (Energinet.dk & Danish Energy Association, 2010).

- **The scope of smart grid project (Location, Project Period & Technologies deployed)**

A number of network companies are either engaged in or planning to roll out automated metering systems (AMR) to private households. Moreover, the replacement of oil-fired burners with electric heat pumps is already in progress partly due to the payment of public subsidies to customers. Although the major challenge in relation to electric and plug-in vehicles is still some year away, extensive work is carried out today to develop concepts and charging stations and to plan the expansion of the entire charging infrastructure.

In recent years, the Danish Energy Association and Energinet.dk have worked determinedly on investigating the opportunities and challenges facing the power system, given the ambitious political climate and energy targets. In the first half of 2010, a joint project was initiated with a view to analyzing the prospects of Denmark taking advantage of the opportunity to make the Danish power system more environmentally friendly and efficient by setting up intelligent demand response in Danish households. The objective of the project has been to describe and analyze the specific challenges facing the power system in the coming 15 to 25 years and to describe in which ways and to what extent Smart Grid solutions can address these challenges.

In this report, they define Smart Grid with the following elements.

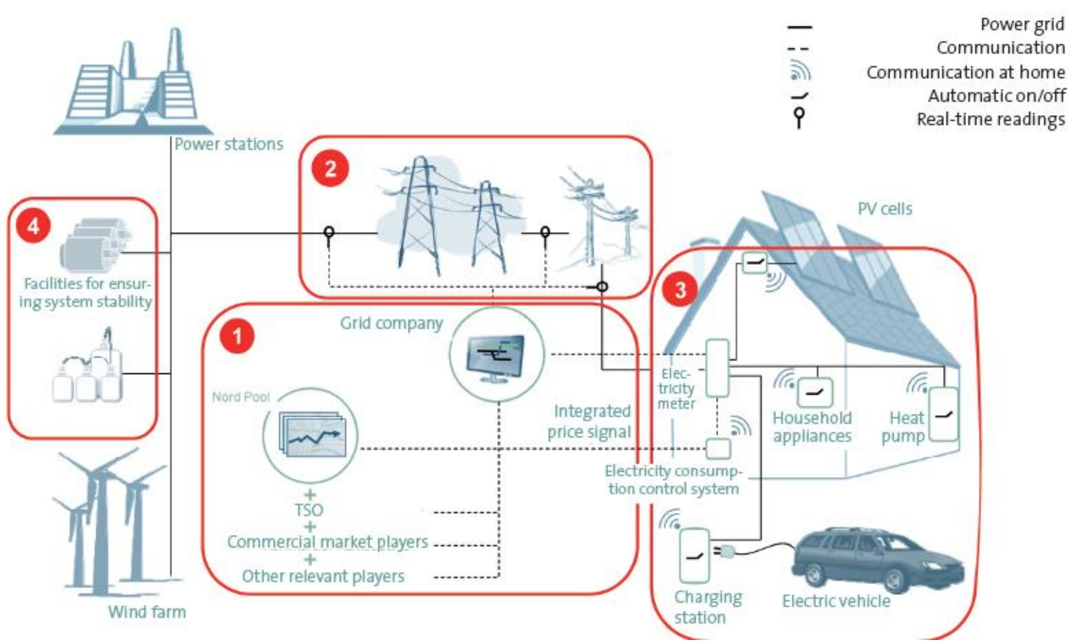

Figure 19 Illustration of the elements of a Danish Smart Grid

Source: Energinet.dk & Danish Energy Association (2010)

The elements shown in above graph are:

1. Systems for interdisciplinary coordination and data exchange between the players in the power system
2. Equipment for measuring the condition of the distribution network
3. Equipment for flexible control and settlement of the consumption of consumers investing in a heat pump or an electric vehicle
4. Facilities for ensuring system stability

This report describes briefly the way towards an intelligent power grid in three phases.

- ***Facilitating phase (2010-2012)***

  The society will experience an increasingly widespread use of electric heat pumps and the first proper launch of electric and plug-in hybrid vehicles by commercial players. By the end of this period, the electricity sector should have ensured that the relevant players both inside and outside of the electricity sector are mobilized and involved in considering the power system of the future. Also, a wealth of experience should have been gained through development and demonstration projects which can form the basis for frameworks and standards.

- ***Establishment phase (2012-2020)***

  The Changes on the demand side will begin to take shape as the use of heat pumps will have become significantly more widespread and consumers will have begun to purchase electric and plug-in hybrid vehicles on a larger scale. By the end of this period, this development will have brought about a power system in which the fundamental Smart Grid infrastructure has been established. At the same time, the system should be so mature that commercial solutions supporting intelligent demand response start to find more widespread use.

- ***Commercialization phase (2020-)***

  This phase is expected to occur after 2020. By that time, electric heat pumps will be the most widespread source of heating outside areas supplied with district heating and natural gas. At the same time, electric and plug-in hybrid vehicles will be recognizable and commonplace on the streets. This situation makes it possible to balance the power system via Smart Grid functionality in the form of intelligent and automated control of the consumers' flexible appliances while Smart Grid services should be further developed so that consumers have a wide range of products to choose between.

- **The methodology and/or toolkits used for BCA**

The economic calculations in the project have been performed in the individual working groups. All calculations are performed on the basis of a socioeconomic consideration and are calculated as present values based on an annual discount rate of 5 per cent.

The report assumes in its analyses that the Danish electricity sector in 2025 is able to handle the followings – 1. Wind turbine capacity is expanded to cover approximately 50 per cent of annual Danish electricity consumption, 2. The number of electric and plug-in vehicles totals 600,000, and 3. There are 300,000 individual heat pumps.

- **The list and definition of benefits**

The analyses have investigated the benefits of a Smart Grid in a Danish context. It shows that there are no significant Smart Grid benefits to be gained from improving security of supply since the Danish power system today is very robust with high security of supply. However, the analyses show that the other areas of benefit contain a significant Danish potential that can provide socioeconomic benefits amounting to approximately DKK 8.2 billion distributed on the following areas.

  - ***Savings on reserves and regulating power***

- ✓ Reduce costs of supplying reserves and regulating power by utilizing the consumers' decentralized resources
- ✓ Detailed analyses of current costs for reserves and regulating power, including future requirements

  - ***Savings on electricity generation***

- ✓ Reduce costs of generating power by moving demand response to times with a more efficient generation portfolio
- ✓ SIVAEL simulation of future electricity consumption and the generation portfolio

  - ***Savings on energy-saving initiatives***

- ✓ Reduce costs for alternative achievement of the energy saving-initiatives, which will be a derived result of an automated Smart Grid
- ✓ Analysis of a report concerning energy savings in other countries and the transfer of their results to Denmark

- **The list and definition of costs**

The report has identified the necessary investments and costs, which amount to total socioeconomic costs of approximately DDK 9.8 billion. These costs comprises of the following items.

  - ***Grid reinforcements***

- ✓ Reinforcement of the distribution network (0.4 kV, 10 kV and 50 kV) to prevent overloading

- ✓ Analyses of the distribution network of seven large grid companies extrapolated to country level

  - ✧ ***Facilities for ensuring system stability***

- ✓ Installation of synchronous compensators and SVCs that can create the necessary inertia and short-circuit capacity
- ✓ Analysis of the need for additional inertia and short-circuit capacity in a future with an increased wind power share

  - ✧ ***Software installed with the TSO and DSOs***

- ✓ Software installed with the TSO and the grid companies that can aggregate and process all information collected in the distribution network and at the consumers' premises
- ✓ Specific investment expectations from TSO and two grid companies

  - ✧ ***Metering equipment in distribution network***

- ✓ Metering equipment in all 10 kV and 50 kV substations and in one third of all 0.4 kW substations
- ✓ Results from ongoing projects at both Energinet.dk and a grid company

  - ✧ ***Intelligent solutions at the end user's premises***

- ✓ Electronics for automated control of heat pumps, domestic generation as well as demand response and generation at the customers' premises
- ✓ Analyses of current pricing of similar technology and historic price development for similar electronics

  - ✧ ***Upgrading of electronic electricity meters***

- ✓ Upgrading of electronic electricity meters so that they can facilitate hourly settlement for consumers with electric and plug-in vehicles, heat pumps and electricity generation
- ✓ Analyses based on actual experiences with electricity meters and expected price development

- ➢ **Deliverables**

  - ✧ ***Results***

The project calculations show that the socioeconomic investment in converting the power system up to 2025 will be approximately DKK 9.8 billion by establishing Smart Grid. This investment will realize a socioeconomic benefit of approximately DKK 8.2 billion and thus result in total socioeconomic costs of approximately DKK 1.6 billion. The alternative to Smart Grid is a traditional expansion strategy, in which the socioeconomic investment will be in the range of DKK 7.7 billion, which in contrast to Smart Grid will not yield any social benefits. Consequently, the advantage of pursuing the Smart Grid strategy is estimated to be around DKK 6.1 billion.

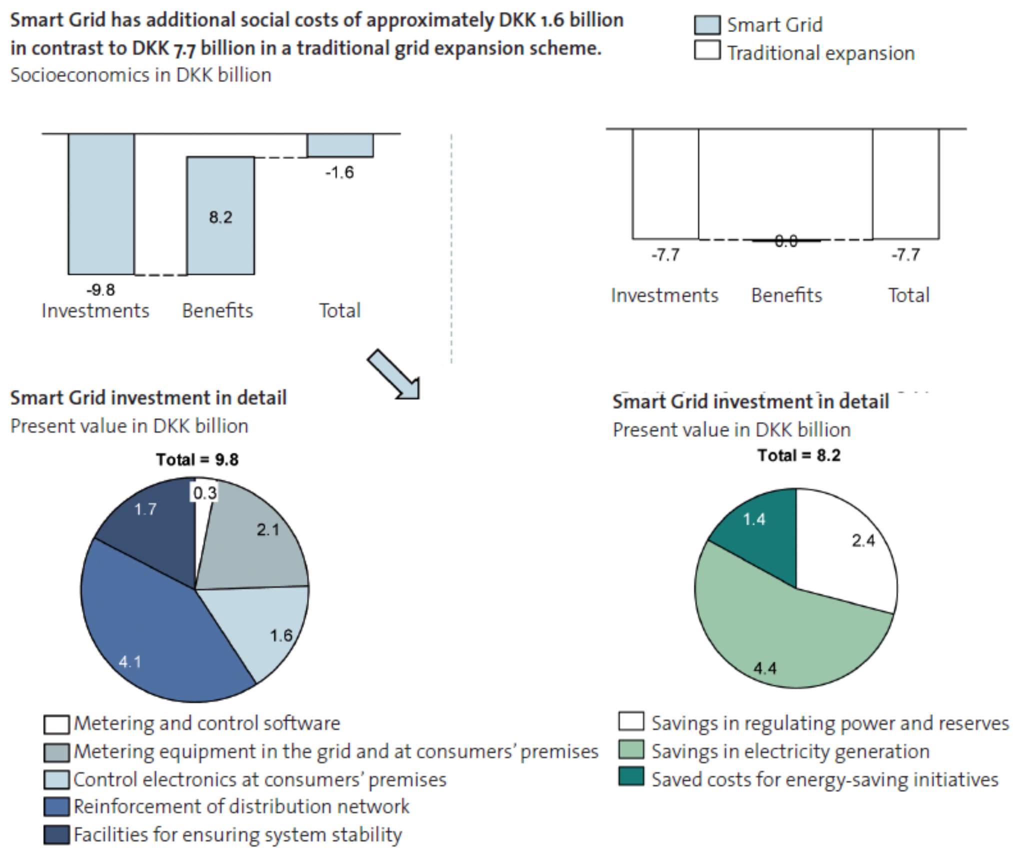

Figure 20 Investments and benefits of establishing the power system of the future

Source: Energinet.dk & Danish Energy Association, 2010

✧ ***Policy and Regulatory***

The report says that the political preconditions encourage a proactive behavior among all the players. It describes the two necessary preconditions which will be essential for supporting this behavior. One is that Future-proofing financial regulation in the electricity sector should create incentives. The other is that Smart Grid development and demonstration activities can accelerate development. It advises that the society should continue granting financial support to conduct focused and coordinated development and demonstration activities that encourage the advancement of those technologies and solutions that will form the building blocks for the intelligent power system of the future. These activities should both optimize development within the individual parts of the value chain and simultaneously ensure that interdisciplinary solution models are developed and tested.

II.2.3 Ireland

- **Background**

This section of Ireland case is a summary of the result from the BC Analysis conducted by Energy Needs Ireland (ENI) 2013. ENI started in 2007 as an interdisciplinary summer education & research program which is based in the Electricity Research Centre (ERC) in University College Dublin (UCD). The 2013 group consists of 21 undergraduate students from universities throughout Ireland who spent the summer working on the technical, business and social aspects of projects that are related to the Smart Grid. The objective of this analysis was to judge the suitability of a full immediate Smart Grid rollout in Ireland to attaining the goal of making Ireland's electricity supply more efficient and environmentally friendly.

The report reminds that the European Union's Third Energy Package asks Member States to carry out an analysis of intelligent metering systems. The Directive 2009/72/EC2[13] of the European Parliament and of the Council states that all countries with a positive Cost Benefit Analysis must ensure that 80% of electricity consumers are supplied with Smart Metering systems by 2020.

- **The scope of smart grid project (Location, Project Period & Technologies deployed)**

ENI has introduced its own definition of a Smart Grid. Smart Grid is an electrical grid system that encompasses each of the following features.

- ✓ Smart Metering systems implemented into every building
- ✓ Upgraded grid infrastructure (transmission lines, etc.)
- ✓ Smart, energy efficient appliances installed in every household
- ✓ A population that is fully educated on Smart Grid concepts
- ✓ The facilitation of two-way data flow between consumer, supplier and grid operator
- ✓ Increased wind generation on the grid

- **The methodology and/or toolkits used for BCA**

Many European countries have carried out a Cost Benefit Analysis on the feasibility of the national rollout of a Smart Grid. The European Union's Third Energy Package asks Member States to carry out an analysis of intelligent metering systems. The Directive 2009/72/EC2 of the European Parliament and of the Council states that all countries with a positive Cost Benefit Analysis must ensure that 80% of electricity consumers are supplied with Smart Metering systems by 2020. Some European countries carried out a CBA on an entire Smart Grid rollout, including Germany, Great Britain and Denmark. Ireland's CBA was done on the implementation of Smart Metering systems and had a positive outcome. ENI's CBA studies the prospect of a full deployment of a Smart Grid in Ireland, beginning this year and its conclusions and recommendations are developed to inform members of the general public, the energy industry, policy-makers and all interested parties.

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[13] Official Journal of the European Union 2009, Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009.

In the calculation, the discount rate of interest chosen for use in this CBA was 6.62% . This value was applied as it is the value given by the Department of Finance for projects estimated to be completed between ten and twenty years from now. This CBA speaks of an immediate implementation of a Smart Grid, however, it must be recognized that time will be required for all aspects of the Smart Grid to be adopted all across Ireland. ENI estimated that if a Smart Grid rollout begins now, then it will take between ten and twenty years before full implementation is achieved.

ENI accounted for a best and worst case scenario in order to cover the range of possible outcomes. As well as this ENI has assessed a number of issues that are included in a Smart Grid rollout, that each could affect effect the outcome of the CBA. It classed the following elements as sensitivities.

- ✓ Business As Usual
- ✓ Educating the Public
- ✓ Integrating Smart & Efficient Appliances
- ✓ Renewables and Integration

➢ **The list and definition of benefits**

The CBA can be divided into two categories: those that are quantifiable, and those that are non-quantifiable.

✧ ***Quantifiable benefits***

- ✓ Benefits of smart meters
  - ◆ Smart Meters are likely to encourage consumers to reduce their usage and increase savings. As manual meter readings will no longer be necessary, further savings will also be made on labor costs.
  - ◆ ENI interprets the best case scenario as a saving of €174 million, which includes the installation of Smart Meters.
- ✓ CO2 Reduction
  - ◆ The European Commission has declared that the reduction in CO_2 emissions from the completion of a Smart Grid will be 9%[14] below the target baseline figure[15] of 55.607Mt, given in the Kyoto Agreement in 2005.
  - ◆ At the lowest European carbon price ever recorded[16], €2.63 per tonne on 16th of April 2013, will be a saving of approximately €7.1 million; and at the highest price ever recorded[17], €32 per tonne in April 2006, the saving will be approximately €87.4 million approx.
- ✓ Fuel Savings

[14] CEN-CENELEC, 2012. European standards organisations make progress towards Smart Grid standards and reference architecture.
[15] Kyoto Protocol, 2005. Kyoto Protocol.
[16] Lynch S., 2013.Carbon prices fall to record low as MEPs vote against intervention in market.
[17] EurActiv, 2013. EU carbon market in 'freefall' after back loading vote.

- In this analysis, these targets are being met by integrating wind generators, and the fuel saving is based on the amount of gas that will be saved.
- The average system demand for the year 2012 was calculated to be 2,917 MW[18]. ENI takes the 'Business as Usual' wind energy percentage to be 19.5% of the electricity fuel mix and the Smart Grid wind energy percentage to be 40%. Therefore the yearly gas savings are 5.2 TWh, by assuming that only gas is saved by wind power. Assuming the average gas plant operates at 46% efficiency the yearly MMBtu(Million Metric British Thermal Unit) savings become 38,964,203.9 MMBtu. Using projected gas prices[19], the fuel cost savings were found to total €1.7 billion and €1.5 billion as a best and worst case scenario respectively.

✧ ***Non-quantifiable benefits***

✓ Benefits to the consumer
- Demand Side Management – it benefits the consumer as it saves them money, and it will change their behavior making them smarter and more efficient energy users.

✓ Benefits to the overall economy
- Increased renewables on the grid – it helps to significantly reduce Ireland's carbon footprint. Increasing the renewable, indigenous generation capacity of the grid also makes Ireland's electricity supply more secure, reducing dependence on imported fossils fuels.
- Advanced reliability - due to the increased role of telecommunications on the grid and improved infrastructure, facilitating faster response times to issues and faster acting ancillary services.
- Better electricity trade - Ireland will be able to import and export electricity more efficiently due to the improved infrastructure and faster response times.
- Improved telecommunication infrastructure - Public communication systems could easily be improved alongside the telecommunication infrastructure implementation for Smart Grid technologies.
- Other applications for the data collected - The data collected about electricity consumption by Smart Meters has the potential to be used for a variety of purposes, such as academic studies and health studies.
- Opportunities for innovation

➢ **The list and definition of costs**

The CBA can be divided into two categories: those that are quantifiable, and those that are non-quantifiable.

[18] EirGrid, 2012. System Demand.
[19] World Bank, 2013. Global Economic Prospects.

✧ ***Quantifiable costs***

✓ Installing smart meters

- The major cost here will be the cost of buying and testing the Smart Meters, as well as installing them in all buildings in the country.
- The best case scenario, taken from ENI's evaluation of the CER report[20], on Smart Metering shows a cost of €45 million while the worst case has a cost of €58 million.

✓ Renewables & integration

- The cost of integrating renewables is based on the capital cost, installation, maintenance and decommissioning of enough wind generation capacity to ensure Ireland meets its 2020 targets.
- For Ireland to reach its 40% of electricity from renewable energy sources goal there must be between 3.5 and 4 GW of wind energy on the system[21] (currently, existing wind farms have the capacity of 1.8GW[22]). The best case scenario needs 1.7GW, which will cost €1.362 billion; while in the worst case an extra 2,237MW would be required and will cost €2.44 billion.

✓ Updating infrastructure

- EirGrid's GRID25[23] project proposes to upgrade the grid infrastructure.
- The best cost scenario of GRID25 is €3.2 billion which is a sunk cost; while the worst case scenario is based on the possibility that the project were to go over its current estimated cost and revert to the original cost set out in the initial GRID25 literature, €4.035 billion. Therefore, for the worst case scenario in the final calculation, the cost of updating the grid infrastructure is entered as €563.7 million.

✓ Educating the public

- This cost will include that of producing and distributing materials which will be used to educate the general public on the Smart Grid and Smart Metering.
- The best case scenario is the lower cost of €2.9 million as it is hoped that consumers would be made aware of the Smart Grid without excessive advertising[24]. The worst case is an expense of €8.5 million, this would involve an increased scale advertising campaign and would be more intensive[25].

✧ ***Non-quantifiable costs***

✓ Public Opposition

[20] CER, 2012. Smart Metering Cost-Benefit Analysis and Trials Findings Reports.
[21] EirGrid, 2013.All Island Generation Capacity Statement.
[22] IWEA, 2012.Wind Energy in Ireland Statistics.
[23] EirGrid, 2013. What is Grid25?.
[24] Department of Communications, Energy and Natural Resources, 2012. Digital Switchover in Ireland Information and Awareness Campaign.
[25] Department of Communications, Energy and Natural Resources, 2008.Campaign Progress Report No.3 1st July 2007 - 30th April 2008.

- Data monitoring – the public may concerns about what private information will be transferred and stored.
- New infrastructure – there will be public opposition to the construction of new grid infrastructure as it will have an effect on their land and local scenery.

✓ Environmental costs

➢ **Deliverables**

✧ ***Results***

ENI concludes that the although the Smart Grid can achieve the goal of making Ireland's electricity supply more efficient and environmentally friendly, there is such a significant amount of risk involved in the full and immediate implementation of a Smart Grid in Ireland, that it cannot currently be justified.

Table 7 The Quantifiable Benefits and Costs of a Smart Grid (in millions)

	BEST CASE	***WORST CASE***
BENEFITS	€	€
SMART METER SAVINGS	174	170
FUEL SAVINGS	1,700	1,500
REDUCTION IN CO_2	87.4	7.1
TOTAL BENEFITS	1,961.4	1,677.1
COSTS		
UPGRADING INFRASTRUCTURE	-	562.7
INSTALLING SMART METERS	45	58
RENEWABLES & INTEGRATION	1,362	2,439
EDUCATING THE PUBLIC	2.9	8.5
TOTAL COSTS	1,409.9	3,069.2
BENEFIT/COST	551.5	-1392.1

Source: ENI, 2013

From the calculation given in Figure above, and on a purely quantitative basis, it is clear that a full and immediate implementation of a Smart Grid in Ireland would lead to a net benefit of over €0.5 billion as a best case, and a net loss of approximately €1.3 billion as a worst case.

And there are non-quantifiable costs present also, that could alter the result. The following intangibles have the potential to affect the outcome of the monetary analysis above.

✓ The benefit of the public being more educated, as benefits
✓ The useful solutions to Smart Grid challenges, so called 'Opportunity for Innovation,' as benefits
✓ Better trade of electricity between Ireland and UK, as benefits
✓ Public Opposition, as cost

✧ ***Policy and Regulatory***

ENI recommends that the Smart Grid is rolled out in stages. The following sequence to implement the main Smart Grid component.

- ✓ Public education should be carried out shortly before the Smart Meter rollout in order to achieve the full benefit of the Smart Meters
- ✓ Smart metering systems due to be implemented in 2020, EU policy
- ✓ Integration of renewables by 2020, to meet 20% target set by EU
- ✓ As per EirGrid's GRID25 report, grid infrastructure will need to be updated by 2025
- ✓ Smart Appliances implemented gradually as old appliances degrade in the next 15 to 20 years

II.2.4 Lithuania

➢ **Background**

Technology and Innovation Centre (TIC) coordinating the project for smart electricity grid development in Lithuania announced the procurement for drafting the cost-benefit analysis (hereafter the Analysis) of the roll-out of smart metering system in Lithuania, and the contract was awarded to JSC Ernst &Young Baltic. The report (Ernst & Young, 2012) is summarized in the following sections.

➢ **The methodology and/or toolkits used for BCA**

The project reports established three scenarios of the smart metering roll-out. The establishment of scenarios was based on:

- ✓ Technical task of the project;
- ✓ Results of the alternatives' analysis of smart metering system parameters;
- ✓ Results of stakeholder expectations analysis and evaluation of parameters;
- ✓ Recommendations of the EU cost-benefit analysis on the smart metering roll-out.

Three roll-out scenarios were established for which a detailed cost-benefit analysis will be carried out.

Table 8 Parameters of the Scenarios of the Smart Metering Roll-out

MAIN PARAMETERS OF THE SCENARIOS	BASE CASE SCENARIO	ADVANCED FUNCTIONALITY SCENARIO	MULTI-METERING SCENARIO
MARKET MODEL	Distribution system operator's model	Distribution system operator's model	Data management company model

FUNCTIONALITY OF METERS	Basic functionality	Basic functionality with HAN[26] support and in-house display	Basic functionality with HAN support, in-house display and a Multi-metering option
COMMUNICATION TECHNOLOGIES	"Last mile" PLC[27] and GPRS From data concentrator: GPRS[28]		
ROLL-OUT TIME	By the year 2020		
SCOPE OF ROLL-OUT	80% of consumers	100% of consumers	80% of consumers
MODELS OF PRICING	Obligatory time of use pricing		

Source: Ernst & Young, 2012

Based on cost-benefit analysis guidelines[29], the cost-benefit analysis is comprised of the two main parts:

- ✓ Financial analysis, which includes costs and benefits to the project operator, i.e. the Distribution System Operator (DSO)
- ✓ Economic analysis, where the social and financial parts of the project are assessed together generated benefits to the project operator and to both the state and society. All alternatives are analyzed and compared to each other in order to determine the most effective alternative from the economic perspective

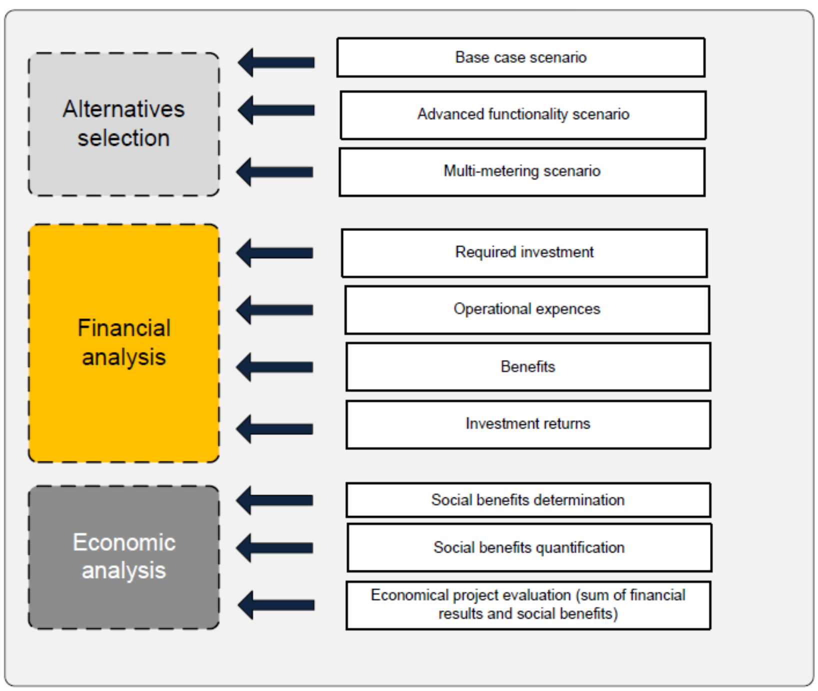

Figure 21 General Cost-benefit Analysis Guidelines

Source: Ernst & Young, 2012

[26] Smart grid communication tool to transfer information from/to the smart meter to/from any operating appliance in the house of the consumer

[27] Communication technology, which enables data transfer through the energy distribution network cables

[28] Mobile communication technology for data transfer within the GSM network

[29] Guide to Cost Benefit Analysis of Investment Projects, European Commission, 2008

A sensitivity analysis was conducted to demonstrate which variables have the most influence on the project results.

- ✓ Electricity price
- ✓ Changes in electricity consumption habits
- ✓ Price of smart metering equipment
- ✓ Forecasts of electricity demand

- ➢ **The list and definition of benefits and costs**

The calculation of financial indices for investments includes the investments, smart metering system implementer's operational costs and emerging benefits and savings are listed in the following table.

Table 9 Components of Financial Indicator Estimates

	Basic case scenario	**Advanced Functionality scenario**	**Multi-metering scenario**
Investments	• Smart meters; • Data concentrators; • Balance meters; • Data collection system; • MDM system; • Roll-out of the smart metering system; • Employee training; • Project management; • Project publicity;	• Smart meters; • Data concentrators; • Balance meters; • Data collection system; • MDM system; • Roll-out of the smart metering system; • Employee training; • Project management; • Project publicity; • In-house display;	• Smart meters; • Data concentrators; • Balance meters; • Data collection system; • MDM system; • Roll-out of the smart metering system; • Employee training; • Project management; • Project publicity • In-house display; • Multi-metering controller;
Operating costs	• Data transmission costs; • IS support costs; • Repair of smart meter and other device failures; • Smart meter and other equipment electricity costs;	• Data transmission costs; • IS support costs; • Repair of smart meter and other device failures; • Smart meter and other equipment electricity costs;	• Data transmission costs; • IS support costs • Repair of smart meter and other device failures; • Smart meter and other equipment electricity costs;
Benefits and savings generated for the smart metering System implementer (DSO)	• Standard meter replacement program savings; • Standard meter installation cost savings; • Savings on taking the meter readings; • Commercial loss	• Standard meter replacement program savings; • Standard meter installation cost savings; • Savings on taking the meter readings; • Commercial loss	• Standard meter replacement program savings; • Standard meter installation cost savings; • Savings on taking the meter readings;

	reduction; • Improved money flow management; • Call centre cost savings; • Standard meter electricity cost savings; • Power disconnection/ restriction/ reconnection savings;	reduction; • Improved money flow management; • Call centre cost savings; • Standard meters electricity cost savings; • Power disconnection /restriction /reconnection savings;	• Commercial loss reduction; • Improved money flow management; • Call centre cost savings; • Standard meters electricity cost savings; • Power disconnection /restriction /reconnection savings;

Source: Ernst & Young, 2012

And the report identifies the economic benefits and savings that a state and society would accrue:

- ✓ Reduction of total electricity consumption
- ✓ Increase of consumption in off-peak hours and reduction in peak hours
- ✓ Reduced amount of CO_2 emissions
- ✓ Commercial loss reduction
- ✓ Saved costs of temporary electricity disconnection / reconnection

- ➢ **Deliverables**

  - ✧ ***Results***

The result of the financial analysis for investments demonstrated that none of the scenarios result in a positive return for the project operator, i.e. the DSO. The main reasons they report are:

- ✓ Smart metering roll-out takes place to the lesser extent (80%) – smaller numbers of meters are required.
- ✓ Smart meters with minimal functional requirements are installed (without HAN communications[30] and in-house display), which means that the price of meters is lower.
- ✓ Due to the smaller scale, the costs of smart meter roll-out are lower.

