ISGAN Project Annex 3 BENEFIT & COST ANALYSES AND TOOLKITS

A Manual for

Smart Grid BCA Toolkit Revised by EML

AJOU UNIVERSITY

February 2015

International Smart Grid Association Network (ISGAN)

Primary Investigator: Suduk Kim (Professor, Ajou University)

Researcher:

Jaeick Oh (Professor, Ajou University)

Eunju Min (Ph.D. Course Student, Ajou University)

Zulfikar Yurnaidi (Ph.D. Course Student, Ajou University) Minho Baek (Ph.D. Course Student, Ajou University) Minyoung Roh (Master Course Student, Ajou University) Seungho Jeon (Master Course Student, Ajou University)

Juhwan Oh (Intern, Ajou University)

Graphic Design:

Heera Kim (GreenAD Wraps Korea co., LTD.)

List of Contents

List of Contents	3
List of Figures	
List of Tables	7
I. Introduction	1
II. A Brief Review of SGCT	
III. Replicated and Revised Version of SGCT	6
III.1 Installation Process	6
III.2 File Structure when installed	8
III.3 Brief Explanation of the program – How to use the program? Project information	9
III.3.1 How a member country can use this program Country	10 10
III.3.2 How to modify the given parameters using default excel files	
III.3.3 How to choose Assets, Functions and Mechanisms	17
III.3.4 Continuing for Final Results	20
III.4 Detailed Architecture in the Revised SGCT	
III.5 Project Characterization Module in SGCT and Its GUI Replication	
III.6 Comparison of Data Input Module in SGCT and Its GUI Replication	36
III.7 Computational Module in SGCT and Its GUI Replication	
Appendix I Overview of SGCT	41
A1.1 SGCT Framework and Work Flow	41
A1.2 Project Characterization Module (PCM) Assets to Functions Functions to (Mechanisms to) Benefits	42 43 46
A1.3 Data Input Module (DIM) Benefits Monetized Value Cost Representation	49 49 51
A1.4 Computational Module (CM) Macro (VBA) Code	52
Appendix II Default Parameters in SGCT	60

List of Figures

Figure 1 Illustration of the Input and Output of SGCT2
Figure 2 Easy Representation of the Linkage among Assets, Functions, and Benefits
Figure 3 Illustration of the Translation of Smart Grid Assets to Monetary Value
Figure 4 Installation CD for Smart Grid BCA Toolkit Revised by EML (Energy Modeling Lab., Ajou Univ.)6
Figure 5 Directory Setting Dialog Box7
Figure 6 User's Choice of Folder for Installation7
Figure 7 Initial Page of the Replicated Program9
Figure 8 Initial Page of Program10
Figure 9 Expansion of Country Choices to all ISGAN Member Countries11
Figure 10 Pull-down Menu of Menu13
Figure 11 Addition of a New Country14
Figure 12 Dialog box for 'Configuration' in Menu14
Figure 13 Addition of New Region and the Use of Parameter Values15
Figure 14 Detailed Items for the Change of Default Parameter Values16
Figure 15 Values Shown at the Dialog Box16
Figure 16 Dialog box for 'New Project' in Menu17
Figure 17 Choosing among Assets, Functions and Mechanisms18
Figure 18 Choice of Function Gives Following Choice of Mechanisms
Figure 19 Data Input Module Dialog Box Replicated21
Figure 20 Replication Reference case: Result Table22
Figure 21 Replication Reference case: Result Chart23
Figure 22 Replication Reference case: Net present value Analysis24

Figure 23 Replication Sensitivity case: Escalated Input Data	25
Figure 24 Replication Sensitivity case: Benefit Table	26
Figure 25 Replication Sensitivity case: PV Benefit Table	27
Figure 26 Replication Sensitivity case: Sensitivity Graphs	28
Figure 27 Replication Sensitivity case: Sensitivity Chart	29
Figure 28 Detailed Architecture of DIM in Replicated Tool Kit	30
Figure 29 Asset Category DB	31
Figure 30 Asset DB details	31
Figure 31 Function Details	31
Figure 32 Benefit Details	31
Figure 33 Input Data Details	32
Figure 34 User Input Data Details	32
Figure 35 PCM Project Information Screen	33
Figure 36 PCM Asset Selection Screen	33
Figure 37 PCM Function Selection Screen	33
Figure 38 PCM Mechanism Selection Screen	33
Figure 39 Project Information and Asset/Function/Mechanism Selection Screen (Replicated Tool Kit))34
Figure 40 PCM Benefits Screen (DOE SGCT)	35
Figure 41 Benefits Screen (Replicated Tool Kit)	35
Figure 42 Electricity tariff data and customers served data entry tables	36
Figure 43 Cost calculation inputs	36
Figure 44 Escalation factor table	36
Figure 45 Data input sheet	36
Figure 46 Data Input Module (DIM) Screen (Replicated Tool Kit)	37
Figure 47 CM Main Page (DOE SGCT)	38

Figure 48 CM Main Page (Replicated Tool Kit)	
Figure 49 Results table (DOE SGCT)	
Figure 50 Result Charts (DOE SGCT)	
Figure 51 NPV Analysis (DOE SGCT)	40
Figure 52SGCT Architecture	41
Figure 53 The Structure of SGCT	42
Figure 54 Illustration of Asset, Function, Mechanism, Benefit Mapping (Navigant, 2011)	43
Figure 55 Choosing Assets in DOE's SGCT	46
Figure 56 Choosing Functions in DOE's SGCT	46
Figure 57 Choosing Mechanisms in DOE's SGCT	48
Figure 58 Function-Benefit Chartin DOE's SGCT	49
Figure 59 Benefit Calculation Input in DOE's SGCT	50
Figure 60 Calcs Object (Sheet 38) in Macro code	51
Figure 61 Cost Input in SGCT Macro	52
Figure 62 CM Main Page	53
Figure 63 Benefit Calculation Window	54
Figure 64 Example of Benefit Calculation which is Related to Its Functions	55
Figure 65 Example of Benefit Calculation which is Generalized and Simplified	55
Figure 66 List of Microsoft Excel Object and an Example of Properties (Sheet 11)	57
Figure 67 Example of Form (Choose Assets)	58
Figure 68 Example of Module (Module 3)	59

List of Tables

Table 1 Mapping of Assets to Functions (DOE SGCT)	43
Table 2 Mapping of Functions to Benefits (with comparison to EPRI version)	47
Table 3 Average Hourly Generation Cost	60
Table 4 Price of Capacity at Annual Peak (1)	61
Table 5 Price of Capacity at Annual Peak (2)	61
Table 6 Average Price of Reserves	62
Table 7 Average Price of Frequency Regulation	62
Table 8 Average Price of Voltage Control (1)	63
Table 9 Average Price of Voltage Control (2)	63
Table 10 Average Price of Congestion	64
Table 11 Average Price of Wholesale Energy	64
Table 12 Inflation Factor	65
Table 12 Inflation Factor Table 13 Restoration Cost per Event (1)	65
Table 12 Inflation FactorTable 13 Restoration Cost per Event (1)Table 14 Restoration Cost per Event (2)	65 65 66
Table 12 Inflation FactorTable 13 Restoration Cost per Event (1)Table 14 Restoration Cost per Event (2)Table 15 Average Fuel Efficiency for Truck Roll Vehicle	65 65 66 66
Table 12 Inflation FactorTable 13 Restoration Cost per Event (1)Table 14 Restoration Cost per Event (2)Table 15 Average Fuel Efficiency for Truck Roll VehicleTable 16 CO2 Emissions per Gallon of Fuel	65 65 66 66 67
Table 12 Inflation FactorTable 13 Restoration Cost per Event (1)Table 14 Restoration Cost per Event (2)Table 14 Restoration Cost per Event (2)Table 15 Average Fuel Efficiency for Truck Roll VehicleTable 16 CO2 Emissions per Gallon of FuelTable 17 Value of CO2	65 65 66 66 67 67
Table 12 Inflation FactorTable 13 Restoration Cost per Event (1)Table 14 Restoration Cost per Event (2)Table 14 Restoration Cost per Event (2)Table 15 Average Fuel Efficiency for Truck Roll VehicleTable 15 Average Fuel Efficiency for Truck Roll VehicleTable 16 CO2 Emissions per Gallon of FuelTable 17 Value of CO2Table 18 SOx Emissions per Gallon of Gas	65 65 66 66 67 67 68
Table 12 Inflation FactorTable 13 Restoration Cost per Event (1)Table 14 Restoration Cost per Event (2)Table 14 Restoration Cost per Event (2)Table 15 Average Fuel Efficiency for Truck Roll VehicleTable 16 CO2 Emissions per Gallon of FuelTable 16 CO2Table 17 Value of CO2Table 18 SOx Emissions per Gallon of GasTable 19 NOx Emissions per Gallon of Gas	
Table 12 Inflation FactorTable 13 Restoration Cost per Event (1)Table 14 Restoration Cost per Event (2)Table 14 Restoration Cost per Event (2)Table 15 Average Fuel Efficiency for Truck Roll VehicleTable 16 CO2 Emissions per Gallon of FuelTable 16 CO2 Emissions per Gallon of FuelTable 17 Value of CO2Table 18 SOx Emissions per Gallon of GasTable 19 NOx Emissions per Gallon of GasTable 20 Value of SOx	
Table 12 Inflation FactorTable 13 Restoration Cost per Event (1)Table 14 Restoration Cost per Event (2)Table 14 Restoration Cost per Event (2)Table 15 Average Fuel Efficiency for Truck Roll VehicleTable 16 CO2 Emissions per Gallon of FuelTable 16 CO2 Emissions per Gallon of FuelTable 17 Value of CO2Table 18 SOx Emissions per Gallon of GasTable 19 NOx Emissions per Gallon of GasTable 20 Value of SOxTable 21 Value of NOx.	

Table 23 Average Fuel Efficiency	
Table 24 Electricity to Fuel Conversion Factor	71
Table 25 Escalation Factors	71

I. Introduction

The SGCT is an analysis tool that identifies the benefits of a SG project and guides the user through an analysis which quantifies those benefits. It characterizes smart grid (SG) projects by identifying what technology will be installed and what functionality that technology will enable. Based on the characterization of a project it identifies the economic, reliability, environmental and security benefits the SG project will yield. The SGCT uses user entered data to calculate the monetary value of benefits and prepares graphs and tables that compare the costs and benefits to help determine the project's overall value. The SGCT can also perform a sensitivity analysis.

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. The linkage among them, however, is not quite clear and not easy to understand by just examining this excel based SGCT. It also leads to an inability to handle unusual situations and circumstances.



Figure 1 Illustration of the Input and Output of SGCT

Above all, the current SGCT is basically designed for the use of US smart grid projects and is not for any other member countries.

This manual is for the simple replicated version of SGCT of DOE, but it expands the users to all the member countries and all the parameters which are hidden in SGCT can be modified explicitly by the users.

In the following, a brief introduction of SGCT is given first, especially with its focus to the linkage among assets, functions, and benefits. Other details of the workflow including project characterization module (PCM), data inputmodule (DIM) and computational module (CM) will be summarized in the appendix I.

Then, the current replicated and revisedversion of SGCT is presented:

- 1. Installation process
- 2. File Structure when installed
- 3. Brief Explanation of the program How to use the program?
 - A. How a member country can use this program
 - B. How to modify the given parameters using default excel files details of the parameters used in SGCT is provided at Appendix II.
 - C. How to choose Assets, Functions and Mechanisms
 - D. Continuingfor Final Results
 - E. Other issues to run the program
- 4. Detailed Architecture in the Replication of SGCT
- 5. Project Characterization Module in SGCT and Its GUI Replication
- 6. Comparison of Data Input Module in SGCT and Its GUI Replication
- 7. Computational Module in SGCT and Its GUI Replication

II. A Brief Review of SGCT

In the following diagram, the linkage among assets, functions, and benefits is presented in a very easy way, although the diagram looks a bit complicated. The explanation on such linkage is not quite straight forward when using SGCT of DOE. At appendix I, the details of the linkage between Assets and Functions are given at one table, while the linkage between function and benefits are presented in another table. Combining the two tables into one diagram will simply produce the following diagram.

Once Asset types are selected for smart grid out of 22 assets, those will be linked to 15 types of functions. Those functions will have their linkage to related types of benefits. There are 22 types of benefits presented in SGCT.

1			h -							Funct	ionas							
		Benefits	with Convert Limiting	Add Area Wardbarry, Insufficiency, and Control	wares Caudelity Rating	ower filow Control	And a second second	diseased featured inc	Internetion	dueune Witigs we'Vel	lagrasis & Notficature of quipment Candidian	manual Fault Protoction	No. The Lod Weakered &	exitine Land Transfer	estimation Districtly Use optimization	turing discretity for Later Unit	national fradaction of leaferthy	
Constra.	Heprinsed Asset UDELation FBD Capital Savings TBD ORM Savings TBD ORM Savings Their Reduction Energy Foreign Foreign Foreign Savings Foreign Savings Foreign Savings	Optimizing demarginer Opportion Definition (Generation Copportion Definition) Generations Capacity International Restauced Analities Standards Capacity International Definition Congestion Cool Definition Congestion Cool Restaured Table Demarktions Cool Restaured Table Demarktions Cool Restaured Table Demarktions Cool Restaured Table Demarktions Cool Restaured Hearthicity Cool Restaured Standards Octogen			•							•	•		•	•	•••••	15
Relationy Fouriermental Tocurity	Priver Guarty Ar Emission	Reduced Restoration Cast Reduced Restoration Cast Reduced Sign and Swells Reduced CO, Environme Reduced CO, Environme Reduced CO, Kob, and PM-10 [Investme Reduced CO] Usage (not monitized]				•	•				•	•	•		•	•	•	
	[22				•			• 10					•				Advensed Internating Switch Advensed Internating Switch Advensed Internating Switch ControlMoleComparison Investore ControlMoleComparison Distribution Advancement Distribution Advancement Distribution Advancement Distribution
			Fault Current Limbing	While Area Manufaring, Vinastication, and Contral	Dynamic Capability Mating	Power Flaw Cartrol	Adaptive Protection	Automated Perder and Line Switching	Accounted Handby and Accountion	Automated Vehige and VMA	Dispersit & Notification of Equipment Candition	Esthemoted Fault Prystercline	Real-Time Load Measurement & Navageneeri	Real Fire Load Transfer	Curtemer Electricity Une Optimization	Storing Thermicity for Later Lite	Electricity Production of Electricity	Smart Grid Assets



Figure 2 Easy Representation of the Linkage among Assets, Functions, and Benefits

Figure 3 Illustration of the Translation of Smart Grid Assets to Monetary Value

Source: USER GUIDE FOR THE U.S. DEPARTMENT OF ENERGY SMART GRID COMPUTATIONAL TOOL (SGCT) Guide for SGCT Public Version 1.3, Navigant Consulting, March 2011

In the above diagram of SGCT, however, you will see 'Mechanisms' not in the linkage described above. But these are the detailed functional forms to be applied once the linkage between functions and benefits are identified. Appendix I provides a couple of examples of the detailed functional form of 'Mechanisms'.

III. Replicated and Revised Version of SGCT

III.1 Installation Process

First step of installation is really an easy process. Just insert the CD into the computer and the program will automatically install the program. This CD contains installation program 'dotNetFx45_Full_setup.exe'.



Figure 4 Installation CD for Smart Grid BCA Toolkit Revised by EML (Energy Modeling Lab., Ajou Univ.)

All you have to do is to determine where to install at the following dialog box. Choosing the 'change ...' button at the following dialog box will give the user a chance to change the default directory to his own choice.

Once the file is installed, the following icon can be see at the desktop background such as following:



9	Revised	dSGCT_EMI	- InstallS	nield Wizard	
Destina Click N	tion Folder ext to install to this f	older, or cli <mark>c</mark> k Cl	nange to instal	to a different fold	er, 2
Ø	Install RevisedSG C:₩Program File	CT_EML to: s (x86)₩Revise	dsgct_eml₩	RevisedSGCT₩	Change
ıstallShield	·				

Figure 5 Directory Setting Dialog Box

Change	Current Destination Folder	mera mizara	
Browse	to the destination folder		
Diowac			
Look in:			
📥 R	evisedSGCT	~	E 😽
Eolder r	name:		
Eolder r	name: ogram Files (x86)₩RevisedSGCT_EML₩RevisedS	GCT₩	
Eolder r C:\#Pr stallShield	name: ogram Files (x86)₩RevisedSGCT_EML₩RevisedS	GCTW	

Figure 6 User's Choice of Folder for Installation

III.2 File Structure when installed

Once installed, you will see the directory structure such as following:

At the root directory, you will see the following files:

/data /xml ClassLibrary.dll ControlLibrary.dll DevExpress.Charts.v14.1.Core.dll DevExpress.Data.v14.1.dll DevExpress.Mvvm.v14.1.dll DevExpress.Xpf.Charts.v14.1.dll DevExpress.Xpf.Controls.v14.1.dll DevExpress.Xpf.Core.v14.1.dll dotNetFx45_Full_setup.exe ISGAN Project.exe For the subfolder of /data, /data/constants.csv /data/default-values.csv /data/escalated-factors.csv For the subfolder of /xml, /xml/config.xml /xml/input-def.xml /xml/project-def.xml /xml/sys-def.xml

'ISGAN Project.exe' is the execution file for the Smart Grid BCA Toolkit Revised by EML. Following is the initial page of the replicated and revised version of SCGT.



Figure 7 Initial Page of the Replicated Program

III.3 Brief Explanation of the program – How to use the program?

Clicking any place on the initial page will guide to the initial program page of the following:



Figure 8 Initial Page of Program

Project information

At the top of the page, you will see the project information related boxes. Default values for

- ✓ Project Name
- ✓ Organization
- ✓ Start Year

will be given for convenience. User will edit or change the project information for his own.

III.3.1 How a member country can use this program

Country

As is explained, the SGCT is originally designed for North America composed of 10 NERC (North American Electric Reliability Corporation) regions and extra one region not in NERC. For this program to be usable for all ISGAN member countries, this designated region should be expanded to all the member countries of ISGAN.

NPCC North America Region Country Ŧ Australia Austria Belgium Canada China European Commission Finland France Germany India Ireland Italy Japan Republic of Korea Mexico nditic Netherlands Norway Russia Singapore

> South Africa North America

Spain Switzerland United Kingdom

Sweden

In the following diagram, it can be seen that the choice is expanded for all the member countries.

Figure 9 Expansion of Country Choices to all ISGAN Member Countries

However, the parameters used in SGCT are predefined only for those 11 regions including NERC and non-NREC. This part of the SCGT is one of the most important parts of the program. How to choose the choice of your own region and related parameters proper to use will be the critical part of the proper utilization of the program.

Let's first look at the all the parameters applied in this part, once the region of your choice is selected. Followings are the list of parameters required to use for analysis of your own region:

- ✓ Average Hourly Generation Cost (\$/MWh), which is the average hourly cost to generate 1 MWh of energy, which could also be the average hourly cost to purchase 1 MWh of electricity from a supplier, which number is multiplied by the Avoided Annual Generator Dispatch to monetize the value of this benefit
- ✓ Price of Capacity at Annual Peak (\$/MW) , which is the price paid for peak capacity,
- ✓ Average Price of Reserves (\$/MW), which is the price of electricity reserves, which could be spinning or non-spinning type.
- ✓ Average Price of Frequency Regulation (\$/MW), which is the price of frequency regulation service.
- ✓ Average Price of Voltage Control (\$/MW), which is the price of voltage control service.
- ✓ Average Price of Congestion (\$/MW), which is the price of congestion relief
- ✓ Average Price of Wholesale Energy (\$/kWh), which is the average of wholesale price of electricity, which input will be used to monetize electricity losses.
- ✓ Inflation Factor
- ✓ Restoration Cost per Event(\$/event), which is the average cost of restoration after one outage event
- ✓ Average Fuel Efficiency for Truck Roll (miles/ gallon), which is the average vehicle or fleet fuel efficiency of the vehicles used for service calls and truck rolls.
- ✓ CO2 Emissions per Gallon of Fuel (tons/ gallon), which is the typical amount of CO2 emitted from burning a gallon of fuel in vehicles used for service calls and truck rolls. The default data is based on gasoline.
- ✓ Value of CO2, the anticipated/current market price of CO2 emissions
- ✓ SOx Emissions per Gallon of Gas (tons/gallon), which is the typical amount of SOx emitted from burning a gallon of fuel in vehicles used for service calls and truck rolls. The default data is based on gasoline
- ✓ NOx Emissions per Gallon of Gas (tons/gallon), which is the typical amount of NOx emitted from burning a gallon of fuel in vehicles used for service calls and truck rolls. The default data is based on gasoline
- ✓ Value of SOx, the anticipated/current market price of SOx emissions
- ✓ Value of NOx, the anticipated/current market price of NOx emissions
- ✓ Value of PM-2.5, the anticipated/current market price of PM-10 (or PM-25) emissions
- ✓ Average Fuel Efficiency (miles/gallon), which is the average vehicle or fleet fuel efficiency of the vehicles used for service vehicle.
- Electricity to Fuel Conversion Factor (gallons/kWh), the equivalent amount of gasoline a PEV would use by consuming one kWh of electricity

Details of the parameter values are found at Appendix II. Some of the parameters could be directly obtained from domestic market conditions, while others may not be. Until the detailed data base for all the possible choices of the regions for each member countries, not all of those parameter information may be available.

Configuration and Other Choices in Menu

Here is how we revised, once again, for the use of the program:

- 1. Choose Menu at the lower left corner of the initial program page.
- 2. Clicking Menu will give the following pull-down menus.



Figure 10 Pull-down Menu of Menu

- 3. Select Configuration, then you will see the following diagram. There are many options you can choose.
 - A. Digit will allow you to control the digits below decimal point.
 - B. Parameter setting will allow you to take the default values from North America and modify them at your own disposal. That is, you can choose any specific region out of NERC or take the average of NERC with 'similarity weight' of your own choice in between 0 to 100%. Details are as following:
 - In the following dialog box after choosing 'Configuration' in Menu, user can add country name (when a new member country is added or any other country might want to try the program!) by clicking 'Add' button just below the Country list.

Menu

Country Name:	
Country Name.	

Figure 11	Addition	of a New	Country
-----------	----------	----------	---------

JI Setting Digit : 1				
Parameter Setting	Escalated Factors (%)			
uustria Jelgium Canada China Luropean Commission Jaland	Population: Default Value Default Value :	Load	Inflation:	Energy Price:
rance Sermany ndia reland				
anan				
lepublic of Korea Aexico	•			
Region	*			
Add Edit Deleti				
Add Edit Delets				

Figure 12 Dialog box for 'Configuration' in Menu

- When a country is selected and a user's choice of region is to be added, choose the button 'Add' down below the Region.
- This will give the user a choice of parameter values to be used. He can give his own region name and choose to copy the default parameter values from North America's

NERC regions. Even if he chooses not to, this process of copying the parameter values will create and save the values for his own region so that he can modify it later at his disposal.

- 'Similarity weight (%)' is what you can use for discounting the default parameter values at 0 to 100% range. Once the values are saved, user can utilize the saved data file for further modification. (Details are explained in the following subchapter.)
- User may also want to modify the values one by one once the region of his choice is added. With the cursor on the newly added region (here, it is named as 'My Region' as below), choosing the pull-down menu next to 'Default Value' will give all the detailed choices possible.

Copy th	e parameter from another reg	jion
Country :	North America	÷
Used th	e average parameter of a sel	ected count
Region :	NPCC	Ŧ

Figure 13 Addition of New Region and the Use of Parameter Values

ConfigDig					1.22	
UI Setting Digit : 1						
Country	Escalated Fact	ors (96)				
Ireland Italy Japan Republic of Korea Metherlands Norway Russia Singapore South Africa North America Spain Switzerland United Kinodom Add Edit Delete Region My Region	Population: 0.2 Default Value :	Average Hourly Price of Capacil Average Price of Average Price of Average Price of Average Price of Average Price of Average Price of Value of Service Value of Service Value of Service Value of Service Average Fuel Ef CO2 Emissions PM-25 per Gal Value of SOx Value of SOX	Load: 0.8 Generation Cost by at Annual Peak of Reserves of Protage Control of Voltage Control of Congestion of Con	Inflation: Weight(%) :	2.7 Vehicle Management Servic	Energy Price: 33
		Save	Cancel	Close]	

Figure 14 Detailed Items for the Change of Default Parameter Values

 Suppose the user chose 'Average Price of Wholesale Energy', there will be the default values of the user's choice shown as below and the user can edit them right at the dialog box.

Default Value Average Price of Wholesale Enel • Weight(%) : 100 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	0.1	0.1	L 0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	•												Þ

Figure 15 Values Shown at the Dialog Box

- C. (For advanced users) You can also change the excel files which contains the parameter values of your own choice once your project is 'Save'd at the above Menu. Detailed explanation will be given in the next subchapter.
- 4. Once the parameter values are properly input, you can 'Save' and 'Close' the dialog box to continue.

- 5. Other items in the above Menu are simple:
 - A. The choice of 'New Project' will ask you whether you want to save the current project to initiate a new one as following:

	×
Do you want to save this project?	
예(Y) 아니요(N) 취	<u>^</u>

Figure 16 Dialog box for 'New Project' in Menu

- B. The choice of 'Save' or 'Load' will ask you whether you want to save the current project or load any existing project.
- C. The choice of 'Information' will provide information on those who worked for this project.

III.3.2 How to modify the given parameters using default excel files

(For advanced users) As discussed, user can also change the excel files which contains the parameter values of your own choice once your project is 'Save'd at the above Menu. This will be useful when there are so many parameters to modify. You don't have to go through the GUi of the revised SGCT one by one. Rather, you can go directly to the portion of excel file which contains the values for your region after you saved your project, and modify the values with your prior knowledge of domestic market with all the functionalities provided by excel.

III.3.3 How to choose Assets, Functions and Mechanisms

This replicated and revised SGCT by EML has very much simplified the process of linkage among assets, functions and mechanisms shown in the following diagram.



Figure 17 Choosing among Assets, Functions and Mechanisms

For the test, suppose the user choose AMI/Smart Meters among all types of Assets. It will give available choices in functions as shown above. The boxes on the left of the list of functions which are related to the selection of asset is given in different colors.



Figure 18 Choice of Function Gives Following Choice of Mechanisms

Choosing one of the candidate choice of functions will give the list of available Mechanisms as shown above. Once the choice of assets, functions and mechanisms are made, the user can move to the next

stage by clicking the right arrow box

Suppose the user chose all the choices given in Mechanisms, the next page will be given as following:

->

Benefits Review
Reduced Ancillary Service Cost
Reduced T&D Operations Cost
Reduced Electricity Losses
Reduced CO2 Emissions
Reduced SOX, NOX, and PM-2.5 Emissions
Optimized Generator Operation
Coherest Generation Capacity Investments
fiedused .Congestion Cost
Defended Yrammission Capacity Investments
Delevent Distribution Capacity Investments
Reduced Epupment Fakures
Reduced 7.0/D Equipment Malintenance Cost
Reduced Meter Reading Cost
Reduced Electricity Theth
Reduced Electricity Cast
Reduced Sudament Outages
Reduced Major Outages
Reduced Rettonation Cost
Reduied Momentary Outages
In the second post of the second

This page shows what kind of benefits are being considered for monetary value calculation. On the left hand side, there is a diagram which shows the selected choices of assets, functions and mechanisms and their relationship for the user's information.

III.3.4 Continuing for Final Results

When the user close the above dialog box, the following page will be shown. This part is basically the replicated DIM (Data Input Module) of SGCT. This stage will require a bunch of detailed information on power market of user's choice:

- ✓ For each customer class (Residential, Commercial, and Industrial), information on average energy rate, average demand charges, and customer served for sub-classes are required to be entered.
- ✓ Escalation factors and cost data are also required to enterred for the user's choice of assets.

Project asigning	ation											
Project Name	My_projec	t01 Org	panization	Ajou_Univ_01	Start Year	2015		Country	Republic of Kor	ea • Reg	ion Empty	•
Custom	iers & Ta	riff										
Residential C	ustomer (lass		Commercial	Customer C	lass			Industrial Cu	stomer Class		
	Average Energy Ra (\$/kWh)	Average Demand Charge(\$/ kWmonth)	Custom Serves	ers d	Average Energy Rate (\$/kWh)	Aver Dom Chan kWm	age and pe(\$/ onth)	Customers Served		Average Energy Rate (\$/kWh)	Average Domand Charge(\$/ kWmonth)	Customers Served
Sub-Class 1	0	0	0	Sub-Class 1	0	0		0	Sub-Class 1	0	0	0
Dub Class 7	0	0	0	Euk Class 1	0	0		0	Dub Class 3	0	0	0
SUD-Class 2	U.	v	u	Sub-Class 2	U	v		•	500-0855-2	U.	v	
Sub-Class 3	0	0	0	Sub-Class 3	0	0		0	Sub-Class 3	0	0	0
Sub-Class 4	0	0	0	Sub-Class 4	0	0		0	Sub-Class 4	0	0	0
Sub-Class 5	0	0	0	Sub-Class 5	0	0		0	Sub-Class 5	0	0	0
Average Rate:	0	0	Total:	0 Average Rate	0		05	Total: 0	Average Rate.	0	0	Total: 0
esca opulation Gro	wth Factor	Description	IV.	0.2		Use C	ustom C	ost Schedule	No		•	
Esca	alation Fact	or De	efault Valu	e Value		Disco	int Rate		0		%	
opulation Gro	wth Factor	Description	1	0.2	5	Use C	ustom C	ost Schedule	No		1.00	
and Growth Es	artor	Description	120	0.8		Initial	Vear of	Project Spendi	ng 0		yr	
		- esterile starte	-		- Ĵ.	Final	ear of P	Project Spendin	g 0		yt	
conomic Inflat	ion Factor	Description	×	27.	%	Total	-	Toot of Desinct	0			
nergy Price Fa	ctor	Description	1	3.3	%	i cuar	coprise s	cost al ridjets				
inal Year of Be	nefits	Description	¥.	2040	yr	Yearly	Amortia	ed Payment	U.	NaN	5	
Enter B	enefit Ca	lculation Inp	out Data									
Benefit			Option	Input Name		Unit	Detault	Base 2015 6	ase 2016 Base	2017 Base 2	018 Base 20	19 Project 2
Reduced Ancil	lary Service	Cost	03	Ancillary Services Cost	r -	5		0.0	0.0	0.0	0.0	p.ol
LAP REPORT FRAME	Operations	Cost	四	Distribution Operation	ns Cost	5		0.0	0.0	0.0	0.0	0.0
Reduced T&D	Operations	Cost		Transmission Operatio	ons Cost	\$		0.0	0.0	0.0	0.0	0.0
Reduced T&D Reduced T&D	ricity Losse	5		Distribution Feeder Lo	bad	MVA.		0.0	0.0	0.0	0.0	2.0
Reduced T&D Reduced T&D Reduced Elect	ricity Losse	1		Distribution Losses		%		0.0	0.0	0.0	0.0	0.0
Reduced T&D Reduced T&D Reduced Elect Reduced Elect	ricity Losse			Transmission Line Loa	d	MVA		0.0	0.0	0.0	0.0	0.0
Reduced T&D Reduced T&D Reduced Elect Reduced Elect Reduced Elect	states i support			Transmission Losses		%	-	0,0	0.0	0.0	0.0	0.0
Reduced T&D Reduced T&D Reduced Elect Reduced Elect Reduced Elect Reduced Elect	nony cosse	1	- 1	Average Price of Who	lesale Energy	\$/kWh	10	0.0	0.0	0.0	0.0	0.0
Reduced T&D Reduced T&D Reduced Elect Reduced Elect Reduced Elect Reduced Elect	ricity Losse			Value of CO2		\$/ton	101	0.0	0.0	0.0	0.0	2.0
Reduced T&D Reduced T&D Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced Elect	ricity Losse Emissions		8 S	value of SCX		S/ton	111	0.0	0.0	0.0	0.0	10
Reduced T&D Reduced T&D Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced CO2 Reduced CO2	ricity Losser Emissions NOIc and P	M-25 Emissions		DOMESTIC: NOT BE AND INCOME.		\$/001	121	0.0	0.0	0.0	0.0	
Reduced T&D Reduced T&D Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced CO2 Reduced SOK, Reduced SOK	nony cosser ricity cosser Emissions NOx, and P NOx, and P	M-25 Emissions M-25 Emissions		Value of Res OF		C. iber	1000	20.20	the second se	71.771		
Reduced T&D Reduced T&D Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced Sox, Reduced Sox, Reduced Sox,	ricity Losser Emissions NOx, and P NOx, and P NOx, and P	M-2.5 Emissions M-2.5 Emissions M-2.5 Emissions		Value of PM-25		\$/ton	10	0.0	uoj	0.0	0.0	0.01
Reduced T&D Reduced T&D Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced Elect Reduced SOK Reduced SOK Reduced SOK	ricity Lossen Finitisions NOX, and F NOX, and F NOX, and F	M-25 Emissions M-25 Emissions M-25 Emissions	5	Value of PM-25		\$/ton	12	0.0	- WM	0.0	0.0	onl.