Net present value (in 2014 – 2029), LTL		
Base case scenario	Advanced Functionality scenario	Multi-metering scenario
-725,414,068	-1,087,445,035	-899,343,135

Note: The project does not generate positive cash flow in any of the year, therefore the internal rate of return is not calculated.
Source: Ernst & Young, 2012

[30] Smart grid communication tool to transfer information from/to the smart meter to/from any operating appliance in the house of the consumer.

The result also shows that the economic analysis of the scenarios has demonstrated that none of the scenarios is economically viable, so it concluded that the smart metering roll-out in Lithuania is not beneficial under any scenario. The main reasons led to the negative results of the CBA, the report mentioned, are:

- ✓ The average bill for electricity per household in Lithuania is one of the lowest in the EU.
- ✓ Transmission and distribution networks have significant spare capacity, so more efficient consumption will not affect them
- ✓ Electricity producers in Lithuania have a lot of spare capacity, so more efficient consumption will not have an influence on them.
- ✓ Profile of electricity consumption shows that the peaks in Lithuania are minimal.

Table 10 Result of Economic Analysis

Net present value (in 2014 – 2029), LTL		
Base case scenario	Advanced Functionality scenario	Multi-metering scenario
-419,955,787	-520,877,553	-447,032,302
Internal rate of return (years 2014 – 2029), %		
Base case scenario	Advanced functionality scenario	Multi-metering scenario
-16.87%	-10.37%	-10.78%

Source: Ernst & Young, 2012

In conclusion, the report listed some factors that can change the result dramatically even though the CBA here shows none of the scenarios is economically profitable.

- ✓ Rapid development of smart metering equipment technologies, increase in its demand and the influence of these factors' over the prices
- ✓ Result of pilot projects
- ✓ Increase in electricity consumption (e.g. rapid growth in electro-mobile demand)
- ✓ Integration to the Europe's electricity markets after the introduction of LitPol Link and NordBalt link
- ✓ Changes in electricity consumption habits (rising consumption in peak times)
- ✓ Principles of determining the distribution and transmission tariffs
- ✓ Rapid development of micro-generation
- ✓ Individualization of heating metering

II.2.5 Netherland

- **Background**

In the latter half of 2011 and in early 2012 a number of large-scale trials to explore Smart Grids were initiated in the Netherlands: the so-called ‘Pilots Smart Grids’. The question posed by the commissioning party, the Dutch ministry of Economic Affairs, Agriculture and Innovation, was to identify and quantify the costs and benefits, both direct and indirect, of a national roll-out of Smart Grids. It deals only with Phase 1 of BCA. In Phase 2 the results obtained in the Pilots Smart Grid will be incorporated in the analysis, to reduce uncertainties and gain a more accurate picture of the social costs and benefits.

The full report of this project, done by several researchers from CD Delft and KEMA (*Keuring Van Electrotechnische Materialen*), is written in Dutch and downloadable on www.ce.nl. The summarized contents below refer to the English version of the report.

- **The scope of smart grid project (Location, Project Period & Technologies deployed)**

This report assesses the implications of introducing Smart Grids over the period 2011-2050. Although the notion of Smart Energy Grids can in principle encompass grids for all forms of energy and energy carriers, this study deals solely with the grid for electricity transmission and distribution (thus excluding Smart Thermal Grids). In line with the definition employed by the Dutch Taskforce on Smart Grids, the report define a Smart Grid as being an ‘enabler’: a Smart Grid makes it possible to respond effectively and efficiently to future changes in the energy market. Incorporation of electric transport, distributed energy production (in many cases renewable), home automation (‘domotica’) as well as large-scale wind farms and the emergence of new services like ‘demand response management’ and ‘real time pricing’ are examples of such changes that dovetail with the Taskforce definition. This report has opted to restrict the concept to a communications infrastructure ensuring that grid connections and grid components meet demand for power transmission and distribution in a smarter and more secure manner.

- **The methodology and/or toolkits used for BCA**

Three scenarios were considered to cover potential future trends in the variables such as climate-neutrality, flexibility and amount of distributed generation.

- ✓ Business As Usual (limited CO2 emissions reduction)
- ✓ Renewables & Gas (80-95% CO2 reduction)
- ✓ Coal-CSS & Nuclear (80-95% CO2 reduction)

Scenarios	Busniness as usual (BAU)	Renewables & Gas (R&G)	Coal-CCS & Nuclear (C&KN
CO_2 emissions of E sector	High	Zero	Zero
Power demand (excl. ET, HP)	High	Low	Medium
- elecric transport (ET)	Zero	High	High
- electric heat pumps (HP)	Low	Medium	High
Distributed capacity	Low	High	Low
Central capacity			
- gas-fired	yes	yes	(very) limited
- coal-fired	yes	no	yes
- renewable (biomass)	(very) limited	yes	(very) limited
- renewable (offshore wind)	no	yes	no
Flexibility	yes	yes	(very) limited
Central storage capacity	no	yes	no
Hydrogen production for transport	no	no	yes

= yes
= (very) limited
= no

Figure 22 Three Scenarios of Social Cost-benefit Analysis

Source: CE Delft and KEMA, 2012

For each scenario a baseline was defined in which no Smart Grids are rolled out. This baseline comprises the following:

- ✓ Introduction of smart meters
- ✓ Active grid management
- ✓ Simplified control strategies
- ✓ Greenhouse horticulture and heavy industry

On the basis of a literature study the potential changes in consumer behavior with respect to usage patterns were charted with and without the support of a Smart Grid. Focus is on potential shifts in electricity consumption over time and the potential achievable energy savings. In each scenario the magnitude of these behavioral changes were then calculated using a simple profile model in which the impact on grid load and on the merit order of central capacity was determined.

Behavioral changes (demand response) can occur as a result of improved usage information (feedback via home displays), tariff differentiation and remote capacity control by the grid operator for example. From the literature study it is concluded that improved usage information is an essential enabler for a Smart Grid: without appropriate information, no control. Smart meters and the demand response to which these give rise cannot therefore be allocated to the Smart Grid. In the Netherlands we do not anticipate 'hard control' on the part of the grid operator (user disconnection) without this being financial compensated. There will always be a 'priced in' shift via a contract. Ultimately, this is also a form of behavioral change, i.e. demand response, triggered by means of a financial incentive.

Tariff incentives can engender three kinds of behavioral change: *absolute savings* (not all peak savings are shifted to other times), *daily peak shaving* and *incidental peak shaving*. The difference between *daily* and *incidental* peak shaving is that the latter occurs at critical times of scarcity when there are strong price incentives at play, which is on only a limited number of occasions per year when demand is exceptionally high. The following table shows the magnitude of the behavioral effects as found in the literature.

- **The list and definition of benefits**

Table 11 The List of Benefits

	Benefits
Direct effects	✓ Avoided grid investments ✓ Avoided grid losses ✓ Avoided investments in central generating capacity ✓ Avoided investments in large-scale storage ✓ More efficient use of central generating capacity ✓ Additional energy savings ✓ Reduced imbalance
Indirect and external effect	✓ External effects ✓ Welfare gains due to new services (pending)

Source: CE Delft and KEMA, 2012

- **The list and definition of costs**

Table 12 The List of Costs

	Cost
Direct effects	✓ Investments in smart grids ✓ Smart grid operation and maintenance (O&M) ✓ Cost on location for equipment
Indirect and external effect	✓ Welfare losses due to shift in functional energy demand (pending)

Source: CE Delft and KEMA, 2012

- **Deliverables**
  - ***Results***

In each of the three scenarios for the Netherlands' future energy system, the balance of costs and benefits (net present value) proves positive. In other words, this positive balance is robust for each of the energy scenarios, even a system with no substantial CO2 reduction (BAU 2050) or with a high share of renewables (R&G 2050). For the climate scenarios the balance is considerably more positive than for the BAU 2050 scenario. This means that regardless of how the energy system develops, rolling out Smart Grids is an economically sound choice for society as a whole and represents an attractive investment.

Table 13 Costs and Benefits of Three Scenarios

NPV (€ billion)	BAU 2050	C&N 2050	R&G 2050
Benefits	€ 7.1	€ 14.1	€ 12.5
Costs	€ 4.6	€ 4.6	€ 4.6
Balance (benefit-costs)	€ 2.5	€ 9.5	€ 7.9
Internal Interest Rate	13%	28%	31%

Source: CE Delft and KEMA, 2012

- ✓ The result shows that Smart Grids are cost-effective not only in the scenario with substantial distributed generation of intermittent solar and wind power (R&G 2050) but also in the scenario with central generation and limited flexibility (C&N 2050). While the former (R&G 2050) was to be expected and was already forecast by the Smart Grid Taskforce, for example, the latter (C&N 2050) can be taken as a new finding.
- ✓ The net gains delivered by Smart Grids are due to various benefit items, particularly the lower grid investments and of centralized generating capacity. In the R&G scenario the benefits accrue less from central capacity, but above all from avoidance of imbalance.
- ✓ The greatest grid savings occur in the Medium-Voltage grid.
- ✓ The benefits are due above all to direct effects and only to a very limited extent to indirect effects such as welfare impacts, reduced emissions, etc.

From the sensitivity analysis the following conclusions can be drawn:

- ✓ The savings on grid costs are due to a shift in demand in time, leading to a flatter user pattern and to absolute energy savings. This derives from permanent relinquishment of functional energy demand at times of high prices rather than from savings arising through improved feedback of user information due to smart meters.
- ✓ Consumer behavior has a substantial impact on the benefits of Smart Grids and is thus the key to unlocking the financial gains potentially available in the overall system (production, transmission and imbalance). At the same time, the tariff benefits can only be 'passed on' to consumers if there is also indeed greater efficiency of supply and transmission.
- ✓ The benefits accrue roughly evenly to small and medium-sized businesses (SME) and households, but with far lower costs to the former. This makes it more appealing to start with SME and only then move on to households.

The report conclude that the key element will be the demand response of consumers engendered by flexible supply and transport tariffs. This response will lead to savings on the costs of grid construction and power generation. There are considerable uncertainties in the analysis, however, including uncertainty as to the magnitude of certain cost items and the degree of demand response that will be achieved through flexible tariffs. Whether and to what extent this demand response indeed occurs is a key issue that needs to be investigated in the Pilots Smart Grids (1st phase: preparations).

II.2.6 Great Britain

➢ **Background**

According to UK government plan "The Carbon Plan" of 2011, *the Climate Change Act established a legally binding target to reduce the UK's greenhouse gas emissions by at least 80% below base year levels by 2050, to be achieved through action at home and abroad. The first three carbon budgets were set in law in May 2009 and require emissions to be reduced by at least 34% below base year levels in 2020. The fourth carbon budget, covering the period 2023–27, was set in law in June 2011 and requires emissions to be reduced by 50% below 1990 levels.*

Table 14 Proposed Carbon Budgets

	First carbon budget (2008–12)	Second carbon budget (2013–17)	Third carbon budget (2018–22)	Fourth carbon budget (2023–27)
Carbon budget level (million tonnes carbon dioxide equivalent ($MtCO_2e$))	3,018	2,782	2,544	1,950
Percentage reduction below base year levels	23%	29%	35%	50%

Source: DECC (2011)

For that matter, UK considers to have major changes in how to use and generate energy and energy efficiency is thought to be increased dramatically across all sectors. As for this DECC (2011) notes that "*The oil and gas used to drive cars, heat buildings and power industry will, in large part, need to be replaced by electricity, sustainable bioenergy, or hydrogen. Electricity will need to be decarbonised through renewable and nuclear power, and the use of carbon capture and storage (CCS). The electricity grid will be larger and smarter at balancing demand and supply*."

Deployment of Smart Grid in this perspective of decarbonization becomes even more important issue to be further analyzed.

✧ ***UK's Smart Grid Road Map***

According to ENSG (Feb. 2010), ENSG or Electricity Networks Strategy Group, jointly chaired by the Department of Energy and Climate Change (DECC) and Office of Gas and Electricity Markets (Ofgem), aims to identify and co-ordinate work to help address key strategic issues that affect the transition of electricity networks to a low-carbon future. From previous examination of SGF, it becomes clearer what ENSG has been promoting. By endorsing the road map (routemap in UK), ENSG urges that the smart grid road map must recognize the smart meter roll-out program and respect its timetable.

For this context, end state vision of smart grid is presented first.

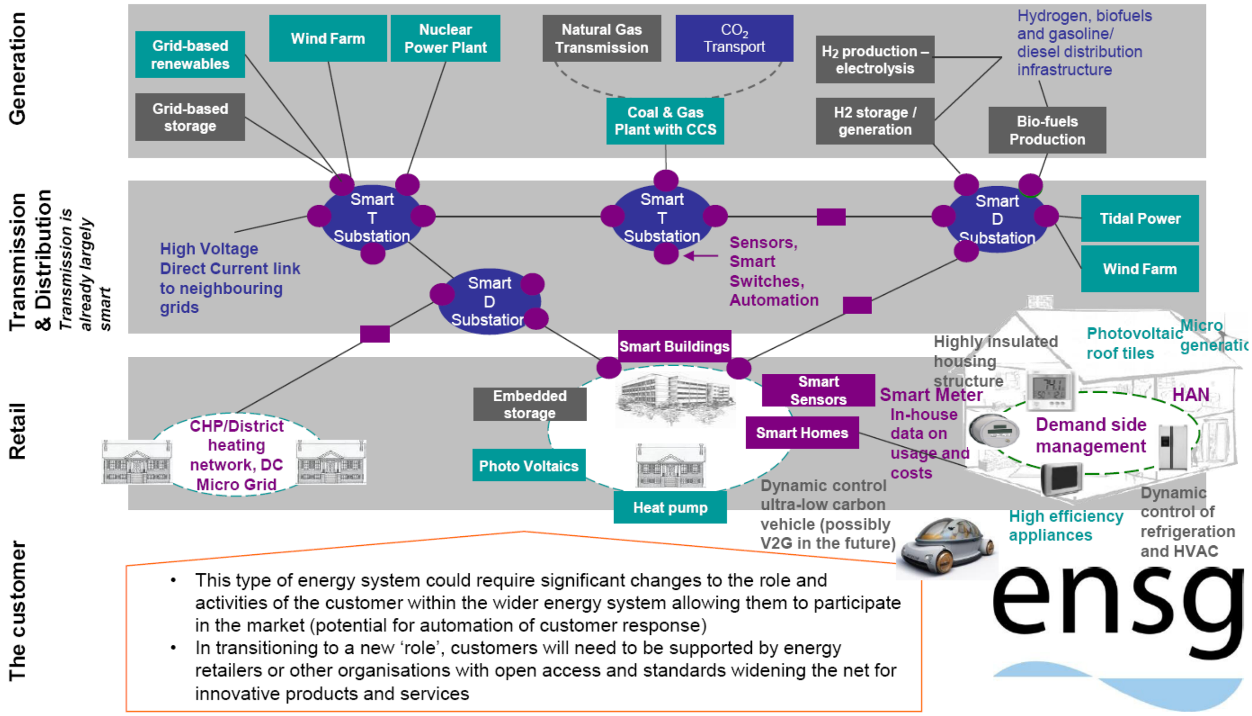

Figure 23 Potential Smart Grid End State

Note:

- Storage and demand shifting
- Electricity / heat generation
- Sensing, control and integration
- Other infrastructure

Source: ENSG (Feb. 2010)

It is noted that deciding now the precise nature of the UN energy system of 2050 is not desirable, however, it is noted important to have and end state in mind even if it changes and evolves over time.

Given high level objectives such as Carbon reduction, Energy security, and Economic competitiveness & affordability, road map is focused on three critical smart grid roles for the UK's planned low carbon transition: Integration of inflexible generation, electrification of transport and heating, and integration of DER.

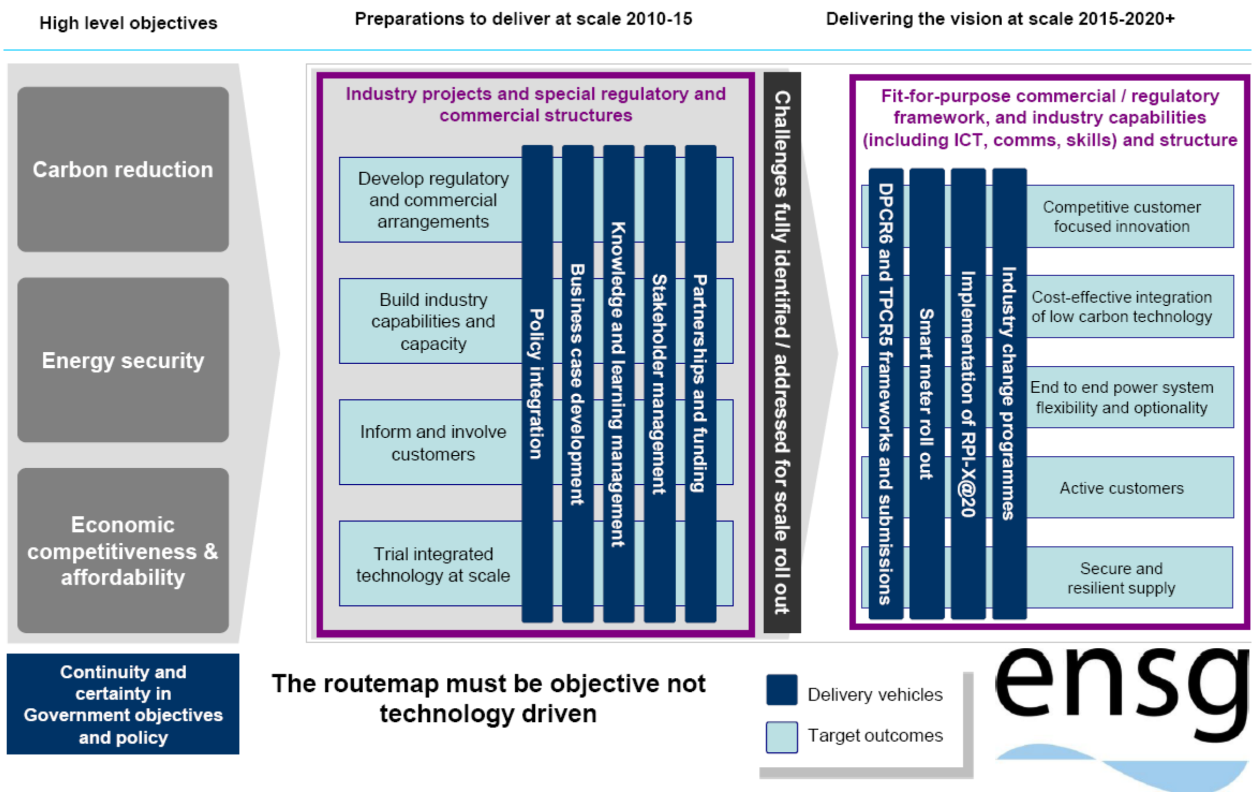

Figure 24 Road Map Linkage of High Level Objectives with Wider Energy System Development

Source: ENSG (Feb. 2010)

The road map is said to have been generated by working down from the high level vision objectives whilst considering wider energy system development out to 2050 depicted as above. Then, a potential set of projects with a logical structure for project delivery and interdependency is considered to establish a platform for a smart grid roll-out. For this matter, following sample projects are listed and elaborated in detail at Appendix:

- ✓ Active Dynamic Rating
- ✓ Active Voltage Control
- ✓ Super-Conducting Fault Current Limiters
- ✓ Smart meter communications pilots (HAN, LAN and WAN)
- ✓ Active network monitoring
- ✓ Active DG Curtailment
- ✓ Power Electronic Applications
- ✓ Embedded Storage
- ✓ Integrated Active Network Mgmt.
- ✓ Smart asset management
- ✓ Demand side management trials
- ✓ Integrated smart meter / smart grid trials
- ✓ Scheduling and dispatch of DER / DER commercials / value evaluation / customer
- ✓ Network integration of smart appliance / smart home –commercials / allocation

- ✓ Security, resilience and data protection
- ✓ Trialing of new network charging regimes
- ✓ Smart grid city
- ✓ Intelligent city
- ✓ Rural smart grid
- ✓ Island smart grid
- ✓ End to end integration of intermittent renewables

Those pilot projects will continually and iteratively support each other as complexity and functionality is progressively layered in view of the series of layers such as Individual technology, Multiple integrated technologies, Customer and technology integration, and finally, End to end integration.

The near term and long run smart grid road maps should be integrated so that near term deliverables can be used for the preparation for the future. They also should be integrated with high level activities over time.

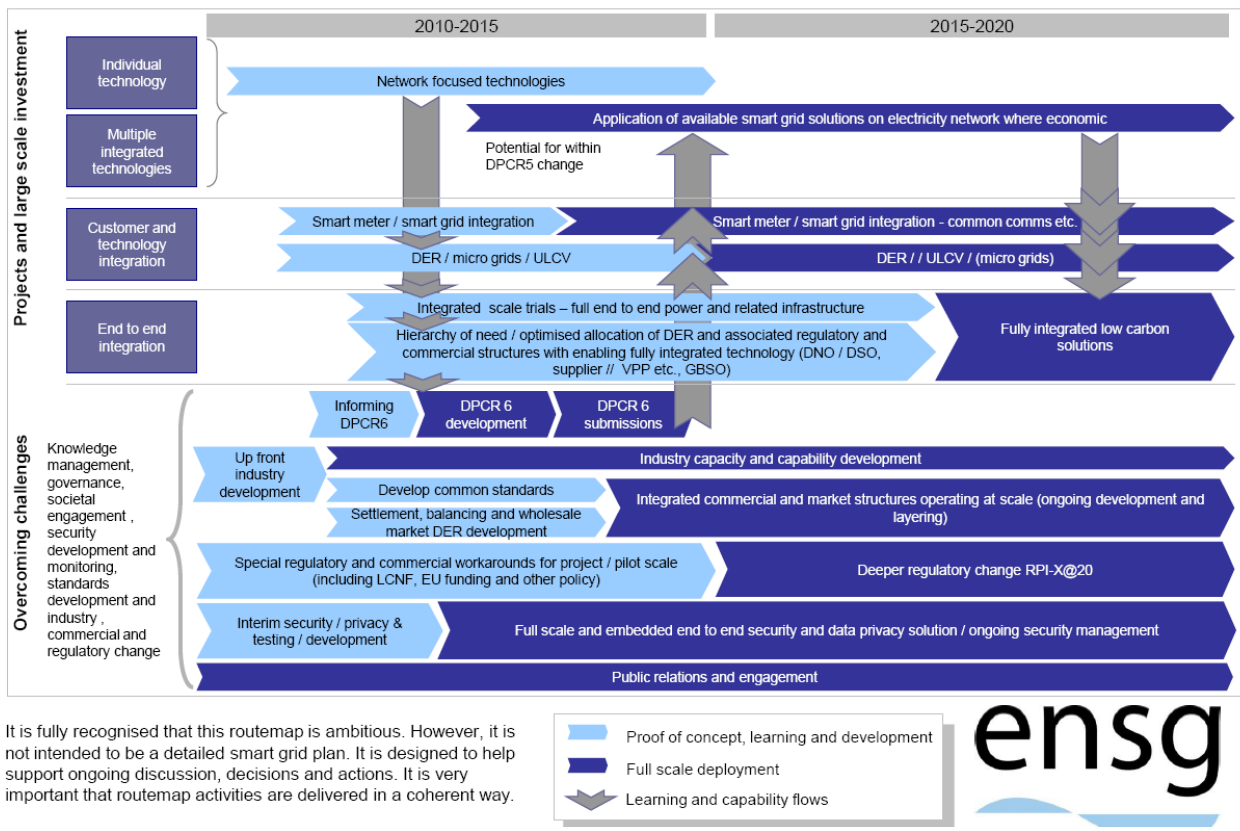

Figure 25 Integrated UK SG Road Map up to 2020 - delivering in the near term to prepare for the future

Source: ENSG (Feb. 2010)

➢ **The scope of smart grid project (Location, Project Period & Technologies deployed)**

ENSG (Feb. 2010) proposed many of following sample projects for smart grid. Following table summarizes the sample projects proposed. The capacity of any given project to deliver against these objectives will be dependent upon the specifics of project scope and the way in which the project is delivered, but the list gives an indication of how a set of projects could establish a platform for a smart grid roll-out.[31]

Table 15 List of Sample Projects Proposed

Sample projects	CBA benefit evaluation	Transport / heating electrification	Core smart capability development	Inflexible generation integration	DER integration	Commercial development	Customer engagement
Active Dynamic Rating	◑	◑		◑	◑		
Active Voltage Control				◕	◑		
Super-Conducting Fault Current Limiters			◑		◑		
Smart meter communications pilots (HAN, LAN and WAN)			◑				◑
Active network monitoring	●	◑			◑		
Active DG Curtailment			◑		◑	●	
Power Electronic Applications			◑				
Embedded Storage			◑	●	◔		
Integrated Active Network Mgmt.	●		●	●	●		
Smart asset management	◑		●				
Demand side management trials	◕	◑		●	◕	●	●
Integrated smart meter / smart grid trials		◕					●
Scheduling and dispatch of DER / DER commercials / value evaluation / customer	◕	◕	●		●	●	●
Network integration of smart appliance / smart home – commercials / allocation		◕			◕	●	●
Security, resilience and data protection			●				●
Trialling of new network charging regimes		◑	●	◑	◕	●	
Smart grid city							
Intelligent city							
Rural smart grid	Dependent upon scope but should look to cover majority of objectives in a fully integrated way						
Island smart grid							
End to end integration of intermittent renewables							

● Very high ◕ High ◑ Medium ◔ Low ○ Very low

This is an illustrative list of projects. ENSG is not suggesting that the UK should necessarily deliver this particular set of projects or that these projects if delivered would achieve all the target outcomes.
The capacity of any given project to deliver against these objectives will be dependent upon the specifics of project scope and the way in which the project is delivered.
Other objectives (as per slide 16) will be worth pursuing – the table has been prioritised and simplified for clarity

ensg

Source: ENSG (Feb. 2010)

In the following table, those potential sample projects are summarized in one table based on the 6 drives of efforts and 4 of values.

[31] It is noted that high level objectives such as Carbon reduction, Energy security, and Economic competitiveness & affordability could be considered but not been prioritized for the simplicity and clarity.

Table 16 Potential Pilot Sample Projects with Efforts Required and Value to be Created (summarized)

	Effort								Value			
Sample Projects	1	2	3	4	5	6	7	8	1	2	3	4
Smart meter communications pilots	◑	◕	◕	◑	◕	◑	◕	◔	◔	◑	◔	◕
Active Dynamic Rating	◑	○	◕	◔	◕	◑	○	◔	◔	◕	○	◕
Active Voltage Control	◑	○	◕	◔	◕	◑	○	◔	◔	◕	○	◕
Super-Conducting Fault Current Limiters	◑	○	◕	◔	◕	◑	○	◔	◔	◕	○	◕
Smart meter communications pilots (HAN, LAN and WAN)	◑	◕	◕	◑	◕	◑	◕	◔	◔	◑	◔	◕
Active network monitoring	◑	○	◕	◔	◕	◑	○	◔	◔	◕	○	◕
Active DG Curtailment	◑	○	◕	◔	◕	◑	○	◔	◔	◕	○	◕
Power Electronic Applications	◑	○	◕	◔	◕	◑	○	◔	◔	◕	○	◕
Embedded Storage	◕	◑	◑	◔	◑	◕	◔	◑	◑	◑	◑	◑
Integrated Active Network Mgmt.	◑	○	◕	◔	◕	◑	○	◔	◔	◕	○	◕
Smart asset management	◕	○	◕	○	◕	◑	○	◑	◔	◕	○	◑
Demand side management trials	●	◕	◕	◑	◕	◕	●	◕	◕	●	●	◑
Integrated smart meter / smart grid trials	◕	◑	◑	◔	◑	◑	◔	◑	◑	◑	◔	◕
Scheduling and dispatch of DER / DER commercials / value evaluation / customer	◕	◑	◕	◕	◑	◕	◕	◕	◕	◕	◕	◕
Network integration of smart appliance / smart home –commercials / allocation	◕	◕	◕	◑	○	◕	●	●	◕	◑	●	◕
Security, resilience and data protection	◑	◔	◕	◔	◕	◕	○	◔	◑	◕	◑	◕
Trialling of new network charging regimes	◕	◑	◑	◔	◑	◑	◕	◔	◕	◕	◑	○
Smart grid city	●	●	●	●	◑	●	●	●	●	●	●	●
Intelligent city	●	●	●	●	●	●	●	●	●	●	●	●
Rural smart grid	◕	◕	◑	◑	◔	◕	●	◑	◑	◕	●	◑
Island smart grid	◕	◕	◑	◑	◑	◕	●	◑	◑	◕	●	◕
End to end integration of intermittent renewables	●	●	●	●	●	●	●	●	●	●	●	●

Effort		Value	
1	Business change	1	Develop regulatory and commercial arrangements
2	Consortia size and complexity / number of stakeholders	2	Build industry capabilities and capacity
3	Standardisation and infrastructure integration	3	Inform and involve customers
4	Funding complexity	4	Trial integrated technology at scale
5	Geographic scale		
6	Functional depth and complexity		
7	Customer interaction		
8	Commercial and regulatory supportIndividual		

Effort: Efforts required for the successful accomplishment of the given project.

1. Business change
2. Consortia size and complexity / number of stakeholders
3. Standardisation and infrastructure integration
4. Funding complexity
5. Geographic scale
6. Functional depth and complexity
7. Customer interaction
8. Commercial and regulatory support

Value: Values to be created by the deployment of the given project.

1. Develop regulatory and commercial arrangements
2. Build industry capabilities and capacity
3. Inform and involve customers
4. Trial integrated technology at scale

- **The methodology and/or toolkits used for BCA**

  - ***SGF Methodology and ToolKits***

Toolkit used: BCA tool utilizing real options valuation developed by Frontier Economics and EA Technology

Based on the UK government plan "The Carbon Plan" of 2011 (DECC, 2011), the activities and the tools developed by SGF have been discussed in the previous chapter. BCA tool developed by Frontier Economics and EA Technology is utilizing the 'real options' valuation method. The details of the tool cannot be examined directly. Although it is noted that the developed spreadsheet model is distributed and made freely available to the network companies following 4th SGF meeting, February 2012, it is not accessible on the webpage.

  - ***SmartGridGB***

SmartGridGB, one of the summary of respondents of Frontier Economics (March 2012), a report prepared for OFGEM, or broadly for SGF, published their own report on smart grid of Great Britain with Ernst & Young. SmartGridGB (Oct. 2013) introduces SmartGrid GB as 'an independent, cross-industry stakeholder group acting as the national champion for smart grid development in Britain.'[32] Two reports discussed below by SmartGridGB are concerned with consumer protection and flexibility for both consumers and industries: greater focus on consumer engagement and at the same time on consumer protection with sufficient network investment to protect against the risks, and future projects need not take the current industry model as a given since smart grid should be flexible. Although it is found from SGF discussions and meeting minutes that focuses on various participants of smart grid will be taken into consideration as the research and activities on smart grid progresses, two of the reports from SmartGridGB clearly criticizes that the current smart grid project funded by Low Carbon Networks Fund (LCNF) established by Ofgem only focuses on distribution network, not making smart grid investment that will be crucial for economy's international competiveness.

  - ***SmartGridGB and Ernst & Young (April 2012)***

Toolkit used: Input-Output Analysis with wider definition of benefits

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[32] SmartGridGB is an independent, cross-industry stakeholder group acting as the national champion for smart grid development in Britain. Our members include energy suppliers, distribution network operators, technology manufacturing and services companies and other significant players in the energy sector. We provide Ofgem and the Department of Energy and Climate Change (DECC) with an industry view on what kind of smart grid Britain will need and how it might be achieved.
Despite representing many different sectors, SmartGrid GB members share one common view: that smart technologies and the emergence of a smart grid are vital for the upgrade of Britain's energy infrastructure, to allow new markets to emerge, and as enabling technologies for the integration of low-carbon and intermittent generation. (SmartGridGB, October 2013)

For the calculation of the direct, indirect and induced impacts on the economy, UK input-output tables are used.

- **The list and definition of benefits**

SmartGridGB and Ernst & Young (April 2012) views as smart grid as a core component for facilitating a low carbon transformation of the entire energy ecosystem. The report explicitly defines its scope to include 'smart energy system', or effective interaction of all of these broader elements with the networks that characterize 'smart' operation while Britain has been focusing only on proving the economic merits of smart grid from a networks perspective alone.

From this perspective, benefits are viewed from core benefits, benefits across the supply chain, benefits from secondary industries and many other wider opportunities to be maximized.

- ***Core benefit***

Core benefit defined by this report is from a network perspective. This report notes that SGF counts net benefit as the cost savings associated with deploying smart technologies rather than conventional technologies. But those quantifications of the costs only includes those relating to distribution network reinforcement, distribution network interruption costs, distribution network losses, customer 'inconvenience' costs, direct CO2 emissions costs, generation costs and transmission network reinforcement. Referring to SGF BCA result, SmartGridGB acknowledges that this benefit is one of the many primary benefits of smart grid.

- ***Benefits across the supply chain***

As expenditure on smart grid investments permeates throughout the economy, this will flow along the supply chain and multiply. The approach adopted in this report focuses on the contribution of smart grid deployment to the British economy in terms of Gross value added (GVA) – the economic value to Britain of the expenditure on smart grid.

- ***Benefits from secondary industries***

The report emphasizes the importance of the role of smart grid in facilitating the growth of a variety of 'secondary' industries including electric vehicles, heat, renewables and distributed generation. Some estimates associated with the value at stake from a number of secondary industries are also set out and is evaluated to be consistent with those of SGF's. But additional values is said to be there in the customer products and services industry which is likely to grow as a result of smart grid.

- ***Many other wider opportunities to be maximized***

The economic benefits from the deployment of smart grid are also expected to translate into an increase in the level of goods and services exported, and UK also can benefit from foreign direct investment (FDI) potential. Thus, move ahead in a timely manner for smart grid deployment is said to be necessary. Timely deployment of smart grid is fundamental in the sense that smart grid would enable a number of things to occur:

- ✓ Expertise can be gained: companies can research, develop and commercialize their products and export products or IP, a light manufacturing base could be established, and consultants can export implementation or operational expertise
- ✓ Skills can be developed: smart grid requires a range of technological, engineering and ICT skills.
- ✓ Global reputation can be built: a timely roll-out will encourage other countries to look to the UK for best-practice and advice.
- ✓ Secondary industries will be enabled.

✧ ***SmartGridGB (Oct. 2013)***

SmartGridGB (Oct. 2013) made another publication on potential consumer side benefits and how to enhance consumer awareness for smart grid. 'Consumers', in this report, are not viewed as one homogenous group – instead the interests of different types of consumer (both domestic and non-domestic) were looked at and that engagement is targeted and relevant to their interests. For the reasoning of only focusing on consumer side, it is noted that most important benefits of smart grid are those that help consumers while these are some of the most difficult to understand and communicate.

Among all beneficiaries such as electricity industry, to consumers, and to wider society, different categories of consumers are considered: domestic; small and medium-sized enterprises; and industrial & commercial.

- ✓ Industrial & commercial (I &C) - They will want to understand the impact of joining new demand side response schemes on their existing energy buying commitments.
- ✓ Small & medium enterprises - SMEs may exhibit some of the commercial concerns and drivers of business consumers, with some of the more value-driven judgements exhibited by domestic consumers.
- ✓ Domestic Customers categorized based on Smart Grid Austria (SGA)[33]
  - ◆ Uncommitted – customers who are unconcerned about levels and patterns of energy consumption and the associated energy cost both for themselves and the environment.
  - ◆ Informed – customers who are dedicated to reducing energy consumption and its impacts.
  - ◆ Frugal – customers who are highly focused on price and service and tend to be more driven by price. They are likely to respond well to 'time of use' tariffs.
  - ◆ Hardship – customers with health issues, disabilities and/or on low incomes. These customers may struggle to adjust consumption patterns and therefore benefit from smart grids.

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[33] Smart Grid Australia - Maximizing Consumer Benefits", Smart Grid Australia, Available at http://smartgridaustralia.com.au/SGA/Documents/SGA_Consumer_Report_Media_Release.pdf

This report seems to start by assuming that consumer engagement in smart grid will be beneficial. How to make consumers engage in smart grid activities, how to communicate better are the main topic of this report. Although this report do not provide any technical methodology or tool kit for BCA, it may be of use to refer to, when consumer related sample projects are initiated. As is noted in the report, especially when most of smart grid project funded in UK by Low Carbon Networks Fund (LCNF) are about distribution network, it is noted that Smart grid benefits are not limited to those accruing to distribution networks but arise both from many dispersed elements within the system from generation, to transmission, distribution and supply, and benefits which are external to the energy system.

- **The list and definition of costs**

Since both of SGF and SmartGridGB view the benefit as the cost savings associated with deploying smart technologies rather than conventional technologies, it would not be relevant to list the itemized costs here in terms of CBA. That is, cost of not adopting smart grid could be the same as the missing benefit to be obtained by the deployment of smart grid compared to conventional technology in a narrow sense. However, the cost could include all the missing potential benefits listed by SmartGridGB in a broader sense. SmartGridGB argues that inaction or delaying the development of smart grid will bring about the missed opportunities or potential risks.

- **Deliverables**

  - ***Recommendation***

To address the complexities and challenges associated with developing smart grid infrastructure, an d to make the race for Smart Grid worth winning, SmartGridGB and Ernst & Young (April 2012) makes following recommendations:

- ✓ Policy makers need to provide the maximum degree of policy guidance possible: creating some additional flexibility in current standards will also be important. It may also be possible to say more about what is not needed yet, and a holistic energy roadmap could be usefully constructed.
- ✓ There needs to be greater focus within the regulatory process on protecting customers by ensuring that there is sufficient network investment to protect against the risks. This could come from both the regulator and companies being expected to publish a risk review, and also a requirement to identify and evaluate what might be termed “no or at least low regrets” investments.
- ✓ The risk / reward balance faced by DNOs for innovating should include incentives to actually apply the learnings to their networks or seek to move faster than others in delivering smart grid.
- ✓ There needs to be greater focus on consumer engagement both to ensure that consumers understand the positive attributes of smart grid, and also how a smart meter will contribute to this. It will also be important to explore how best different types of customers are engaged on a day to day basis and whether a degree of automation is required.

- ✓ It is important that future projects do not take the current industry model as a given. There are some complex challenges to work through and so alternative models will need to be actively explored.
- ✓ Further investment in skills is required, for example by an extension of the workforce renewal elements of DPCR5, and a coordinated national approach covering the whole smart grid supply chain.
- ✓ There is a need to ensure that projects under the successor scheme to the LCNF progress to a larger scale of test, both in the sense of using a number of elements together, and to deploy them at a higher level of penetration over a larger area.

SmartGridGB (Oct. 2013) made three main recommendations for enhancing the consumer opportunity for smart grid such as following:

- ✓ Recommendation 1 : SmartGrid GB recommends further research is conducted to quantify the value of smart grid schemes that do need customers to act, versus those smart grid technologies that do not. Access to this data will help industry to build business cases for their smart grid consumer engagement campaigns.
- ✓ Recommendation 2: SmartGrid GB recommends that industry should work towards a whole energy system demonstrator project or consolidation of a number of projects including both new projects, and working with those that already exist. The demonstrator project should ensure full representation from across the value chain and would help stakeholders better understand smart grid consumer benefits.
- ✓ Recommendation 3 : SmartGrid GB believes that a collaborative cross-value chain group to support consumer education and awareness of smart grid benefits should be investigated. Further, SmartGrid GB recommends that messaging in all areas of energy policy is coordinated by government or an appointed objective central body and that a general nationwide education program is conducted to build awareness of the challenges facing the energy system.

II.2.7 New York

- ➢ **Background**

The New York State Energy Plan as developed in 2009 is the background for the vision and the benefits analysis. Key elements of the plan are how much energy will come from renewable resources; how many of the vehicles in the state will be replaced by electric / hybrid forms; and, what electric load growth will be in the future.

This report assesses the broad economic, customer and social impacts to New York State as a consequence of an aggressive deployment of the technologies and changed electric power operations and business models associated with Smart Grid technologies.

- **The methodology and/or toolkits used for BCA**

For each of the cost elements and quantifiable benefits of Smart Grid, projections were made for each of the years 2011-2025, and the total Net Present Value calculated.

- **The scope of smart grid project (Location, Project Period & Technologies deployed)**

In order to create an evaluation framework, estimates may be made of likely scenarios and financial parameters. The key assumptions include:

- ✓ The "end state" is a full statewide deployment of Smart Grid by 2025 as described below
- ✓ NY State Energy Plan is used as a Baseline (load growth, renewables penetration, energy prices/costs)
- ✓ Smart Grid Costs Reflect Current Filings, National Experience, and Forward Cost Projections
- ✓ Costs are incurred in 2011-2025 and benefits accrue as the technologies are deployed. Benefits after 2025 not considered.
- ✓ 6% EV / PHEV penetration is assumed by 2025 (inferred from state plan). An estimate is made for fleet (commercial) EV development as well.

- **The list and definition of benefits**

The following are the key benefits associated with Smart Grid:

- ✓ Market Cost Savings from peak savings
- ✓ Savings from reduced usage
- ✓ Price savings from lower usage
- ✓ Reduced Losses
- ✓ Gas Conservation Savings
- ✓ Total Savings from Reduced Outages
- ✓ Total Benefit of Enabled Renewables
- ✓ DA/SA (Distribution Automation/Substation Automation) Deferred Distribution CapEx (Capital expenditure)
- ✓ DA/SA Deferred Distribution OpEx(Operational expenses)
- ✓ AMI operational savings
- ✓ Transmission loss reduction Benefits
- ✓ AMI Dynamic Pricing Distribution Capex
- ✓ Benefits of Grid Connected Storage
- ✓ Smart Charging Energy Price Benefits
- ✓ Smart Charging Distribution Capex

- **The list and definition of costs**

The following are the key costs associated with Smart Grid:

- ✓ Reduction in Customer Energy Bills
- ✓ Total Savings from Reduced Outages
- ✓ Total Benefit of Enabled Renewables
- ✓ Total T&D "rqate" Benefits
- ✓ DA/SA Costs
- ✓ Metering
- ✓ Transmission Automation
- ✓ Grid Connected Storage
- ✓ Smart Charging

➢ **Deliverables**

✧ ***Results***

Below figures show a high level waterfall chart of overall costs and benefits from Smart Grid on a Net Present Value basis over the period 2011 – 2025.

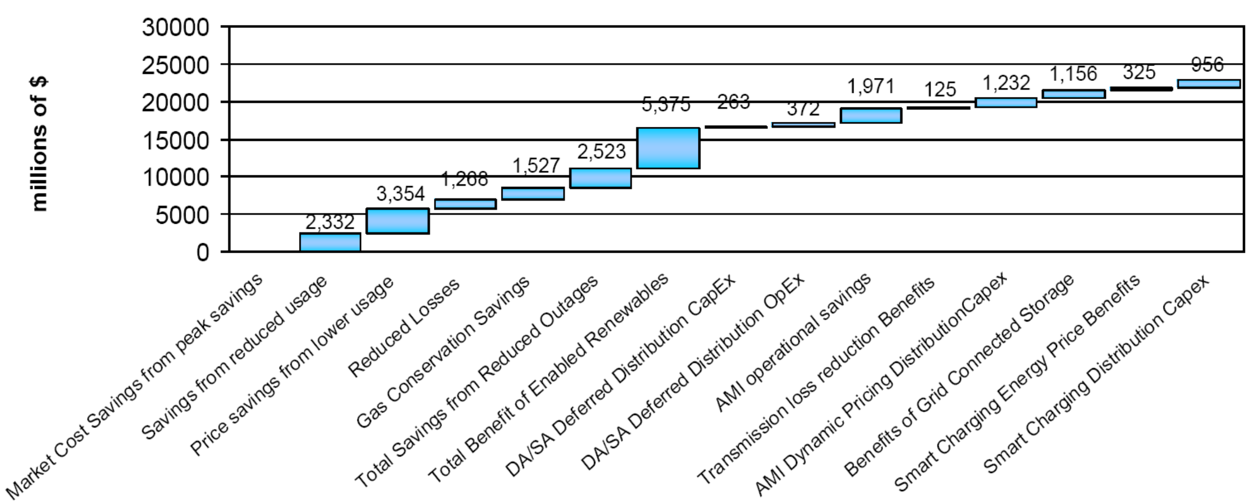

Figure 26 NY Smart Grid Benefit Cost Analysis - Benefits 2011 – 2025 Costs Occur 2011 – 2025

Source: New York State Smart Grid Consortium, Smart Grid, Smart Grid Roadmap the State of New York, September 2010

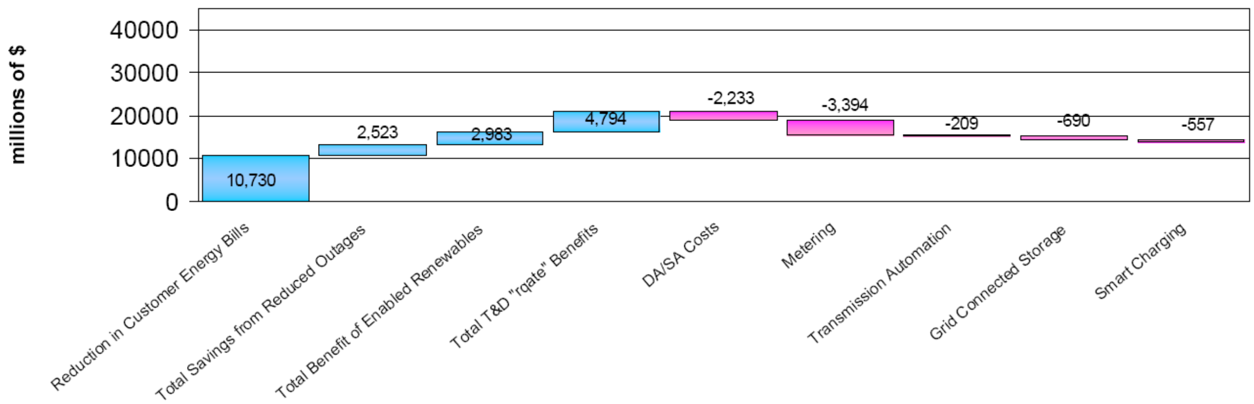

Figure 27 NY Smart Grid Benefit Cost Analysis - Benefits 2011 – 2025

Source: New York State Smart Grid Consortium, Smart Grid, Smart Grid Roadmap the State of New York, September 2010

II.2.8 United States: ARRA 2009

- **Background**

This study analyzes the economy-wide impacts of the American Recovery and Reinvestment Act of 2009 (Recovery Act or ARRA) funding for Smart Grid project deployment in the United States, administered by the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability (DOE OE). The time period of the investments analyzed cover expenditures from August 2009 to March 2012, which encompasses nearly three billion dollars in publicly documented expenditures. The Smart Grid support from the U.S. Department of Energy (DOE) included the Smart Grid Investment Grants (SGIG) and the Smart Grid Demonstration Program (SGDP). These investments under the Recovery Act were intended to serve a dual mission: a primary mission of economic stimulus for the American workforce and the nation's economy as a whole, and a secondary mission of supporting the specific program or Agency mission through the authorizing department, which in this case is the modernization of the United States electricity grid. Both missions are reflected in the ARRA Smart Grid projects, as they have generated economic benefits and are beginning to demonstrate that the deployment of Smart Grid technology is leading to operational, customer, and reliability benefits. These benefits, however, are being realized on different time horizons, and the present analysis follows the economic effects of the immediate spending, and represents a measure of performance towards the primary mission.

- **The methodology and/or toolkits used for BCA**

In this report, model inputs are based on actual SGIG and SGDP payments to vendors. The first step of impact modeling was the classification of the economic inputs for two different scenarios. From many researches, OE[34] evaluated 580 vendors and 400 vendors were designated as core Smart Grid vendors.

[34] U.S. Department of Energy Office of Electricity Delivery and Energy Reliability (DOE OE)

For the Smart Grid Vendors Only Scenario, direct payments made only to core Smart Grid vendors (and matching industry funds) were used as input to the model. For the All Vendors Scenario, payments to core Smart Grid as well as "non-core" vendors (and the total associated matching industry funds) were included as input to the model

Next, each vendor was matched to the relevant industry code, based on NAICS codes. DOE obtained the primary NAICS codes for nearly 300 core Smart Grid vendors (mostly based on data from INFOUSA and additional analysis). Using these NAICS codes, and mapping between NAICS code and IMPLAN sectors, DOE mapped the relevant vendors to IMPLAN sectors. The Smart Grid vendors with NAICS code were mapped to 33 IMPLAN sectors, about 8% of total IMPLAN sectors.

Once the data was prepared for input into IMPLAN, DOE ran the model for each scenario and generated the outputs. Outputs were reported for the direct, indirect, and induced impacts under each scenario in terms of employment, labor income, GDP, total economic output, and state/local and federal tax revenue. The sector level output for employment is shown in the following tables.

The table below provides the amount of input dollars for the relevant IMPLAN sectors. The grayscale rows in the All Vendors Scenarios are those sectors that are not in the Smart Grid Vendors Only Scenario (see below). Input includes federal and matching funds.

Table 17 All Vendors Scenario

Sector	IMPLAN Description	Input ($)
372	Computer systems design services	$ 548,123,115
380	All other miscellaneous professional, scientific, and technical services	$ 489,710,913
374	Management, scientific, and technical consulting services	$ 456,380,269
389	Other support services	$ 220,394,672
275	All other miscellaneous electrical equipment and component manufacturing	$ 213,334,266
247	Other electronic component manufacturing	$ 166,672,933
238	Broadcast and wireless communications equipment	$ 164,590,316
369	Architectural, engineering, and related services	$ 143,679,426
319	Wholesale trade	$ 111,065,889
345	Software publishers	$ 98,469,751
373	Other computer related services, including facilities management	$ 96,565,424
268	Switchgear and switchboard apparatus manufacturing	$ 63,498,980
36	Construction of other new nonresidential structures	$ 39,136,784
371	Custom computer programming services	$ 35,744,116
31	Electric power generation, transmission, and distribution	$ 21,247,297
351	Telecommunications	$ 18,700,250
272	Communication and energy wire and cable manufacturing	$ 14,087,764
270	Storage battery manufacturing	$ 10,492,938
239	Other communications equipment manufacturing	$ 5,504,558

393	Other educational services	$ 5,381,210
271	Primary battery manufacturing	$ 5,354,932
367	Legal services	$ 5,343,773
352	Data processing, hosting, and related services	$ 5,179,261
269	Relay and industrial control manufacturing	$ 4,662,432
376	Scientific research and development services	$ 3,034,313
244	Electronic capacitor, resistor, coil, transformer, and other inductor manufacturing	$ 2,539,453
236	Computer terminals and other computer peripheral equipment manufacturing	$ 2,499,344
171	Steel product manufacturing from purchased steel	$ 1,682,900
234	Electronic computer manufacturing	$ 1,565,968
368	Accounting, tax preparation, bookkeeping, and payroll services	$ 1,332,464
251	Industrial process variable instruments manufacturing	$ 1,049,020
265	Other major household appliance manufacturing	$ 1,045,205
266	Power, distribution, and specialty transformer manufacturing	$ 624,247
353	Data processing, hosting, and related services	$ 157,640
250	Automatic environmental control manufacturing	$ 124,898
TOTAL		**$ 2,958,976,719**

Table 18 Smart Grid Vendors Only Scenario

Sector	IMPLAN Description	Input (spending $)
372	Computer systems design services	$ 513,959,678
380	All other miscellaneous professional, scientific, and technical services	$ 365,715,573
374	Management, scientific, and technical consulting services	$ 304,833,665
275	All other miscellaneous electrical equipment and component manufacturing	$ 240,330,185
247	Other electronic component manufacturing	$ 157,283,816
238	Broadcast and wireless communications equipment	$ 129,153,916
373	Other computer related services, including facilities management	$ 99,716,979
369	Architectural, engineering, and related services	$ 89,413,077
268	Switchgear and switchboard apparatus manufacturing	$ 60,858,809
371	Custom computer programming services	$ 33,235,786
31	Electric power generation, transmission, and distribution	$ 20,386,870
345	›ftware publishers	$ 20,017,741
389	Other support services	$ 18,229,463
36	Construction of other new nonresidential structures	$ 14,697,497
351	Telecommunications	$ 10,531,237
270	Storage battery manufacturing	$ 9,466,084

239	Other communications equipment manufacturing	$ 5,504,558
352	Data processing, hosting, and related services	$ 5,179,261
319	Wholesale Trade	$ 4,245,541
244	Electronic capacitor, resistor, coil, transformer, and other inductor manufacturing	$ 2,539,453
234	Electronic computer manufacturing	$ 1,565,968
236	Computer terminals and other computer peripheral equipment manufacturing	$ 1,507,573
265	Other major household appliance manufacturing	$ 1,004,566
266	Power, distribution, and specialty transformer manufacturing	$ 664,885
269	Relay and industrial control manufacturing	$ 266,433
353	Data processing, hosting, and related services	$ 157,640
250	Automatic environmental control manufacturing	$ 124,898
TOTAL		**$ 2,110,591,152**

- **The scope of smart grid project (Location, Project Period & Technologies deployed)**

The ARRA funding companies are total 117 of Smart Grid vendors which cover the entire United States. The time period of the investments analyzed cover expenditures from August 2009 to March 2012, which encompasses nearly three billion dollars in publicly documented expenditures. And technologies deployed by each company and the whole funding program are not specified in this report.

- **The list and definition of benefits**

In this report, benefits are not clearly identified but it can be inferred from the model utilized in this report and its results. This report indicated that the Smart Grid deployment positively impacted on the job support and the ecosystem of Smart Grid industry directly and indirectly. This report provided scenario analysis results of *All vendors scenario* and *Smart Grid vendors scenario.* Each scenario has GDP, output, employment, labor income, labor per-worker income, taxes are available as results *More detailed benefits by each industry, household and state and federal government are provided by the model the report utilized*

- **The list and definition of costs**

In this report, costs of the smart grid are not clearly defined. Instead, the report presents the total invested value of $2.96 billion to support the Smart Grid projects for grid modernization and lists the top 20 Smart Grid vendors out of a total of 117 Smart Grid vendors reported as receiving payments.

Table 19 Top 20 Smart Grid Companies Receiving Smart Grid ARRA and Matching Funds

Company	ARRA Funds($)
Itron	$304,828,804
Trilliant	$99,494,396

Accenture	$53,955,271
Honeywell	$50,856,201
GE	$44,646,429
Landis+Gyr	$44,388,260
Sensus	$38,900,498
IBM	$36,461,152
S&C Electric	$33,590,952
Alcatel-Lucent	$33,171,014
Elster	$30,223,339
Oracle	$26,730,073
Tantalus	$21,059,544
Black&Veatch	$19,787,742
Silver Spring Networks	$14,417,285
BPL Global	$12,728,072
ABB	$12,424,186
Grid One Solutions	$10,014,822
Cooper Power Systems	$8,964,545
Quanta Services	$8,646,263
Total (top 20)	**$905,288,847**

Source: US Department of Energy, Office of Electricity Delivery & Energy Reliability, Economic Impact of Recovery Act Investments in the Smart Grid, April 2013

- **Deliverables**

  - ***Results***

- ✓ ARRA funding and matching support from utilities and the private sector in the SGIG and SGDP programs generated a significant impact on the U.S. economy.
- ✓ Smart Grid deployment positively impacted employment and labor income throughout the economy.
- ✓ Investment in core Smart Grid industries supports high-paying jobs.
- ✓ The Smart Grid Gross Domestic Product (GDP) multiplier is higher than many forms of government investment.

Table 20 Summary Results of All Vendors and Smart Grid Vendors Only Scenario

	Total Impact	
	All Vendors	**Smart Grid Vendors Only**
Employment (jobs)	47,000	33,000
Labor Income (2010$)	$2.86 Billion	$2.07 Billion
GDP (2010$)	$4.18 Billion	$2.91 Billion
Economic Output (2010$)	$6.83 Billion	$4.79 Billion
State and Local taxes (2010$)	$0.36 Billion	$0.26 Billion

Federal taxes (2010$)	$0.66 Billion	$0.49 Billion

Source: US Department of Energy, Office of Electricity Delivery & Energy Reliability, Economic Impact of Recovery Act Investments in the Smart Grid, April 2013

✧ ***Policy and Regulatory***

Since 2007, the United States has been promoted the policy to modernize the electricity infrastructure for the economic well-being and security of the nation. In this report, the investment in Smart Grid Investment Grant and Smart Grid Demonstration programs keep pacing the grid modernization and improving the economic and operational benefits.

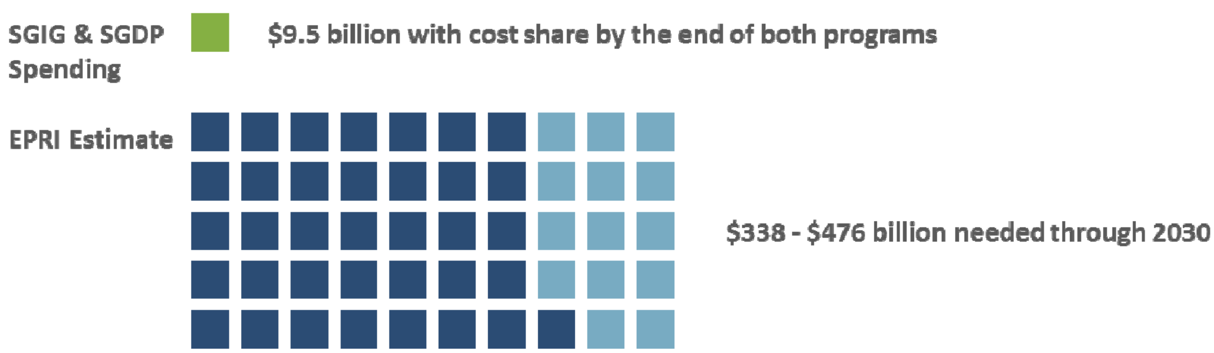

Figure 28 Required Smart Grid Investments

Source: US Department of Energy, Office of Electricity Delivery & Energy Reliability, Economic Impact of Recovery Act Investments in the Smart Grid, April 2013

II.2.9 United States: Smart Grid Consumer Collaborative (SGCC)

➢ **Background**

By macroeconomic analysis, many researchers have forecast the cost and benefit of Smart Grid. As the real-world experience is growing, Smart Grid Consumer Collaborative (SGCC) reviewed available research quantifying benefits – economic, environmental, reliability, and customer choice – and costs associated with Smart Grid investments.

➢ **The methodology and/or toolkits used for BCA**

In this report, benefit cost analysis was fulfilled with reference case and ideal case. Reference (low end) case embodies conservative assumptions typical of the current average capability deployment. Ideal (high end) Case is based on the achievable, "the state of the possible" Smart Grid deployment goal. Also this report describes the benefit drivers for each Smart Grid capability. Benefit-cost analysis is done by calculation of Net Present Value for 13 year deployment of Smart Grid infrastructure and its operation. The table below compares the assumptions of Reference and Ideal case.