Figure 19 Data Input Module Dialog Box Replicated

After all appropriate data are inputted into the program, then the user can go to the Result tab. Followings are all types of result related dialog boxes available:

				Mair	Window									
roject informati	ion													
oject Name	lest3	Organization Test3 Start Year	2015	Country	North Ame	rica 🔹	Region	NPCC						
ference Case	Sensitivity Case													
oudi Table 18	and the set of the test													
NNUAL Beneil	nisi	event value voleyus												
Cartegory	Sub Cartegory	Benefit	2015	2016	2017	2018 2	019	2020	2021	2022	2023	2024 20	25	2026
Economic	Electric Cost Saving	Reduced Electricity Cost	19.00	16.51	12.38	9.89	5.75	5,95	6.16	6.38	6.60	6.83	7.07	7
Economic	Energy Efficiency	Reduced Electricity Losses	62020800.00	13549975.00	19349171.43 1	1057761.904	143792.86	4314782.33	4492827.50	4678219.54	4871261.59 5	072269 33 52	31571.455	49951
Economic	Improved Asset Ut	Optimized Generator Operation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Economic	Improved Asset Ut	Deferred Generation Capacity Investments	50.00	37.04	25.93	16.67	9,26	9.64	10.0	10.45	10.88	11.33	11.80	1
Economic	Improved Asset Ut	Reduced Ancillary Service Cost	5.00	4.44	3.89	3.33	2.78	2.89	3.01	3.13	3.26	3.40	3.54	-
Economic	Improved Asset Ut	Reduced Congestion Cost	7.00	6.12	436	3.50	1.75	1.82	1.90	1.97	2.06	2.14	2.23	- 1
Economic	T&O Capital Savino	Deferred Transmission Capacity Investments	-2.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Economic	T&D Capital Saving	Deferred Distribution Capacity Investments	-2.60	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	-
Economic	T&D Capital Saving	Reduced Equipment Failures	0.53	0.34	0.24	0.12	0.06	0.06	0.0	0.06	0.07	0.07	0.07	
Economic	T&D O&M Savinot	Reduced T&D Equipment Maintenance Cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Economic	T&D O&M Savings	Reduced T&D Operations Cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Economic	T&D OAM Saving	Reduced Meter Reading Cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Economic	Theft Reduction	Reduced Electricity Theft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Environmental	Air Emissions	Reduced CD2 Emissions	15.00	8.75	5.62	1.56	1.25	1.28	1.3	1.35	1 39	1.45	1.47	-
Environmental	Air Emissions	Reduced SOx NOx and PM-25 Emissions	19.00	11.85	7.61	4.84	2.58	2.65	27	2.80	2.87	2.95	3.03	-
Reliability	Power Interruption	Reduced Sustained Outages	2686.00	1479.10	719.17	280 12	63.17	131.05	135.0	141.00	146.26	151 72	157 37	16
Reliability	Power Interruption	Reduced Major Outages	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3
UMULATIVE B	eneift(\$)													
Cartegory	Sub Cartegory	Senefit	2015	2016	2017	2018	2019	2020	2	021	2022	2023	2024	1
Economic	Flectric Cost Saving	Bedured Electricity Cost	longe	35.51	47.8	d 577	al	63.53	60.48	75.64	82.01	88.61	1	05.44
Economic	Energy Efficiency	Reduced Electricity Cont	63020800.001	05570775.00	124010046.4	124077700.2	01.055231	101 10 14442	6702 57 14	2020111/02/2	53677330 56	152470802.13	1635500	61 47 1
Economic	Impercent Assat Lit	Optimized Generator Operation	0.00	0.00	0.0	0/	0	6.00	0.00	0.00	0.00	0.00	10335500	0.00
Economic	Improved Asset Ut	Deferred Generation Capacity Investments	50.00	\$7.04	1120	120.6	7	22.00	1.40 52	150.57	160.02	170.00	1	0.00
Economic	Improved Asset Dr	Performed Germandon Capacity Investments	5.00	01.04	13.2	76.6	9	10.14	22.2.4	26.36	20.40	31.7		25.1.4
Economic	improved Asset (it	Radivad Connection Cost	7.00	1244	12.5	350	0	22.75	24 57	25.55	29.44	30.50		22.54
Economic	T&D Capital Saure	Deferred Transmission Canacity Investments	.3.70	.7.74	,73			.3.78	.2.29	-2.29	.3.30			-2.28
Economic	TBO Canital Savin	Deferred Distribution Canacity Investments	-2.60	-2,20	.36	1	0	-2.60	-2.60	-2.60	-4-40	-2.64		-2.60
confighting.	TRID Capital South	Parking Control Contro	0.52	-2.0	-2.0	-2.0	3	1.70	1.25	1.00	-2.00	-2.0	-	1.60
Fennomic	LINES PROVIDE SHALL	Linking and a hard set and set	0.33	5.67		14	0	0.00	2.00	0.00	1.97	1.54	-	0.00
Economic	TRO OBM STING	Party and TBD Environment Maintenance Cost	0.00			- 12.5		0.00	0.00	0.00	0.00	0.00		0.00
Economic Economic Economic	T&D O&M Savings	Reduced T&D Equipment Maintenance Cost	0.00	0.00	0.0	-	0	0.00	0.00	0.001	0.00	0.00		-WANK
Economic Economic Economic	T&D O&M Savings T&D O&M Savings T&D O&M Savings	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Mater Reading Cost	0.00	0.00	0.0	0.0	0	0.00	0.00	0.00	0.00	0.00		0.00
Economic Economic Economic Economic	T&D O&M Savings T&D O&M Savings T&D O&M Savings Theft Barketton	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Meter Reading Cost Reduced Electrony The#	0.00	0.00	0.0	0.0	0	0.00	0.00	0.00	0.00	0.00		0.00
Economic Economic Economic Economic Economic	T&D O&M Saving: T&D O&M Saving: T&D O&M Saving: Theft Reduction	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Neter Reading Cost Reduced Electricity Theft Reduced CO2 Employer	0.00 0.00 0.00 0.00 0.00 0.00	0.00 0.00 0.00	0.0	0.0 0.0	0	0.00	0.00	0.00 0.00 0.00 34.70	0.00	0.00		0.00
Economic Economic Economic Economic Economic Economic Environmental Environmental	T&D O&M Savings T&D O&M Savings T&D O&M Savings Theft Reduction Air Emissions	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Neter Reading Cost Reduced Electricity Theft Reduced CO2 Emissions Reduced CO2 Emissions	0.00 0.00 0.00 0.00 15.00	0.00 0.00 0.00 23.75	0.0	0 0.0 0 0.0 0 0.0 9 0.0 9 30.9	0 0 44	0.00 0.00 0.00 32.19 45.98	0.00 0.00 33.47 48.53	0.00 0.00 0.00 34.79	0.00 0.00 36.14	0.00		0.00
Economic Economic Economic Economic Economic Environmental Environmental	T&D O&M Savings T&D O&M Savings T&D O&M Savings T&D O&M Savings Theft Reduction Air Emissions Air Emissions	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Neter Reading Cost Reduced Electricity Theft Reduced Electricity Theft Reduced CO2 Emissions Reduced SOx, NOx, and PM-2.5 Emissions Each and Electronic October	0.00 0.00 0.00 0.00 15.00 19.00	0.00 0.00 0.00 0.00 23.75 30.85	0.0 0.0 0.0 0.0 29.3 38.4	0 0.0 0 0.0 0 0.0 8 30.9 6 43.3		0.00 0.00 32.19 45.88	0.00 0.00 33.47 48.53	0.00 0.00 34.79 51.26	0.00 0.00 36.14 54.05	0.00		0.00 0.00 38.96 59.87
Economic Economic Economic Economic Economic Environmental Environmental Reliability	T&D Q&M Seving: T&D Q&M Seving: T&D Q&M Seving: Theft Reduction Air Emissions Air Emissions Power Interruption Power Interruption	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Meter Reading Cost Reduced Electricity Theft Reduced Electricity Theft Reduced Electricity Theft Reduced SOx, NOx, and PM-2.5 Emissions Reduced Sustained Outages Partnard Naior Outages	0.00 0.00 0.00 15.00 39.00 2686.00	0.00 0.00 0.00 23 75 30 85 4165 10	0.0 0.0 29.3 38.4 4884.2	0 0.0 0 0.0 0 0.0 8 30.9 6 43.3 8 5164.3	0 0 44 10 13 15	0.00 0.00 32.19 45.88 227.55	0.00 0.00 33.47 48.53 5358.60	0.00 0.00 34.79 51.26 5494.54	0.00 0.00 36.14 54.05 5635.54	0.00 0.00 37.52 56.92 5781.8	59	0.00 0.00 38.96 59.87 33.52
Economic Economic Economic Economic Economic Environmental Environmental Reliability Reliability	Tab OAM Sevings Tab OAM Sevings Tab OAM Sevings Theft Reduction Air Emissions Air Emissions Power Interruption Power Interruption	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Meter Reading Cost Reduced Electricity Theft Reduced Electricity Theft Reduced CO2 Emissions Reduced SOx, NOx, and PM-2.5 Emissions Reduced Sustained Outages Reduced Maior Outages	0.00 0.00 0.00 15.00 2686.00 0.00	0.00 0.00 0.00 23.75 30.85 4165.10 0.00	0.0 0.0 29.3 38.4 4884.2 0.0	0 0.0 0 0.0 0 0.0 8 30.9 6 43.3 6 43.3 5 164.3 0 0.0	00 00 10 14 14 10 18 15 10	0.00 0.00 32.19 45.88 227.55 0.00	0.00 0.00 33.47 48.53 5358.60 0.00	0.00 0.00 34.79 51.26 5494.54 0.00	0.00 0.00 36.14 54.05 5635.54 0.00	0.00 0.00 37.53 56.93 5781.81 0.00	59	0.00 0.00 38.96 59.87 33.52 0.00
Economic Economic Economic Economic Economic Environmental Environmental Reliability Reliability	T&D O&M Saving: T&D O&M Saving: T&D O&M Saving: Theft Reduction Air Emissions Air Emissions Air Emissions Power Interruption Power Interruption	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Neter Reading Cost Reduced Electricity Thaft Reduced CO2 Emissions Reduced CO2 Emissions Reduced SOR, NOX, and PM-2.5 Emissions Reduced Sustained Outages Reduced Major Outages	0.00 0.00 0.00 15.00 39.00 2686.00 0.00	0.00 0.00 0.00 23.75 30.85 4165.10 0.00	0.0 0.0 29.3 38.4 4864.2 0.0	0 0.0 0 0.0 0 0.0 9 30.9 6 43.3 8 5164.3 0 0.0	0 0 10 14 10 18 15 10	0.00 0.00 32.19 45.88 227.55 0.00	0.00 0.00 33.47 48.53 5358.60 0.00	0.00 0.00 0.00 34.79 51.26 5494.54 0.00	0.00 0.00 36,14 54,05 5635,54 0.00	0.00 0.00 37.53 56.9, 5781.81 0.00	59	0.00 0.00 38.96 59.87 33.52 0.00
Economic Economic Economic Economic Economic Environmental Environmental Reliability Reliability	T&D O&M Savings T&D O&M Savings T&D O&M Savings TAB O&M Savings Theft Reduction Air Emissions Air Emissions Power Interruption Power Interruption	Reduced T&D Equipment Maintenance Cost Reduced T&D Operations Cost Reduced Weter Reading Cost Reduced Electricity Theft Reduced Electricity Theft Reduced CO2 Emissions Reduced SOx, NOx, and PM-2.5 Emissions Reduced Sox NOx, and PM-2.5 Emissions Reduced Sox Intaneous Reduced Maior Outages	0.00 0.00 0.00 15.00 39.00 2686.00 0.00	0.00 0.00 23.75 30.85 4165.10 0.00	0.0 0.0 0.0 293 384 4884.2 0.0	0 0.0 0 0.0 3 0.0 8 30.9 6 43.3 8 5164.3 0 0.0	0 0 14 18 5 10	0.00 0.00 32.19 45.88 227.53 0.00	0.00 0.00 33.47 48.53 5358.60 0.00	0.00 0.00 34.79 51.26 5494.54 0.00	0.00 0.00 36.14 54.05 5635.54 0.00	0.00 0.00 37.5: 56.9; 5781.8: 0.00	59	0.00 0.00 38.96 59.87 33.52 0.00

Figure 20 Replication Reference case: Result Table



Figure 21 Replication Reference case: Result Chart



Figure 22 Replication Reference case: Net present value Analysis

					Ma	inWir	ndow									+		
oject Information oject Name Test3 Organization Te	est3			Sta	rt Ye	ar 20	15		Co	ountry	North	n Amer	rica	¥	Regior	NPC	c	
ference Case Sensitivity Case scalated Input Data Benefit Table PV Benefit Table	Sensi	itivity (Grapi	ns Sei	nsitiv	vity Ch	arts											
Run Sensitivity Anlysis Changing the whole r	atio :	100	~	100	~	2015	2010	2017	2010	2010	2020	2021	2022	2022	2024	2025	2020	2027
Price of Capacity at Annual Peak	\$/MV	LOW(76) V	Hing(76) V	2015	2016	2017	2018	2019	0.34	0.36	2022	2023	2024	2025	2026	0.43
Total Customer Peak Demand	MW	50	~	135	~	4.00	3,56	3.11	2.67	2.22	2.24	2.26	2.28	2.29	2.31	2.33	2.35	2.37
Ancillary Services Cost	\$	50	~	135	~	4.00	3.56	3.11	2.67	2.22	2.31	2.41	2.51	2.61	2.72	2.83	2.94	3.06
Congestion Cost	s	50	~	135	~	1.00	0.88	0.62	0.50	0.25	0.26	0.27	0.28	0.29	0.31	0.32	0.33	0.34
Capital Carrying Charge of Transmission Upgrade	\$	50	Ŷ	135	Ŷ	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transmission Investment Time Deferred	yrs	50	Ŷ	135	v	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capital Carrying Charge of Distribution Upgrade	\$	50	Ŷ	135	~	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Distribution Investment Time Deferred	yrs	50	Ŷ	135	v	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capital Replacement of Failed Equipment	\$	50	×	135	v	1.00	0.78	0.67	0.44	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41
Portion Caused by Fault Current or Overloaded Equ	%	50	×	135	~	1.00	0.83	0.67	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Distribution Feeder Load	MVA	50	~	135	Ŷ	3.00	2.00	1.71	1.43	1.14	1.15	1.16	1.17	1.18	1.19	1.20	1.21	1.22
Distribution Losses	%	50	×	135	v	1.00	0.78	0.67	0.44	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Transmission Line Load	MVA	50	~	135	~	1.00	0.83	0.67	0.50	0.33	0.34	0.34	0.34	0.34	0.35	0.35	0.35	0.36
Transmission Losses	%	50	~	135	~	1.00	0.88	0.62	0.50	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Average Price of Wholesale Energy	\$/kW	50	~	135	Ŷ	3.00	3.00	2.00	2.00	1.50	1.55	1.60	1.65	1.71	1.76	1.82	1.88	1.94
Total Residential Electricity Cost	\$	50	~	135	~	1.00	0.83	0.67	0.50	0.33	0.34	0.36	0.37	0.38	0.40	0.41	0.42	0.44
Total Commercial Electricity Cost	\$	50	Ŷ	135	v	2.00	1.78	1.33	1.11	0.67	0.69	0.71	0.74	0.77	0.79	0.82	0.85	0.88
<																		>
Menu							PCM			->		DII	м		->			Result

Figure 23 Replication Sensitivity case: Escalated Input Data

							Main	Wind	ow										-		L
roject Informa	tion																				
roject Name	Test3	Organization	Test3			Sta	irt Year	2015	1		Coun	try	North	Americ	a	¥ ş	Region	NPCO	2		
eference Case	Sensitivity C	ase																			
Escalated Inpu	it Data Benef	it Table PV Benefit T	able S	ensitivit	ty Grap	hs Se	nsitivity	Chart	s												
ANNUAL Ben	eift (\$)																				
Cartegory	Scenario	Sub Cartegory	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	ī
Economic	Reference	Improved Asset Util	0.00	0.00	62.00	47.61	34.19	23.50	13,79	14.35	14.95	15.56	16.20	16.87	17.56	18.29	19.04	19.82	20.64	21.49	1
Economic	Low Case	Improved Asset Util	0.00	0.00	18.50	14.54	10.61	7.58	4.58	4,77	4.96	5.17	5.38	5.60	5.83	6.07	6.32	6.58	6.85	7.13	t
Economic	High Case	Improved Asset Util	0.00	0.00	107.33	81.77	58.41	39.60	22.99	23.93	24.92	25.95	27.02	28.13	29.29	30.49	31.75	33.06	34.42	35.84	I
Economic	Reference	T&D Capital Saving	0.00	0.00	-4.35	0.34	0.24	0.12	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	I
Economic	Low Case	T&D Capital Saving	0.00	0.00	-1.20	0.09	0.06	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	I
Economic	High Case	T&D Capital Saving	0.00	0.00	-7.40	0.63	0.43	0.21	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	I
Economic	Reference	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	I
Economic	Low Case	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	I
Economic	High Case	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1
Fronomic	Reference	Theft Reduction	1.000	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	1 0.00	0.00	0.00	1
CUMULATIVE	Beneift (\$)																				
Cartegory	Scenario	Sub Cartegory	2013	2014	2015	2016	2017	2018	2019	2020	2021	202	2 202	3 20	24 20	25 2	026 2	027 2	028	2029	
Economic	Reference	Improved Asset Util	0.00	0.00	62.00	109.61	143.80	167.30	181.08	195.4	4 210.38	8 225.	95 242	15 259	02 276	5.58 29	94.87 3	13.91 3	33.73 3	54.37 3	3
Economic	Low Case	Improved Asset Util	0.00	0.00	18.50	33.04	43.66	51.24	55.82	60.5	9 65.55	5 70.	72 76	10 81	.70 8	7,53	93.60	99.92 1	06.50 1	13.35 1	1
Economic	High Case	Improved Asset Util	0.00	0.00	107,33	189.09	247.50	287.10	310.09	334.0	2 358.94	4 384.	89 411	91 440	.03 469	9.32 49	99.82 5	31.57 5	64.62 5	99.04 6	6
Economic	Reference	T&D Capital Saving	0.00	0.00	-4.35	-4.01	-3,77	-3.65	-3.59	-3.5	3 -3.47	7 -3.4	41 -3.	34 -3	.27 -	3.21	-3.13	-3.06	-2.99	-2.91	
Economic	Low Case	T&D Capital Saving	0.00	0.00	-1.20	-1.12	-1.06	-1.03	-1.0	-1.0	0 -0.98	8 -0.1	97 -0	95 -0	.93 -(0.91	-0.90	-0.88	-0.86	-0.84	
Economic	High Case	T&D Capital Saving	0.00	0.00	-7.40	-6.78	-6.35	-6.13	-6.03	-5.9	-5.80	0 -5.	69 -5	57 -5	.44 -	5.32	-5.19	-5.06	-4.92	-4,78	
Economic	Reference	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.0	0 00	00 0	00.00	0.00	0.00	0.00	0.00	0,00	
Economic	Low Case	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.0	0 00	00 0	00.00	0.00	0.00	0.00	0.00	0,00	
Economic	High Case	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.0	0 00	00 0	00.00	0.00	0.00	0.00	0.00	0,00	
Fronomic	Reference	Theft Reduction	1.000	0.00	0.00	0.00	0.00	0.00	1. o or	0.0	n n n	n I	nol_o	nni r	innl i	nnnl	n nnl	n nnl	n nnl	nnol	
Men							1						7		ŝ	1					
Men	u .							PC	-M		->			DIM			-9		Re	suit	