Table 21 Reference Case and Ideal Case benefit assumptions

Capability	Primary Benefit Drivers	Reference Case Assumptions	Ideal Case Assumptions
Integrated Volt/VAr Control	• Average reduction in peak demand • Average reduction in energy use	• 3.5% peak reduction • n/a	• 3.5% peak reduction • 2.7% energy reduction
Remote Meter Reading	• Type of meter reading (manual or automated) prior to Smart Meter rollout • Policy regarding move ins/move outs (is prorating allowed between meter reads or must meters be read on customer move dates?)	• Routine monthly meter reads previously automated • Prorating prohibited	• Meter reading previously manual • Prorating prohibited
Time-Varying Rates	•Customer participation rates (opt in) • Customer response level to price differentials • Conservation impact • Average peak demand per residential customer • Value of generation capacity avoided • Average usage per residential customer per year • Value of electricity use avoided	• 2% participation • 20% load shift • 4% usage reduction • 2.575kW/customer (1) • $134.28/kW year(1) • 11,280 kWh/ year (1) • $0.0682/kWh (1)	• 20% participation • 20% load shift • 4% usage reduction • 2.575kW/customer (1) • $134.28/kW year (1) • 11,280 kWh/year (1) • $0.0682/kWh (1)
Prepay and remote disconnect/ reconnect	•Customer participation rates • Conservation impact • Existence of remote disconnect prohibitions	• 2.5% participation • 11% usage reduction • No remote disconnect prohibitions	• 5% participation • 11% usage reduction • No remote disconnect prohibitions
Revenue Assurance	• Level of electricity theft prior to Smart Meter deployment • Average age of meters being replaced		
Customer	•Customer participation rates	• 2% participation	• 5% participation

Energy Management	• Feedback mechanism Type • Conservation impact	• In-home display • 5% usage reduction	• In-home display • 5% usage reduction
Service Outage Management; Fault Location and Isolation	• Value assigned to a minute of reliability improvement	• $1.80/minute (weighted average opportunity cost to residential, commercial, industrial)	• $1.80/minute (weighted average opportunity cost to residential, commercial, industrial)
Renewable Generation Integration	• Difference in cost of relative to central resources • Difference in environmental impact vs. central • Value of environmental impact reductions • Ratio of customer-sited to central resources over time		

Note: (1) These assumptions are used throughout the report as appropriate.

Source: Smart Grid Consumer Collaborative (SGCC), Smart Grid Economic and Environmental Benefits: A Review and Synthesis of Research on Smart Grid Benefits and Costs, October 2013.

The following table shows assumptions of benefit drivers for calculation. And the value of each variable is utilized to calculate the benefit values.

Table 22 Benefit driver assumptions for calculations

Variable	Assumption	Value
A	Average energy use per U.S. residential electric customer per year[35]	11,280 kWh
B	Average peak demand per U.S. residential electric customer[36]	2.575 kW
C	The variable cost of electricity per kWh[37]	$0.0682
D	The value of generation investments delayed or avoided per unit of demand reduced[38]	$134.28 per kW yr.

35 U.S. Energy Information Administration, 2011 Annual Electric Power Industry Report (File 2, Electric sales, revenue, and average price, Column W, total consumers), April 2012.

36 Calculated based on 11,280 kWh per year for an average U.S. residential electric customer assuming a 50 percent capacity factor. Peak demand = (average demand/8,760 hours annually)/capacity factor.

37 U.S. Energy Information Administration, "Table 5.3. Average Retail Price of Electricity to Ultimate Consumers" (Line 14, 2011, Column D, Industrial), September 20, 2013.

38 Kathleen Spees, Cost of New Entry Estimates for Combustion Turbine and Combined-Cycle Plants in PJM, The Brattlle Group, August 24, 2011. Page 2, Table 1, final column average (PJM 2014/15 CT CONE).

E	CO2 equivalent emissions (lbs.) per kWh[39]	1.22
F	Percentage reduction in peak demand from IVVC	3.25%
G	The amount of electric use reduced per year from IVVC	2.7%
H r	Assumed participation rate in time-varying rates, Reference Case	2%
Hi	Assumed participation rate in time-varying rates, Ideal Case[40]	20%
I	The amount of demand reduced at a point in time from "shifting" by customers participating in time-varying rates	20%
J	The amount of electric use reduced per year among those participating in time-varying rates[41]	4%
K	The amount of electric use reduced per year among those participating in prepayment programs	11%
Lr	Assumed participation rate in prepayment programs, Reference Case	2%
Li	Assumed participation rate in prepayment programs, Ideal Case	5%
M	Billing and collection expense reduction per prepayment customer	$300
N	Average monthly bill per prepayment customer[42]	$110
O	Average days' sales outstanding[43]	53
P	Utility weighted average cost of capital (daily)[44]	0.0095%
Q	Bills per year	12
R	The amount of electric use reduced per year among those utilizing an in-home display (conservative end of the range found in research)	5%
Sr	Assumed participation rate in home energy management, Reference Case	2%
Si	Assumed participation rate in home energy management, Ideal Case	5%

Source: Smart Grid Consumer Collaborative (SGCC), Smart Grid Economic and Environmental Benefits: A Review and Synthesis of Research on Smart Grid Benefits and Costs, October 2013.

The table below indicates that how the benefits are calculated by scenario.

[39] U.S. Environmental Protection Agency, eGRID 2012 Subregion GHG Output Emission Rates for Year 2009, April 2012. Summary table 1, column = total output emissions rate (lb/MWh). http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_SummaryTables.pdf.

[40] Testimony of J. Richard Hornby to the Arkansas PSC in Docket 10-109-U, Exhibit JRH-4, page 2, May 20, 2011. "OG&E assumes 20 percent of residential customers will voluntarily enroll in its VPP rates."

[41] Chris King and Dan Delurey, "Efficiency and Demand Response: Twins, Siblings, or Cousins?" Public Utilities Fortnightly, March 2005, 55.

[42] U.S. Energy Information Administration, "Table 5A. Residential Average Monthly Bill by Census Division, and State 2011." Table 5_a, Line 66 (U.S. total), Column C ("Average Monthly Consumption").

[43] Top-quartile (better than 75 percent) utilities. Cash on the Meter (white paper), Ernst & Young, May 2009, 6.

[44] 3.47 percent divided by 365 days. Aswath Damodaran, "Cost of Capital by Sector," January 2013. Analysis of 6,177 firms in the Value Line dataset; "Electric Utility (Central)."

Table 23 Benefit calculations for Reference Case and Ideal Case

Capability	Calculation	Reference Case Value	Ideal Case Value
Integrated Volt/VAr Control peak demand reduction	B x D x F	$11.24	$11.24
Integrated Volt/VAr Control conservation benefit	A x C x G	N/A	$20.77
Integrated Volt/VAr Control CO2e reduction	A x E x G	Likely	372 lbs.
Time-varying rate peak demand reduction	B x D x H x I	$1.38	$13.83
Time-varying rate conservation benefit	A x C x H x J	$0.62	$6.15
Time-varying rate CO2e reduction	A x E x H x J	11 lbs.	110 lbs.
Prepayment program conservation benefit	A x C x K x L	$1.69	$4.23
Prepayment program conservation benefit per participant	A x C x K	$84.62	
Prepayment program billing, collection and Interest reduction benefit	[M + (N x O x P x Q)] x L	$6.13	$15.33
Prepayment program CO2e reduction	A x E x K x L	30 lbs.	76 lbs.
Customer energy management benefit	A x C x R x S	$0.77	$1.92
Customer energy management CO2e reduction	A x E x R x S	14 lbs.	34 lbs.

Source: Smart Grid Consumer Collaborative (SGCC), Smart Grid Economic and Environmental Benefits: A Review and Synthesis of Research on Smart Grid Benefits and Costs, October 2013.

- **The scope of smart grid project (Location, Project Period & Technologies deployed)**

Smart Grid Consumer Collaborative (SGCC) is supported by 101 organizations including utilities, research centers, and public utility commissions. U.S. DOE's Smart Grid Investment Grant (SGIG) programs including 24 of Smart Meter Projects and 12 of Distribution Automation Projects were used to estimate costs per customer for entire U.S.

- **The list and definition of benefits**

In this report, direct and indirect benefits are calculated by capability per customer per year. Direct benefits are those that could affect customers' bills.

- ✓ Integrated Volt/VAr Control (IVVC) helps utilities optimize the power delivered to customers.
- ✓ Remote meter reading
- ✓ Time-varying rates
- ✓ Prepayment programs and remote disconnect/reconnect
- ✓ Revenue assurance
- ✓ Customer energy management
- ✓ Service outage management

Also Smart Grid capabilities offer the indirect benefits to customers and communities, focusing on electricity distribution and renewable generation integration:

- ✓ Fault Location and Isolation
- ✓ Renewable Generation Integration

Table 24 Benefits by Smart Grid capability per customer per year

Capability	Direct Economic Benefits	Reliability Improvement	CO2 Equivalent Reduction3	Indirect Economic Benefits4	Customer Choice Benefits
Integrated Volt/ VAr Control	$11.24–32.01	Improved power quality (value not quantified)	Likely –372 lbs.	Likely –$2.59	
Remote Meter Reading	$13.68–23.92		Possible	Possible	
Time-Varying Rates	$2.00–19.98		11–110 lbs.	$0.08–0.76	Yes
Prepayment and Remote Dis-/Reconnect	$7.82–19.56		30–76 lbs.	$0.21-0.53	Yes
Revenue Assurance	$3.00				
Customer Energy Mgmt.	$0.77–1.92		14–34 lbs.	$0.10–0.24	Yes
Service Outage Management	$1.18	4.5% 4.9 minutes		$8.82	
Fault Location and Isolation		20.5% 22.3 minutes		$40.14	
Renewable Generation Integration	Possible	Likely	Likely		Yes
● TOTALS	$39.69–101.57	25% 27.2 minutes	55–592 lbs.	$49.35-53.08	Yes

Source: US Department of Energy, Office of Electricity Delivery & Energy Reliability, Economic Impact of Recovery Act Investments in the Smart Grid, April 2013

Table 25 Drivers of Smart Grid capability benefits

Capability	Utility Operating Characteristics	Customer Participation and Behavior	Speed of Cost Reduction and Recognition	Market Prices for Electricity and Capacity
Integrated Volt/VAr Control	X			X
Remote Meter Reading	X		X	
Time-Varying Rates		X		X
Prepayment and Remote Dis-/Reconnect	X	X		X

Revenue Assurance				X
Customer Energy Management		X		X
Service Outage Management	X			
Fault Location and Isolation	X			
Renewable Generation Integration	X	X		X

Source: US Department of Energy, Office of Electricity Delivery & Energy Reliability, Economic Impact of Recovery Act Investments in the Smart Grid, April 2013

- **The list and definition of costs**

In this report, summary grant application data was reviewed to calculate the average cost per customer for Smart Meter and Distribution Automation projects. This includes:

- ***Capital investments***

- ✓ Proposed funding from both utilities and SGIG grants.

- ***Ongoing expenditures***

- ✓ For asset operation and maintenance.

- **Deliverables**

- ***Results***

For the NPV calculation for the Reference Case and Ideal Case, assumptions below include:

- ✓ Capital costs are evenly split over the first three years of a deployment.
- ✓ A three-year ramp-up period is assumed for capabilities requiring customer participation.
- ✓ A 10-year post-implementation evaluation period is used to reflect the likely useful life of Smart Grid components.
- ✓ Indirect benefits from reliability improvements (service outage management and fault location and isolation) are included, but indirect environmental benefits (that is, the value of carbon emission reductions) are not.

The following two tables provide the NPV calculation for Smart Grid benefits and costs for Reference Case and Ideal Case. The ratio of benefits (both direct and indirect) to costs is 1.5 to 1 in the Reference Case[45] and 2.6 to 1 in the Ideal Case[46].

[45] Reference Case benefits to cost ratio = ($306.95 + $390.27)/$449.82 = 1.5 (to 1).

[46] Ideal Case benefits to cost ratio = ($772.75 + $390.27)/$449.82 = 2.6 (to 1).

Table 26 Net Present Value calculation for Smart Grid benefits and costs: Reference Case

Cost or Benefit Category	NPV	Deployment Year 1	2	3	4	5	6	7	8	9	10	11	12	13
IVVC	89.60				11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24
Meter Reading	109.05				13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68
Time-Varying Rates	14.16				0.66	1.34	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Prepayment	55.38				2.58	5.24	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82
Revenue Assurance	23.91				3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Customer Energy Mgmt.	5.45				0.25	0.52	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Outage Mgmt (direct)	9.41				1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Total Direct Benefits	**306.95**													
Outage Mgmt (indirect)	70.31				8.82	8.82	8.82	8.82	8.82	8.82	8.82	8.82	8.82	8.82
Fault Location & Isolation	319.96				40.14	40.14	40.14	40.14	40.14	40.14	40.14	40.14	40.14	40.14
Total Indirect Benefits	**390.27**													
Smart Meter Costs	-369.22	-97.18	-97.18	-97.18	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66
Distribution Automation Costs	-80.60	-21.21	-21.21	-21.21	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55
Total Costs	**-449.82**													

Source: Smart Grid Consumer Collaborative (SGCC), Smart Grid Economic and Environmental Benefits: A Review and Synthesis of Research on Smart Grid Benefits and Costs, October 2013.

Table 27 Net Present Value calculation for Smart Grid benefits and costs: Ideal Case

Cost or Benefit Category	NPV	Deployment Year 1	2	3	4	5	6	7	8	9	10	11	12	13
IVVC	255.16				32.01	32.01	32.01	32.01	32.01	32.01	32.01	32.01	32.01	32.01
Meter Reading	190.67				23.92	23.92	23.92	23.92	23.92	23.92	23.92	23.92	23.92	23.92
Time-Varying Rates	141.49				6.59	13.39	19.98	19.98	19.98	19.98	19.98	19.98	19.98	19.98
Prepayment	138.52				6.45	13.11	19.56	19.56	19.56	19.56	19.56	19.56	19.56	19.56
Revenue Assurance	23.91				3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Customer Energy Mgmt.	13.60				0.63	1.29	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92
Outage Mgmt (direct)	9.41				1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Total Direct Benefits	**772.75**													
Outage Mgmt (indirect)	70.31				8.82	8.82	8.82	8.82	8.82	8.82	8.82	8.82	8.82	8.82
Fault Location & Isolation	319.96				40.14	40.14	40.14	40.14	40.14	40.14	40.14	40.14	40.14	40.14
Total Indirect Benefits	**390.27**													
Smart Meter Costs	-369.22	-97.18	-97.18	-97.18	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66	-11.66
Distribution Automation Costs	-80.60	-21.21	-21.21	-21.21	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55	-2.55
Total Costs	**-449.82**													

Source: Smart Grid Consumer Collaborative (SGCC), Smart Grid Economic and Environmental Benefits: A Review and Synthesis of Research on Smart Grid Benefits and Costs, October 2013.

- **Policy and Regulatory**

In this report, the results show that the direct and indirect economic benefit of the grid modernization is larger than the cost of deployment of Smart Grid infrastructure and its maintenance. Also it indicates that the grid modernization has a significant benefit on the environment through conservation and renewable generation integration.

Looking forward, candid conversations among stakeholders about the critical role that the electric distribution grid plays in a community and the kind of grid a community wants to have are essential. Grid upgrades require long lead times; flexibility and reliability must be designed and built well in advance of when they will be needed. The grid we use today was not designed for the demands society seems poised to place on it in the future. Communities need to be asking key questions about the kind of grid they want, the costs required to build it, and priorities and trade-offs they can agree upon.

II.3 Summary of BCA Frameworks and Application Cases

The Methodology of EPRI (EPRI, 2010) could be considered as the general approach of estimating benefits and costs of a smart grid project. Other institutions that built their BCA tools upon the Methodology are US Department of Energy (DOE) with its Smart Grid Computational Tool (SGCT) and European Commission's Joint Research Centre (EC JRC) although with integration of its own elements such as smart grid characteristics, Key Performance Indicators (KPI), and qualitative analysis. Similar frameworks are developed by McKinsey and Smart Grid Investment Model (SGIM).

The main focus of these BCA is the definition of benefits. In general, most of the smart grid benefits is in form of reduced costs. As to which benefits are considered and how to quantify those benefits, each framework could have different interpretations compared to others. Some of the general benefits are reduced generation cost, reduced CO_2 emissions, reduced meter reading cost, reduced outages, and reduced cost of transmission and distribution system.

Interesting framework is presented by Frontier Economics, that works closely with Smart Grid Forum (SGF) of UK. The model they developed applies real options valuation, that is application of option valuation techniques to capital budgeting decisions. The reason is to avoid a stuck-in scenario where only one specified investment path can be chosen. In a sense, it is similar to integrating the advanced version of sensitivity analysis to the main BC Analysis itself. Also, the Frontier Economics combine their Real options BCA model with network model and generation model to provide the network and generation costs to the BCA model.

In IMPLAN discussion (as well as others) it is notified that a impacts of smart grid could be more than a direct economic impact. Utilizing input output data, the model could analyze the indirect economic impacts and induced economic impacts of smart grid, in addition to the normative direct economic impacts.

In this report, there are nine country (and states) reports of BCA application to smart grid projects that has been reviewed. The surveyed reports range from Czech Republic and Denmark, to the USA's state of new York and research institutions such as Smart Grid Consumer Collaborative (SGCC). The discussions use several key points to generalize the information gathered (background, scope, benefits and costs definition, results), in consideration to the uniqueness of each study.

The main focus of the comparison between the studies is the definition of benefits and costs. It can be observed that depending on the background and scope of each project, the list of benefits and costs would differ one from another. It must be noted also, that not all studies surveyed here has a clear documentation of the exact calculation (quantification and monetization) of the benefits, which could be tricky sometimes.

Taking Czech Republic case as an example, the smart grid project there focus more on reshaping the electricity load, thus the smart grid benefits are categorized into load leveling effect, time shifting effect, and off-peak time shifting effect. The calculation of these benefits, then, would base on the cost avoidance resulting from the project.

Meanwhile in Denmark, the benefits of smart grid is divided into savings on reserves and regulating power, savings on electricity generation, and savings on energy-saving initiatives. The method of benefits quantification--seeing this categorization--would be the reduced cost that stems from the reduced electricity consumption.

Both Czech Republic and Denmark cases have similarities that they don't consider much the benefits related with the transmission and distribution. As can be seen, most of the benefits are related with reduced generation or load saving. Netherland's report also shares the same point of view for benefits estimation. On the other hand, Lithuania does not consider the savings from generation side, but mostly deals with benefits related with smart metering.

The environmental benefit of smart grid, that is reduction of CO_2 emission, also becomes more important. The BCA report of Ireland is one of those that take this into account. In relation to CO_2 emissions, the McKinsey framework also made it into their list of smart grid's major benefits. The same goes for SGCC report that covers several utilities.

In conclusion, the list and definition of benefits may differ between cases and a standardized list and definition that encompass the whole possible benefits must be generated. Table below compares the benefits definition from various BCA reports. It basically expands the similar table from the previous report. As usual, the benefits categorization coined by EPRI (2010) is used as the base. Even so, it is still possible for some reports to have listed benefits that cannot be conformed to the EPRI's benefits. In same case, such as of Lithuania, several listed benefits (standard meter replacement program savings, standard meter installation cost savings, and savings on taking the meter readings) could be crammed into one Reduced Meter Reading Cost. Meanwhile in others, the listed benefits might have unclear monetization method. The estimation of benefits, then, is quite a delicate process.

Table 28 Benefits Comparison from Various BCA Reports

Benefits (EPRI 2010)			BCA REPORTS												
			EPRI 2004	EPRI 2011	FERC 2006	FSC 2008	IEE 2011	McKinsey	Czech	Denmark	Ireland	Lithuania	Netherland	New York	SGCC
Economic	Improved Asset Utilization	Optimized Generator Operation						X	X	X	X		X	X	X
		Deferred Generation Capacity Investments		X		X	X	X	X	X			X	X	X
		Reduced Ancillary Service Cost	X	X	X				X	X			X	X	X
		Reduced Congestion Cost	X	X					X	X			X		X
	T&D Capital Savings	Deferred Transmission Capacity Investments	X	X		X	X	X					X		
		Deferred Distribution Capacity Investments	X	X		X	X	X					X	X	
		Reduced Equipment Failures	X	X										X	
	T&D O&M Savings	Reduced T&D Equipment Maintenance Cost	X	X				X		X				X	
		Reduced T&D Operations Cost	X	X		X		X				X		X	
		Reduced Meter Reading Cost		X	X	X	X	X			X	X		X	X
	Theft Reduction	Reduced Electricity Theft													X

	Energy Efficiency	Reduced Electricity Losses	X	X								X	X	X	
	Electricity Cost Savings	Reduced Electricity Cost	X	X		X	X	X		X	X	X		X	X
Reliability	Power Interruptions	Reduced Sustained Outages	X	X	X	X	X	X						X	
		Reduced Major Outages	X	X	X	X	X	X						X	
		Reduced Restoration Cost	X	X	X	X	X	X				X	X		
	Power Quality	Reduced Momentary Outages	X	X	X	X		X				X		X	
		Reduced Sags and Swells	X	X											
Environ-mental	Air Emissions	Reduced CO2 Emissions	X	X		X	X	X			X				X
		Reduced SOx, NOx, and PM-10 Emissions	X	X											
Security	Energy Security	Reduced Oil Usage					X	X			X				
		Reduced Wide-scale Blackouts	X	X				X							

Task III: Develop Toolkits to Evaluate Benefit-Costs at the Technology or Subsystem Level

Subtask 3.1: Trial application of the DOE Benefit-cost analysis computational tool and results discussion
Subtask 3.2: Guidelines for the development of a new ISGAN benefit-cost analysis tool

III.1 Update of EPRI Procedures

In 2011 and 2012, EPRI produces two reports titled "Guidebook for Cost/Benefit Analysis of Smart Grid Demonstration Projects". Both reports discuss about the process of estimating smart grid's benefit and cost in a step-by-step approach. Although the reports are built on the previous report of EPRI (2010)[47], "Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects", the guidebook is designed as a standalone user manual.

In comparison with the precursor report (EPRI, 2010), the new reports extensively broaden in detail the steps required for BCA of a smart grid project. As discussed in the previous chapter, the original EPRI approach has 10 steps that are divided into three parts: Characterize the Project, Estimate Benefits, and Compare Costs to Benefits. Meanwhile in the guidebook (EPRI, 2011b, 2012) the steps are now extended into 24 steps that are divided into three big categories:

- ✓ Project Overview
  - ◆ Project Overview Documentation: This phase serves as preliminary overview and documentation of the project, which could be useful for communicating about the project to parties outside the utility.
- ✓ Research Plan
  - ◆ Technology Description: The first step of research plan phase describe the technologies that are deployed in the smart grid project, including the functions enabled, how they will be applied, and the expected impacts and benefits
  - ◆ Developing a Research Plan: The second step is to detail the experiment to be run, including the physical quantities that would be measured, develop the experiment itself and the hypotheses, and specify the algorithm for impacts calculation
- ✓ Cost/Benefit Analysis
  - ◆ Estimating Project Impacts, Costs, and Benefits: This phase analyzes the data collected in the experiments, and turns it into benefit and cost analysis.

Figure below shows the comparison between the two.

[47] The approach taken in this report has been discussed extensively in the previous report and summarized in this report, Task II.

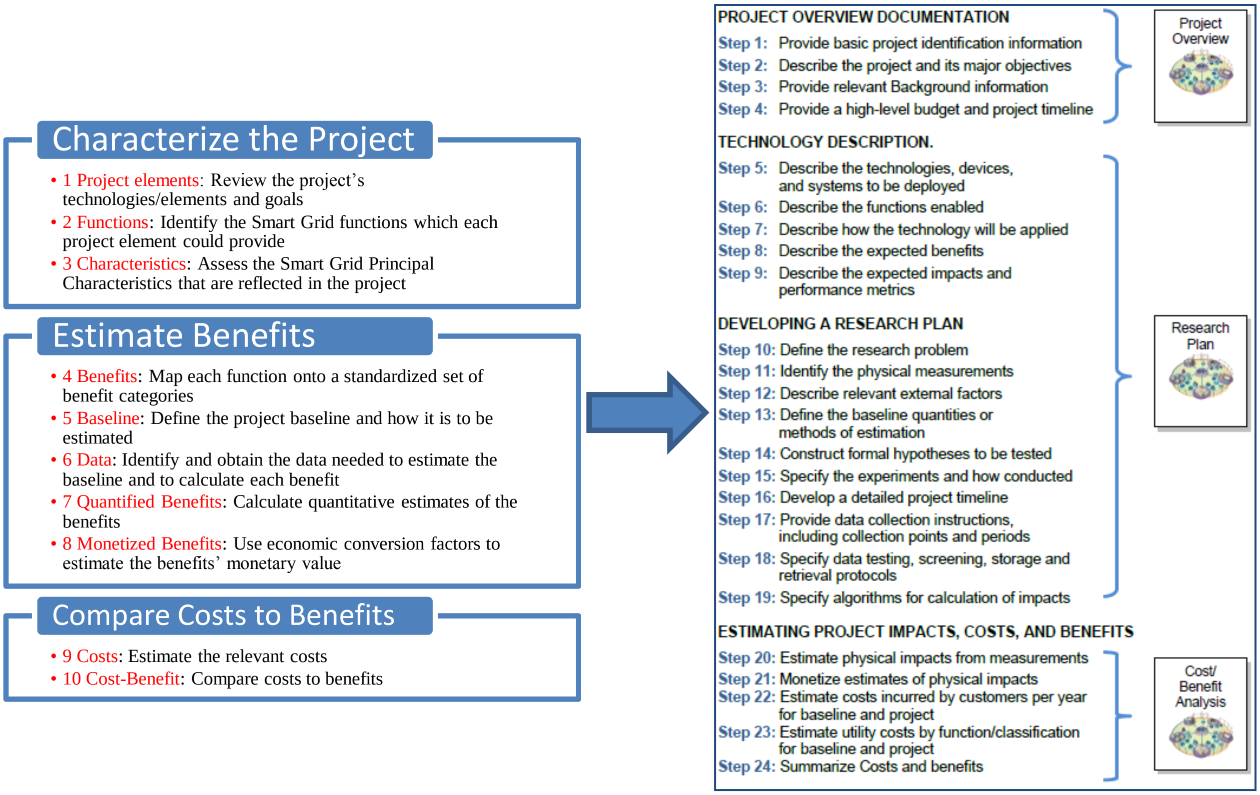

Figure 29 The Expansion of Steps in Estimating Benefit and Cost of Smart Grid Project Proposed by EPRI

Although both reports attempt on developing further the original EPRI approach, both are still incomplete, in a sense that not all steps are fully explained in the reports. While in the first report (EPRI, 2011b) only 17 steps are explained in detail, the second report (EPRI, 2012) extends the discussion to 21 steps. In both reports, additional materials are provided to assist the utilities better understand the approach as well as applying the benefit cost estimation process itself: the example of application and the templates for BCA following the approach. The summaries of those steps would be given in the next subsections.

III.1.1 Project Overview Documentation

There are four steps in this part, which is related to documentation of the project basic information. The reports propose a standardized format of information and statements that would be useful to communicate the project with outside entities, also to compare it with other projects.

The first step outlines the general information related with the project's identification, which includes the project's name, description, participants, and total budget. The second step then provides the general description of problem to be solved (problem statement), the current situation (baseline/business-as-usual scenario), and the objective of the project.

The third step describes the high level background information, such as utility description, the situation of market structure and regulatory, and project's information: geographic scope, enabled functions, basic elements, expected impacts and benefits, and targeted groups. The fourth step would discusses the high level information related with projects organizational. Some information that must be provided are role and responsibility of project's participants, budget and timeline, also technology deployed. Figure below shows the proposed table for high level budget and timeline information for the project.

Table 29 High Level Project Budget and Timeline

High-level Project Budget and Timeline		Date		2013				2014				2015				2016			
Task	Budget	Begin	Complete	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Project Development																			
Project Summary Development																			
Identify roles & responsibilities																			
Outline project goals and objectives																			
Develop project budget																			
Identify project partners and collaborators																			
Internal Approvals (Budget & Scope)																			
External Approvals (Budget & Scope)																			
Regulatory Approvals																			
Local, State, Federal Approvals																			
Regulatory Commission Approval																			
Pre-Planning & Preparation																			
Equipment Purchases																			
Equipment Installation																			
Marketing Material Development																			
Communication & Customer Recruitment																			
Baseline Measurements																			
Identify quantities and durations for baseline measurement																			
Measure baseline quantities																			
Field Implementation																			
Technology installation (by project phase or sub-project)																			
Data Collection																			
Data collection (start - end)																			
Data processing (start - end)																			
Data analysis (start - end)																			
Reporting																			
Internal reporting (start - end) per requirement																			
DOE reporting (if applicable)																			
Other reporting requirements																			

Source: EPRI, 2012

III.1.2 Technology Description

After the description and documentation of the project overview, the next steps has a purpose of providing information related to the technology that would be deployed through the smart grid project. There are five steps (Step 5 to 9) in this part, that are describing the: technologies, systems, and devices to be deployed; the functions enabled; how the technology will be applied; the expected benefits; the expected impacts and performance metrics. Figure below outlines the conceptual BCA process from assets to benefits, with examples of each level.

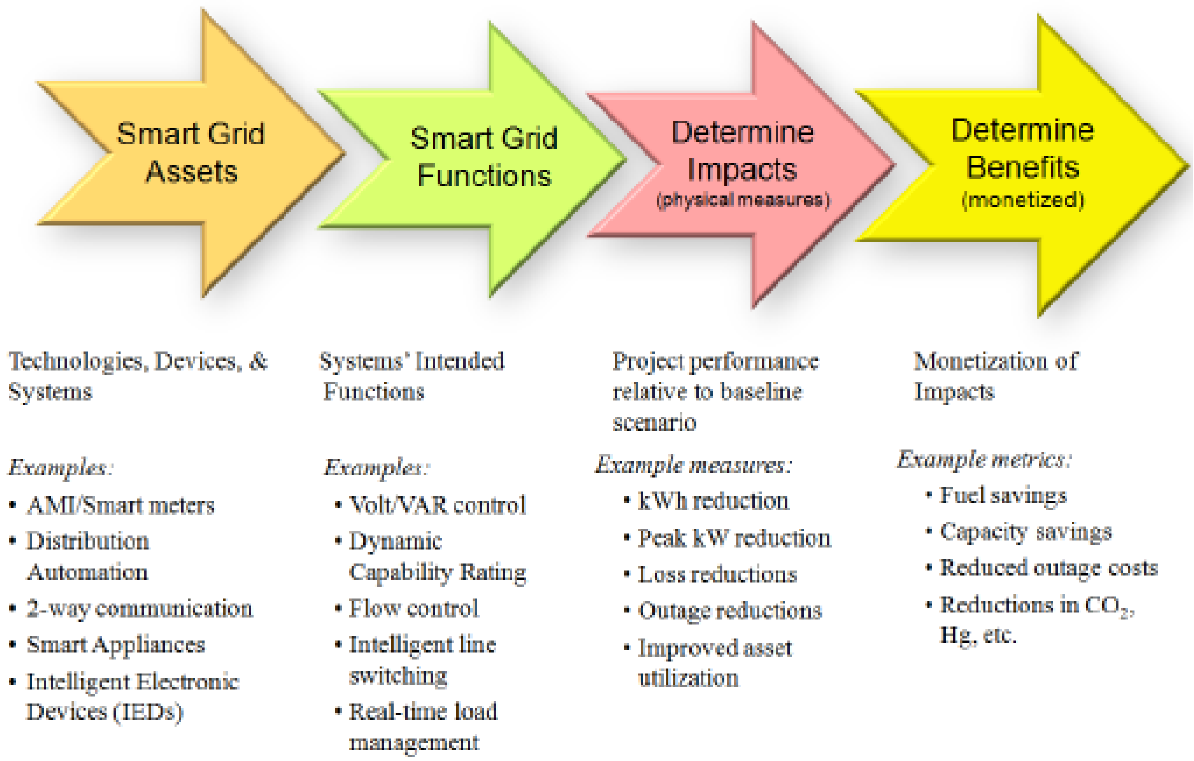

Figure 30 Examples of Systems, Functions, Impacts, and Benefits

Source: EPRI, 2012

The linkage between assets to functions and benefits to functions are also proposed in form of two matrixes, similar to those found in EPRI (2010) and DOE (Navigant, 2011) reports[48]. The reports describe 19 smart grid assets and 13 functions that can be categorized into: Transmission, Distribution, Substation, and Costumer. Additional category of Energy Resources is added for the benefits to functions linkage matrix.