Figure 24 Replication Sensitivity case: Benefit Table

							Main	Wind	ow									+	-	
roject Informat	ion																			
	Test3	Orrenientien	Test3				- N	2015					Jorth	moric	2			NDC	_	
oject Name		Organization	10303			Sta	rt year	2010			Cour		vorun	Americ	a	Ť	region	NPC	-	
eference Case	Sensitivity Ca	ise																		
scalated Input	Data Benefi	t Table PV Benefit Ta	ble Se	ensitivit	ty Grap	hs Se	nsitivity	/ Charts	s											
ANNUAL PV B	eneift (\$)																			
Cartegory	Scenario	Sub Cartegory	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Economic	Reference	Improved Asset Utili:	0.00	0.00	62.00	45.23	30.86	20.15	11.23	11.11	10.99	10.87	10.75	10.63	10.52	10.40	10.29	10.18	10.07	9.96
Economic	Low Case	Improved Asset Utili:	0.00	0.00	18.50	13.82	9.58	6.50	3.73	3.69	3.65	3.61	3.57	3.53	3.49	3.45	3.42	3.38	3.34	3.30
Economic	High Case	Improved Asset Utili:	0.00	0.00	107.33	77.68	52.71	33.95	18.72	18.52	18.32	18.12	17.92	17.73	17.54	17.34	17.16	16.97	16.79	16.60
Economic	Reference	T&D Capital Savings	0.00	0.00	-4.35	0.33	0.21	0.10	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Economic	Low Case	T&D Capital Savings	0.00	0.00	-1.20	0.08	0.05	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Economic	High Case	T&D Capital Savings	0.00	0.00	-7.40	0.59	0.39	0.18	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07
Economic	Reference	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Economic	Low Case	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Economic	High Case	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fconomic	Reference	Theft Reduction	0.00	0.001	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CUMULATIVE	PV Beneift (\$)																			
Cartegory	Scenario	Sub Cartegory	2013	2014	2015	2016	2017	2018	2019	2020	2021	202	2 202	3 20	24 20	25 2	026 2	027	2028	2029
Economic	Reference	Improved Asset Utili:	0.00	0.00	62.00	107.23	138.08	158.23	169.40	6 180.5	7 191.5	5 202.4	42 2 1 3	17 223	8.80 234	4.3224	4.722	55.012	65.182	75.25 2
Economic	Low Case	Improved Asset Utili:	0.00	0.00	18.50	32.32	41.90	48.40	52.13	3 55.8	2 59.4	6 63.0	07 66.	64 70	.17 73	3.66 7	7.12 8	80.53	83.91	87.25
Economic	High Case	Improved Asset Utili:	0.00	0.00	107.33	185.01	237.72	271.67	290.39	9 308.9	1 327.2	3 345.3	35 363.	27 381	.00 39	8.54 41	5.88 43	33.04 4	50.01 4	66.79 4
Economic	Reference	T&D Capital Savings	0.00	0.00	-4.35	-4.02	-3.81	-3.71	-3.66	6 -3.6	1 -3.5	7 -3.	52 -3.	48 -3	3.44 -:	3.40	-3.36	-3.32	-3.28	-3.24
Economic	Low Case	T&D Capital Savings	0.00	0.00	-1.20	-1.12	-1.07	-1.04	-1.03	3 -1.0	2 -1.0	1 -0.9	99 -0.	98 -0).97 -(0.96	-0.95	-0.94	-0.93	-0.92
Economic	High Case	T&D Capital Savings	0.00	0.00	-7.40	-6.81	-6.42	-6.24	-6.15	5 -6.0	6 -5.9	8 -5.9	90 -5.	82 -5	.74 -	5.67	-5.59	-5.52	-5.45	-5.38
Economic	Reference	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0 0	00 0	.00 (0.00	0.00	0.00	0.00	0.00
Economic	Low Case	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0 0.	00 0).00 (0.00	0.00	0.00	0.00	0.00
Economic	High Case	T&D O&M Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0 0.0	0 0.	00 0).00 (0.00	0.00	0.00	0.00	0.00
Fconomic	Reference	Theft Reduction	0.00	0.00	0.00	0.00	0.00	0.00		n n	ol oo	0 0	nol o	ool c		nool	0.00	0 001	0.00	0.00
									C 1 1					DIA A						

Figure 25 Replication Sensitivity case: PV Benefit Table



Figure 26 Replication Sensitivity case: Sensitivity Graphs


Figure 27 Replication Sensitivity case: Sensitivity Chart

III.4 Detailed Architecture in the Revised SGCT

After the separation of UI and data, it is possible for us to design flexible and extensible UI at our disposal. For example, if data changes to new data or edits some data, UI does not have to be designed. Since the controls in SGCT is fixed already by predefined data set, but controls in our program are created from data when program begins.

DB structure can be summarized as is shown below. Contents in the colored boxes in the following diagram presents some of data information included in several files.

- ✓ Data in blue box are PC (Project Characterization) data which consist of definition of assets, functions and benefits. PC data is defined in 'sys-def.xml'.
- ✓ Data in green box are defined data to calculate benefit and it defined in 'input-def.xml'.
- ✓ Data in brown boxes are rearranged default values and it is defined in 'defulat-values.xlsx.
- ✓ Lastly, data in black box is saved information data of project and it is defined in 'projectdef.xml'.

Original default values are hidden in SGCT. User can save and load those data information which is being utilized by the software program.



Figure 28 Detailed Architecture of DIM in Replicated Tool Kit

In the following, each of the component boxes in the above diagram are show in detail for the information it contains.





Figure 34 User Input Data Details

III.5 Project Characterization Module in SGCT and Its GUI Replication

First, four dialog boxes from PCM are compiled in a single dialog box in the following page.

ase input project information below.		of access. If a particular access that is being in	talled does not appear a	splittly in this lot choose the assoct group that is re	night classicy related to
Organization Name		auter being kataloù. The anada that are (hou folkweng page	en in Tel Joge vil debr	nees the subset of functions that you ed be able	to choose from on th
The local division of		Quatomer Assets		Enamentealon.Asseta	
Project Name		C Dathew DRG/Digite/Vehal	Cashanar ()	Phase sign Replang Transferran	Silves .
Project Start Vear		Canari spatiarum and tipan and diatores)	Delute	T Make Manufacture Technology	Selder
MERC Region	-	Contracts to load Charging Station	(ginne)	C Schware - Ank and a subset of humanitation	Saturation
	1	AML Assets		Office: Assetts	
		C and Social Venue	Infation (C Interest Fault beliefen Terreitige	- Individual
hevious Exit	Rent	Distribution Assets		C Suprovi Half-Server	Service:
re 25 DCM Project Inform	nation Scroon	Calculation in the sector		- Plantin diterating Darwid Watermoon	infram.
re 55 PCIVI Project inform	nation screen	Constitution of the second	Intern 1	C Pault (Langest Lineses	-
		C burtann Annun	Tableton 1	There was Communities (Pupiliardwellin)	infrain-
		Contractor Management Justem	talana	- Wey Line Imperiary a High Tumperstan	1000
		T Lasting Having	Serene	Superconducting calles	- Carto
		E Horop et comulee	Partners 1	Converticited Gamerator (stand, PV, wind)	Service .
				Concerned Starting developing (e.g., better), Review(, PDr wb)	Selvier
		in second distance of the			
		CONTRACTOR OF CONTRACTOR			
Security and a second	enert to ender Fine a defense of a la forester in a defense of	Project and the set of the set of the	of the loanse of the last		er Proid in parced
Constant was a second of the second s	entra ender: For a defense of a factories may be diabled of endoated on the preceding page	Projection of the type of the start for the type of type of the ty	where insulance on the parameter of a generative works	p Paragelade reducers for soft action face matter will Carl bit in the approximation matter will Carl bit in the approximation	or the off is solved and the solution is a solution of the solution of the sol
Constructions are also all functions that was expect the swart of the construction the two and of the function. Certain apped out) because the recember project assists were re to pro-	entransister Finn a definier of a factorier may be disabled of industried on the preceding page	Network in the second s	whe halles with party of the halles with a specific method in the hall be with the hall be	P The applicate developments for such and and and the sector of the super-strategy of the sector of the super-strategy of the sector of the se	er druck in samme a f the andra f barn and fake safet pri
Construction and each of functions that was expectible source parts and device the functions the register of the function. Carbon apped out/ because the recembary project assets were re 1. If (a) a construction (b) 2. If (a) a construction (b)	the results: For a definition of a factories may be dealed on technolog page	Project of the second s	whe name: nm participant	p Pa galace reducers for add acted face mattee will Carl bit of the approximation mers for and Carl bit of the approximation mers for and Carl bit of the approximation mers for and Carl bit of the approximation mers for any Carl bit of the approximation for an	haraka ki barkan 17 Ye adalah kera Jawa Jaka Salara 18 Salara Jawa
Constitutions are used if a constraint on one constitution or an analysis of the constraint of the constraint or an and out because the constraint of the function of the output of the constraint of the constraint or an all of the constraint of the constraint of the 1 The constraint of the constraint of the constraint 2 The constraint of the constraint of the constraint 3 The constraint of the constraint of the constraint of the 3 The constraint of the constraint of the constraint of the constraint of the 3 The constraint of the	constant to produce Fire a definition of a foregraphic dealership to age to the dealership to age	Picture of the second s	of be feature. 2:20 per control of the feature of the feature of the method feature of the second of again the result of the second of a second of a second of the second of t	Program reducers to advactation are provided in the second	er trutt is second ar fee ander turs and the selectors and the selectors
Control from the second	Tantina Saction Say be dealers of a Saction Say be dealers to solute of one provide page (dealers Satisfies) Satisfies Satisfies	Produced and a second sec	wherease of the same of the sa	Program industry for self-action for self-acti	er strukt in second in the analytic trans- and the selfer per 1 - 1 -
Control from two and set of all functions that was expect the small call property that the batter is being of the function. Control and with because the occursivy project assists even 1. Project Control on the set of the function of the function 2. Provide Analytic Transmission of the function of the function 3. Project Control on the function of the function of the function 4. Project Control on the function of the func	e text to endet. For a definition of a facebone may be dualed to solution of one preceding page setteme facebone facebone facebone facebone facebone facebone	Pigure S		Program in and a construction of a construction	n tradic anext in the addet take and the other per 1 1 - 1 1 -
Control free sease and sease of all Spectrames that way expect the senset of all produces that way expect the senset of all pro- near sold because the near sense project assists were in 1. Project assists were in- 2. To Make Anna Monitoring, Vesalitation, and control 3. Project assists of the near sense 4. The near sense the sense of the sense of the sense 5. The sequence sense the sense of the sen	test to enoble. For a definition of a facetore may be dualed of solution of the preceding page interest fateres fateres fateres fateres fateres fateres fateres	Provide Sectors Prov		Provide Antonio Contraction and the second s	er strad is assessed in the sold at these asset this sold are pro-
Dense forward see used: all Spoctars that was expect the small off particles see used: all Spoctars that was expect the small off particles. Cetar see of out) because the operand project assists were of I Project Control of the operand project assists were of I Project Control of the operand project assists were of I Project Control of the operand project assists were of I Project Control of the operand project assists were of I Project Control of the operand project assists were of I Project Control of the operand project assists were of I Project Control of the operand project assists were of I Project Control of the operand project assists were of I Project Control of the operand project assists I Project Control of the operand project assists I Project Control of the operand project I Pro	e test tu mobile. Par a definitien of a faceborn may les dualed of sidualed on the precoding page nations Selense Definities Definities Definities Definities Definities Definities Selense Selense Selense	Rest in the second		Photosoft Screen Street Screet	er studtisgewood under sign before in ander sign before in ander sign before possible possible
Construction Series and all functions that was expect the sover grip To access the functions the region of the function. All and To access the region of the region of the sover of To access the region of the region of the sover of To access the region of the region of the sover of To access the region of the region	a transf. to receive five a defense of a factorize novie dualitied of elduated on the preceding page	Real-Time Load Measurement & M		Processing and a sector	er frud is perset inter alle bester set for a star better set for a star better set for a star Possible Archanisms
Control (concerned) and another production of the second part of the second part of the second part of the function. Cathodia and concerned part of the function. Cathodia and concerned part of the function of the second part of the second p	Transit to receive five a reference of a factorian	Real-Time Load Measurement & M Real-Time Load Measurement & M Partners description by the second second second second second by the second second second second second second Real-Time Load Measurement & M Real-Time L		Progenities reducers for add readed face rest agents in add readed face rest for and Each of refer to age represent or rest for any for the rest of the agent rest agent to inflate induced rest rest agent to inflate induced rest	er duad is parced to the solar bars and the solar bars and the solar parce of the solar parce of the solar parce of the solar parce of the solar parcel of the solar p
Constitutions	terretur revolue Pri a seferica di a terretur revolue Pri a seferica di a terreturi con un un diadadi ori d'allutate (v) din pressiong page terretur ter	Real-Time Load Measurement & M Submets were set of a submit for the format of the system and the system is the submit for the format of the system and the system of the system		Progettate reducers for add analytics provide the second second second for additional for a provide second for the second second second second second second second second second second second second second second second	n dradije secod te de sedecijen und te sedecijen de second possible dechanisms
Cleare for two special controls of the control of the second of the region of the for the control of the fore the control of the control of the control of the fore the control of the control of the control of the fore the control of the control of the control of the control of the control of the control of the control of the control of the control of the control of the control of the control of the control of the control of the control of the control of the control o	e rent ti render Pro a default i dentario con più dialitati ot ridicale (vi the precolleg page i reness fairen fai	Real-Time Load Measurement & Market Sec. 1999 Real-Time Sec. 1999		PRO applicate inclusions for add analysis for any process for add analysis for additional for additionad for additional for ad	er struct is parent to the state three and the solve per line of t
Constitution	Tantano Sector Sector S	Produces and a second sec		Progenities inclusions for additional factor and application inclusion for additional factor applications with a second second second factor applications and factor for the second factor functions	er struct lie sweenet in de waard te soler por uwel tet soler por lie so
Control free trees Control free haston to be right of the former and protocol biol. The haston to be right of the former and protocol biol.	Tantan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan Santan	Product Sector Sec		Progenities inclusions for additional factor provides and additional factor provides for add	er trudie second in the ended have and the other per- l
Construction Series and all functions that was expect the soviet of the design of the functions the english of the functions of the function	e torst tu molete. Far a defretem of a farction sory is-dualed in tradicate of the precoding page interes- interes- fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse fateuse	Read-Time Load Measurement & M Read-Time Read-Time Re		Processing and the second seco	en structure ander twee tradition and the structure of the structure and the structure and the structure of the structure and the structure and the structure of the structure and the structure and the structure and the structure of the structure and the structure of the structure and th
Construction of a functions that was expect the soviet grip of the soviet of the functions the end of the functions of the region of the soviet of the sovi	Contract of the production of a fractions of the fractions of the proceeding page of the fractions of the proceeding page of the proceedi	Real-Time Load Measurement & M Real-Time Load Measurement & M Point the second secon		Processing and a sectorement for such and and faces and the sectorement of such and a sectorement of a sectorement of the secto	r fradis secol of the adaptive sector in a despite (1
Constitutions The end of Sectors that was expectible rough of the probability because the notionary project assists were no 1 Proposition to the right of the further to the 2 Proposition of the notionary project assists were no 2 Proposition of the notionary constitution and control 3 Proposition of the notionary 4 Proposition of the notion of the notion of the notion 5 Proposition of the notion of the notion of the notion 5 Proposition of the notion of the notion of the notion 5 Proposition of the notion of the notion of the notion 5 Proposition of the notion of the notion of the notion of the notion 5 Proposition of the notion of the noti	erent to revolve. Fire a selfense of a firefacture of the firefacture of the preceding page.	Real-Time Load Measurement & Market States Real-Time Load Measurement & Market States by coast Age Real-Time Load Measurement & M Particles and exception Real-Time Load Measurement & M Particles and exception Real-Time Load Measurement & M Particles and exception Real-Time Load Measurement & M Particles and exception Particles and exception Particles and exception Particles and exception Particles and and any time of the test of the test Particles and any time of the test of the test Particles and the test of the test of the test Particles and the test of the test of the test Particles and the test of the test of the test Particles and the test of the test of the test of the test Particles and the test of the test of test of the test of the test of test Particles and the test of test of test of test of test Particles and the test of test of test of test of test Particles and test of test of test of test of test of test Particles and test of test of test of test of test of test Particles and test of		Procession of the second secon	er fradhis second international second second second second second second second particular second Possible dechanisms
Constitutions The end of a functions that was equal the invest of a function dub the back in the function of the functions and out/ because the non-many project assists were in 1 Fourier and the non-many project assists were in 2 Fourier and the non-many constitution and control 2 Fourier and the non-many constitution and control 3 Fourier and the non-many 4 Fourier and the non-many 5 Fourier and the non-many 5 Fourier and the non-many 6 Fourier and the non-many 8 Fourier and the non-many	The section is not the section of a section of the	Real-Time Load Measurement of the first set of the first		Progenize reducers for addressed face provide the second	ri thad is second to the solar three used the other pos- tion of the solar post- tion of the solar post
Constitution See and if functions that was expect the invest of a see and if the destine the invest of the functions I I I is a constrained in obtaining investment I I I is a constrained in the investment I I is a constrained interface investment I I is a constrained interfac	The set of the control of the contro	Real-Time Load Measurement of the first or the first or the second secon		Programme reducers for addressed face provide the set of the set	Provide line second to the male line second and the second second Possible Arechanisms

- 0
Complete PCN
have and MAD Control
stage and VAR Control
power factor and voltage reducing the amount of voltage anoliary service required
e and VAR levels to reduce T&D losses
ns from carbon based fuel due to losses
labor hours associated with capacitor switching and/or regulator operation
tricity Use Optimization
om peak time to reduce distribution peak load
om peak time to reduce transmission peak load
orn peak time to reduce generation peak capacity required
om peak time to reduce regulared anciliary services related to peak load
hape through customer pricing and incentives to reduce electricity losses
ns from carbon based fuel due to losses
ig on congested transmission pathways
er with information which encourages alternate usage patterns or conservation resultin
n Research
reflection
in equipment through faster fault detection or reduced reclosing
nates reclosing for fault clearing
rs hard-to-detect faults more precisely and quickly to reduce scope of outage
is high impediatce faults more precisely and quickly to reduce the frequency and seve
antrol
sa to surifi overloadion lines or environment
ns from carbon based fuel due to losses
Now around congested system element
10.00



The SCGT selects the benefits that the smart grid project shouldyield, given the assets, functions, and mechanisms user have selected. The PCM Benefits Screen displays related benefits.

Optionized Generalizer Optimation	Explanation	Reduced Electricity Losses	Explanation
Definited Generation Capacity Universities to	Explanation	Renarced Electricity Cont.	Explanation
teduced Ancillary Service Cost	Explanation	Reduced Surfameri Outages	Explanation
ieduced Gingeetion Colif.	Explanation	Reclared Major Dolagini	Explanation
elerted Transmissin Capacity Divertments	Explanation	Recursed Reviewstory Cost	Explanation
Deferred Distribution Capacity Investments	Explanation	Reduced Monentary Durages	Explanation
induced Edupment Failures	Explanation	Reduced Sage and Swith	Explanation
seboerd TBD Equipment Maintenance Cost	Explanation	Reduced CO2 Emissions	Explanation
edyard TSD Operations Cont	Explanation	Reduced SOV, NOV, and PM-10 Emissions	Explanation
leduced Meter Reading Conc	Explanation	Reduced OI (reage (not incrimitized)	Explanation
educed Electricity Trioff	Explanation	Received Protestate Electricity	Explanation

Figure 40 PCM Benefits Screen (DOE SGCT)

Following dialog box is from Replicated Tool Kit – left hand side of the box is still to be incorporated with further information on the detailed asset, function, mechanism and benefits. Current diagram is simple example of what it would be after the details are implemented in the code.

	Netword Destination Capacity Sensitive Defend Destination Capacity Sensitives Defend Tenantics Capacity Sensitives Defend Tenantics Capacity Internet Capitricial Generative Capacities Reduced Capitricians Reduced Destinaty Capit
	Differed Distriction Capacity Sweetwork Defend Denorship Capacity Investment Optimized Denorship Capacity Investment Reduced COLI Deficiency Reduced COLI Deficiency Reduced Districtly Cast
	Defend Deventral Davidy systemet Defend harmonic Davidy Internet Optimized Defender Optimize Reduced COL Deficient Reduced Competition Cast Reduced Declary Cast
	Softward Transmission Capacity Investment Optimized Softwards: Operators Reduced COI Detectors Reduced Competition Cast Reduced Disconty Cast
	Optimized Generator Operative Reduced COIL Entreprise Reduced Congestine Cost Reduced Distantly Cost
	Rodund 2001 B-Henry Rodund Congestur East Rodund Distory East
	Andered Congestion Con- National Decision Cont
	Radiand (Subscry Car)
	Haddand Diamony Linns
	Reduced Dispurphenet
	Addared Epolyment Sylline:
	Radiand Water Calimpte
the state of the second s	Restand More Reading Cold
	Reduced Westwettary Cutages
	Addared DB longs mut concerned.
	Sellard Selector Coll
	Related Signard South
	Repaired Sox, NGE, and PA 4.3 Decision
5 5 5 5	Reduced Summery Dubger
	Andrew The Equipment March 201
	Related (120 Operatoria Crist

Figure 41 Benefits Screen (Replicated Tool Kit)

III.6 Comparison of Data Input Module in SGCT and Its GUI Replication

In DIM Step I, the user is required to enter information on electricity tariff and customer population. This data entry is required regardless of which benefits were enabled by the PCM because it used in many of the benefit calculations. The two tables are the Electricity Rates by Customer Class and the Number of Customers by Class tables, or Table 1 and 2 respectivelyin upper left figure in the following table.



The above four dialog boxes are now compiled in a single box presented in the following in Replicated Tool Kit.

						MainV	rindow.										
Customers &	Tariff																Complete DIM
Residential Customer	Class				Commercial Custo	ner Class					industrial	Cutionar Clar	2				
	Average Energy R kWhi	Rate(S/ /	werage Demand arge(\$/kWmonth)	Customers	Served	ved Average Energy Rate(\$/ Average Demand Customers Served With Charge(\$/ Average Energy Rate(\$/ Average With Charge(\$/ Average)							Demand (Wmonth)	Customers Served			
Sub-Class 1	5	2		1	Sub-Class 1	9	4		2		Sub-	Class 1		- 11	ŝ		7
Sub-Class 7	1	3		4	Sub-Class 7	0	ó		0		Sub-	lass 2			0		0
	0	0				0	A		A					_	a0.		0
BUD-Class #		-		ř	SUD-CHE X	•	* ·	_	Č		5004	2003 3					
Sub-Class 4	0	a		¢	Sub-Class 4	0	0		0		Sub-	Class 4	-		D		0
Sub-Class 5	0	0		0	Sub-Class 5	0	0		0		Sub-	Class 5			0		σ
Average Rate:	2.71428571428	8571	25	Totat	7 Average Rate:	0	4		Tota	8.2	Arera	e Rate:	3			5	Total: 7
Water and the second second					White the second s												
Enter Escalation Facto	rs 27				Enter Project Cost Data												
Enter Escalation Facto Escalation Fi	rs ector D	Selavit Valu	e vaha	e –	Enter Project Cost Data Discount Rate	3	*										
Enter Escalation Facto Escalation Fi Opulation Growth Facto	rs ector D or Description	oelauit Valu	e Value		Enter Project Cost Data Discount Rate Use Custom Cost Schedule	3 No	× 5										
Enter Escalation Facto Escalation Fi Opulation Growth Facto	ns Inctor D Description	Default Valu	e Value		Enter Project Cost Data Discount Rate Use Curtom Cost Schedule Initial Year of Project Spending	3 No 2013	5 										
Enter Escalation Facto Escalation Fi Population Growth Facto Load Growth Factor	ns ector D Description Description	Default Valu 121 121	e Value	-	Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Final Year of Project Spending	3 No 2013 2034	s yr yr										
Enter Escalation Facto Escalation Fi Population Growth Facto Load Growth Factor Economic Inflation Facto	ns Description Description Description	Default Valu 21 22 23	e Value 0.2 0.8 2.7	-	Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Final Year of Project Spending Table Cost of Design Cost of Design	3 No 2013 2034	s yr yr										
Enter Escalation Facto Escalation Fi Appulation Growth Facto Load Growth Factor Economic Inflation Facto Energy Price Factor	ns Description Description Description Description Description	velaut vau R R R R	e Value 0.2 1.8 2.7 3.3		Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Final Year of Project Spending Total Capital Cost of Project	3 No 2013 2034 100	5 17 17 1										
Enter Escalation Facto Escalation Facto Population Growth Facto Load Growth Factor Economic Inflation Facto Economic Inflation Factor	nc Description Description Description Description Description Description Description Description	efault Valu R R R R R	e Value 0.2 11.8 2.7 2.9 2090		Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Final Year of Project Spending Total Capital Cost of Project Interest Rate	3 No 2013 2034 100 4	К 17 17 15 15										
Enter Escalation Facto Escalation Fr Population Growth Facto Load Growth Factor Economic Inflation Facto Energy Price Factor Final Year of Benefits	rs Description Description Description Description Description Description Description	Relauit valu Rel Rel Rel Rel Rel Rel Rel Rel Rel Rel	e Value 0.2 0.8 2.7 5.3 2090		Enter Project Cost Data Discount Rate Use Custom Cost Schedule Imital Year of Project Spending Final Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment	3 No 2013 2034 100 4 6.92	К и и я 5 5 5										
Enter Escalation Facto Escalation Facto Population Growth Facto Load Growth Factor Economic Inflation Factor Energy Price Factor Final Year of Benefits	rs Description Description Description Description Description Description Description Description Description Calculation Inp	Default Valu 20 20 20 20 20 20 20 20 20 20 20 20 20	e Value 0.2 0.8 2.7 2.3 2.3 2.3 2.090		Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Pinal Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment	3 No 2013 2034 100 4 6.92	5 17 17 5 5 5										
Enter Escalation Facto Escalation Facto Appulation Growth Facto Economic Inflation Factor Economic Inflation Factor Energy Price Factor Energy Price Factor Energy Price Factor Energy Factor Enter Benefit (Benefit	rs Description Description Description Description Description Description Description	Default Valu 20 20 20 20 20 20 20 20 20 20 20 20 20	e Value 0.2 0.8 27 23 2090	s s yr	Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Proal Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment	3 No 2013 2034 100 4 6.92	N Pr Pr S S S	Detail	Baratron	Bandfrut	Ratefra2 (List	Fral Scoling	4 Projecto	Project1	Diritort2 0	Noiact3 : Bro	and
Enter Escalation Facto Escalation Facto Appulation Growth Facto Economic Inflation Facto Economic Inflation Facto Energy Price Factor Energy Price Factor Energy Price Factor Energy Factor Enter Benefit Benefit Reduced Ancillary Sami	rs betor D or Description Description Description Description Description Calculation Inp	elault Valu R R R R D D D D D D D D D D D D D D D	e Value 0.2 0.8 27 23 2090 Coption	s s yr Input Name Andlary Serv	Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Proal Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment	3 No 2013 2034 100 4 6.92	N Pr Pr S S S Unit	Default	Bassire0	Baustre1	Baselre2 Jass	fine) Sateline	4 Project0	Project1	Project2 P	Yoject3 Proj	ect4
Enter Escalation Facto Escalation Facto Reputation Growth Facto Load Growth Factor Economic Inflation Factor Intel Year of Benefits Enter Benefits Benefit Reduced Ancillary Sami Deferred Distribution C	rs - Description Description Perception Perception Perception Description Description Description Description Calculation Inp	elault Valu 20 20 20 20 20 20 20 20 20 20 20 20 20	e Vviku 0.2 2.7 2.3 2030 Coption	input Name Antiliary Servi	Enter Project Cost Data Discourt Rate Use Custom Cost Schedule Initial Year of Project Spending Prod Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment	3 No 2013 2034 100 4 6.92	5 97 97 5 5 5 5	Default	BaseStre0	Baulitet 4 2	Baseline2 Base	finel Baseline	4 Projecto Z 7	Projecti 0 ti 5 -	Project2 P 0 0 4 3	Yoject3 Ptoj d 2	ect4
Enter Escalution Facto Escalation Facto opulation Growth Factor sconomic Inflation Factor inal Year of Benefits Enter Benefits Enter Benefit C Benatit Reduced Ancillary Sarvi Defened Distribution C	rs - Description Description Description Description Description Description Description Description Description Calculation Inp	elaut vau 2 2 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	e Velve 0.2 0.6 2.7 2.3 2090 2090	trput Name Andilary Serv Capital Canya Distribution ir	Enter Project Cost Data Discourt Rate Use Custom Cost Schedule Initial Year of Project Spending Final Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment	3 No 2013 2034 100 4 6.92	s yr yr s s s s yr	Default	BaseSine() 5 1 9	Baselitet 4 2. 1 5. 1	Baselne2 Hass 5 2 5 1 7 2	inel Baceine B 3 1	4 Project0 2 7 3	Project1 0 1 5 2 1 3	Project2 P 0 0 4 3 2 3	Nojec13 Proj 0 2 4	ect4
Enter Escalation Facto Escalation Facto opulation Growth Facto conomic Inflation Factor inal Year of Benefits Enter, Benefits Enter, Benefits Defend Distribution C Defend Distribution C Network Sustained Cul	rs tetor D pr Description pescription Description Description Description Calculation Inp ca Cost apacity investment ages	elaut vau 2 2 2 2 2 2 2 2 2 2 2 2 2	e Velve 0.2 2.7 2.3 2030 Ception	Input Name Anditary Servi Distribution in SAIDI Oystem	Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Pinal Year of Project Spending Total Capital Cost of Project Interest Rabe Vearly Amortized Payment Vearly Amortized Payment	3 No 2013 2034 100 4 6.92	S S yrr S S S S S S S S S S S S S S S S	Default	Baseire0 5 1 8 0	BaselineT 4 2 5 5	Baselive2 Base 8 2 5 1 7 2 7 3	irred Gacelore 0 3 4	4 Project0 2 7 3 2	Project1 0 1 5 2 1 3 0 0	Project2 9 0 0 4 3 2 3 0 0 0	hoject3 Proj 0 2 4 0	Hets4
Inter Escalation Facto Escalation Facto opulation Growth Facto conomic Inflation Facto nergy Price Factor inal Year of Benefits D Enter Benefits Defend Distribution C befered Distribution C befered Distribution C	rs tetor D pr Description (Description Description Description Description Calculation Inp ca Cost apacity investment apacity investment ages, Reduced Ma	elault valu	Volve 0.2 0.2 0.2 0.2 2 2 2 2 2 2 030	trput Name Anditary Servi Capital Carryo Distribution It SAID! (system Value of Servi	Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Final Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment Vearly Amortized Payment	3 No 2013 2034 100 4 6.92	5 5 7 7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	Default	Baseline() 5 1 9 6 3	Baseline1 4 2 5 5 9	Baselos2 Hass 5 2 5 1 7 3 5 2	finel Baceline 8 3 1 4 1	4 Project0 2 7 3 2 3	Project1 0 1 5 4 1 2 0 0 7 4	Project2 P B 0 4 3 0 0 0 0 0 0	Nojeci3 Proj 0 2 4 0 0 0	ecs4
Enter Escalation Facto Escalation Facto opulation Growth Facto conomic Inflation Facto nergy Price Factor inal Year of Benefits Enter Benefits Defend Distribution C Defend Distribution C Defend Distribution C Defend Distribution C Defend Distribution C Defend Distribution C	rs - Description Description Description Description Description Description Description Description Description Calculation Imp ca Cost apactly investment ages Reduced Ma ages. Reduced Ma ages. Reduced Ma	elault valu 2 2 2 2 2 2 2 2 2 2 2 2 2	e Velve 0.2 0.3 2.3 2030 Coption 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Input Name Antiliary Servi Capital Canys Distribution II Value of Servi Value of Servi Value of Servi	Enter Project Cost Data Discount Rate Use Custom Cost Schedule Initial Year of Project Spending Final Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment ices Cost of Charge of Distribution Upgrade Interest Time Deferred 0 co - Residential co - Commercial	3 No 2013 2034 100 4 6.92	5 yr yr 5 5 5 yr 10dex 5,400h 5,100h	Default	Bateline() 5 1 8 8 9 9	BassifireT 4 2 5 5 4 7	Baseline2 Hass 6 2 5 1 7 3 6 2 8 0	inel Baceline 0 3 5 4 5 5	 Project0 2 7 3 3 	Project1 0 1 5 4 1 2 0 (7 4 0 4	Project2 9 0 0 4 3 2 3 0 0 0 0 0 0 0 0	hoject3 Proj 0 2 4 0 0 0 0 0	ect4
Enter Escalation Facto Escalation Facto Ropulation Growth Facto Load Growth Factor Economic Inflation Facto Energy Price Factor Final Year of Benefits Enter Benefit Reduced Ancillary Servi Deferred Distribution C Reduced Sustained Cut Reduced Sustained Cut Reduced Sustained Cut	rs - Description Description Description Description Description Description Description Description Description Calculation Inpoca Cast apacity investment ages Reduced Ma ages. Reduced Ma ages. Reduced Ma ages. Reduced Ma	elault valu	e Vvikue 0.2 2.7 2.3 2030 2030 2030 2030 2030 2030 2030	Input Name Antiliary Servi Capital Carrys Distribution in SAUD (system Value of Servi value of Servi value of Servi	Enter Project Cost Data Discourt Rate Use Custom Cost Schedule Initial Year of Project Spending Prod Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment Vearly Amortized Payment Sector Cost of Carge of Distribution Upgrade reactment Tame Deferred Once - Residential Cost - Sesidential Cost - Sesidential Cost - Sesidential	3 No 2013 2034 100 4 6.92	S yr yr S S S Unit S S yrs Index S/Wh S/Wh		BaseSine() 5 1 8 6 6 3 9 1	Baselitet 4 2 2 2 5 5 1 7 2 8	Baselne2 Bas	Finel Baseline 6 3 5 4 5 5 5 5 3	 Project0 2 7 5 2 3 3 1 	Projecti 0 0 0 5	Project2 P 0 0 4 3 2 3 0 0 0 0 0 0 0 0 0 0 0 0	Yoject3 Ptoj 0 2 4 0 0 0 0 0	ect4
Enter Escalation Facto Escalation Facto Escalation Growth Facto Economic Inflation Facto Economic Inflation Facto Energy Price Factor Final Year of Benefits Enter Benefits Benefit Reduced Ancillary Serio Deferred Distribution C Reduced Sustained Out Reduced Sustained Out Reduced Sustained Out	rs - Description Calculation Imp C	elault Valu	e Velve 0.2 0.5 2.7 2.3 2030: Coption 0 0 0 0 0 0 0 0 0 0 0 0 0	riput Name Andilary Servi Capital Canys Distribution in SAIDI (system Value of Servi Value of Servi Value of Servi Value of Servi Average Hour	Enter Project Cost Data Discourt Rate Use Custom Cost Schedule Initial Year of Project Spending Final Year of Project Spending Total Capital Cost of Project Interest Rate Yearly Amortized Payment Vearly Amortized Payment Cost Cost Ing Charge of Distribution Upgrade tose Cost Ing Charge of Distribution Upgrade Cost Cost Ing Charge of Distribution Upgrade Ing Charge of Distribution Upgrade Ing Charge of Distribution Upgrade	3 No 2013 2034 100 4 6.92 per Customer - Residential	5 S		Bassine() 5 1 9 0 3 9 1 1 2	Baseline1 4 2 5 5 4 7 7 8 8 3	Baselne2 Hass 5 2 5 1 7 2 7 3 5 2 8 8 4 7 4	finel Baceline 1 3 1 4 5 9 4	 Project0 2 7 3 3 1 5 	Project1 0 1 5 2 7 4 0 6 0 1 2 0	Project2 0 0 4 3 2 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	hoject3 Proj 0 2 4 0 0 0 0 0 0	ect4

Figure 46 Data Input Module (DIM) Screen (Replicated Tool Kit)

III.7 Computational Module in SGCT and Its GUI Replication

CM Main page allows you to run the cost-benefit analysis with the inputs entered in the DIM, collectively referred to as the Reference Case, or it allows for an analysis to be run with high and low sensitivity case inputs, collectively referred to as the Sensitivity Case.