III.1.3 Developing A Research Plan

The next 10 steps (Step 10 to 19) deal with the process of creating a research plan to measure the impacts of a mart grid project. Basically, there are two major questions that must be addressed by the process:

- ✓ The Physical Question: Does it work? To what extent the smart grid application perform?
- ✓ The Economic Question: Is it worth doing? Does the performance justify the cost?

One of the interesting point discussed in this report is the idea of stacking/layering project steps. It must be noted that a single project may incorporate a number of steps; a project may also separated into sub-projects. The interaction between sub-projects must be examined, whose sequence could be important.

[48] The matrix tables could be found in the Appendix

Figure below depicts the hypothetical stacking/layers of the project. In this example, there are three applications that are applied in the smart grid project which would be deployed in a sequence: phase balancing, then capacitors (VAR control and voltage regulation), and finally centralized controls. Since a logical steps can be outlined from the three applications, the entire stack then can be analyzed as one project. The research problem here is to measure the physical performance of smart grid application so that it can be monetized with enough certainty and accuracy. But the research problem should also be broken down into sub-problems that can answer the logical Physical and Economic Questions that might arise.

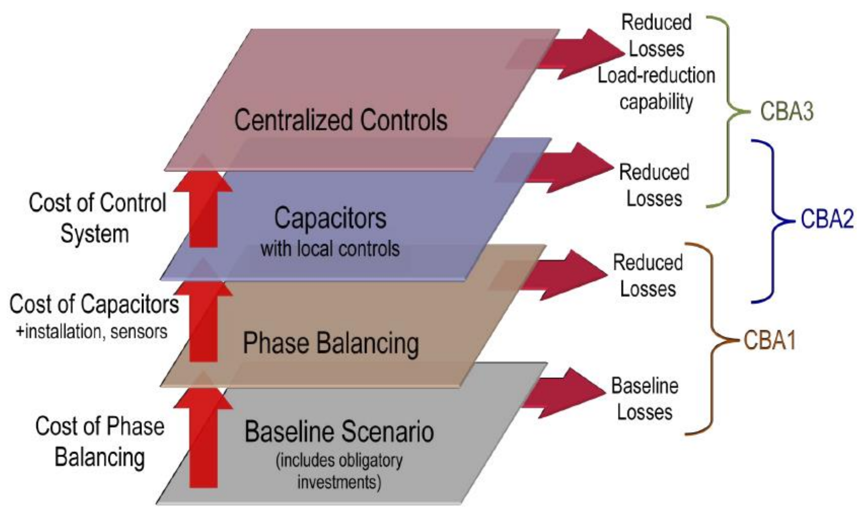

Figure 31 Stacking/Layering of Portions of a Project to Isolate a Series of Physical and Economical Questions

Source: EPRI, 2012

The ten steps that must be conducted to develop a proper research plan includes: defining the research problem, identifying the physical measurement needed, listing the relevant external factors and their measurement, defining the baseline quantities, constructing formal hypotheses to be tested, specifying the experiments and how they will be conducted, developing a detailed project timeline, providing data collection, specifying data testing, screening, storage and retrieval protocols, and finally, specifying algorithms for calculation of impacts and impact metrics.

III.1.4 Estimating Project Impacts, Costs, and Benefits,

A BCA is usually an extrapolation/forecast into the future, thus determining the scope of the BCA--what to be included and what time frame to be analyzed--is an important factor to make sure that a proper physical observations are taken during the experimental demonstration phase. The questions to be answered then are: what will be the time period of the BCA? And will the impacts be stable across the time? It must be noted that the BCA *is not* an analysis of the experiment result but rather an analysis of information provided by the experiment result that is casted to be a representative of realistic implementation of smart grid beyond the scope of demonstration.

In general, the conversion of impacts to its monetary equivalents can be simplified to:

$$Monetary\_equivalent = Cost / unit \times (\mathrm{Quantity}_{measured} - \mathrm{Quantity}_{baseline})$$

In addition to the difficulties of getting an appropriate baseline for measured quantities in real life smart grid demonstrations, the proper cost/unit figures could also not readily available, especially considering the fact that the numbers must be projected across the BCA period.

In order to estimate project impacts, some categories of cost and benefit can be identified, that are:

- ✓ Reliability -> frequency and duration of customer interruptions
- ✓ Utility Operations -> non fuel O&M, non production assets, public and employee safety
- ✓ System Operations -> how efficient the power system runs: losses, combustion, emissions
- ✓ Utility Assets -> production assets required in the GT&D
- ✓ Power Quality -> harmonics, sags/swells, voltage violations
- ✓ Customer -> customer-borne costs, changes in service amount or value

The report discusses in some details those categories of cost and benefit, but to summarize the discussions, table below can be used.

Table 30 Cost/Benefit Analysis Summary Table

				Δ Present Value	Year 1	Year 2	...	Year n
Economic Costs and Benefits	System Operations		Fuel					
			Purchased Power					
			Ancillary Services					
			Emissions - SO_2, NOx, CO_2					
			Operator Costs					
			Revenue on Enabled Sales					
	Utility Operations	Non-Fuel O&M (Operating and Maintenance)	G					
			T					
			D					
			Customer					
			Admin & General					
		Non-Prod Assets	Trucks, A&G, Tools					
	Capital Revenue Requirements	Capital Deferral/ Advancement	G					
			T					
			D					
	Reliability		Interruption Costs, Sustained					
			Interruption Costs, Momentary					
			Interruption Costs Major Event					
			Interruption Costs, Other					
	Customer		Value of Service (Comfort, Light, etc)					
			Cost of equipment (Devices)					
	Other		Savings from Theft Reduction					
	Environment		Δ Tons SO_2					
			Δ Tons NOx					
			Δ Tons CO_2					
			Δ Pounds Hg					
			Δ Particulates					
Security Impacts			Oil Saved					
			Major Blackouts Avoided					
Power Quality Impacts			Change in Momentary Outages					
			Change in Sags, Swells, Voltage violations	n/a				
Efficiency Impacts			ΔkWh System Losses	n/a				
			ΔkW System Losses	n/a				
			ΔkWh Consumed	n/a				
			ΔkW Consumed	n/a				
Metering Impact			Metering Accuracy					
Safety Impact			Public Safety					
			Employee Safety					

Source: EPRI, 2012

Additional items (other than the categories mentioned above, which are those within Economic Costs and Benefits in above table) such as Security Impacts and Safety Impact, are those that would not be included in monetary analysis, but might be useful for the purpose of scoring a qualitative characteristics of a project. If there is an item (or items) that can be monetized, then it should be moved to the Economic category.

While table above basically shows the 'changes in cost' (economics) and other quantitative and qualitative impacts of smart grid demonstration project, additional linkage of benefit categories above to the benefit tables from Methodological Approach (EPRI, 2010) is still needed.

Table 31 Benefits from Methodological Approach (EPRI, 2010) Related to CBA Items and Categories

Costs and Impacts for CBA		Methdology Approach Benefits →	Optimized 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 Distribution Equipment Maintenance Cost	Reduced Distribution Operations Cost	Reduced Meter Reading Cost	Reduced Electricity Theft	Reduced Electricity Losses	Reduced Electricity Cost	Reduced Sustained Outages	Reduced Major Outages	Reduced Restoration Cost	Reduced Momentary Outages	Reduced Sags and Swells	Reduced CO_2 Emissions	Reduced SO_x, NO_x and PM-10 Emissions	Reduced Oil Usage (not monetized)	Reduced Wide scale Blackouts
			Economic													Reliability					Environmental		Security	
			Improved Asset Utilization				T&D Capital Savings			T&D O&M Savings			Theft Reduction	Energy Efficiency	Electricity Cost Savings	Power Interruptions			Power Quality		Air Emissions		Energy Security	
Economic Costs and Benefits	System Operations	Fuel	●	●		●	●							●	●									
		Purchased Power	●	●		●	●							●	●									
		A/S	●	●	●									●	●									
		Emissions - SO2, NOx, CO2	●	●		●	●							●	●									
		Operator Costs																						
		Revenue on Enabled Sales	●	●		●	●							●	●									
	Utility Operations	Non-Fuel O&M – G	●	●			●		●					●	●									
		Non-Fuel O&M – T					●		●						●									
		Non-Fuel O&M – D						●	●	●	●				●			●						
		Non-Fuel O&M – Customer										●												
		Non-Fuel O&M – A&G										●												
		Non-Prod Assets – Trucks, A&G, Tools																						
	Capital Revenue Requirements	Capital Deferral/ Advancement – G		●					●						●									
		Capital Deferral/ Advancement – T					●		●						●									
		Capital Deferral/ Advancement – D						●	●						●									
	Reliability	Interruption Costs Sustained/Normal							●							●								
		Interruption Costs Momentary																	●					
		Interruption Costs Major Event															●							
	Customer Efficiency	Value of Service (Comfort, Light, etc)													●									
		Cost of equipment (Devices)													●									
	Equity	Theft Reduction											●											
	Environment	ΔTons SO2	●											●	●							●		
		ΔTons NOx	●											●	●							●		
		ΔTons CO2	●											●	●						●			
		ΔPounds Hg	●											●	●									
		ΔParticulates	●											●	●							●		
Security Impacts		Oil Saved	●																				●	
		Major Blackouts Avoided																						●
Power Quality Impacts		Change in Momentary Outages																	●					
		Change in Sags, Swells, Voltage violations																		●				
Efficiency Impacts		ΔkWh System Losses												●										
		ΔkW System Losses												●										
		ΔkWh Consumed													●									
		ΔkW Consumed													●									
Equity Impact		Metering Accuracy																						
Safety Impact		Public Safety																						
		Employees Safety																						

Source: EPRI, 2012

Then, the Step 20 and 21 of estimating physical impacts from measurements and monetizing the physical impacts can be carried out. Two tables below shows the example of those steps provided in the report (EPRI, 2012)

Table 32 Example of Impacts for Layers of Project Investments

		Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10
Baseline Scenario											
Feeder Losses, Baseline Scenario	MWh	3,504	3,557	3,610	3,664	3,719	3,775	3,831	3,889	3,947	4,006
Capacitors Added, Local Controls											
Feeder Losses	MWh	3,066	3,112	3,159	3,206	3,254	3,303	3,352	3,403	3,454	3,506
Loss Reduction	MWh	438	445	451	458	465	472	479	486	493	501
Capacitors Added + VVO/CVR											
Feeder Losses, w/caps + VVO/CVR	MWh	2,978	3,023	3,068	3,114	3,161	3,209	3,257	3,306	3,355	3,405
Loss Reduction w/caps + VVO/CVR	MWh	88	89	90	92	93	94	96	97	99	100
Consumption Reduction w/caps + VVO/CVR	MWh	2,628	2,667	2,707	2,748	2,789	2,831	2,874	2,917	2,960	3,005
Energy Savings w/caps + VVO/CVR	MWh	2,716	2,756	2,798	2,840	2,882	2,925	2,969	3,014	3,059	3,105

Source: EPRI, 2012

Table 33 Example of Monetized Benefits, with Present Value

		Present Value	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10
Marginal Cost of Energy	$/MWh		40.0	46.4	47.9	50.0	51.4	53.9	57.1	59.8	62.1	66.0
Baseline Scenario												
Cost of Losses, Baseline Scenario	k$	**1,403.8**	140.2	165.0	173.0	183.3	191.1	203.3	218.7	232.6	245.1	264.3
Capacitors Added, Local Controls												
Cost of Losses	k$	**1,228.3**	122.6	144.4	151.4	160.4	167.3	177.9	191.4	203.6	214.5	231.3
Loss Savings	k$	**175.5**	17.5	20.6	21.6	22.9	23.9	25.4	27.3	29.1	30.6	33.0
Savings attributable to Capacitors	k$	**175.5**	17.5	20.6	21.6	22.9	23.9	25.4	27.3	29.1	30.6	33.0
VVO/CVR												
Cost of Losses	k$	**1,193.3**	119.1	140.2	147.1	155.8	162.5	172.8	185.9	197.7	208.3	224.7
Loss Savings	k$	**35.1**	3.5	4.1	4.3	4.6	4.8	5.1	5.5	5.8	6.1	6.6
Consumption Savings	k$	**1,052.9**	105.1	123.7	129.8	137.5	143.4	152.5	164.0	174.5	183.8	198.2
Savings attributable to VVO/CVR	k$	**1,088.0**	108.6	127.9	134.1	142.0	148.1	157.5	169.5	180.3	189.9	204.9
Total for Project												
Loss Savings	k$	**210.6**	21.0	24.7	26.0	27.5	28.7	30.5	32.8	34.9	36.8	39.6
Consumption Savings	k$	**1,052.9**	105.1	123.7	129.8	137.5	143.4	152.5	164.0	174.5	183.8	198.2
Savings attibutable to Project	k$	**1,263.4**	126.1	148.5	155.7	164.9	172.0	183.0	196.8	209.4	220.6	237.9
Present-Worth Factor	8%		1.0000	0.9259	0.8573	0.7938	0.7350	0.6806	0.6302	0.5835	0.5403	0.5002

Source: EPRI, 2012

The additional tree steps that are not covered in both reports are: estimating the costs incurred by customers per year (baseline and project), estimating the utility costs by function/classification (baseline and project), and summarizing the costs and benefits. These issues are left for future editions of the EPRI report.

The discussions above elaborate the new development of BCA guidelines extending the Methodological Approach (EPRI, 2010). Since the DOE toolkit which is going to be used as a base for ISGAN's Annex 3 was developed using the EPRI Approach outlined in EPRI (2010), it can be argued that the updated version of it must be considered, too. Even so, since most of the expanded steps are served as a mere guidelines for the utilities and users of the approach, it is possible that there would not be much additional features that should be designed and integrated with the original toolkit.

III.2 Analysis on the DOE Toolkit from Software Engineering Point of View

III.2.1 Introduction to US DOE Smart Grid Computational Tool

The U.S. Department of Energy (DOE) Office of Electricity Delivery and Energy Reliability (OE) works to modernize and improve the electric grid by investing funds in smart grid technologies and infrastructure through the American Recovery and Reinvestment Act (ARRA) Smart Grid Investment Grant (SGIG) program and Smart Grid Demonstration (SGD) program. The OE created a Smart Grid Cost-Benefit Analysis team to develop a methodology for evaluating the benefits and costs of all smart grid projects. The team defined a standardized set of smart grid assets, functions, and benefits as well as guidelines for providing data in order to calculate associated benefits.[49]

The methodology seeks to translate the various benefits that result from a smart grid project into a monetary value. With this approach in mind the Navigant Consulting Inc. (Navigant) developed the Smart Grid Computational Tool (SGCT). The SGCT is a benefit cost analysis (BCA) computational tool “designed to streamline the implementation of the EPRI methodology to DOE funded projects.”[50] The SGCT uses a modified version of the EPRI method in its own BCA process. The SGCT simplifies or bypasses some of the 10 steps process of EPRI. For example, there are no detailed characteristics needed in the use of the SGCT, requiring only a mapping of the assets-functions-mechanisms-benefits. The other major difference is the inclusion of several additional analyses in the tool, such as sensitivity analysis.

There are basically three modules in SGCT, which are: first the Project Characterization Module (PCM); second the Data Input Module (DIM); and third the Computational Module (CM), as shown in the figure below. The first module helps users determine the functionality of the projects by mapping the various assets provided by a smart grid project onto a standardized set of benefit categories. This module represents the first to fourth steps in EPRI’s ten step approach. In the second module, users can input

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the required data to calculate the project's specific benefits. The list of anticipated benefits is derived from the first module and the list of inputs needed is dependent on the individual formulas of the various benefit calculations. This module represents the fifth, sixth and ninth steps of EPRI's ten step approach. The last module then calculates the project's costs and benefits. It also provides a mean of sensitivity analysis, by changing the range of some basic inputs, such as costumer number, electricity price, and various inputs for further benefit calculations.

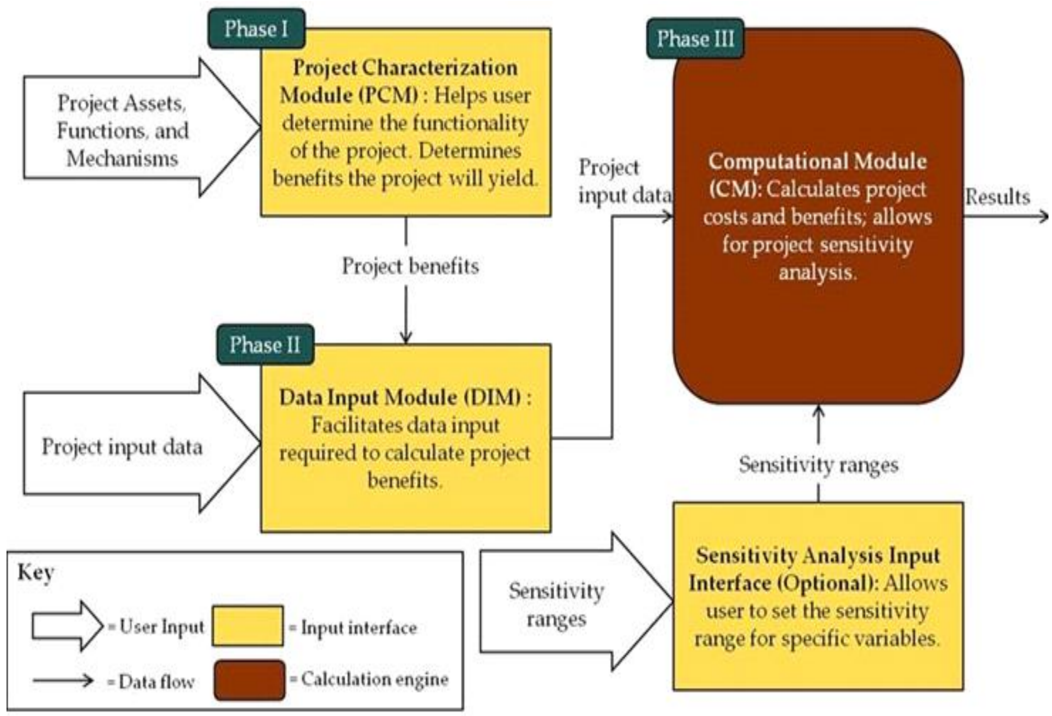


Figure 32 SGCT Architecture

Source: Navigant, 2011

III.2.2 Overview of the SGCT

The SGCT adopts an EPRI-based methodology to evaluating the Cost-Benefit Analysis of smart grid projects. The SGCT calculates the incremental costs and benefits of individual existing smart grid technologies. The user inputs the assets that their project will add to the power grid. Next the user chooses the functions that will be added to the grid by the application of the assets. Then the user adds mechanisms that result from the functions. These mechanisms determine the benefits that the project will yield. The final step is to monetize the value of these benefits through the use of provided calculation formulas.

The SGCT has a few issues that limit it from producing a definitive assessment of smart grid value. A key trait that could use more representation in the SGCT is flexibility. It struggles to combat some of the most common challenges of evaluating smart grids. The combined factors of fast-changing information technology, novel and cost-effective resources, multiple and overlapping energy markets, and new business strategies leads to high uncertainty about the future of smart grids, yet the SGCT relies on predefined assets that affect predefined functions that define predefined mechanisms which lead to predefined benefits. All of these predefined inputs are less valuable when considering the uncertainties and the assumptions being made.

Along with uncertainties of the future there is also some uncertainty as to what defines a smart grid. It is nearly impossible to take into account all of the complicating differences between one project and another. There can be any number of differing factors as a result of location alone.

The combined influence of all these uncertainties reduces the value of the single estimate of smart grid value that the SGCT produces. The SGCT methodology defines a standardized set of assets, functions, and benefits in order to evaluate all smart grid projects consistently. Yet it does not help address the numerous uncertainties.

The value of smart grid will be driven by future demand and supply side developments in the electricity sector. The SGCT provides an estimate based on the state of the present and current technologies and is unable to be updated as new information arises.

Another issue with the SGCT is based on its execution. The SGCT is an Excel-based program that was developed using Excel macro. While Excel macro combined with spreadsheet capability is a powerful platform to develop a program such as the SGCT, it has a number of disadvantages.

The excel-based toolkit has less than stellar performance. When running an analysis on an example smart grid project the SGCT has a long execution time which can be frustrating when trying to run detailed analyses with many different scenarios and assumptions.

Excel macro has low scalability and limited capability. The SGCT does not have the analysis capabilities required to accurately study the value of future smart grid power systems. It is limited in its ability to run truly detailed analyses. The SGCT attempts to provide reliable data on the incremental costs and benefits of smart grid technologies but it does not have the scale to do so. The SGCT lacks the potential to accommodate for growth in future smart grid investments.

In a similar vein the excel macro program is also limited in writing sophisticated computational algorithms. The SGCT relies on a simplified modelling approach by evaluating a standardized set of assets, functions, and benefits. It also leads to an inability to handle unusual situations and circumstances.

III.3 Plans and Progress for the Development of OOP Based Stand Alone Program

III.3.1 Proposal

Rather than attempting to provide a complete package populated by a comprehensive set of smart grid technologies such as the SGCT, our goal is to provide a highly flexible and scalable framework that allows users to quickly develop tools specific to their requirements. Flexibility and handling uncertainty are two key principles in our framework.

Similar to Ofgem's framework developed by Frontier Economics and EA Technology we have taken a more simplified approach to evaluating smart grid value. Our framework will be limited to the key factors that have the biggest impacts on smart grid value, and will instead be highly flexible in order to facilitate crafting the model to match the level of detail required by the user. New information and technologies constantly become available as smart grids become more developed. Our framework will be built to allow for updates as new information arises. This ensures flexibility and grants the framework the ability to handle uncertainties.

Our framework will use multiple technologies to provide a powerful development platform including XML, Excel spreadsheet, and Object Oriented Programming (OOP). In this proposal we will focus on addressing the shortcomings of the current SGCT and what improvements will be made on our own framework. Figure below shows the proposed hybrid architecture of the framework.

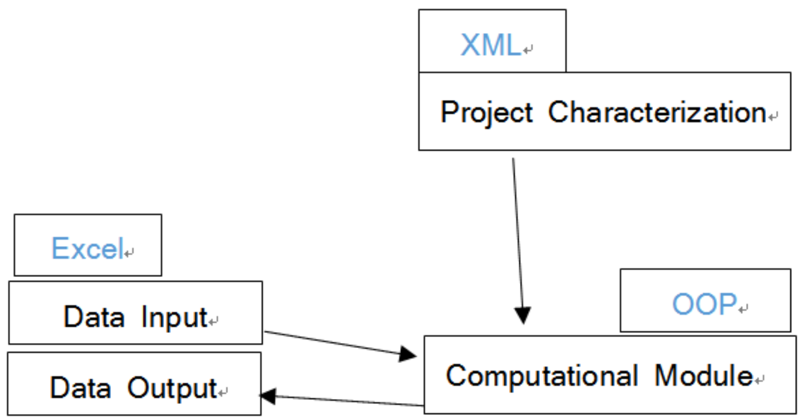


Figure 33 Hybrid Architecture of the Proposed Framework

- **Project Characterization**

The Project Characterization Module (PCM) in the SGCT allows users to characterize their projects by selecting project items such as assets, functions, mechanisms and benefits. The types of assets, functions and benefits are predefined limiting the amount of selections users can make.

It is ineffective to create a model with a set list, when dealing with the rapid development of smart grid technologies. It is much more desirable to allow for flexibility of adding or modifying the list of project items.

The user will be allowed to define project items through the use of XML.

XML is a popular standard technology commonly used to represent hierarchical data structure and relationships. The use of XML allows the user to freely edit and define project items according to the user's specific requirements. Users will be able to edit project items by editing XML data files or through the GUI that will be provided by the framework. XML enables flexible defining and mapping of assets, functions and benefits.

- **Data Input**

We will use Excel for data input because spreadsheet is an ideal environment that allows users to efficiently enter data and user inputs. The framework will read data from the Excel spreadsheet. There will be no predefined requirements for format of input data. The user will only need to specify the name of data, number of rows and columns and where the data starts in the spreadsheet.

Framework will read the data and then store it in a generic array, which will be fed into a corresponding computational module.

- **Computational Module**

The computational module should provide high scalability because it varies widely in complexity from a simple spreadsheet type calculation to highly sophisticated algorithm. The user may want to apply a different equation or algorithm for the same item based on location or circumstance.

Using this approach the runtime of execution should be very fast. This is where object oriented programming (OOP) and complied programming language such as C++ or C# comes into play.

Inheritance combined with polymorphism in object oriented language allows a framework to apply different algorithms by simply switching instance of client class object without changing the framework structure. Users can develop a class with custom algorithms derived from a template class in the framework. This class can be plugged in the framework as an add-in component at runtime.

For instance the framework has an abstract class called *Benefit* with empty virtual function called *Compute()*. The user defines a subclass derived from *Benefit* class called *AMIBenefit* with *Compute()* function which will actually compute benefits from advanced metering infrastructure.

If the user wants to apply a different computational model to AMI benefit, he can define another class called *AltAMIBenefit* with *Compute()* function different from *AMIBenefit* compute function.

The framework can compute alternative AMI benefits by simply creating an instance of *AltAMIBenefit* class instead of *AMIBenefit*.

The above example is an application of the *strategy pattern*. The strategy pattern is one of the software design pattern introduced in Gamma, et al (1994), which lets the algorithm to be selected at run-time independently from clients that use it.

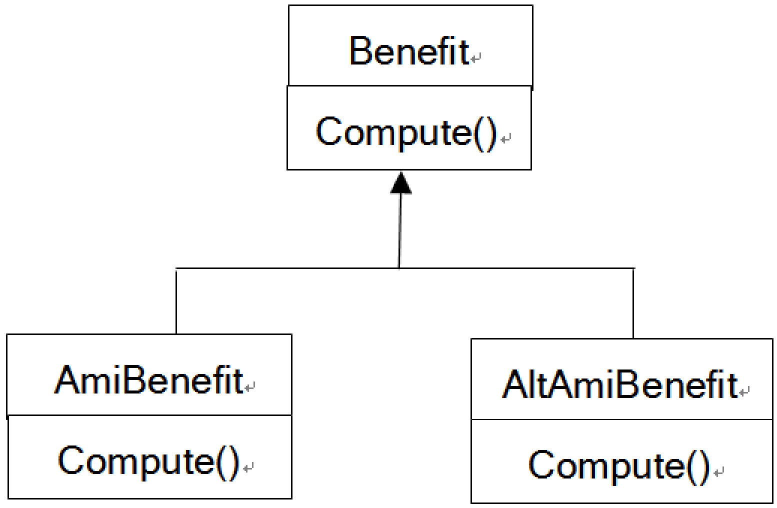


Figure 34 Strategy Pattern in UML

Computational modules developed with a compiled language are much faster than a program in an interpreted language such as Excel VBA macro.

- **Data Output and Visualization**

Since Excel provides powerful and flexible graphs and chart capabilities, we will use Excel to output data including graphs and charts.

Much like the Smart Grid Investment Model (SGIM) we will use multiple-tabbed worksheets to display data in an organized and meaningful way. Having multiple frames of references to compare results to and ease of access to changing the scenario and assumptions is a valuable tool.

- **Multiple Scenarios and Batch Mode**

The user will want to run multiple scenarios in batch mode to compare results in different options and environments.

The framework will allow the user to define multiple scenarios such as different benefit selections and different application of computational model to create multiple results at once and allow a medium for easily comparing data.

III.3.2 Smart Grid Program Development Plan

The development of the proposed Smart Grid program would be divided into three phases, which can be seen in the figure below.