Sensitivity Analysis								
Nam CM with Survivinity Grout Party		-						
		6	Address To survey he agent	-	Reference Carer Vallam groups	0.5		
Bod New .	and the second se	1001	Software a	1.000	1813	3063	3014	1015
writer of Collories Residents file (v.e. Cleer 1	4	33791	10(76)	100%				
entier of Catherine Medifering Note (Ld-Class 7		130%	LOOTS.	1000				
inder of Cultomers Readenda kate Isid-Class 8	*	330%	120%	100%			2.5	1.00
antow of Customers Residential Rate II.4-Class 4		300%	100%	100%			2.2	1.00
antar of Customers Residents Aste Lub-Class 5	4.	200%	120%	100%		2.8	14	
antise of Customers All Residential Classes		320%	102%	100%				
etter et Outorets Eintreetta Rein Eck-Clato 1		300%	100%	100%		3.4	7.4	
etilier of Oustomm Commercial Nets Scill-Class II.	4	330%	102%	100%		14		
prime of Customers Commercial Nate Sub-Class 3	4	300%	100%	100%				
union of Outlomers Commercial Bale Sub-Class 4	8	390%	100%	100%		1.0	1.12	
union of Outbornet Commercial Rate Sub-Class 1	a .	300%	100%	100%		14	14	
uniter of Customers all Commercial Classes	#	220%	100%	100%		5. A.		
antie at business toductiel Tudi-State 1	÷ .	122%	100%	1000				
inter of Catories bidattal Lab-Class 2		10%	100%	100%		3.4	14	
atter of Customer Industria Sub-Class I		300%	100%	1005		14	- C.	
entar of Curtomen Industrial Solo-Class 4		30%	100%	100%			2.4	
entor of Customers Industrial Sub-Class II		300%	100%	LOPS.		1.2		
antise of Contraven all Indicated Classes		122%	10%	LOOK.		10		

Figure 47 CM Main Page (DOE SGCT)

The above dialog box is now compiled as the following in Replicated Too	ol Kit.
---	---------

Contraction (Independent of Party Contractual Party																			
and the second second second second second																			
rgul faithe	eit j 2	004.3	2012	2018	2817	2014	2014	2080	3831	2022	4853	1014	1825	2006	3827	3028	2529	2000	
esifaiy Service: Got 1	1		1	14.3	0.8	14	0.42	\$4L	0.45	0.47	3.40	0.51	2.52	0.50	1.17	8.0	1042	心把	
Capital Camping Charge of Distribution Upprate 1	1	1		411	3	1	0	2	00	0.0	9	0	2.	ĉ	16	0.	1	10	
Det Bution Investment Time Defetred gro	r. [1		100	1	4	100	D	0	0	0	0	1	0	0	00	0	0	
AD pyten) bi	501 I	1	11	110	÷	14	135	156.	1.51	1.34	134	计级	158	136	1.56	1.38	5.04	135	
alue of Senice - Relatential St	kh i	1	(\$T3 [44 L	171	1.1	1.05	1.8	北河	2 .	2:01	2.11	10	142	228	2,25	241	
faliat of Semice - Commercial \$1	IW I	12	14.5	447	2	147	1.71	1.76	t ilt	146	1.8.2	194	2.04	100	212	218	2.22	2.29	
talas of Senica - Industrial	ION:1	- 14	1.1	1.	ő	¥	124	8.66	6.75	10.61	10.26	12.58	16:四	11.14	11.04	11.75	12:00	1239	
weakge waarly Load Not Tenned During Outsue pe Mi	N 5	1	11	6.07	147	記録・	289	2.71	2.13	112	2.36	24	1065	1.84	114	THE.	2.91	187.	
sumage-Haurly Load fast lakked During Outage pe W	N . 1	1	h	1.5	0.75	25	0.0	2111	12.0	0.52	3.52	0.52	2.52	6.53	2.54	6.1e	0.05	0.55	
wetage waining Load foor lanved Duiting Curtaine pa W	N. 12	10	haf.	1.11	1.67	1	1.62	101	2.69	106	2.88	2.1	2.it	1.61	1.11	230	2.16	12	
Net Bullion Netballion Cast 4	4	- 4	6	10.1	H4	4	4.1.2	8.04	8.67		8.14	4.34	9.64	6.6	10.17	11.44	190.72	11,08	
hammaan kestoration Cost	1	1	1.1	¥ - 1	T	÷ .	1100	116	1.11	1.14	8.48.	1.12	2.66	2.71	1.81	÷#2	4.00	\$13	
hybrituition feeder (cast 50	1/2 1	1		1.	1	1	1.01	1:02:	1 82	1.02	1.84	1.0%	1.08	1.07	1.07	1.09	1.09	11	
Netribution Losses 55	1	10	171	6.63	9.12	6.26	0.29	0.26	0.38	0.26	0.00	0.76	5.10	6.26	2.76	0.28	0.28	0.16	
tanunäisike Line Loat	14.5	11	13.	10	18.	10	10.04	12.15	10:24	10.32	10.41	13.42	16.57	13.88	10.74	12.00	10:40	111	
furnitianicy Losses N.	1	1	\$25	5	3	5	3	3	5	1	5	1	5.	9	5	5	11	5	
Average Phile of Witchisiale Energy	IW 4	- 14			5	14	18.54	17.67	17.84	18.22	16.67	18.44	2004	20.75	21.41	12.14	22-80	15.63	
C/2 Emissions per Gallati of Fuel 10	nu la	1		4	41	4.0	44	4.0	4.4	4.4	44	4.4	4.6	4.8	4.0	4.2	4.6	4.8	
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	10-1			4	1	half.	11.64	57	0.72	11.74	3.36	6.78	0.6	6.84	0.23	0.gT	12.98	0.83	
tak fulls	1.1	- 1		Ed.	1.4	1.3	0.1	0.0	2.1	8.1	11.2	6.5	4.2	6.1	4.1	0.5	11.1	10.2	
parties blief Visialist our Tirch Bull. (1)	1	1	76	1.14	1.1	4.28	1.84	4.14	4.34	+ 14	4.99	+ 14	1.24	1.14	1.14	1.10	4.110	4 14	-
Carbon dual d'Anance for Tours and Column 10	And A	- K		1.1	11	2.1	100	P. 1	10.0		11.		4.1	11	14.04	0.6	111	10.0	
in Residual cardilla of the		1				1	1	4	1	1	1	1.	1		1	1	17	1.	
The Restaurcher and Product of Case				10-1	1.14	1.10		P. 14	- 10	- 10		11.100		17 MA		100	1 14	1	
to the cardination of the	2011		10.1	1.14	1.42	10.4.1 · · ·	10-	A 44	10.67	1.1.4	10	0.44	122-	0.67	11.00	0.67	122	10.61	
W-1.1 (R. 5980) (r. 680) [10		-13	- T-	1-1-1		1.	10.01	100	2.7	1.0	1.1.	0.2	1.11	10.21	1.00	10.21	10.00	0.21	
#18 SI 200 20	22.12	-11	-	in t	1.11		1.1.1	266	24	1.11	1	122	125 -	122.	12.08	1.66	12.5	1.44	
Will V. Hut	1216	-13	100	5.00	1.62	12		1.02	1.54			1.10	100	1.00	100.00	1.00	HC.	1.0	
and the box of the second seco	100.1	- 13		14.		47	61.20	02.17	111.13	11.11	21.09	100	10.51	32.89	1000	10.4	100.13	1.01 11	
somber of Committee Neoderthal New Sub-Jakist, In	-	-8	281	1.00	1.54	205	2.62	3-04-	1104	3.01	3.00	306	2.61	303	1.09	2.09	12.00	11.1	
rantoe or canonieri rescente Gex 3/6-camp #		- 1	11	4,02	452	401	ALPA	4.00	4.00	400	4,67	408	429	4.1	411	4.51	4.12	418	
Involve of Constant International And Adv-Cattol	-	- 1	L		N	£	0	R	12.	8	P	10	12.	£ .	12	10.	1	19	
Aunther of Customers Reoldentiel Nets Sub-Class+		- 10	10		10		0.7	D	10	8	2	0	1	0	14	R.	1	10	
Remoter of Costomers Residential Rase SUS-CASES	-12	14	1.		ų	R	0	0	10	0	2	D	10	ç	P	0	0	0	
Rumber of Constreen All Residential Class	- 17	-	111	100	7.24	7,98	7.47	1.00	7.9	7.11	7.12	7.54	7.14	711	[7.1IF	14	7.18	111	
iumber of Cultomers Commercial Tura Sub-Outif	1	10	1	1	0	1	£	2	10.	2	9	0	P	C	11.	0.	12	10	
sumber of Comment Commencial Rame Sub-Classif #	-	- 19	2	E	2	1	B	D	1	0	2	9	B	C	11	0	ł	0	
iumber of Cumpment Commencial Autor Sub-Classif #	1	9	2	1	9	0	0	P	0.	9	2	0	2	¢	1	0	1	0	
rumber of Culturners Continessal Rate Sub-Classe #	10	0	1	1.0	9	0	0	0	0	0	0 .	0	0.	0	0	0	1	10	
lamber of Costomers Commencel Nets Sub-Cleant #	11	10	1	P	0	R., .	0.	P	10	8	0	Q :	1	0.	12	0	Ø	0	
Aurither of Customers All Commercial Class 4	2	12	ε.	2.01.3	211	2.02	2,12	2.02	2.01	2.05	234.	2.04	2.64	205	2,05.	2.04	2.06	1.2.88	
Remoter of Contomers Midjotrial Rate Sob-Class?	10	10	3.	B	0	8	12	p	4	Ø	2	0	15	6	1	Ø.	10	0	
Rember of Costomers Industrial Rate Sub-Class2 +	1	1	P.	1.1	0	0	0	0	0	0	0	0	0	0	10	0	1	0	
wrbe of Curomen Induitive Rela Sub-Class?	1	0	2/	E (0	1	10	2	10.	0.1	0	0	0.	¢	16	0.	1	10	
and the second se	1	10	Ð	E	0	0	10.0	D	0	0	0 0	0	1	0	10	00	11	0	

Figure 48 CM Main Page (Replicated Tool Kit)

For the results, the below three graphs would show how it was done in the original SGCT program. As for the case of the Replicated Toolkit, please refer to the previous subchapter

Reference The telfes helps and totaled by to Replay will at the h	Case Out dropley the ex- tengory and rel entropy of each	Iput: Annual and Cumulative F raid and registed to project based to and cress bicategory. The total group based, total case, a clast. 33 reliances are represented to constant defi-	Results Tables The benefits are expensed and not becade are also are			NETLAWN TO C	M MAIN PAGE			
		samilities for Company Baratily						- 4		
		ANNUAL Benath (B)					_	12		
3	075		Solubility	3411	1203	2294	2835	3194	307	10.0
		Optimized Generative Optimize	Utility Bategoryan	290		1924	2947	181		
		Despectioners of Capacity Scientisation	Utility finispere			1.6	1.21			141
		Kalauki And Day Service Sat	Childy Rolepien	- 4						
		Pedacal Crogetics Cre	US By Balegieve				2.8			
	1	Ingentried Areat Utilization TOTAL		241	(4)	(14)	(4)	100	(4)	141
	TERDANE	Dalamai Tuesmiator Gasarity Interferent	Diate Dataparer	(14)		- 1 K	100	1.0	- 1961 P	
	Barbaga	Deknet Estimator Capy/M Investments	Unity Grogerse							
		Kenned Sylphet Tallet	Utility Temperat		-	-				
		TRD Capitel Swittigs TOTAL		1.8	1.4	(1.8		(+)	
Recorder 1	Tab Dalis	Designed T&C Tapagement Handmarked Com	Dially Gampers	2.6						
	Sectory .	Endoord 14/2 Cartolicite Cell	Didle Datestane	1						
	Ta TA	Tartood literer Tauting Cell	Dury Easpane						-	
		TAD OWNER Mgs TOTAL	- I wanted and the second	18		19.	181	14.1	141	
	Teel Calurian	Federal Distanty Traff.	Unity Talepayer		3. P			141	10 A	
	they though	Reduced Directority Losses	Linite Damper			+	+	~		
	Terlige	Restored Electrony Core	Carrante .				14			
	1 mar 1	ECONOMIC TOTAL		(#)		(A)				
	1.1	Radional Dictional Company	Camana	1.1	1.1	5.4	540	1.00	2.4	1
	and the second second	Pederal Hos Dinge	L'Onteres	0.4	1.1		1.4			
		Endered Detroution Cett	15:00 Talegore .	5.4			1.41			
120202	10	Poyoe Intemptions TOTAL								τ.
No.	in the second	Basin and Fridmandery Onlinger	Categorie			354	196	14.1		(A)
		Relicet by at heals	()mass	5.4						1
	11	Power Quality TUTAL		1.0	1.4			14.1	+	
		BELLABILITY TOTAL	1 1	1.4		141	+	44	+ -	4.7
		Reduced COC Reminer	1 Toursto							
Service encountry.	AP CRIME	Reduced SDs, MDs and FL01.3 Excessor	Livert-	4						
		ENVIRONMENTAL TOTAL			+					
		The second second second second second	Thirty	100			1001			
faintly.	Trange Security	Sector 10 (Sector Technology	(house							
		OCCUPTTY TOTAL	-		24		12.51			
	-	SECONTITIONE			*	-			-	÷.,
		GROSS BENEFITS TOTAL	-	*	*		1			-
		TOTAL COST								
		NET BENEFIT	- E						-	





Figure 50 Result Charts (DOE SGCT)

Reference Case O The table and graphs below a These results are displayed or	utpu	I: Present Value or the present value had best as well as of	Ilue Cost and of costs, benefits, and t on a comulative basis.	Benefit Analy he het present value o	rsis If the project			RETURN	O CM MAIN PAGE		
0			120006	122	1	0.47	0.6406	0.912673	Laborat	6 stahlwood	0.810
		and the second s	and the second division of the local divisio	and the second second second	It Your of the freder	<u>م المتحديد معام المعام الم</u>	ويترك للتحصيص		and the second	and the second second second	
and the second		Total	2011	2012	2015	2014	2015	2016	2017	1018	2019
Annual Cost	5	(080.47)	0.00	0.00	0.00	8.00	15.88	15.00	-15.M	-75.88	
Annual Benefit	- 6	(8,108,829.57)	0.00	0.00	-18505.34	-54095.32	-148805.77	-82111.94	199915.61	·TTTS75.84	/12
Annual Present Value (PV) C	145.5	(257.94)	8.00005	8.0000	0.00005	0.00005	-14.0236	-04.4782	1142416	183.82075	
Armuel PV Benefit	. 5	12 195 517 440	0.003	0.001	14501391	- 03072.404	-152841.16-	-28107.755	1208628	-101052.240	-12
Annual PV of Net Benefit	5	12.198.105.421	0.001	0.001	14501.89	(81012.40)	100.00011-	-39422.10	(121880.32)	-101001367	-12
Cumulative PV Cost			0.067	0.201	0.005	0.00	14.92	-25.42	-45.44	9126	
Cumulative PV Benefit			0.007	0.00	18105.38	101578.032	-240298.51	-310927.21	-100300.48	-404443.74	-58
Completive PV of test Senet?			0.00	0.00	ration and	01578.315	.211224.44	-2700556.61	DOM: N	-adaptic tot	-80





Appendix I Overview of SGCT

A1.1 SGCT Framework and Work Flow

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 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 52SGCT Architecture

Source: Navigant, 2011



Figure 53 The Structure of SGCT

A1.2 Project Characterization Module (PCM)

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.

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 54 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 1 Mapping of Assets to Functions (DOE SGCT)

Smart Grid Accate	Functions		
Sillart Griu Assets	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													V		
EMS/Display/Portal													v		
Distribution					v	v	v	v				v			
Automation					•	•	•	•				•			
Distribution			v		v	v	v	v			v	v			
Management System															
Enhanced Fault Detection Technology										V					
Equipment Health			v						v						
EACTS 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													V		
Equipment (Customer)													•		
Software - Advanced		v	v												
Analysis/Visualization		14			14	3.4	1.1	14			14	1.1			
Two-way		V			V	V	V	V			V	V			

Communications (high bandwidth)									
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

Customer Assets		Transmission Assets	
Customer BMS/Display/Portal	Definition	Phase Angle Regulating Transformer	Definition
Smart Appliances and Equipment (Oustomer)	Cefinition	Phasor Measurement Technology	Definition
Vehicle to Grid Charging Station	Definition	F Software - Advanced Analysis/Visualization	Definition
AMI Assets		Other Assets	
ANE/Smart Meters	Definition	Finhanced Fault Detection Technology	Definition
Distribution Assets		F Equipment Health Sensor	Definition
Advanced Interrupting Switch	Definition	F Flexible Alternating Current Transmission	Definition
Controllable/regulating Inverter	Definition	Fault Current Limiter	Definition
Distribution Automation	Definition	Two-way Communications (high bandwidth)	Definition
Distribution Management System	Cefinition	- Very Low Impedance (High Temperature	Definition
Loading Monitor	Definition	Superconducting) cases	0.00
P Microgrid Controller	Definition		Demaion

Figure 55 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.