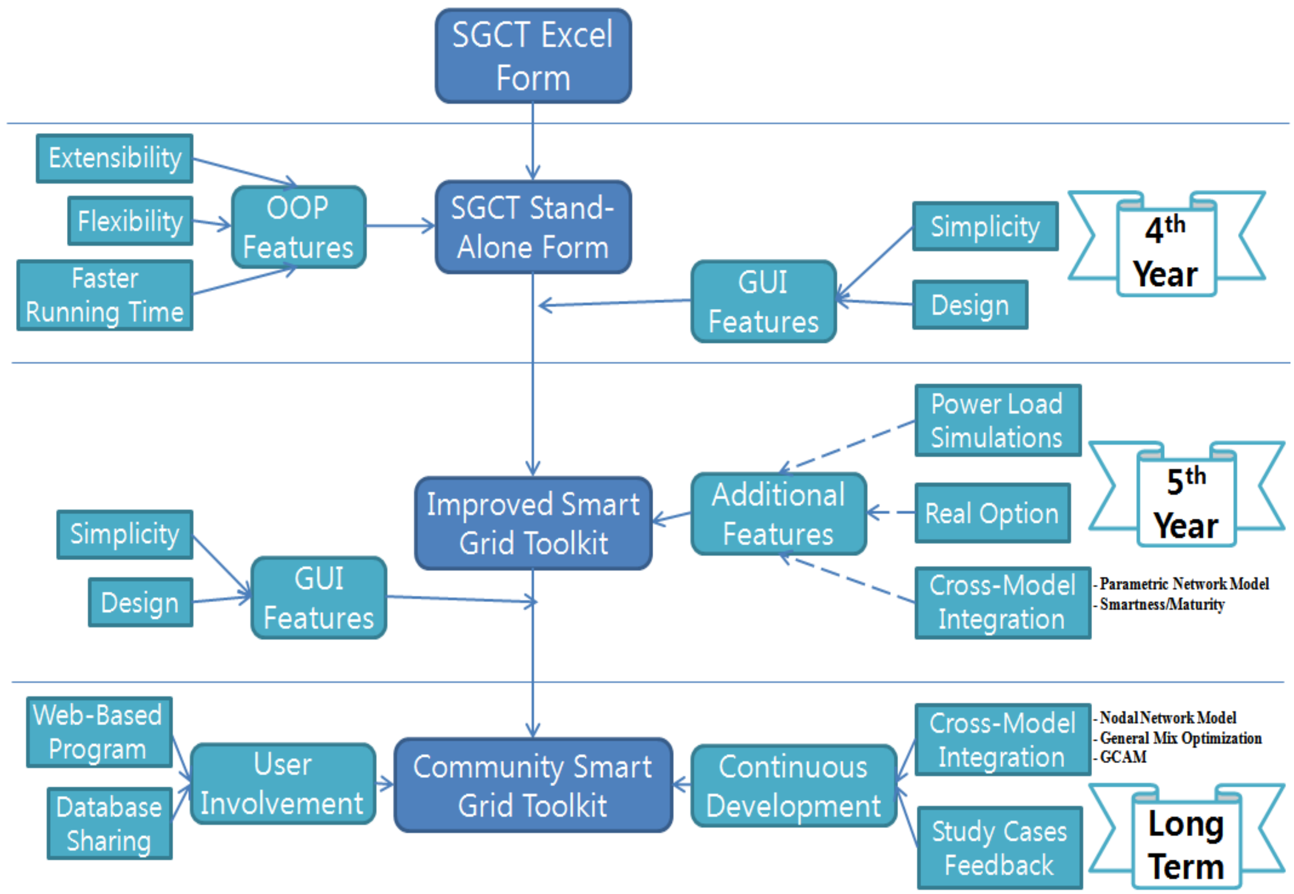


Figure 35 Evolution of the Smart Grid Program

- **SGCT Excel Form to SGCT Stand Alone From**

In this phase, the original SGCT which is made by DOE would be transformed into a stand-alone program. This step is basically done to ease the future development of the program itself. Within the whole project, this step would be done in the 4th Year. There are two things that would be the features in this step, that are Object Oriented Programming (OOP) and Graphic User Interface (GUI).

In the previous part, the discussion of Smart Grid Computational Toolkit from the software engineering point of view has been done in length. In essence, by translating the excel based toolkit into an object oriented program using C#, the program would be more flexible, extendable, and with faster running time. Although of course, as discussed before, the excel would still have an important role in this new toolkit, the main paradigm would still be an OOP.

The features that are expected from an OOP are based on these four major principles:

- ✓ Encapsulation, that is the ability to hide and bind data within a class. This feature would protect the data from uncontrollable change from the outside of a class.
- ✓ Abstraction, that is the ability to represent a data only based its basic properties. This feature would provide flexibility.

- ✓ Inheritance, that is the ability to a class to reuse an available class, if needed. This feature would make a program simpler by offering extensibility. Thus, a programmer does not have to rewrite some lines of program that have been available before.
- ✓ Polymorphism, that is the ability to set multiple definitions for a method/object. Similar to the previous feature, it would give simplistic yet flexible approach on programming the toolkit.

For the purpose of our toolkit development, the OOP would offer:

- ✓ Helping the definition and further addition of assets, benefits, functions, and the quantification/monetization formula of benefits
- ✓ Faster running time due to compilation
- ✓ Flexibility to incorporate other features and/or combining the toolkit with other models

The other things that would be done is the GUI design. To be noted, this step would also be available on the next phase of program development. By this phase, the translated program would have a GUI that is easy to use and with appearance that is designed for the user's comfortability.

- **SGCT Stand Alone Form to Improved SG Program**

This is the main phase of the program improvement. In this phase, the additional network model and wider electricity sector model (following Frontier Economics, among other) would take place. In the discussion of other countries BCA's, the report done in UK by OFGEM, Frontier Economics and EA Technologies is one of those that have interesting features and could be potentials for the improvement of our Smart Grid Program. Figure below shows the three models within Frontier Economics' BCA. In the evolution of the Smart Grid Toolkit graph, the introduction of additional features in this phase would include: power load simulations, real option, and cross model integration, such as parametric network model and smartness/maturity

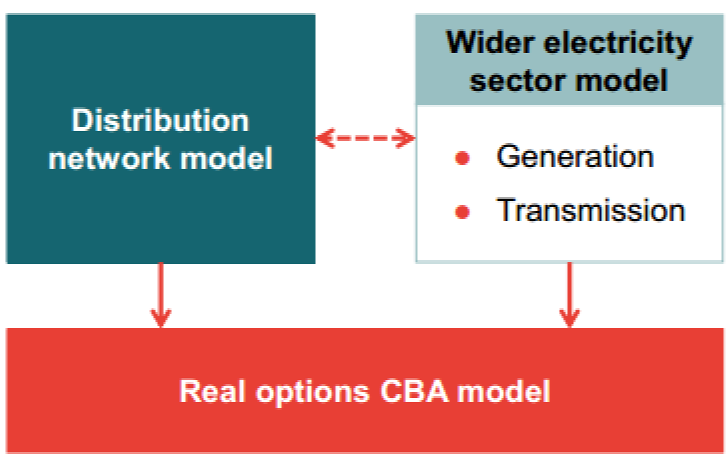


Figure 36 The Three Models in Frontier Economics' BCA

The concept of real options CBA model has been discussed in the previous parts. For the purpose of improving the smart grid program, the real options could be potentially used for sensitivity analysis and long term scenarios work. Although the issues of work flow and the complication risen from it should be considered and discussed. Still, it could give the BCA a new perspective--one that is not based on a linear timeline, but composed of an array of scenarios.

Power load simulations module is needed to properly estimate the expected power load through the period of the BCA. It is important for the BCA because it would affect the calculations of the benefits itself, since some formulas of benefit monetization use the values from power load simulations. In Smart Grid Investment Model (SGIM), one of the important features is the hourly load modeling (See figure below) In Frontier Economics, the wider electricity network is basically the power load simulation. Looking at these two BCA tools, it would be a proper move to implement a more sophisticated power load simulations module in the improved smart grid tool.

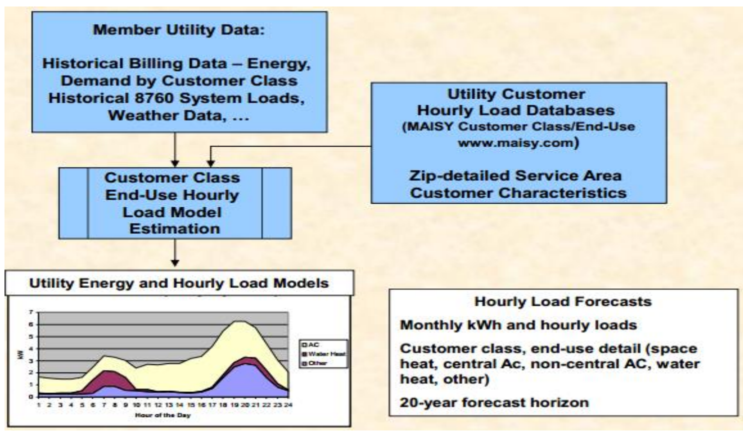


Figure 37 SGIM Hourly Load Models

For a cross model integration, an obvious choice is the smart grid smartness/maturity measurement, which is also developed in Annex 3. Using the questionnaires developed by Annex 3 Expert meeting or others, we could improve the smart grid toolkit by incorporate them into the program. By putting the required data, the program could calculate the radar graph of a smart grid project's maturity, similar to those shown in the earlier part of this report. Since some of the technical data asked in the questionnaire would also be used in the benefit calculation, the additional feature could be justified.

The other model that can be included is the network model, which basically simulates the power grid. There are two perspectives of a network model:

- ✓ Nodal Model, which model the full load flow of a network. The line, bus, substations, and other components of power grid would be then modeled as nodes and connections. This model would provide a very detailed representation of a power grid. Some examples of this nodal model is GridLab, ETAP, and ASPEN[51]

[51] http://www.openelectrical.org/wiki/index.php?title=Power_Systems_Analysis_Software would give us other power system analysis softwares

- ✓ Parametric Model, which use a set of representative parameters to model the whole network. One of the examples is the one used by Frontier Economics' BCA. There, the power grid is modeled by its "headroom", the difference between the rating and the actual level of several parameters, such as voltage, power quality, and fault level. The "headroom" can be seen as the how much "available" a certain parameter is. Then, they also model some representative networks, that are 33kV, 11kV, LV urban, LV suburban, and LV rural.

For this phase of the smart grid program development, the parametric model seen in Frontier Economics' BCA would be the best candidate. It must be noted that the current report of the BCA is still quite unclear on the technical details of its network model. Thus, a proper joint work with the OFGEM and/or Frontier Economics is needed.

As mentioned in the previous part, this phase would also have a GUI feature. The addition of new features would undoubtedly add complication and complexion to the program, too. A good GUI design is needed so that the user can utilize the software easily.

- **Improved SG Program to Community SG Program**

In this phase, which would have the long term target of our smart grid program development, the toolkit would be evolved into a community smart grid program. By community, we would like to achieve user involvement and continuous improvement of the program. To do this, some steps are needed:

- ✓ Building the web-based program (or downloadable desktop program) so that various user from all around the world can utilize the smart grid program
- ✓ Developing a database center for various data and parameters related to smart grid BCA
- ✓ Creating a forum so that users can give their feedback of the experience using the smart grid program. It could also serve as study cases sharing between users.
- ✓ Continuous improvement of the smart grid program based on the feedback
- ✓ Exploration of potential features and/or cross-model integrations

By doing that, it is expected that the Smart Grid Program would be viewed and enjoyed by wider audience, which would contribute to the further development of the model itself. Some potentials that can be done to improve the model further is additional modules/connections to detailed nodal network model, power mix optimization software, renewable energy and/or electric vehicle software, or even including it within a broader Integrated Assessment Model, such as GCAM (Global Change Assessment Model).

III.3.3 Future Work, Job Allocation, and Timeline

We propose a framework for developing a smart grid cost benefit analysis tool. Our framework is oriented to provide a highly flexible and scalable environment that gives users tools to develop an end user package like the SGCT, rather than providing a complete tool.

The ideas behind our framework were in part taken from the lessons learned from examining other BCA tools such as the SGCT, the SGIM, and Ofgem.

Our tool will be designed to be a starting point for users. Users will then shape the tool to fit their specific needs. This will make our tool very flexible and accommodating for interfacing with third-party tools. We seek to take the best advantage of state-of-the-art technologies available today.

For the future development of the ISGAN's stand alone program of BC Analysis, the works needed are divided into three big divisions:

- **Review on Methodology and Toolkit**

This part serves as preliminary studies for the whole project. Results from this report and additional experiences from the previous report would be the base for the program development. The ideas of a smart grid BCA program should be discussed among the team members, especially with the software engineering experts. Along the way, additional methodology and toolkit would still be added, if needed.

- **Model Research**

This part deals with the development of the model for the program. Among various frameworks, methodologies, and toolkits surveyed and discussed in the previous part, a model must be developed. The model research team would be responsible for the contents of the program: the benefits quantification and monetization methods (linkage matrixes, calculation procedures, parameters needed), the costs setup, the important results to be shown and their analyses, etc. Also, supplementary techniques such as real options, sensitivity analyses, and load simulation must be set in this part. In Model Research, two important sub-parts are:

- ***Benefits and Costs Setup***

As shown in Task II of this report, there are various ways of quantifying the benefits as well as listing the costs. Since the program should be able to estimate benefits and costs of any smart grid deployment projects, those variations must be considered and incorporated into the program.

- ***Modeling the BCA***

Although the Benefits and Costs Setup would be the main part of the BC Analysis program, there are various elements of the proposed program that should be modeled properly. For example, the results can be represented in various ways, such as Net Present Value (NPV) and Internal Rate of Return (IRR), among others. Sensitivity analysis is another supplementary analysis that should be provided in the program. Also, for a complete review of a smart grid projects, various forms found in the new EPRI report (EPRI, 2012) could be integrated with the program.

- ***Data and Parameters Collection***

This subpart would support the Case Studies, to be explained in the next part. It basically deals with collecting the data and parameters needed to run the BCA, which should've been described in the previous subpart.

- **Program Development**

This part is mainly related with the whole software engineering effort to build the stand alone program itself. Basically there are two subparts here: the hardcode programming and the visualization (GUI) design. Additionally, the case studies using the built program must be done throughout the project period for improvement purpose.

- ***Programming: Design, Coding, Revision***

First, the program must be designed, which includes definition of requirements, case uses, and general workflow and algorithms. The inputs from the other two parts would be the basis for this. The resulting Unified Modeling Language (UML) pseudo-code should assist the programrs on the process of coding. The C# that heavily utilizes Object Oriented Programming would be the candidate for the coding. As usual, debugging and revisions process would always go on based on suggestions from other subparts.

- ***Graphic User Interface (GUI) Design***

The GUI would be one of the most important aspects of this program development. As the user range of this program is quite wide, from those with background in engineering to the energy economists, from the utilities executives to policy makers, the program must exhibit simplicity and user-friendliness. Even so, the design must still able to fulfill the requirements for a proper and powerful BC Analysis.

- ***Case Studies***

Case Studies subpart would utilizes data and parameters gathered in the previous part to test both the model and the program of the BC Analysis. Improvements would be undergone based on the outputs of these case studies.

Figure below shows the proposed job allocation between the available members of the project.

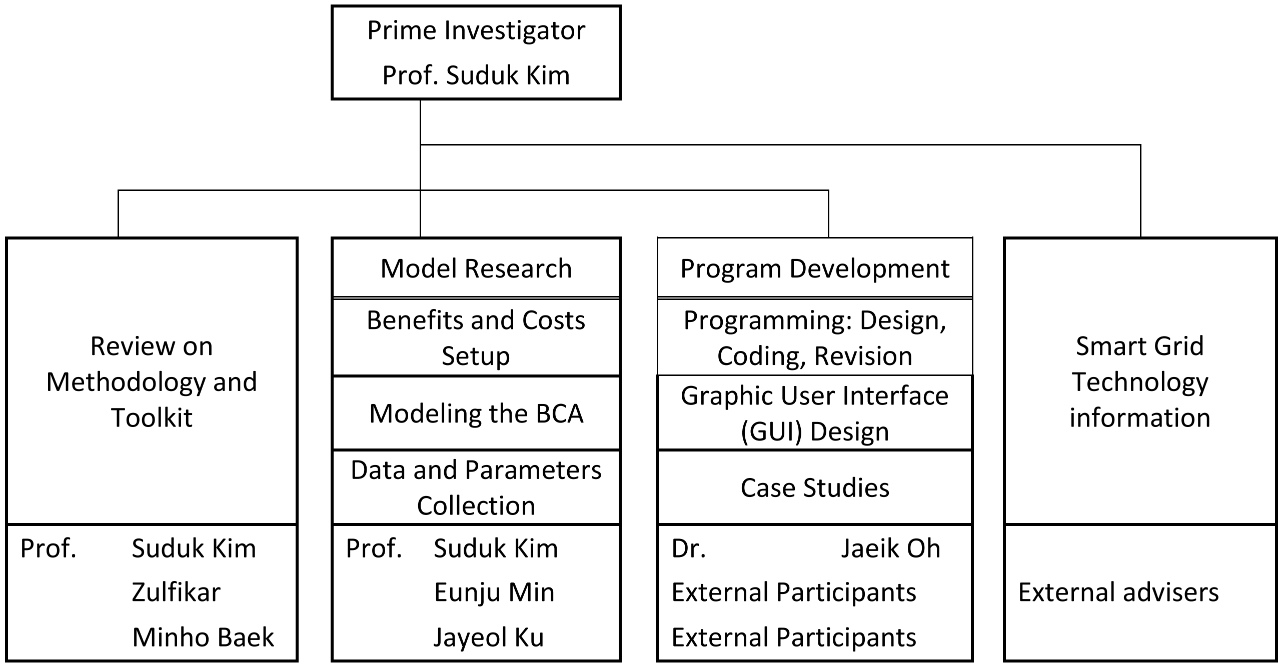


Figure 38 Work Division for the Program Development

Table below then shows the timeline proposed for the program development, within the 2 years period.

Table 34 Timeline for the Program Development

No.	Key Milestones		Timeline											
			4th Year				5th Year				6th Year			
			1/4	2/4	3/4	4/4	1/4	2/4	3/4	4/4	1/4	2/4	3/4	4/4
1	Review on Methodology and Toolkit													
2	Model Research	Benefits and Costs Setup												
		Modeling the BCA												
		Data and Parameters Collection												
3	Program Development	Programming: Design, Coding, Revision												
		Graphic User Interface (GUI) Design												
		Case Studies												

III.4 Fourth Year's Project

III.4.1 Fourth Year's Work to be Done

Table below then shows the works to be done in the first phase of Smart Grid Toolkit development. In this phase, the emphasis would be on the close replication of the DOE's excel based toolkit. Improvement would be taken upon by translating it into a object oriented based program. C# is chosen as the main language for the new toolkit. Other than that, additional works on the maturity measurement would need to be done. This includes the application of ISGAN questionnaires and its follow up with the other Annex 3 members. Also, for the preparation of the next stage, close examination and discussion of the additional features to be added would require us to look through the other smart grid BCA toolkits and related reports for potential application. Although the main candidate would be the Frontier Economics' BCA, others would also be available for consideration.

Table 35 Work for the Fourth Year

Sub-Task Division	Work to Do	Share	Detailed Targets
Follow up of The Maturity Measurement	o Follow up of the Smartness Measurement that has been conducted	10	o ISGAN questionnaires have been filled with data from KEPCO and results graph has been drawn o The result would be discussed among the national experts of ISGAN
	o Possible Improvement of the Maturity Measurement	10	o Results from other countries would be gathered together to get better idea of the effectiveness of the available measurement method (questionnaire) o Based on inputs and the results of questionnaires, an improvement (content or method) might be done
Replication of Smart Grid Following DOE's Smart Grid	o Close examination on the DOE's SGCT	10	o Examination of the current excel type SGCT, especially the building blocks (matrixes, calculations formula, VBA codes) o Analysis of the current model's limitations and possible improvements

	o Conversion from an Excel based program to Stand Alone type	40	o DOE's SGCT would be the basis of the toolkit development o The models would be converted following Object Oriented Programming (OOP)s framework which would provide extensibility, flexibility and faster running time o The excel forms would still be used an integrated with the stand alone program seamlessly
	o Graphic User Interface Development	15	o The GUI would be developed so that user can use the stand alone SGCT easily o The GUI would be designed following software development principle
Study of Additional Features to be Added	o Discussions with OFGEM and Frontier Economics o Other Models Study	15	o Discussion of the path taken for the BCA toolkit development within the working group of ISGAN national experts o Discussion with selected members of ISGAN national expert and UK's OFGEM contact point o Study the detailes of Frontier Economics network model, wider electricity model, and real option model o Study on the other models, such as SGIM, and discuss the possibility of its integration to the toolkit
Total	-	100	-

III.4.2 Fourth Year's Preparation: Details on DOE's Toolkit

In the preparation of the fourth year work, we have looked on the current DOE's toolkit and examined its features. Within that, the flow of works, the concept and matrixes, even the code itself have been discussed. In this part of report, the summaries of those would be reported.

- **Benefit Calculation.**

This process takes up from phase one to phase two. The process done in the tool is explained by the figure below. It started from identification of Smart Grid technologies available (Assets) in the project. Then from those assets, the user must determine the functions those Assets can do. Each function would have several mechanisms, which in turn would provide some benefits, to the utility, consumer or society. Then based on the list of benefits that can be provided by a smart grid project, a monetized value is calculated.

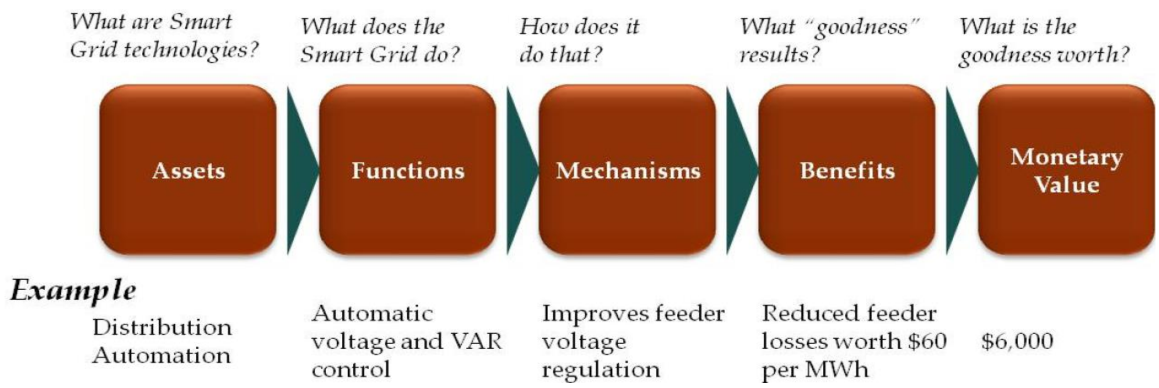


Figure 39 Illustration of the Translation of Smart Grid Assets to Monetary Value (Navigant, 2011)

Source: Navigant, 2011

Each process above will have its own standardized map. Figure below shows the illustration of Assets to Functions to Mechanisms to Benefits mapping in SGCT. It can be seen that the function can be mixed, such as that an asset can have several functions as well as a function can be done by several assets. The same goes for any of the mapping, up to mechanisms to benefits mapping.

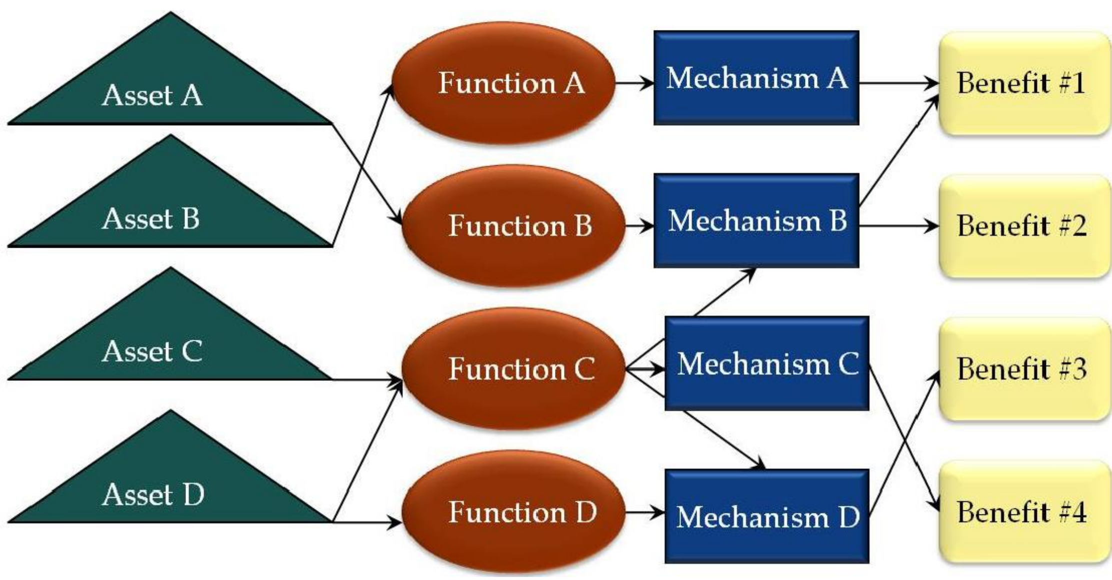


Figure 40 Illustration of Asset, Function, Mechanism, Benefit Mapping (Navigant, 2011)

Source: Navigant, 2011

- ***Assets to Functions***

There are 21 assets listed in the tools, which can be divided into five categories: Customer Assets, AMI Assets, Distribution Assets, Transmission Assets, and Other Assets. Please note that the listed assets here is different from the one in EPRI's Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects (2011, Table 4-4 Linkage of Smart Grid Assets and Functions), which has 19 assets.

Table below shows the mapping of Assets to Functions in SGCT. There are 15 functions that are defined in the tools, starting from Fault Current Limiting to Distributed Production of Electricity. In EPRI (2010), the function is divided into two parts, which is called Functions and Enabled Energy Resources (due to Functions). Here the Enabled Energy Resources is just another part of Functions (as Other). Also, it must be noted that the PEV (Plug-in Electric Vehicle) and Distributed Generation in EPRI (2010) are combined together into Distributed Production of Electricity in DOE's SGCT.

Table 36 Mapping of Assets to Functions (DOE SGCT)

Smart Grid Assets	**Functions**														
	Delivery												Use	Other	
	Fault Current Limiting	Wide Area Monitoring, Visualization and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder and Line 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	Storing Electricity for Later Use	Distributed Production of Electricity
Advanced Interrupting Switch										V					
AMI/Smart Meters								V			V		V		
Controllable/regulating Inverter							V	V							
Customer EMS/Display/Portal													V		
Distribution Automation					V	V	V	V				V			
Distribution Management System			V		V	V	V	V			V	V			
Enhanced Fault										V					

Detection Technology															
Equipment Health Sensor			V						V						
FACTS Device				V											
Fault Current Limiter	V														
Loading Monitor			V						V			V			
Microgrid Controller							V								
Phase Angle Regulating Transformer				V											
Phasor Measurement Technology		V	V	V	V		V	V		V					
Smart Appliances and Equipment (Customer)													V		
Software - Advanced Analysis/Visualization		V	V												
Two-way Communications (high bandwidth)		V			V	V	V	V			V	V			
Vehicle to Grid Charging Station													V		
Very Low Impedance (High Temperature Superconducing) cables				V											
Distributed Generator (diesel, PV, wind)								V							V
Electricity Storage device (e.g., battery, flywheel, PEV etc)								V						V	

Figure below shows the windows that show up in the process of executing DOE's SGCT. In this window user is required to choose the assets of its own smart grid project from various list of defined assets. It is classified into four class which are:

- ✓ Customer Assets
- ✓ AMI Assets
- ✓ Distribution Assets
- ✓ Transmission Assets
- ✓ Other Assets

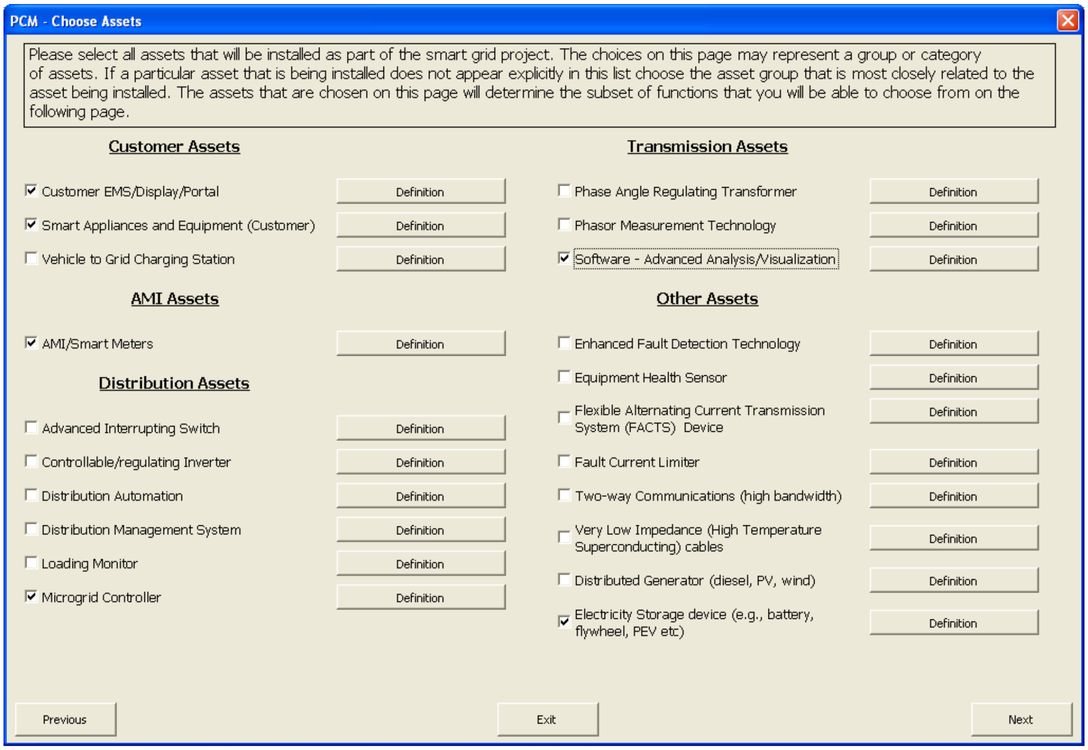


Figure 41 Choosing Assets in DOE's SGCT

The next step is choosing functions that can be enabled by the assets that already chosen in the previous step. Figure below shows the example of the window that showed up for that process.

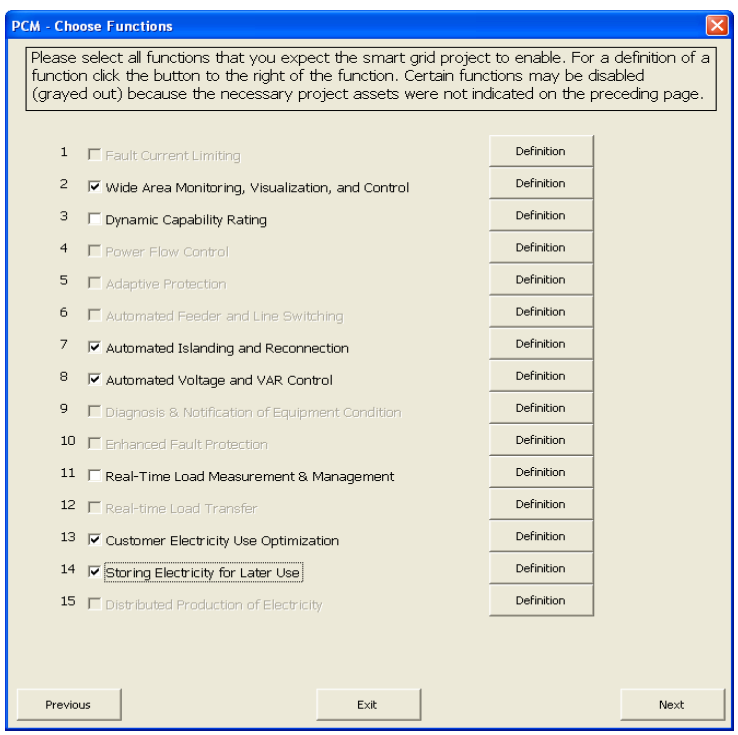


Figure 42 Choosing Functions in DOE's SGCT

In the macro code (Visual Basic for Applications, VBA), the mapping of function to asset can be found in object "Function to Asset Map" (sheet 16)

✧ *Functions to (Mechanisms to) Benefits*

In the original EPRI's Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects (2010), there is only a mapping of Functions to Benefits, such as shown below. There are four categories of benefits: Economic, Reliability, Environmental and Security, which then translates into 22 types of benefits, starting from Optimized Generator Operation to Reduced Widescreen Blackouts.7

Table 37 Mapping of Functions to Benefits (with comparison to EPRI version)

EPRI: Stationary Electricity Storage + Plug-in Electric Vehicle

Benefits			Functions														
			Fault Current Limiting	Wide Area Monitoring, Visualization, and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder and Line 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	Storing Electricity for Later Use	Distributed Production of Electricity
Economic	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 T&D Equipment Maintenance Cost									•						
		Reduced T&D Operations Cost						•		•							
		Reduced Meter Reading Cost											•				
	Theft Reduction	Reduced Electricity Theft											•				
	Energy Efficiency	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-10 Emissions				•		•		•	•		•	•	•	•	•
Security	Energy Security	Reduced Oil Usage (not monetized)						•			•		•			•	
		Reduced Widescale Blackouts		•	•							•					

Mapped in EPRI

In the SGCT, though, the concept of mechanisms is introduced as a linkage between functions and benefits. The complete mapping from functions to mechanisms to benefits is shown in the appendix.

Each function can have 1 to 13 mechanisms. Each mechanism, in turn, can lead to one to three benefits. Through these mechanisms to benefits mapping, the resulting functions to benefits mapping in SGCT will be exactly the same with the one from EPRI (2010)

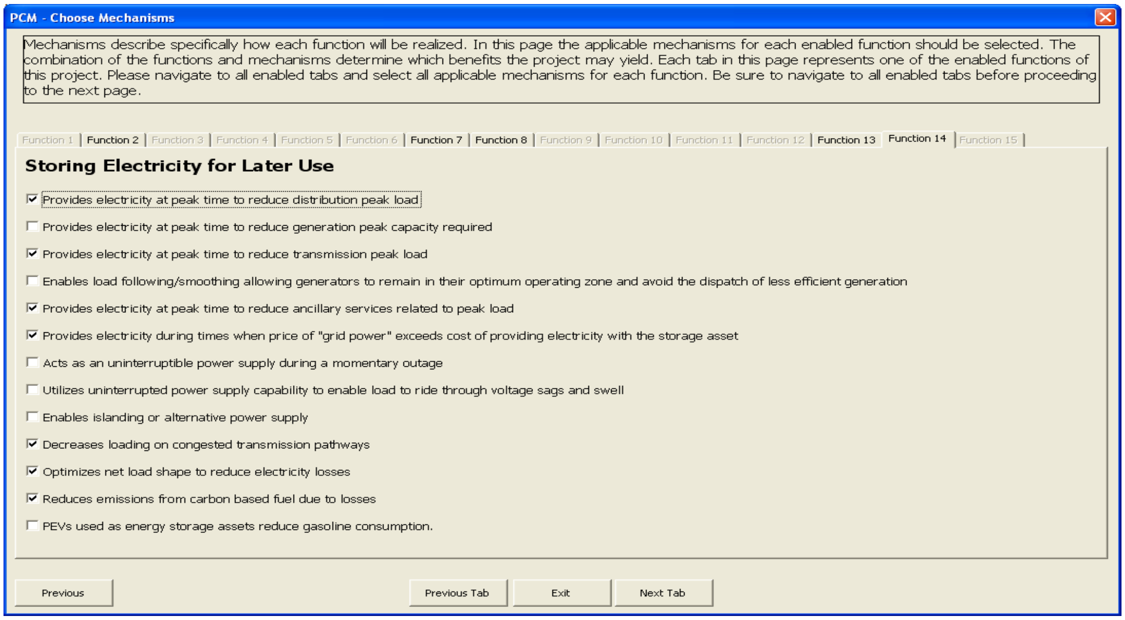


Figure 43 Choosing Mechanisms in DOE's SGCT

Figure above shows the process of choosing mechanism in DOE's SGCT. For each function that has been chosen from the previous step, there will be a unique tab with several pre-defined mechanisms. These mechanisms will lead to the benefits of smart grid. Once we choose all the mechanisms that could be realized by our Smart Grid project, the mechanism to benefit table will give the resulted benefits. Figure below shows the result, which is a function-benefit chart. The green cells show the relationship of function and benefit that can be realized by the Smart Grid project. After this, the next process in monetization of each benefit listed in the chart.

Function-Benefit Chart is
CORRECT
Proceed to the Data Input Module (DIM)

Function-Benefit Chart is
INCORRECT
Return to Initial Project Characterization Module (PCM)

Benefits			Smart Grid Functions														
			Delivery												Use	Other	
			Fault Current Limiting	Wide Area Monitoring, Visualization, and Control	Dynamic Capability Rating	Power Flow Control	Adaptive Protection	Automated Feeder and Line 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	Storing Electricity for Later Use	Distributed Production of Electricity
Economic	Improved Asset Utilization	Optimized Generator Operation		YES													
		Deferred Generation Capacity Investments															
		Reduced Ancillary Service Cost													YES	YES	
		Reduced Congestion Cost													YES	YES	
	T&D Capital Savings	Deferred Transmission Capacity Investments														YES	
		Deferred Distribution Capacity Investments														YES	
		Reduced Equipment Failures															
	T&D O&M Savings	Reduced T&D Equipment Maintenance Cost															
		Reduced T&D Operations Cost															
		Reduced Meter Reading Cost															
	Theft Reduction	Reduced Electricity Theft															
	Energy Efficiency	Reduced Electricity Losses								YES						YES	
	Electricity Cost Savings	Reduced Electricity Cost														YES	
Reliability	Power Interruptions	Reduced Sustained Outages							YES								
		Reduced Major Outages		YES					YES								
		Reduced Restoration Cost															
	Power Quality	Reduced Momentary Outages															
		Reduced Sags and Swells															
Environmental	Air Emissions	Reduced CO2 Emissions								YES					YES	YES	
		Reduced SOx, NOx, and PM-10 Emissions								YES					YES	YES	
Security	Energy Security	Reduced Oil Usage (not monetized)															
		Reduced Wide-scale Blackouts															

Figure 44 Function-Benefit Chart in DOE's SGCT

In macro code (VBA), these mappings can be examined in objects "Fxn_Benefit List" (Sheet 29), "Fxn-Mechanisms" (Sheet 47), "FxnMech to Benefits List" (Sheet 19), and "Function-Benefit Chart" (Sheet 25).

✧ *Benefits Monetized Value*

Once the list of benefits is produced, the SGCT then proceeds to the next step, calculating the monetized value of SG benefit. The complete calculations formula are explained Appendix A.1 Benefit Calculations of "User Guide for the US Department of Energy Smart Grid Computational Tool (SGCT): Guide for SGCT Public Version 1.3 (Navigant, 20100). Its summary can be examined in Table 9.

It must be noted that although in the previous processes a benefit can be achieved by various mechanisms of functions, the benefit calculation process itself does not necessarily need to be based on or contributed by those specific mechanisms. Some benefit calculation only considers the general picture of its benefit itself. In other words, the benefit is not calculated by adding each mechanism's effect on creating the benefit.

Figure below shows the example of benefit calculation which is quite in detail. It can be seen that each function has its own monetization calculation. Thus the total monetized benefit of Optimized Generator Operation is the sum of Wide Area Monitoring, Visualization & Control monetization part and Stationary Electricity Storage and PEV monetization part.

Detailed

Benefit	Functions & Enabled Energy Resources	Input Parameters	Monetization Calculation
Optimized Generator Operation	• Wide Area Monitoring, Visualization, and Control • Stationary Electricity Storage • Plug-in Electric Vehicles	• Hourly Generation Cost ($/MWh) • Annual Generator Dispatch (MWh) • Annual Energy Storage Efficiency (%)	For Wide Area Monitoring, Visualization, & Control: **Value ($)** = [Annual Generation Cost ($)]$_{Baseline}$ - [Annual Generation Cost ($)]$_{Project}$ For Stationary Electricity Storage and PEV: **Value ($)** = {[Hourly Generation Cost ($/MWh) * Annual Generator Dispatch (MWh)]$_{Baseline}$ – [Hourly Generation Cost ($/MWh) * Annual Generator Dispatch (MWh)]$_{Project}$}* Energy Storage Efficiency (%)
Deferred Generation Capacity Investments	• Customer Electricity Use Optimization • Distributed Generation • Stationary Electricity Storage • Plug-in Electric Vehicles	• Price of Capacity at Annual Peak ($/MW), • EER Use At Annual Peak (MW) • Capital Carrying Charge of New Generation ($/yr) • Time deferred (yrs)	**Value ($)** = [Price of Capacity at Annual Peak ($/MW) * EER Use or Customer Optimization at Annual Peak (MW)]$_{Baseline}$ - [Price of Capacity at Annual Peak ($/MW) * EER Use or Customer Optimization at Annual Peak (MW)]$_{Project}$ Or **Value ($)** = Capital Carrying Charge of New Generation ($/yr) * Time deferred (yrs)

Figure 45 Example of Benefit Calculation which is Related to Its Functions

As mentioned above, the calculation of benefit is not necessarily in detailed case as previous case. Figure below shows the example of generalized and simplified benefit calculation. As can be seen, although the benefit of Reduced Wide-scale Blackouts can be realized through Wide Area Monitoring & Visualization, Dynamic Capability Rating, and Enhanced Fault Detection functions, the monetization calculation simply uses the number of events (Wide-scale Blackouts) times the estimated cost per event in baseline case and project case. Thus there is no "Dynamic Capability Rating-contributed benefit" or "Enhanced Fault Detection-contributed benefit".

Benefit	Functions & Enabled Energy Resources	Input Parameters	Monetization Calculation
Reduced Oil Usage	• Automated Feeder Switching • Diagnosis & Notification of Equipment Condition • Real-Time Load Measurement & Management • Plug-in Electric Vehicles	• Number of Switching or Maintenance Operations Completed (# of events) • Average Miles Travelled per Operation (Baseline miles/operation) • Average Fuel Efficiency for Service Vehicle (gallons/mile) • kWh consumed (kWh) • Electricity to Fuel Conversion Factor Simplified	For Automated Feeder Switching, Diagnosis & Notification of Equipment Condition, & Real-Time Load Measurement & Management: **Value ($)** = {Operation (# of events) * Average Miles Travelled per Event (miles/event) *Average Fuel Efficiency for Service Vehicle (gallons/mile) * Oil Conversion Factor (barrels of oil/gallon of gasoline)}$_{Baseline}$ - {Operation (# of events) * Average Miles Travelled per Event (miles/event) *Average Fuel Efficiency for Service Vehicle (gallons/mile) * Oil Conversion Factor (barrels of oil/gallon of gasoline)}$_{Project}$ For PEVs: **Value ($)** = {Electricity consumed (kWh) * Gasoline Conversion Factor (gallons of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline)}$_{Baseline}$ - {Electricity consumed (kWh) * Gasoline Conversion Factor (gallons of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline)}$_{Project}$
Reduced Wide-scale Blackouts	• Wide Area Monitoring & Visualization • Dynamic Capability Rating • Enhanced Fault Detection	• Number of Events (# of events) • Estimated Cost per Event ($/event)	**Value ($)** = [Number of Events (# of events) * Estimated Cost per Event ($/event)]$_{Baseline}$ - [Number of Events (# of events) * Estimated Cost per Event ($/event)]$_{Project}$

Figure 46 Example of Benefit Calculation which is Generalized and Simplified

In benefit calculation of SGCT, it is possible to have two types of calculation for each benefit, which is called standard and optional calculation. Each calculation will have different set of inputs that need to be provided by the user. For example, let's examine the calculation for Reduced Ancillary Service Cost. The standard calculation is:

**Value ($) =** [Ancillary Services Cost ($)]$_{\text{Baseline}}$ - [Ancillary Services Cost ($)]$_{\text{Project}}$

which only needs one type of input: Ancillary Service Cost ($).

The optional calculation for the same benefit is:

Value ($) = [Σ (Price of Ancillary Service ($/MW) * Purchases (MW))]$_{\text{Baseline}}$ - [Σ (Price of Ancillary Service ($/MW) * Purchases (MW))]$_{\text{Project}}$

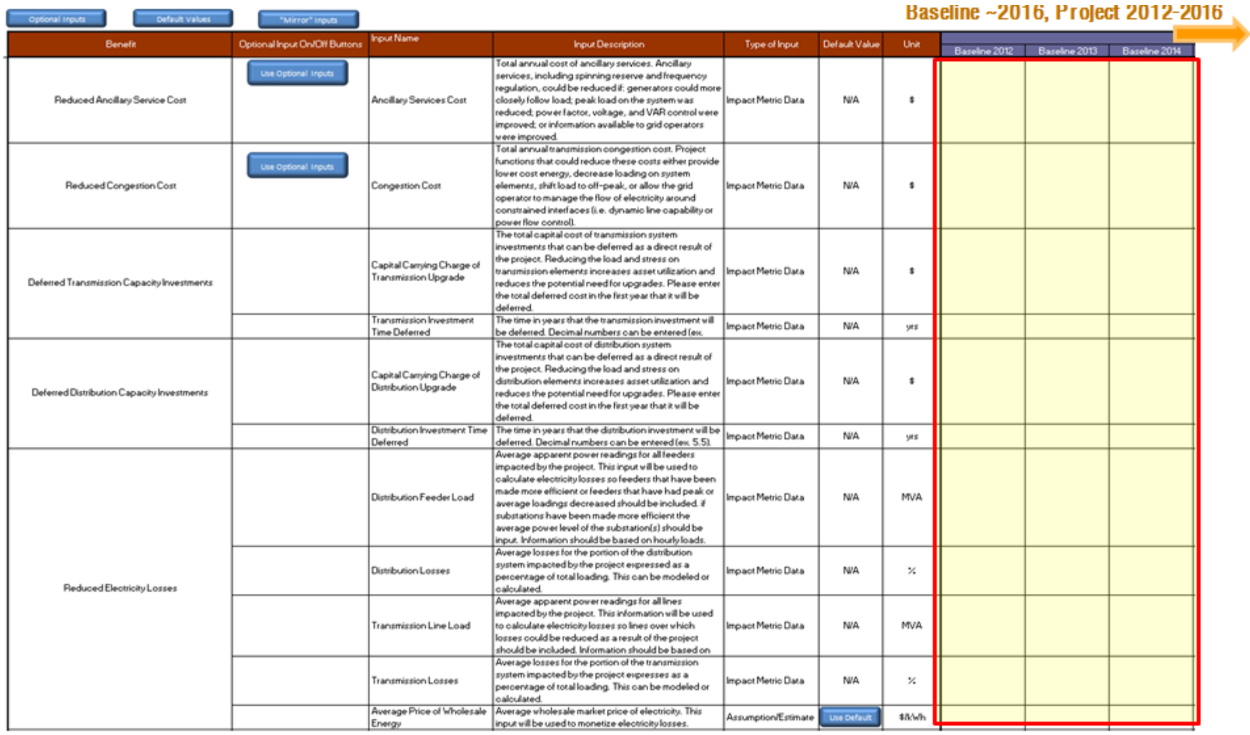
which requires the user to provide these inputs:

- ✓ Average Price of Reserves ($/MW)
- ✓ Reserve Purchases (MW)
- ✓ Average Price of Frequency Regulation ($/MW)
- ✓ Frequency Regulation Purchases (MW)
- ✓ Average Price of Voltage Control ($/MVAR)
- ✓ Voltage Control Purchases (MVAR)

It can be noticed that in this case, the Ancillary Services that is considered in this calculation is Reserve Purchases, Frequency Regulation Purchases, and Voltage Control Purchases.

Since these key concepts can be very technical, it is advisable to examine closely Appendix B.2 Detailed Explanation of SGCT Inputs of the User Guide (2011).

Figure below shows the input sheet that is shown in the DOE's SGCT. In this sheet, a user must input all the data and parameters required to assess/monetize a specific benefit. There is an option to fill it with the default parameter, if available. Another option is provided to change the formula of benefit monetization. As discussed above, a benefit can be monetized following more than one formula. Choosing a formula would depend on the data availability.



Optional Inputs | Default Values | "Mirror" Inputs

Baseline ~2016, Project 2012-2016

Benefit	Optional Input On/Off Buttons	Input Name	Input Description	Type of Input	Default Value	Unit	Baseline 2012	Baseline 2013	Baseline 2014
Reduced Ancillary Service Cost	Use Optional Inputs	Ancillary Services Cost	Total annual cost of ancillary services. Ancillary services, including spinning reserve and frequency regulation, could be reduced if: generators could more closely follow load; peak load on the system was reduced; power factor, voltage, and VAR control were improved; or information available to grid operators were improved.	Impact Metric Data	N/A	$			
Reduced Congestion Cost	Use Optional Inputs	Congestion Cost	Total annual transmission congestion cost. Project functions that could reduce these costs either provide lower cost energy, decrease loading on system elements, shift load to off-peak, or allow the grid operator to manage the flow of electricity around constrained interfaces (i.e. dynamic line capability or power flow control).	Impact Metric Data	N/A	$			
Deferred Transmission Capacity Investments		Capital Carrying Charge of Transmission Upgrade	The total capital cost of transmission system investments that can be deferred as a direct result of the project. Reducing the load and stress on transmission elements increases asset utilization and reduces the potential need for upgrades. Please enter the total deferred cost in the first year that it will be deferred.	Impact Metric Data	N/A	$			
		Transmission Investment Time Deferred	The time in years that the transmission investment will be deferred. Decimal numbers can be entered (ex.	Impact Metric Data	N/A	yrs			
Deferred Distribution Capacity Investments		Capital Carrying Charge of Distribution Upgrade	The total capital cost of distribution system investments that can be deferred as a direct result of the project. Reducing the load and stress on distribution elements increases asset utilization and reduces the potential need for upgrades. Please enter the total deferred cost in the first year that it will be deferred.	Impact Metric Data	N/A	$			
		Distribution Investment Time Deferred	The time in years that the distribution investment will be deferred. Decimal numbers can be entered (ex. 5.5).	Impact Metric Data	N/A	yrs			
Reduced Electricity Losses		Distribution Feeder Load	Average apparent power readings for all feeders impacted by the project. This input will be used to calculate electricity losses so feeders that have been made more efficient or feeders that have had peak or average loadings decreased should be included. If substations have been made more efficient the average power level of the substation(s) should be input. Information should be based on hourly loads.	Impact Metric Data	N/A	MVA			
		Distribution Losses	Average losses for the portion of the distribution system impacted by the project expressed as a percentage of total loading. This can be modeled or calculated.	Impact Metric Data	N/A	%			
		Transmission Line Load	Average apparent power readings for all lines impacted by the project. This information will be used to calculate electricity losses so lines over which losses could be reduced as a result of the project should be included. Information should be based on	Impact Metric Data	N/A	MVA			
		Transmission Losses	Average losses for the portion of the transmission system impacted by the project expresses as a percentage of total loading. This can be modeled or calculated.	Impact Metric Data	N/A	%			
		Average Price of Wholesale Energy	Average wholesale market price of electricity. This input will be used to monetize electricity losses.	Assumption/Estimate	Use Default	$/kWh			

Figure 47 Benefit Calculation Input in DOE's SGCT

In the Macro code (VBA) the main object for benefit calculation can be seen in object “Calcs” (Sheet 38). Below is the screenshot of the sheet. This object is linked with other various objects in the Macro code. It must be noted that the input table in the previous table will also be linked with the object "Calcs" below.

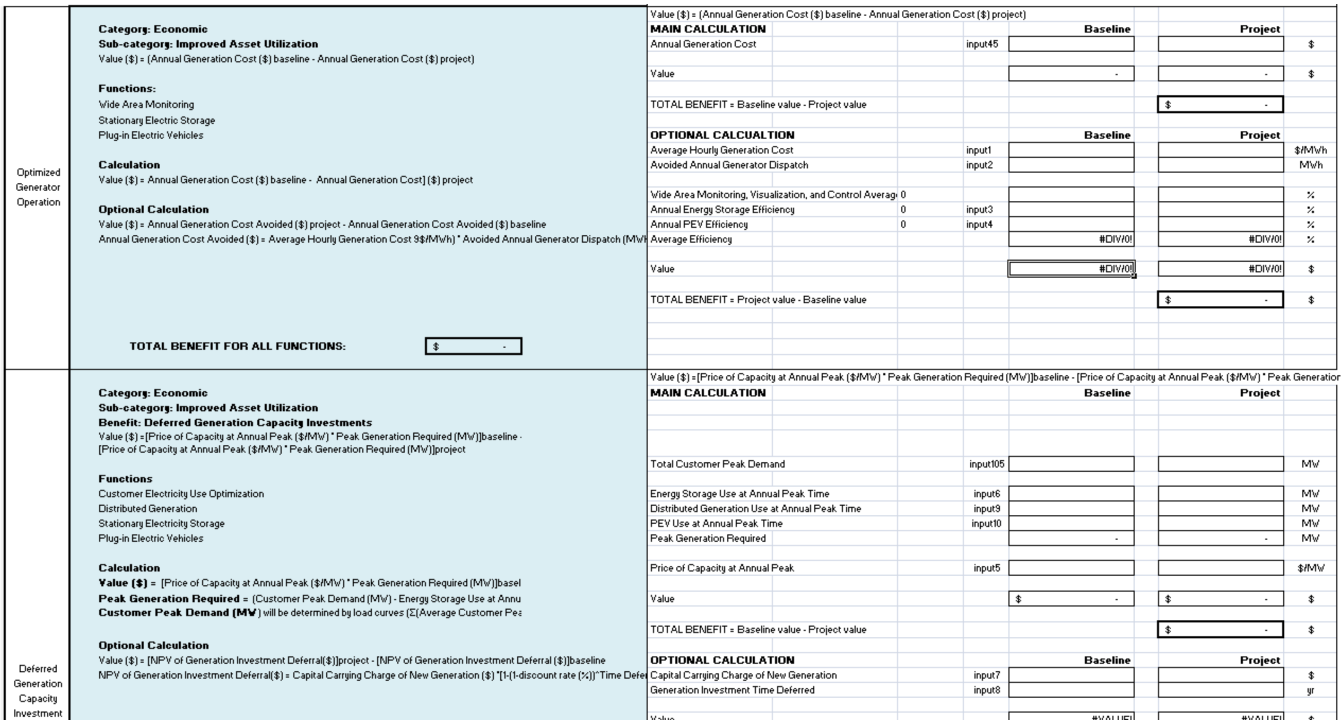


Figure 48 Calcs Object (Sheet 38) in Macro code

- **Cost Representation**

In SGCT, the cost representation is somewhat simple. There are two types of cost schedule that can be inputted to the SGCT. The first is the user must directly enter a nominal cost schedule. But in this case there is no specific guideline from the manual regarding the minimum requirement or the details of the cost structure needed. Also the tools only need one representative cost (capital) for each year of project, as long as the cost spending is still needed by the project.

The second type of cost schedule input is an even more simplified version. The only user inputs that must be provided are: initial and final year of project spending, the total capital cost of the project, and interest rate. Based on those numbers, the SGCT then calculates the amortized yearly cost schedule. In other words, the tools will regard each year's spending of the project to be equal.

Both types of cost representative (as can be seen in the macro) is showed in figure below

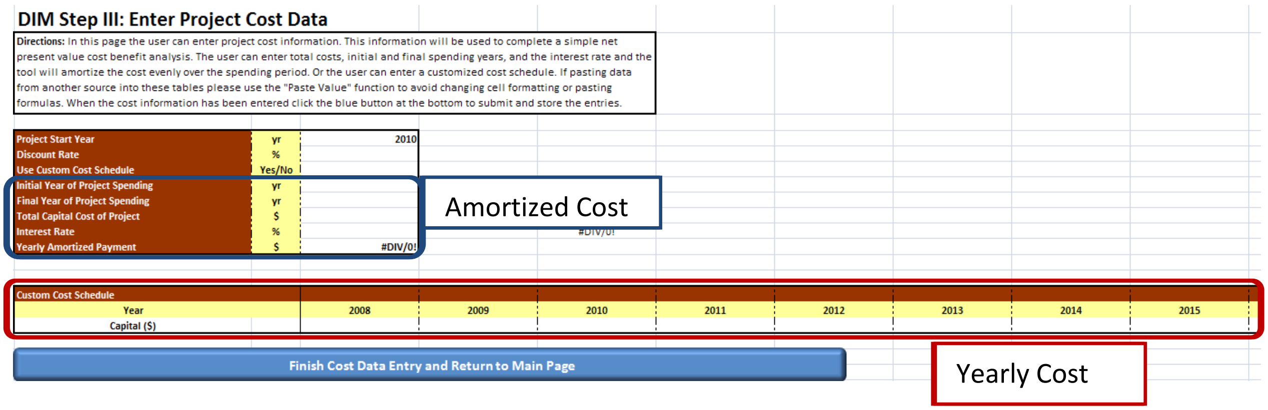


Figure 49 Cost Input in SGCT Macro

- **Macro (VBA) Code**

The SGCT is provided by DOE in form of Microsoft Excel's Macro. For a user who wants to execute Benefit Cost Analysis of a specific smart grid project, the tool can be utilized by following its step-by-step procedure. But it must be noted that to do so, the user needs to fully understand characteristics of its smart grid project (the assets, functions, and mechanisms). The user also needs to understand various concepts of those characteristics and other technical and economical key concepts and provide all the needed data inputs.

In order to understand how the inside of the macro works, a user needs to access and closely examine the macro code, which is written in Visual Basic for Application (VBA) environment. Once the access is granted, it can be seen that the code contains three parts:

- ***Microsoft Excel Objects***

An object in VBA is something like a tool or a thing that has certain functions and properties, and can contain data. For example, an Excel Worksheet is an object, a cell in a worksheet is an object, range of cells is an object, a command button is an object, and a text box is an object. In SGCT, there are various sheets which range from all the mappings, user inputs, calculations, showing summaries, sensitivity analyses, results, etc. There are total 43 sheets listed in the SGCT VBA.

Figure below shows the list of Microsoft Excel Objects in the US_DOE_Smart_Grid_Computational_Tool_Public_Version_1.xlsb (excel basic) and an example of properties (sheet 11). These sheets are normally hidden, as can be seen in the last property, "Visible: 2 – xlSheetVeryHidden". In order to examine the sheet, the first thing that must be done is changing this property to "-1 – xlSheetVisible". After that, the corresponding sheet can be examined in the excel file.

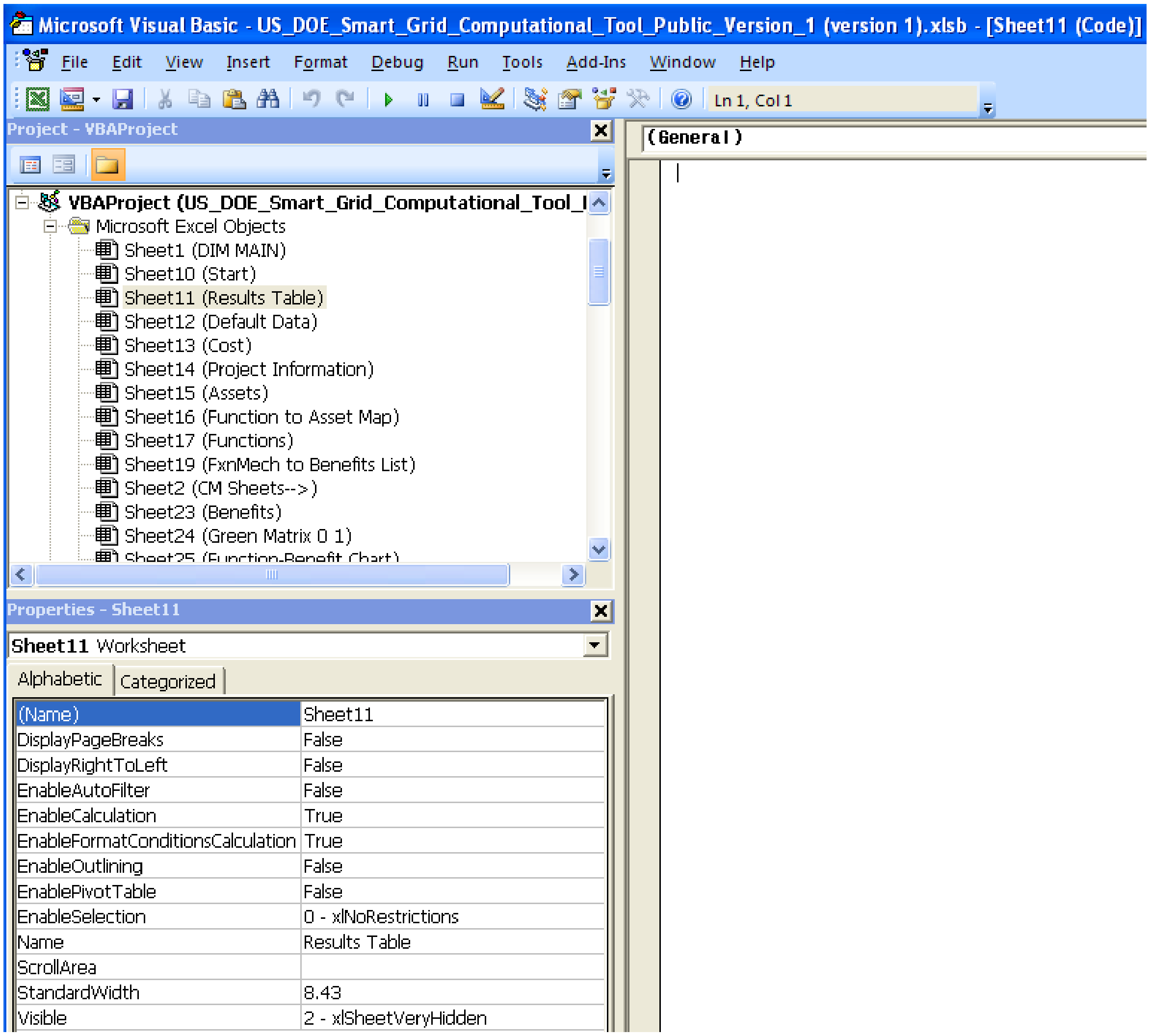


Figure 50 List of Microsoft Excel Object and an Example of Properties (Sheet 11)

- ***Forms***

A user form in VBA is a kind of dialog/message box combined with various control properties. The user can input a text, choose from a bulleted list, open another message box, or move to another user form of worksheet. In SGCT, forms are used to display many dialog boxes and windows, such as for choosing assets, functions and mechanism, showing information about definitions or explanations of various key concepts, reminding user to fill out all needed input data, etc. There are total 13 forms listed in the SGCT VBA.