1 Fisch Community	Definition
2 😥 Wide Area Monitoring, Visualization, and Control	Definition
3 C Dynamic Capability Rating	Definition
4 Theorem Providence	Definition
5 F nonemon reserve	Definition
• The manufacture and the Sublimity	Definition
⁹ IP Automated Islanding and Reconnection	Definition
8 9 Automated Voltage and VAR Control	Definition
9 F Day too it fundation of pagement Constants	Definition
10 IT before and the differences	Definition
11 / Real-Time Load Measurement & Management	Definition
12 Protect from could be write	Definition
13 SP Customer Electricity Use Optimization	Definition
14 Storing Electricity for Later Use	Definition
15 F Duraumo Production of Decision	Definition

Figure 56 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 2 Mapping of Functions to Benefits (with comparison to EPRI version)

			111. 51	utio						uge							
									F	uncti	ons						
		Benefits	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
		Optimized Generator Operation	_	•												-	•
	Improved Asset	Deferred Generation Capacity Investments	_												•	•	•
1	othization	Reduced Ancillary Service Cost		•				1	l	•	l		•		•	•	•
		Deferred Transmission Canacity Investments	- ·		•	•										•	
1	T&D Capital	Deferred Distribution Capacity Investments	1	-		-							•				
Economic	Savings	Reduced Equipment Failures	•			ĺ		İ	l		•	•					
		Reduced T&D Equipment Maintenance Cost									•						
20011011110	Savings	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													•	•	•
	Power	Reduced Sustained Outages					•	•	٠		•	•	•			•	•
	Interruptions	Reduced Major Outages		•					•				•	•			└──
Reliability		Reduced Restoration Cost					•	•	•		•	•	•				
	Power Quality	Reduced Momentary Outages										•				•	<u> </u>
	,	Reduced Sags and Swells	_	-						-		•			-	•	<u> </u>
Environmental	Air Emissions	Reduced CO ₂ Emissions				•		•	L	•	•		•	•	•	•	•
		Reduced SO _x , NO _x , and PM-10 Emissions				•		•		•	•		•	•	•	•	•
Security	Energy Security	Reduced Oil Usage (not monetized)						•			•		•			•	
Security	energy security	Reduced Widescale Blackouts		•	•												
										Ma	appe	个 d in	EPRI				

EPRI: Stationary Electricity Storage + Plug-in Electric Vehicle

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 57 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.

Fi Proceed 1	unction-Benefit Chart is TOURTOT In the Data Input Modu	le (DIM)	Frincti to Initi	on Bene INCOME al Projec Aodule (1	fit char AC7 t Chara RCM)	tis clerita	lion										
			1					194	heres	Out Fun	10000						
	Paral Central (Include						Adaptive Physician	Automodifieder and Une Solution	Automoditading ad Pactoriologi	Automated Voltage and VAPI Convey	Disposit & Noricanos of Coppensi Condition	Edward Fult Projetice	Nod-TimeLood Monogeneer h Manogeneer	Reading to a film the	Custome Decretary	forming Electronic for Later Use	Darstwet Protection I
	Improved Actien Utilization	Distincted Generator Operation Defended Generation Capacity Investments Reduced Acciliacy Service Cost Reduced Congestion Cast															
Economia	T&D Capital Savings	Deterred Transmission Capacity Investments Deterred Octobution Capacity Investments Reduced Equipment Failures														-	
	T6D O6M Seeingr	Reduced 18D Equipment Mansenance Cost Reduced 18D Operations Cost Reduced Mater Reading Cost				_						_					
1 1	TheirPeducton	Reduced Electricity Thefr		-			-	-						-			
1 1	Energy Efficiency	Reduced Decisions Losses						_								- N	
	Electricity Cost Savings	Reduced Electricity Cost	-				_			-	_						_
Relability	Powerinseruptions	Factured Statianed Outages Factured Main Outages Factured Factor ation Cost					-				-	_		_			
	Power Quality	Reduced Honentary Outages Reduced Sage and Swels			-											-	
Environmental	Artinizarie	Reduced CD2 Emissions Reduced SD4, ND4, and PM-10 Emissions				_						_					
Security	Energy Security	Reduced Of Usage (not monetized) Reduced Widerscale Blackouts												-			

Figure 58 Function-Benefit Chartin 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).

A1.3 Data Input Module (DIM)

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 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.

Defeuit Values	"Marrie" inputs					Bas	eline ~2016, Project 2012-201
Benefa	Optional Input On/OIF Buttons	loput Name	Input Description	Type of Input	Default Value	Unit	Resultan 2017 Resultan 2013 Resultan 2014
Reduced Ancillary Service Cost	Use Options" Injude	Anoillary Services Cost	Total annual cost of anolitary services. Anolitary services, including sprinting reserve and frequency regulation, could be included? a generators could more closely follow load; peak load on the system was reduced; power lactor, what and WAR concole vere improved, or information available to grid operators were improved.	Impact Metric Data	NA	•	
Reduced Congestion Cost	Line Options: Inputs	Congestion Cost	Total annual transmission congestion cost. Project functions that could reduce there costs either provide lower cost energy, decrease loading on system eithereta, shift load to off-peak, or allow the grid operator to manage the filow of decrisity around constrained renefaces (i.e. dynamic line capability or power flow constil.	Impact Metric Data	N/A		
Meleted Transmission Capacity Investments		Capital Carrying Charge of Transmission Upgrade	The total capital cost of transmission system investments that can be delered as a direct result of the project. Reducing the load and stress on transmission elements increases asset utilization and reduces the potential needfor upgrades. Please enter the total delered cost in the first year that it will be delered.	Impact Metric Data	N/A	1	
		Transmission Investment Time Defetted	The time in years that the transmission investment vill be deferred. Decimal numbers can be entered (ex.	Impact Metric Data	N/A	915	
Deferred Distribution Capacity Investments		Capital Carrying Charge of Distribution Upgrade	The total capital cost of dimbusion system investments that can be deferred as a direct result of the project. Reducing the load and stress on distribution elements increases a ster utilization and reduces the potential need for upgrades. These enter the total deferred cost in the first year that it will be deferred.	Impact Metric Data	NVA		
		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	yes	
		Distribution Feeder Load	Average apparent pour readings for all tenders imparted 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 thoud be included a ubstration have been made more efficient the average power level of the substation(s) should be more. Holomasin include be and on housi joinds.	İmpact Metric Data	N/A	MVA	
Reduced Electricity Losses		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	NA	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	ж	
		Average Price of Wholesale Energy	Average whole sale market price of electricity. This input will be used to monetize electricity losses.	Assumption/Estimate	Use Default	\$8/wh	

Figure 59 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.

				and the second se			
- I		Value (8) + (Antrual General	ation Cost (11) hazelite - Annual	Dehetation Cost (E) pro	(iecf)		
	Catalog Ecologia	MAIN CALCUS ATTOM			Daroffice	Publics	
		inter crace and and		1000 March 1000	- California		
	Seb-category: Improved Asper Othranos	Anthoni Demenation Clour		subroad			
	Value (\$) + (Rohuli Generation Cost (\$) baselice - Rohuli Generation Cost (\$) project)				52		
		Telest					
	President					1	
	P MIGHINE.					-	
	Wide Area Monitoring	TOTAL DENEFIT + Dural	ine value - Project salue			4	
	Redenan Flanter, Brease	- Strate Strate Contract State and					
		annount chi cuint	Warhat .		10 H H		
	Page mandae remains	UP HUNAL CALCUM	10.04			Propert	and the second
		Average Hours Generation	n Colt	separate			1000
	Calculation	Avoided Asnual Generator	Dispatok	input2			Mult
Operated	Makes (Max Report Repor	a transfer and a start because of a	11 C. 1 C. 1			-	
Generator	And (1), suggestion of the state of the stat	Contract of the second states			-	-	
Orangino		wide Asea Muterioring, You	Unitation, and Control Aperage	· · · · · · · · · · · · · · · · · · ·		-	
Addition of the	Optional Calentation	Annual Edwigs Storage Elf	laierag (Chepsil 6			- 34
	Value (#) - Americal Denseration Const Availed (#) second - Americal Densetation Const Availabil (#) handless	General PTV Fillesence		a install			
	Record Transmission Provide and Addition And and Addition Provided Addition (Addition of Provide Addition and Provide Additional and Provide Additionand and Provide Addition and Provide Additionanda	Roman Politicania			attende	#C640	12
	search managements of second bits and managements and search structure and search managements but a	Concerns of the second			*L1****		1.10
							5.0
		Yalar			•D//08	#CKA0	
						-	
		TUTAL BENEFIT + Projec	of scalar - Raceline solure			1	
		-					
	TOTAL BENEFIT FOR ALL FUNCTIONS:						
		The second state of the second state of the second	the lot these of the statements of the	of Property Real Works for the	D.P. (10) condition (10) data with Constant	And Address of Marcal Physics, 1998	A Constant
		and bish tas o cabin	ad to second the state of the	er berenston riedfuneo	for a Termana - D. soa ta craba	out a second coar (taxes), con	W CHARLENCE
	Catagory Leonomie	MAIN CALCULATION			Baseline	Project	
	Sub-category Improved Accet Utilization	10102-1017501-02-12000					
	Resulti-Deleured Researching Canadia Investments						
	School Strength and School Strength and School Strength and Strength a						
	Land the first of the second						
	funce or Cabrook in supremulean (busine), users causarion undimed busines	and community and a second					
		Total Castoned Peak Det	hand	- Ingurios		- 13	MV
	Functions						
	Provide the state of the Party state	There Bernard Har is Ann	and French Times	in such as			1414
	Contrast mental for changes.	manual non she care is sea	and P. Par. 12 SP	report		-	- PEW
	Denote and Operandoon	Childebabed Generation Use	e al Annou Prese. Tene	E-ports			MV
	Diatonast Exceticits Storage	PEY Use of Annual Pask 7	Time	inguit0			MV
	Daniel Factor Malines	Park Canadition Banking		part of the			MU
	and a second comment						1.1.1.1.1.1.1.1
· I	Calculation	Price of Capacity M. Anesas	d Past.	input:	1	4.5	211/12
	Value 181 - (Price of Casacity & Asiral Peak (189/b/1" Peak Generation Respond (MVB) and	1. 199 B. 199 B. 199 B. 199 B. 199			Ge 28	10	100100000
		and hits			14	14	
	Late means and under a 2 manual Late control [Ma]. Found printle due to your	1.8.8			4		
	Destoner Peak Demand (MV) white previous to to sold waves (D) Average Dation er Pea	A STATISTICS AND A STATISTICS				1	1220
		TOTAL BENEFIT + Basel	the surface - Project such as			5	
	Optional Calculation	Contraction of the second					
works and	Value (#) - (NPV of Generation Investment Deternal #(gropest - NPV of Generation Investment Deternal (#)(subline	OPTIONAL CALCULA	TICIN		Baseline	Poojest	Star 1
Careeries :	16PV of Generation, Reconvert Deterration - Capital Careton Discontrol New Generation (3): 1117 document care Core Tonic Deterration	Capital Carrains Charter of	Name Classics at Iday	(panel)		200200	
Denimation		in the second seco	the second			-	
Casicilis		Server abort Portugate 11	a service	19/11			
The second second						12	14.5
WARD TREES		Notes -			201011000	#40011181	

Figure 60 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

DIM Step III: Enter Pro Directions, in this page the user can en- preservive to case sevent analysis. It too will enough the cost events over that exother source into these tables formulas. When the cost information of	ject Cost Dat in project soul informe is user one enter total o the operating period D planae use the "Period os been entered claim	a close. This informatio costs, initial and fina in the user can writer i Valua [®] function to av the brue builten at the	n will be used to comp specify sens, and a customized cost othe old changing cell form a bottom to submit and	Nets a single net fre interest rate and the due if pasting deta atting or pasting 5 shore the entries.					
Project Start Poar Discourt East Une Castery Cast Schedule	Yes Die	2018							
ubiat Your of Project Sacrafing Sank Your of Project Sacrafing Final Capital Cont of Project Interest Rate Nearly devolutionst Programmed		#Daw/ite	Amorti	zed Cost					
Server Cont Sciences Year Coaltan (S)		2318	2009	2010	2011	2012	2013	2114	3015
	Finis	h Cent Data Entry	and Return to Ma	iis Fage			Year	ly Cost	

Figure 61 Cost Input in SGCT Macro

A1.4 Computational Module (CM)

The Computational Module is said to be the calculation engine of the SGCT (DOE, 2011). The primary purpose of the CM is totransform the input data either from the DIM default values or from user defined inputs into the costs and benefits of the smart grid project being analyzed. According to DOE (2011), default values are based on the following sources:

- ✓ EIA (Annual Energy Outlook 2009, Form 861, Form 411, etc.)
- ✓ Global Energy Decisions, Energy Velocity (FERC Form 714, etc.)
- ✓ SNL (FERC Form 1, etc.)
- ✓ Public filings, rate cases (PUC, FERC, ISO, etc.)

Then this computation module, CM, calculates costs and benefits on a yearly basis and presents summaries of these results to theuser in tabular and graphical formats.

Computational Module (CM) Main Page

Instructions

Welcome to the Computational Module (CM) phase of the Smart Grid Computational Tool. The CM is the calculation engine of the tool, it crunches the numbers and generates the output. The CM also allows the user to complete a sensitivity analysis if desired. Before running the CM the user can review their inputs and the first five years of projected inputs using the tables below. If the user wishes to change any inputs they can return to the PDIM by clicking the arrow to the right of this directions box.

Running the CM with Reference Inputs - To run the CM with the Inputs that were entered in the DIM phase, simply click the button in the "Reference Case" section that says "Run CM with Reference Case Inputs". The CM will take about 20 seconds to complete the analysis. Once the analysis is complete the results can be viewed by clicking the "View Reference Case Results" button.

Running the a Sensitivity Analysis - Before running a sensitivity analysis the CM should be run with the reference case inputs by following the directions above. To run a sensitivity analysis first change the High and Low sensitivity ranges of the desired inputs by using the toggles that are to the right of every input. After all of the desired sensitivity ranges have been set click the button in the "Sensitivity Analysis" section that says "Run CM with Sensitivity Case Inputs". The CM will take about a minute to complete the analysis. Once the analysis is complete the results can be viewed by clicking the "View Sensitivity Results" button. All of the sensitivity ranges can be reset to 100% by clicking the button above the toggle switches that says "Reset all values to 100%".



Figure 62 CM Main Page

Source: DOE (2011)

Reference Case

Run CM with Reference Case Inputs		View Refz Ro	erence Case sults	
Sensitivity Analysis				
Run CM with Sensitivity Case Inputs		View Sens	itivity Results	
		Re	set all values to 100	*
Input Name	Unit	Low	Deference	c
Number of Customers Residential Rate Sub-Class 1	#	100%	100%	100%
Number of Customers Residential Rate Sub-Class 2	#	100%	100%	100%
Number of Customers Residential Rate Sub-Class 3	#	100%	100%	100%
Number of Customers Residential Rate Sub-Class 4	#	100%	100%	100%
Number of Customers Residential Rate Sub-Class 5	#	100%	100%	100%
Number of Customers All Residential Classes	#	100%	100%	100%
Number of Customers Commercial Rate Sub-Class 1	#	100%	100%	100%
Number of Customers Commercial Rate Sub-Class 2	π.	100%	100%	100%
Number of Customers Commercial Rate Sub-Class 3	Ŧ	100%	100%	100%
Number of Customers Commercial Rate Sub-Class 4	π	100%	100%	100%
Number of Customers Commercial Rate Sub-Class 5	#	100%	100%	100%
Number of Customers All Commercial Classes	Ŧ	100%	100%	100%
Number of Customers Industrial Sub-Class 1	π	100%	100%	100%
Number of Customers Industrial Sub-Class 2	#	100%	100%	100%
Number of Customers Industrial Sub-Class 3	Ŧ	100%	100%	100%
Number of Customers Industrial Sub-Class 4	ff	100%	100%	100%
Number of Customers Industrial Sub-Class 5	#	100%	100%	100%
Number of Customers All Industrial Classes	Ħ	100%	100%	100%

Figure 63 Benefit Calculation Window

Source: DOE (2011)

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.

Benefit	Functions & Enabled Energy Recourses	Input Parameters	Monetization Calculation Detailed
Optimized Generator Operation	Wide Area Monitoring, Visualization, and Control	Hourly Generation Cost (\$/MWh) Annual Generator Dispatch	For Wide Area Monitoring, Visualization, & Control: Value (\$) = [Annual Generation Cost (\$)] _{escente} • [Annua Generation Cost (\$)] _{Propert}
	Stationary Electricity Storage Plug-in Electric Vehicles	(MWN) Annual Energy Storage Efficiency (%)	For Stationary Electricity Storage and PEV: Value (\$) = {[Hourly Generation Cost (\$/MWh) * Annual Generator Dispatch (MWh)] _{Baseine} – [Hourly Generation Cost (\$/MWh) * Annual Generator Dispatch (MWh)] _{enget}]* Energy Storage Efficiency (%)
Deterred 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)] _{Basene} - [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 64 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 (gallona/mile) kWh consumed (kWh) Electricity to Fuel Conversion Factor Simplified	For Automated Feeder Switching, Diagnosis & Notification of Equipment Condition, & Beal-Time Load Measurement & Management: Value (\$) = {Operation (# of events) * Average Miles Travelled per Event (miles/event) *Average Fuel Efficiency for Service Vehicks (gallons/mile) * Oil Conversion Factor (barrels of ol/gallon of gasoline)] _{Raseline} * {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)] _{Preset} For PEVs: Value (\$) = {Electricity consumed (kWh) * Gasoline Conversion Factor (gallons of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels of oil/gallon of gasoline/kWh) * Oil Conversion Factor (barrels
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)] _{essence} - [Number of Events (# of events) * Estimated Cost per Event (\$/event)] _{essent}

Figure 65 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 (\$)]_{Baseline} - [Ancillary Services Cost (\$)]_{Project}

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

The optional calculation for the same benefit is:

Value (\$) = $[\Sigma (Price of Ancillary Service ($/MW) * Purchases (MW))]_{Baseline} - <math>[\Sigma (Price of Ancillary Service ($/MW) * Purchases (MW))]_{Project}$

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).

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 theSGCT 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 66 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.

a po pa	yow prior figural galage Ban-	Just gathe	Weidow - Help	no anno 1		
190 401 - 14	FORM TO FEEK	1 24 19 10	elw .			
	1111		Alland and a second		·····	
	-		PDH - Choose America			
	eet6 (Propert Summary - Template) erWarkbook rwits coox_amats	*	Pease select al assets that will be installed of assets. If a particular asset that is bein asset being installed. The assets that are following page.	l as part of the smart grid g retailed does not appea chosen on this page will di	project. The choices on this page may represent a in explicitly in this list choices the asset group that is aternative the subset of functions that you will be able	a group or category most closely related to the e to choose from on the
	oose_functions oose_mechs		Customer Assets		Inansmission Assets	
	III Defaut Jana III erengu factor III int.factor		C month	1-efemana	j 🗆 avert)	Defeature
in er angesten Beisel, gestanten Beneter angesten Beneter angesten Beneter angesten			T anost15	Definition	Carriet14	Certation
			- anartiti	Infeitin	🖉 🗆 🗖 anatiti	Definition
	Poject Information Weikome 1994		AMI Assets		Other Assets	
= Gt Module	MINE REACT		(market and)			
e		100	300012	Terinston	3 acos?	Definition
inantes the	ner seriets	×.	Distribution Assets		T accet9	Defetion
Choose_assets	UserForm.	치				
Abhabetic CX	agoreed		T arrett	byTratus	T arrests	Deradon
(Name) Sicksta	Choose_assets s+9000000F8		(T stort)	Definition		Defector
BoxderStyle	0 - triBorderStatelane		F an#5	Definition	= anat17	Deficition
Cycle	D - fmOvchuAlPontra		1" accorts	Definition	C anno 10	termine 1
Drave.fler	32000		Provide Contraction of Contraction o			Leration
Englied	True		1 #000111	Develop	T more	
Fant	Tabona		C anort12	Infence	1	10,000
PORE, DEP	B-euconitzs				The second second second second second second second second second second second second second second second se	Parties 1
HabContartit)	0				A MINUTAL	
KeepSoniEarsh	sble 3 - ImécrolBasBoth					
Luit	D					
Mouse(con	(Norse)					
MousePointer	D - ftnMousePointerDefault		Prevent		Eat 111111111111111111111111111111111111	Social Cold Statute Next
PETUR	(969%)		and a second sec		and the second s	



> 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 68 Example of Module (Module 3)

Appendix II Default Parameters in SGCT

Table 3 Average Hourly Generation Cost

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	91.6	87.1	72.4	73.0	72.4	73.2	74.4	77.3	77.5	77.6	80.9	83.3	84.2	83.2	83.3	84.7	85.9	88.9	91.0	92.7	94.5	95.6	96.2
RFC	69.0	67.0	58.6	58.3	57.7	58.1	58.5	59.1	59.9	60.4	61.4	62.7	63.0	63.2	64.0	65.2	66.5	68.4	70.1	71.9	73.3	73.6	75.0
MRO	38.2	39.1	39.8	38.7	38.8	38.9	38.8	38.1	37.5	37.2	36.9	36.7	36.4	35.9	35.8	35.8	35.8	35.4	35.1	35.2	35.6	36.6	37.8
FRCC	87.5	91.6	80.0	83.2	85.3	85.4	85.4	85.8	86.1	86.0	86.6	88.4	90.7	90.7	90.6	90.8	91.6	92.9	94.7	96.8	98.0	99.0	99.6
SERC	56.7	57.4	54.0	53.3	52.6	52.1	51.5	50.9	51.0	51.2	51.6	51.6	51.7	51.7	52.1	52.5	53.6	54.8	56.1	57.5	58.4	59.3	60.0
SPP	56.9	60.0	54.5	55.8	53.5	53.7	53.7	53.7	54.5	54.9	55.4	56.0	56.0	55.6	55.8	56.4	57.5	58.9	60.0	61.5	62.4	63.3	64.1
TRE	76.7	74.0	62.2	62.0	61.5	64.0	64.9	64.9	66.4	69.6	71.8	75.4	77.9	78.4	79.5	80.7	81.9	84.6	88.0	91.5	93.7	94.6	95.5
WECC	63.2	64.4	59.8	57.7	55.5	54.2	53.4	53.3	53.9	55.2	55.9	56.7	56.7	56.2	56.0	58.1	59.4	60.7	62.4	63.8	65.0	66.3	67.2
ASCC	63.2	64.4	59.8	57.7	55.5	54.2	53.4	53.3	53.9	55.2	55.9	56.7	56.7	56.2	56.0	58.1	59.4	60.7	62.4	63.8	65.0	66.3	67.2
HI	63.2	64.4	59.8	57.7	55.5	54.2	53.4	53.3	53.9	55.2	55.9	56.7	56.7	56.2	56.0	58.1	59.4	60.7	62.4	63.8	65.0	66.3	67.2

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NPCC	46,829	46,829	50,144	39,137	29,167	35,958	50,224	63,772	63,466	63,136	62,831	64,199
RFC	40,150	40,150	40,150	40,150	39,194	50,795	64,377	66,021	70,702	75,091	79,833	84,813
MRO	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
FRCC	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
SERC	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
SPP	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
TRE	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
WECC	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
ASCC	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
н	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700

 Table 4 Price of Capacity at Annual Peak (1)

Table 5 Price of Capacity at Annual Peak (2)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	76,909	89,004	100,504	100,478	100,472	100,484	100,510	100,475	100,454	100,513	100,509
RFC	96,727	102,203	110,401	114,992	114,133	105,800	105,515	109,794	114,412	119,436	124,817
MRO	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
FRCC	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
SERC	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
SPP	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
TRE	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
WECC	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
ASCC	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700
н	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700	95,700

											0												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
RFC	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
MRO	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
FRCC	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
SERC	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
SPP	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
TRE	12.8	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
WECC	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
ASCC	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
HI	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3

Table 6 Average Price of Reserves

Table 7 Average Price of Frequency Regulation

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	33.4	33.4	34.1	34.8	35.5	35.6	35.7	35.7	35.8	35.8	35.8	35.9	35.9	35.9	36.0	36.0	36.1	36.2	36.2	36.3	36.3	36.4	36.5
RFC	36.9	40.2	40.2	40.6	41.0	41.1	41.2	41.2	41.3	41.4	41.5	41.6	41.7	41.8	41.9	41.9	42.0	42.1	42.1	42.2	42.2	42.3	42.3
MRO	26.1	28.5	28.5	28.8	29.0	29.1	29.1	29.2	29.3	29.3	29.4	29.5	29.5	29.6	29.7	29.7	29.7	29.8	29.8	29.9	29.9	29.9	30.0
FRCC	26.1	28.5	28.5	28.8	29.0	29.1	29.1	29.2	29.3	29.3	29.4	29.5	29.5	29.6	29.7	29.7	29.7	29.8	29.8	29.9	29.9	29.9	30.0
SERC	26.1	28.5	28.5	28.8	29.0	29.1	29.1	29.2	29.3	29.3	29.4	29.5	29.5	29.6	29.7	29.7	29.7	29.8	29.8	29.9	29.9	29.9	30.0
SPP	26.1	28.5	28.5	28.8	29.0	29.1	29.1	29.2	29.3	29.3	29.4	29.5	29.5	29.6	29.7	29.7	29.7	29.8	29.8	29.9	29.9	29.9	30.0
TRE	14.9	16.2	16.2	16.4	16.5	16.6	16.6	16.6	16.7	16.7	16.8	16.8	16.8	16.9	16.9	16.9	16.9	17.0	17.0	17.0	17.0	17.1	17.1
WECC	19.3	21.1	21.1	21.3	21.5	21.5	21.6	21.6	21.7	21.7	21.8	21.8	21.9	21.9	22.0	22.0	22.0	22.1	22.1	22.1	22.1	22.2	22.2
ASCC	26.1	28.5	28.5	28.8	29.0	29.1	29.1	29.2	29.3	29.3	29.4	29.5	29.5	29.6	29.7	29.7	29.7	29.8	29.8	29.9	29.9	29.9	30.0
н	26.1	28.5	28.5	28.8	29.0	29.1	29.1	29.2	29.3	29.3	29.4	29.5	29.5	29.6	29.7	29.7	29.7	29.8	29.8	29.9	29.9	29.9	30.0

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	2000	2000	_0.0			_0.0		2010			2010	2010
NPCC	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
RFC	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
MRO	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
FRCC	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
SERC	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
SPP	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
TRE	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
WECC	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
ASCC	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8
н	2,187.5	2,220.3	2,253.6	2,287.4	2,321.7	2,356.6	2,391.9	2,427.8	2,464.2	2,501.2	2,538.7	2,576.8

 Table 8 Average Price of Voltage Control (1)

Table 9 Average Price of Voltage Control (2)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
RFC	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
MRO	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
FRCC	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
SERC	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
SPP	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
TRE	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
WECC	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
ASCC	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3
HI	2,615.4	2,654.6	2,694.5	2,734.9	2,775.9	2,817.5	2,859.8	2,902.7	2,946.2	2,990.4	3,035.3

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
RFC	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
MRO	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
FRCC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRE	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
WECC	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
ASCC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Н	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 10 Average Price of Congestion

Table 11 Average Price of Wholesale Energy

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	0.06	0.06	0.07	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.14	0.15
RFC	0.07	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11
MRO	0.04	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
FRCC	0.09	0.07	0.08	0.09	0.11	0.11	0.11	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.15
SERC	0.06	0.04	0.05	0.06	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09
SPP	0.06	0.04	0.05	0.06	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10
TRE	0.08	0.05	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.14	0.14	0.14
WECC	0.06	0.05	0.06	0.06	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10
ASCC	0.06	0.05	0.06	0.06	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10
н	0.06	0.05	0.06	0.06	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10
	Residential	Commercial	Industrial																				
-------	-------------	------------	------------																				
NPCC	2.20	282.00	15.30																				
RFC	2.20	282.00	15.30																				
MRO	2.20	282.00	15.30																				
FRCC	2.20	282.00	15.30																				
SERC	2.20	282.00	15.30																				
SPP	2.20	282.00	15.30																				
TRE	2.20	282.00	15.30																				
WECC	2.20	282.00	15.30																				
ASCC	2.20	282.00	15.30																				
HI	2.20	282.00	15.30																				
Empty	2.20	282.00	15.30																				

Table 12 Inflation Factor

Table 13 Restoration Cost per Event (1)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NPCC	3,000.0	3,081.0	3,081.0	3,164.2	3,164.2	3,249.6	3,249.6	3,337.4	3,337.4	3,427.5	3,427.5	3,520.0
RFC	3,000.0	3,063.0	3,063.0	3,127.3	3,127.3	3,193.0	3,193.0	3,260.0	3,260.0	3,328.5	3,328.5	3,398.4
MRO	3,000.0	3,063.0	3,063.0	3,127.3	3,127.3	3,193.0	3,193.0	3,260.0	3,260.0	3,328.5	3,328.5	3,398.4
FRCC	3,000.0	3,087.0	3,087.0	3,176.5	3,176.5	3,268.6	3,268.6	3,363.4	3,363.4	3,461.0	3,461.0	3,561.3
SERC	3,000.0	3,072.0	3,072.0	3,145.7	3,145.7	3,221.2	3,221.2	3,298.5	3,298.5	3,377.7	3,377.7	3,458.8
SPP	3,000.0	3,063.0	3,063.0	3,127.3	3,127.3	3,193.0	3,193.0	3,260.0	3,260.0	3,328.5	3,328.5	3,398.4
TRE	3,000.0	3,069.0	3,069.0	3,139.6	3,139.6	3,211.8	3,211.8	3,285.7	3,285.7	3,361.2	3,361.2	3,438.5
WECC	3,000.0	3,072.0	3,072.0	3,145.7	3,145.7	3,221.2	3,221.2	3,298.5	3,298.5	3,377.7	3,377.7	3,458.8
ASCC	3,000.0	3,078.0	3,078.0	3,158.0	3,158.0	3,240.1	3,240.1	3,324.4	3,324.4	3,410.8	3,410.8	3,499.5
н	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	3,520.0	3,615.1	3,615.1	3,712.7	3,712.7	3,812.9	3,812.9	3,915.8	3,915.8	4,021.6	4,021.6
RFC	3,398.4	3,469.8	3,469.8	3,542.6	3,542.6	3,617.0	3,617.0	3,693.0	3,693.0	3,770.5	3,770.5
MRO	3,398.4	3,469.8	3,469.8	3,542.6	3,542.6	3,617.0	3,617.0	3,693.0	3,693.0	3,770.5	3,770.5
FRCC	3,561.3	3,664.6	3,664.6	3,770.9	3,770.9	3,880.2	3,880.2	3,992.8	3,992.8	4,108.6	4,108.6
SERC	3,458.8	3,541.8	3,541.8	3,626.8	3,626.8	3,713.8	3,713.8	3,803.0	3,803.0	3,894.2	3,894.2
SPP	3,398.4	3,469.8	3,469.8	3,542.6	3,542.6	3,617.0	3,617.0	3,693.0	3,693.0	3,770.5	3,770.5
TRE	3,438.5	3,517.6	3,517.6	3,598.5	3,598.5	3,681.3	3,681.3	3,766.0	3,766.0	3,852.6	3,852.6
WECC	3,458.8	3,541.8	3,541.8	3,626.8	3,626.8	3,713.8	3,713.8	3,803.0	3,803.0	3,894.2	3,894.2
ASCC	3,499.5	3,590.5	3,590.5	3,683.8	3,683.8	3,779.6	3,779.6	3,877.9	3,877.9	3,978.7	3,978.7
HI	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0

Table 14 Restoration Cost per Event (2)

Table 15 Average Fuel Efficiency for Truck Roll Vehicle

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
RFC	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
MRO	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
FRCC	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
SERC	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
SPP	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
TRE	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
WECC	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
ASCC	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
н	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
Empty	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021-'30
NPCC	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
RFC	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
MRO	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
FRCC	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
SERC	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
SPP	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
TRE	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
WECC	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
ASCC	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
н	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null
Empty	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	null

Table 16 CO2 Emissions per Gallon of Fuel

Table 17 Value of CO2

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
RFC	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
MRO	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
FRCC	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
SERC	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
SPP	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
TRE	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
WECC	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
ASCC	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
н	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4
Empty	20	20	20	20	20	20	20	20	20	20	20	20	20	20.4	20.8	21.2	21.6	22.1	22.5	23.0	23.4	23.9	24.4

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021-'30
NPCC	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
RFC	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
MRO	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
FRCC	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
SERC	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
SPP	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
TRE	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
WECC	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
ASCC	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
н	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null
Empty	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	null

Table 18 SOx Emissions per Gallon of Gas

Table 19 NOx Emissions per Gallon of Gas

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NPCC	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
RFC	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
MRO	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
FRCC	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
SERC	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
SPP	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
TRE	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
WECC	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
ASCC	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
н	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null
Empty	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	null

								1															-
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
RFC	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
MRO	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
FRCC	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
SERC	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
SPP	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
TRE	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
WECC	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
ASCC	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
н	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640
Empty	520	520	520	520	520	520	520	520	520	520	520	520	520	531	542	553	565	577	589	601	614	627	640

Table 20 Value of SOx

Table 21 Value of NOx

	2008-'12	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
RFC	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
MRO	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
FRCC	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
SERC	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
SPP	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
TRE	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
WECC	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
ASCC	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
н	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693
Empty	3000	3063.0	3127	3193	3260	3329	3398	3470	3543	3617	3693

	2008-'20	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NPCC	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
RFC	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
MRO	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
FRCC	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
SERC	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
SPP	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
TRE	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
WECC	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
ASCC	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
н	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9
Empty	36000	36756.0	37527.9	38316.0	39120.6	39942.1	40780.9	41637.3	42511.7	43404.4	44315.9

Table 22 Value of PM-2.5

Table 23 Average Fuel Efficiency

	Feeder Service Vehicle	Diagnosis/Notification Service Vehicle	Real Time Load Measurement/Management Service Vehicle
NPCC	20.3	20.3	20.3
RFC	20.3	20.3	20.3
MRO	20.3	20.3	20.3
FRCC	20.3	20.3	20.3
SERC	20.3	20.3	20.3
SPP	20.3	20.3	20.3
TRE	20.3	20.3	20.3
WECC	20.3	20.3	20.3
ASCC	20.3	20.3	20.3
Н	20.3	20.3	20.3
Empty	20.3	20.3	20.3

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021-'30
NPCC	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
RFC	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
MRO	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
FRCC	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
SERC	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
SPP	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
TRE	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
WECC	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
ASCC	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
н	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null
Empty	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	null

Table 24 Electricit	y to Fuel Conversio	n Factor
---------------------	---------------------	----------

	Та	able 25 Escalation Factors		
	Population Growth*	Load Growth**	Inflation***	Energy Price***
NPCC	0.002	0.008	0.027	0.033
RFC	0.003	0.014	0.021	0.025
MRO	0.004	0.023	0.021	0.015
FRCC	0.020	0.026	0.029	0.025
SERC	0.009	0.022	0.024	0.018
SPP	0.004	0.018	0.021	0.014
TRE	0.016	0.022	0.023	0.039
WECC	0.013	0.016	0.024	0.022
ASCC	0.011	0.022	0.026	0.025

HI 0.60 0.013 0.028 0.072

Source: U.S. Census Bureau, Population Division, Interim State Population Projections, 2005.

**

http://www.census.gov/population/www/projections/projectionsagesex.html 11 Source: 1990 - 2008 Retail Sales of Electricity by State by Sector by Provider (EIA-861), http://www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html Source: US Bureau of Labor and Statistics CPI Database, All Urban Consumers (Current Series) (Consumer Price Index - CPI), All Items, *** http://www.bls.gov/cpi/#tables

Source: 1990 - 2008 Average Price by State by Provider (EIA-861), Industry Sector Category = Full-Service Providers, **** http://www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html