Figure below shows an example of form, which is the Choose Assets form. This form will be shown when a user start a new project in the excel macro file of SGCT.

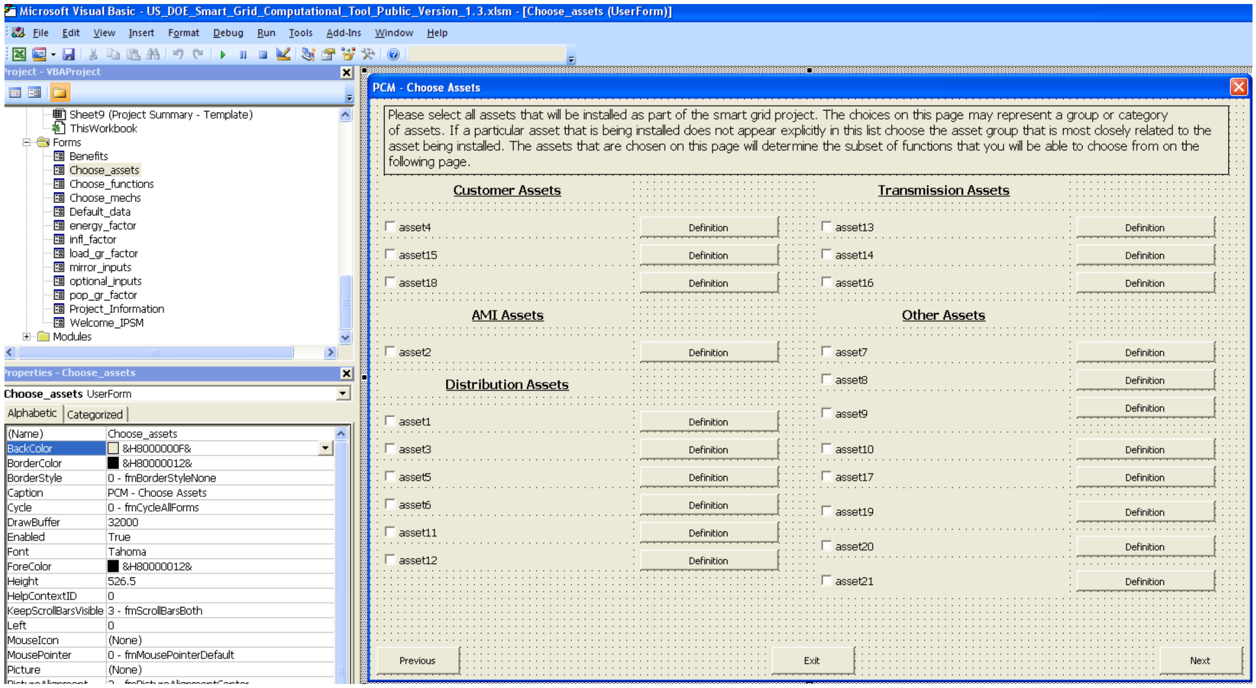


Figure 51 Example of Form (Choose Assets)

✧ *Modules*

Module is a collection of macros. Each macro is able to run a procedure which is composed of several lines of programming codes. The purpose of using macro is to build customized functions or solutions using Microsoft Excel. For example, it can handle the procedure for creating function mechanism table, inputting various data, filling in default input data, or protecting/unprotecting a sheet. There are 5 modules listed in the SGCT VBA:

- ✓ Module 1 contains all of the macros that helped create the tool and will help edit the tool
- ✓ Module 3 contains all of the codes that make the IPSM and DIM work and allow navigation through the tool.
- ✓ Module 4 contains all of the code for showing optional inputs.
- ✓ Module 5 contains all of the codes for filling in the default data inputs.
- ✓ Module 6 contains all of the code for the CM.

Figure below shows the example of Module three, which manages the IPSM (Initial Project Setup Module), DIM (Data Input Module), and navigation through the tool.

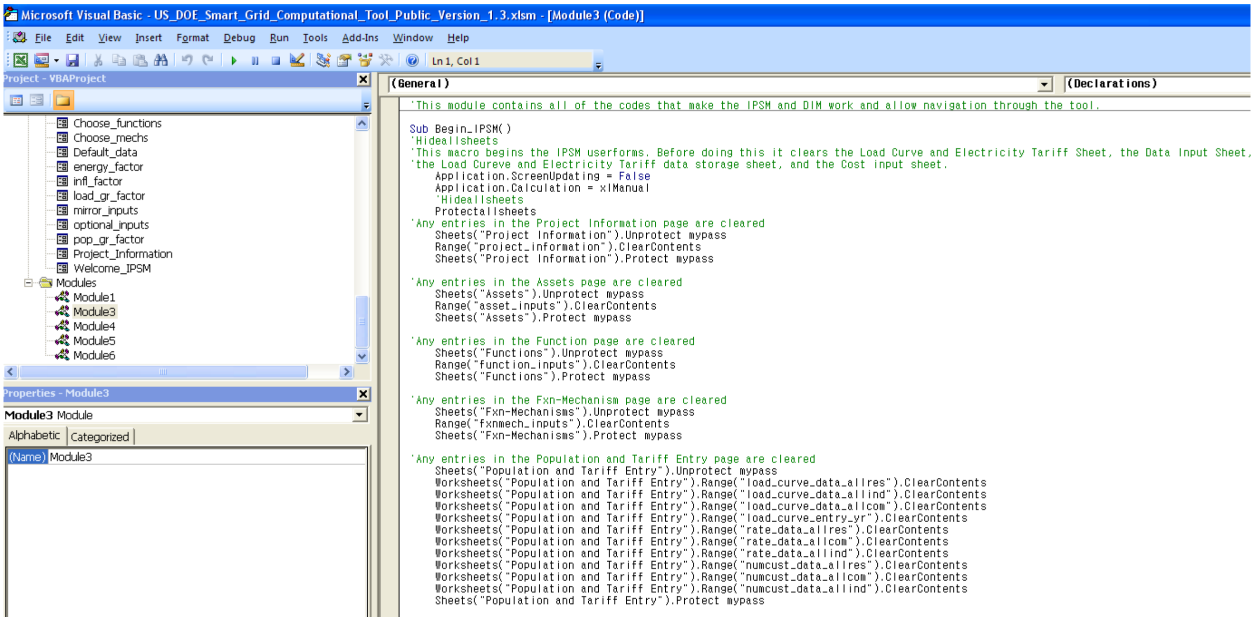


Figure 52 Example of Module (Module 3)

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Appendix A: Questionnaires for Smart Grid Smartness

A.1 ISGAN Annex 3: Preface

The following questionnaire is aimed at collecting technical information about the level of smartness of electricity grids.

The questionnaire is referred to real life distribution (transmission) grids, and consists mainly in quantitative questions, that can be answered based on homogeneous information related to:

1) A specific distribution grid (minimum consistence: at least one HV/MV substation)

2) A specific transmission grid

3) A whole distribution grid belonging to / operated by a single Company (DSO)

4) A whole transmission grid belonging to / operated by a single Company (TSO)

5) A set of distributions grids considered at a national/regional level

6) A set of transmission grids considered at a national/regional level

Before entering the questionnaire, the respondant should declare the case he refers to (1-6).

Policy context; general info about the system

The use of data gathered is influenced by the general policy framework to which the data refer: to this aim, some preliminary information are needed on this subject.

Even if the respondant belongs to cases 1 to 4, this preliminary information is referred to the national (regional) level.

1) How many customers are served by the electricity system? (#)

2) What is the load served? (yearly energy, MWh)

3) Is the electricity system vertically integrated? (Y/N)

4) If N, are network activities (transmission, distribution) separated from generation? (Y/N)

5) Is distribution network operated by DSOs (separated from TSO)? (Y/N)

6) Is there an electricity market in place? (Y/N)

7) If Y, what is the share of demand eligible for the market? (%)

8) Are support schemes for RES in place? (Y/N)

9) What is the share of RES energy wrt total system load (MWh/MWh: %)

10) Are support schemes for EV in place? (Y/N)

General info about the grid under scrutiny

In order to make a correct use of the answers to the questionnaire, some preliminary information about the specific grid under scrutiny are needed.

1) Is it a transmission network (Y/N)

2) Is it a distribution network (Y/N)

3) How many km of HV lines are there?

4) How many km of MV lines are there?

5) How many km of LV lines are there?

6) How many HV customers are served? (#)

7) How many MV customers are served? (#)

8) How many LV customers are served? (#)

9) What is the load served? (yearly energy, MWh)

10) Is the grid connected to the main/continental network (Y/N) [N= the grid covers a geographical island which is not connected to the main/continental network]

A.2 ISGAN Annex 3: Questionnaire

ENABLE INFORMED PARTICIPATION BY CUSTOMERS

1 Advanced meters

By installing advanced metering infrastructure, bi-directional communication ensures that energy consumption data, grid conditions, and real-time price information can be exchanged between the different parties.

Please write your answer(s) here:

A) Percentage of advanced meters installed wrt total meters [%] _______________________

B) Percentage of total demand served by advanced meters [%] ______________________

Only numerical answers are allowed.

Validity range for question A) from 0 to 100

Validity range for question B) from 0 to 100

___

2 Dynamic pricing

Dynamic pricing signals give customers the opportunity to participate in the electric power systems. Real-Time-Pricing (RTP) tariffs are transmitted to the customers (residential, industrial, commercial), who can make informed decisions resulting in greater demand response.

Please write your answer(s) here:

A) Percentage of customers enabled to dynamic pricing [%]___________________________

B) Percentage of customers really involved in dynamic pricing ___________[%]_

C) Percentage of load (in terms of capacity) served by dynamic pricing [%] ___________________________

Only numerical answers are allowed. Validity range: from 0 to 100

---

3 Smart appliances (cancelled)

---

4 Dynamic pricing

Because Dynamic Pricing (DP) influences energy consumption, it forms an indicator for the level of active involvement of the customer in the energy system. In response to changes in the electricity price, end-consumers adapt their usual energy consumption pattern (price demand response). This can result in load shifting and reduced costs through the smoothing of peak power consumption. An electricity grid is smart when it accommodates this behavior.

At local level, DSO

Please write your answer(s) here:

A) Fraction of consumers contributing in DR [%] ________________

B) Percentage of consumer load capacity participating in DR [MW/MW %] ____________________________

Only numerical answers are allowed. Validity range: from 0 to 100

At global level, TSO

Please write your answer(s) here:

A) Fraction of consumers contributing in DR [%] ________________

B) Percentage of consumer load capacity participating in DR [MW/MW %]

Only numerical answers are allowed. Validity range: from 0 to 100

Market design

Indirect electrical energy storage through the use of heat pumps [Y/N] ________________

---

5 Local generation & Prosumers

Distributed generation located in the premises, or building of the end-consumers, is penetrating the electricity market. In an intelligent grid an end-consumer not only buys electricity from the grid, but he can also deliver electricity to the grid becoming a "pro-sumer" in the electricity system. Bidirectional power flows are integrated in the electricity system, without jeopardizing the grid stability.

Please write your answer(s) here:

A) Total electrical energy locally (decentralized) produced versus total electrical energy consumed (limit for DG set to 10 MW) [MWh/MWh %] ________________

B) Percentage of prosumers (household customers with a DER production) [%] __________

C) Percentage of customers (non-households) with a DER production [%] __________

D) ________________

Only numerical answers are allowed. Validity range: from 0 to 100

---

6 Privacy issues

Electricity use patterns could lead to disclosure of not only how much energy customers use but also to deduce information about specific activities of the customers. It might also be possible to discover what types of appliances and devices are present by compromising either the customer's home area network or the AMR network. Also, increases in power draw might suggest changes in business operations. Such energy-related information could support criminal targeting of homes or provide business intelligence to competitors [1]

[1] Handley M, Ning L, Frincke D, Khurana H, "Smart Gird Security Issues", Building Security In copublished by the IEEE Computer And Reliability Societies, January February 2010, pp81-85

Please write your answer(s) here:

A) If applicable: are privacy & security issues covered by policy/regulations/legal provisions? [Y/N] ________________

ACCOMMODATE ALL GENERATION AND STORAGE OPTIONS

7 Distributed generation (DG) and storage

Because of the intermittent nature of distributed generation, a mass implementation of these resources should be accompanied with storage and flexible loads to solve the problem of variability

Please write your answer(s) here:

A) Pumped Storage Hydro plants installed capacity wrt RES plants (TN+DN) [MW/MW %] _____

B) Electrochemical storage installed capacity wrt DG [MW/MW %] _____

C) Indirect storage (heat pumps; partially programmable generation) wrt DG [MW/MW %] _____

Only numerical answers are allowed. Validity range: from 0 to 100

---

8 EVs

EVs are electric vehicles with batteries that can be recharged. This allows customers to recharge their vehicles during off-peak hours and to sell energy to the grid operators during peak hours when prices are high. This helps reducing the peak load and thus also the cost of the power/energy provided.

Please write your answer(s) here:

A) Percentage shares of on-road light duty vehicles, comparing PHEVs [%] __________________________

B) Is recharging controlled/uncontrolled? [Y/N] __________

C) Is bidirectional charging possible? [Y/N] ______________

D) Number of recharging poles (public; private) wrt total household customers

Validity range for question A) from 0 to 100

Validity range for question C) from 0 to 100

Validity range for question D) from 0 to 100

---

9 DER interconnections

Distributed Energy Resources (DER) consist of DG, the storage of electrical (and thermal) energy and/or flexible loads. These resources are rapidly integrating into the electricity system, therefore standard distributed resource interconnection policies should be designed.

Please write your answer(s) here:

Assuming that 10 MW is the limit for DG

A) Is there a standard for interconnecting DG? [Y/N] __________

If YES, report the name of the standard_________

If YES, is this standard company specific? [Y/N] _____________

B) Are there specific technical provisions for interconnection of DG (minimum technical requirements for being connected to the grids) [Y/N] ________

If YES, report the name of the standard_________

If YES, is this standard company specific? [Y/N] _____________

C)

SELL MORE THAN kWhs

10 New energy services

In a smart grid, new services “beyond the meter” (energy efficiency assessment, optimizing energy bills, ….) are offered to customers. In literature, these services are typically performed by an Energy Service Company (ESCO). This is a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in the user’s facility or premises. By integrating the new services in the smart grid, the resulting added value can be captured.

Please write your answer(s) here:

A) Are new energy services (any type of energy service aimed at optimizing bills) offered to customers? [Y/N] _________

B) Are these services offered by retailers/aggregators/DSO/other parties? [Y/N] _________

Number of customers served by ESCO's wrt total customers %_______________

C) Amount of energy served by ESCO's wrt total energy (load) [MWh/MWh %] _______________

Only numerical answers are allowed. Validity range: from 0 to 100

---

11 Flexibility

In an intelligent grid, new market arise on which flexibility becomes a product that can be traded. New market players like aggregators will act as an intermediary between several electricity generators and other players in the electricity system by gathering flexibility and contributions of customers to build active demand services.

Please write your answer(s) here:

A) Number of customers (passive users; prosumers) offering flexibility to aggregators wrt total customers _______________

B) Flexibility that aggregators can offer to other market players wrt total load [MWh/MWh %] ____________________

C) To what extent are storage and DG able to provide ancillary services, as percentage of the total offered ancillary services [%] ________________________

D) Percentage of storage and DG that can be modified vs total storage and DG [MW/MW %]

Only numerical answers are allowed.

Validity range for questions:from 0 to 100

---

12 Customer choice (cancelled)

---

13 Support mechanism

A smart grid holds great potential for enabling new products, services and markets. Because this incorporates investments and risk, public and private interests should support the evolution towards a smart gird. A regulatory framework should stimulate smart grid behavior and appropriate funding should be found encouraging the proper integration of the new products and markets.

Please write your answer(s) here:

A) Are there incentives for smart grid projects? [Y/N] _______

B) Are there incentives for smart grid deployment? [Y/N] __________

Only numerical answers are allowed. Validity range: from 0 to 100

PROVIDE POWER QUALITY FOR THE 21ST CENTURY

14 Power Quality (cancelled)

____

15 Required power quality (cancelled)

____

16 Microgrid

A microgrid (limited to MV/LV grids) consists of an integrated distribution system with interconnected loads and DER which operates connected to the main power grid with coordinated control, providing sources of reliable power quality, capable of operating also in a self-healing way (island).

Please write your answer(s) here:

A) Number of microgrids in operation _______________

B) Capacity of microgrid [MW] ______________

C) Total grid capacity of Microgrid to the capacity of the entire grid [MW/MW %] ____________________

Only numerical answers are allowed.

Validity range for question A) from 0 to 99999

Validity range for question B) from 0 to 99999

Validity range for question C) from 0 to 100

---

17 Microgrid

*

Please choose only one of the following:

_____ Nothing (0)

_____ Research activity (1)

_____ Demonstration activity (2)

_____ Deployment activity (5)

_____ Other____

OPTIMIZE ASSETS AND OPERATE EFFICIENTLY

18 T&D automation

In a smart grid, automation occurs at all levels of the electricity grid from transmission to end-user. This way, components are monitored, coordinated and operated from remote locations. State of the art power technologies are used to operate the system closer to its capacity and stability constrains, eventually leading to a more efficient operation of the electricity grid.

Please write your answer(s) here:

A) Percentage of transmission network substations applying automation technologies [%] ________________

B) Percentage of HV/MV substations (including HV busses) applying automation technologies [%] ________________

C) Percentage of MV/LV substations (including MV busses) applying automation technologies [%] ________________

Only numerical answers are allowed. Validity range from 0 to 100

---

19 Dynamic line rating

Dynamic line ratings form a tool for enhancing the capacity of the electrical grid. It uses actual weather conditions, surface temperature monitoring, tension monitoring, and loading conditions to rate the impact on the transmission grid. This increases the utilization of assets by operating the grid closer to its capacity.

Please write your answer(s) here:

A) Percentage of km of transmission circuits operated under dynamic line rating [%] ___________________

Only numerical answers are allowed.

Validity range for question B) from 0 to 100

20 Capacity factors (cancelled)

---

21 Efficiencies

Smart grid optimize operating efficiency and asset utilization by applying advanced information and communication technologies. An intelligent grid should lead to a more efficient operation of generation facilities and to less energy losses in the transmission and distribution system.

Please write your answer(s) here:

A) Percentage loss factor for transmission networks [MWh_losses/MWh_delivered] ________________

B) Percentage loss factor for DN [MWh_losses/MWh_delivered] ________________

Validity range for questions: from 0 to 100

OPERATE RESILIENTLY TO DISTURBANCES, ATTACK AND NATURAL DISASTER

22 Advanced sensors

Wide Area Measurement Systems (WAMS) apply advanced-technology infrastructure that is used for an increased observability of the electricity grid. This leads to an increased situational awareness with a level of exploitation closer to stability limits and an improved control of the network. Problems can be tracked and solved in a rapid and efficient way, making the grid less susceptible to disturbances.

Please write your answer(s) here:

A) Percentage of transmission grid elements that can be remotely monitored and controlled in real time [%] ________________

B) Percentage of transmission substations equipped with advanced measurement technologies [%] ___________________

Only numerical answers are allowed.

Validity range for question A) from 0 to 100

Validity range for question B) from 0 to 100

Validity range for question C) from 0 to 99999

23 Information exchanges

The integration of advanced sensors throughout the electricity grid makes the development on an information architecture indispensable. System status information should be exchanged between all relevant market players. Information exchange between national TSOs, day-to-day data exchanges between TSO and DSO, and an interconnected information process between the customers and the grid should be set in place in order to counter any disturbances.

Please write your answer(s) here:

A) Percentage of transmission level syncrophasors measurement points shared multilaterally [%] ___________________

B) Performances of the communication channels towards grid elements in term of bandwidth [%] _____________________

C) Performances of the communication channels towards grid elements in term of response speed availability [%] _____________________

D) Is the DSO operational center connected with the TSO? [Y/N] __________

E) Is it an always-on connection? [Y/N] _________________________

Only numerical answers are allowed.

Validity range for question A) from 0 to 99999

Validity range for question B) from 0 to 100

Validity range for question C) from 0 to 100

Validity range for question D) from 0 to 100

Validity range for question E) from 0 to 100

---

24 As well as in a traditional electricity grid, T&D reliability is one of the key aspects of a smart electricity grid. In all circumstances, the reliability has to be assured.

Please write your answer(s) here:

A) System Average Interruption Duration Index (SAIDI) [min/year] ________________

B) If there is a limit for SAIDI, what is the value? _______________

C) Is it a regulatory limit or a voluntary target? _____________

D) System Average Interruption Frequency Index (SAIFI) [interruption/year]___________________

E) If there is a limit for SAIFI, what is the value? _______________

F) Is it a regulatory limit or a voluntary target? _____________

G)

H) Customer Average Interruption Duration Index (CAIDI) [min/year] _____________________

I) Momentary Average Interruption Frequency Index (MAIDI) [interruption/year] _____________________

J) Expected Energy Not Supplied (EENS) for the last year [MWh/year] _____________________

Only numerical answers are allowed. Validity range from 0 to 99999

____

25 Standards

Because of the high interconnected nature of the communication standards, European standards for monitoring, controlling and automation become necessary. European standards in line with the on-going National Institute of Standards and Technology (NIST) approach in the US should be specified to avoid all kind of malfunctions in the electricity grid.

*

A) Information interchange for network automation is managed:

by means of a standard solution (Y/N)

If Y, the standard in use is______________________________

by a company solution (Y/N)

by a proprietary solution (Y/N)

B) Information interchange for AMI is managed:

by means of a standard solution (Y/N)

If Y, the standard in use is______________________________

by a company solution (Y/N)

by a proprietary solution (Y/N)

C) Information interchange for EV charging infrastructure is managed:

by means of a standard solution (Y/N)

If Y, the std in use is______________________________

by a company solution (Y/N)

by a proprietary solution (Y/N)

---

26 Self-healing procedures

The grid is capable of implementing Special Protection System (SP) procedures.

Please write your answer(s) here:

A)

B) Percentage of automated decision making within protection schemes for Transmission Network based on wide area monitoring (the percentage is calculated based on the number of substations) [%]

____

C) Percentage of operational distribution grid that employs advanced outage restoration schemes that automatically resolve (self-heal) or reduce the magnitude of unplanned outages (the percentage is calculated based on the number of substations) [%] _______________

Only numerical answers are allowed. Validity range from 0 to 100

FUNDING AND INVESTMENTS FOR SMART SOLUTIONS

27 R&D programs and funding

Performance level of R&D and demonstration project activity

Please write your answer(s) here:

A) Total investments in R%D smart grid projects/total cost of the projects [€/€ %] ________________

B) Amount of financing received from EU/Total cost of projects [€/€ %] ___________________

C) Amount of financing received from public national funds/Total cost of projects [€/€ %] ___________________

D) Amount of financing received from private founds/Total cost of projects [€/€ %] ___________________

Only numerical answers are allowed. Validity range from 0 to 100

A.3 Smart Grid Research Consortium: Smart Grid Investment Quotient

Smart Grid Investment Quotient Scorecard

Description	Points
I. AMI/DA Investment/Planning Scope (Maximum Category Points: 27)	
Does your investment analysis/planning process: a. Include AMI/smart meters costs and benefits? If yes, add 10 points b. Include CVR costs and benefits (conservation voltage regulation)? If yes, add 8 points c. Include other distribution automation options costs and benefits? If yes, add 4 points d. Consider interactions/synergies between individual AMI/DA technologies and programs (e.g., communications systems, smart meters as voltage sensors for CVR, demand response as a distribution resource)? If no subtract 6 points e. Consider IT legacy integration and new IT investments required to take full advantage of AMI/DA data and related management systems? If yes, add 5 points	
II. Customer Engagement* Investment/Planning Scope (Maximum Category Points: 20)	
Does your investment analysis/planning process: a. Consider reductions in power costs (purchased and/or generated) associated with customer engagement technologies and programs? If yes, add 5 points b. Consider financial benefits of deferred capital investments associated with customer engagement technologies and programs? If yes, add 3 points c. Use information on your utility's customer class/end-use (e.g., residential AC) hourly loads (rather than generic estimates) to model peak period hourly load impacts over the planning horizon? If yes, add 10 points d. Reflect changes in future hourly loads over the planning horizon as a result of changes in customer counts, equipment saturations and efficiencies and other factors? If yes, add 2 points *Includes PCTs, monitors, pricing, information programs, etc	
III. Other Financial Items (Maximum Category Points: 12)	
Does your investment analysis/planning process: a. Consider customer value of increased reliability and power quality by customer class? If yes, add 5 points b. Quantify environmental benefits? If yes, add 3 points c. Quantify management and retraining cost, pilot program and other costs? If yes, add 2 points d. Quantify potential secondary smart-grid related financial benefits (e.g., municipal communications services, other potential utility provided value-added services)? If yes, add 2 points	
IV. Other Utility Customer Detail (Maximum Category Points: 10)	
Does your investment analysis/planning process: a. Apply your utility's detailed cost data to quantify expected AMI and DA savings associated with meter reading, billing, uncollectables, ect. ? If yes, add 5 points b. Include changes over the planning horizon in number of customers by customer class and rate class, saturations of air conditioning, electric space and water heating, swimming pool and well pumps, etc? If yes, add 3 points c. Take into account hourly load Impacts of existing demand response, load control and energy efficiency programs to avoid double-counting benefits? If yes (of if no programs), add 2 points	

Description	Points
V. Investment Analysis Quantitative Framework (Maximum Category Points: 23)	
Does your investment analysis/planning process framework: a. Apply an analysis/forecast horizon of 10 years or more? If no, subtract 3*(10-number of years in your analysis) b. Include all of the following calculations: net present value, internal rate of return, cumulative costs and benefits, cumulative discounted costs and benefits, break-even period, discounted breakeven period, payback and discounted payback? If yes, add 2 points c. Automatically incorporate changes in customer characteristics over the planning horizon including number of customers, electric equipment saturations, equipment efficiency and other characteristics? If yes, add 2 points d. Include user-selectable technology/program parameters that automatically reflect alternative technology characteristics, program penetrations and impacts, and other related flexibility. If yes, add 9 points e. Automatically reflect multiple technology/program scenario analysis and technology/program interactions? If yes, add 5 points f. Automatically reflect alternative customer engagement, CVR and other technology/program parameters on customer class/end-use and system-wide hourly loads? If yes, add 5 points	
VI. Ease of Use/User Interface/ Results Presentation (Maximum Category Points: 8)	
Does your analysis/planning software provide: (add 1 point for each "yes" answer below) a. Menus, check boxes, etc to allow easy application and experimentation? b. Default values for all parameters? c. Push-button selections of single and multiple technology and program scenarios? d. In-program help and guidance? e. Easy access to results at any detail level? f. Graphical representations that reflect intuitive results such as breakeven periods? g. Clear presentation of cost and benefit components (tabular and graphical)? h. The ability to modify and add new tabular and graphical results presentations?	
TOTAL POINTS (100 Points Maximum)	

Appendix B: Guidebook for BCA of Smart Grid Demonstration

B.1 Linkage of Assets to Functions

Smart Grid Assets	Functions												
	Transmission		Distribution						Substation			Customer	
	Flow Control	Wide Area Monitoring and Viasualization	Adaptive Protection	Automated Feeder Switching	Automated Islanding and Reconnection	Automated Volt/VAR Control	Enhanced Fault Protection	Real-time Load Transfer	Diagnosis & Notification of Equipment Condition	Dynamic Capability Rating	Fault-Current Limiting	Customer Electricity Use Optimization	Real-time load Measurement and Management
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 2-way power converter													
VLI (HTS) cables	●												

Source: EPRI, 2012

B.2 Benefits Linked to Smart Grid Functions

Benefits			Functions: Trans-mission		Distribution						Substation			Customer		Energy Resources		
			Flow Control	Wide Area Monitoring & Visualization	Adaptive Protection	Automated Feeder Switching	Automated Islanding and Reconnection	Automated Volt/VAR Control	Enhanced Fault Protection	Real-time Load Transfer	Diagnosis & Notification of Equipment Condition	Dynamic Capability Rating	Fault Current Limiting	Customer Electricity Use & Optimization	Real-time Load Measurement and	Distributed Generation	Stationary Electricity Storage	Plug-in Electric Vehicles
Economic	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 Efficiency	Reduced Electricity Losses						●		●				●	●		●	
	Electricity 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							●								●	
Environ-mental	Air Emissions	Reduced CO_2 Emissions	●			●		●						●	●	●	●	●
		Reduced SOx, NOx and PM-10 Emissions	●			●		●						●	●	●	●	●
Security	Energy Security	Reduced Oil Usage (not monetized)				●					●				●			●
		Reduced Wide scale Blackouts		●					●			●						

Source: EPRI, 2012