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U.S. DEPARTMENT OF ENERGY | Office of Electricity Delivery and Energy Reliability

September 26, 2012

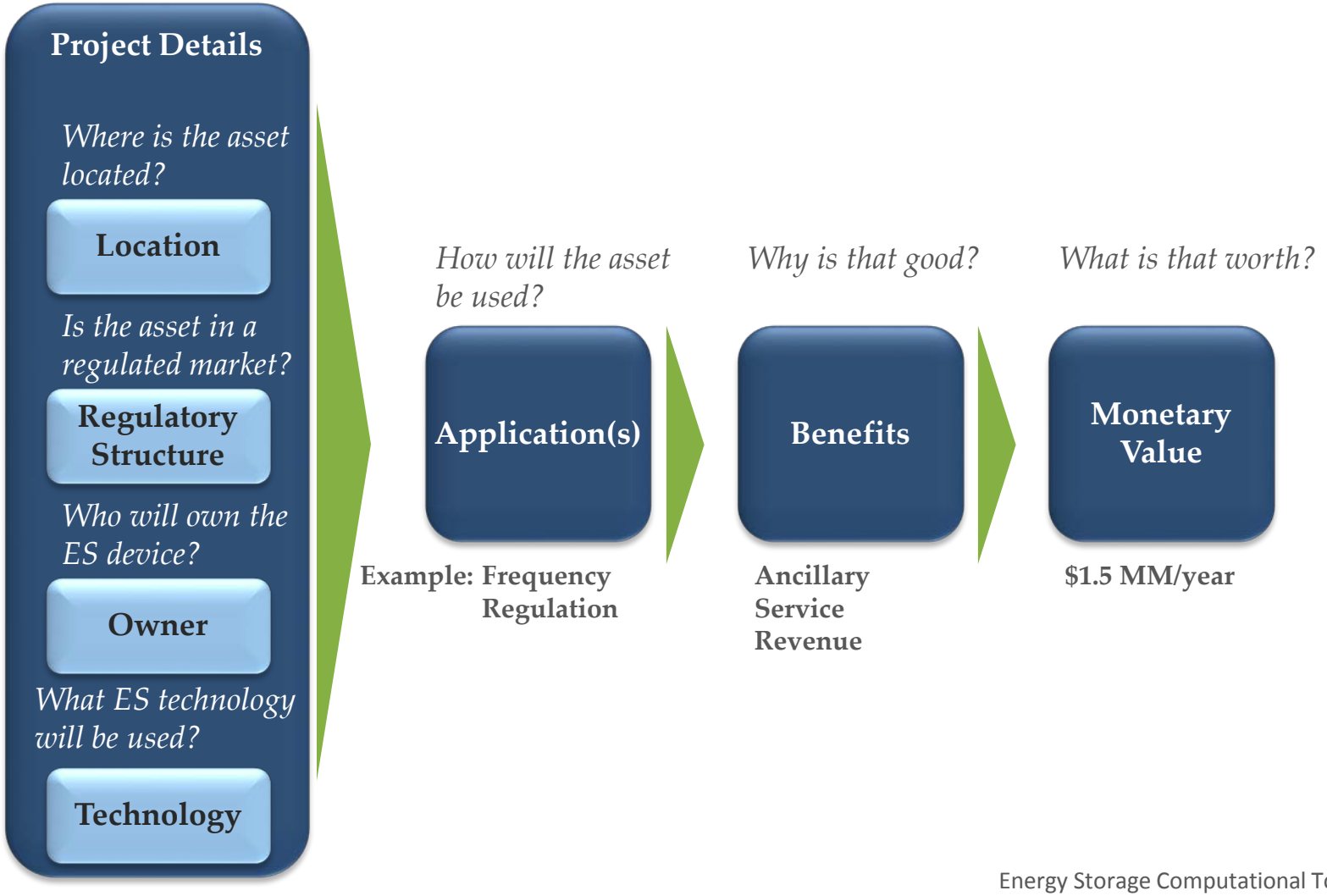
Energy Storage Computational Tool (ESCT) v1.2 Overview

Developed under DOE Contract DE-FE0004001 Task 430.05

The Energy Storage Computational Tool (ESCT) identifies and monetizes the costs and benefits of energy storage (ES) systems deployed in utility applications.

Characteristics of ESCT v1.2		Advantages
Primary Purpose	The ESCT is primarily designed to identify, quantify, and monetize the costs and benefits of an operational ES project. So, many of the inputs represent measured data.	• Straightforward to use • Lends itself to quality control • Provides a consistent and credible method for identification and calculation of benefits • Ensures consistency of results across projects • Well suited for long term analysis
Secondary Purpose	The ESCT can also help the user evaluate the potential costs and benefits of a proposed or hypothetical project. It could also help to optimize the size, type, and location of the ES system.	
Perspective	The ESCT is designed to account for all benefits including those that accrue to the asset owner, ratepayer/consumer, and societal stakeholders.	
Data Inputs	Measured data is used where available and estimated data is used for additional benefits that are difficult to measure or quantify.	
Platform	The ESCT is entirely self-contained in Microsoft Excel and can be saved, edited, and updated.	

The tool identifies potential benefits and estimates the monetized value for an ES project based on the project details and application specified by the user.



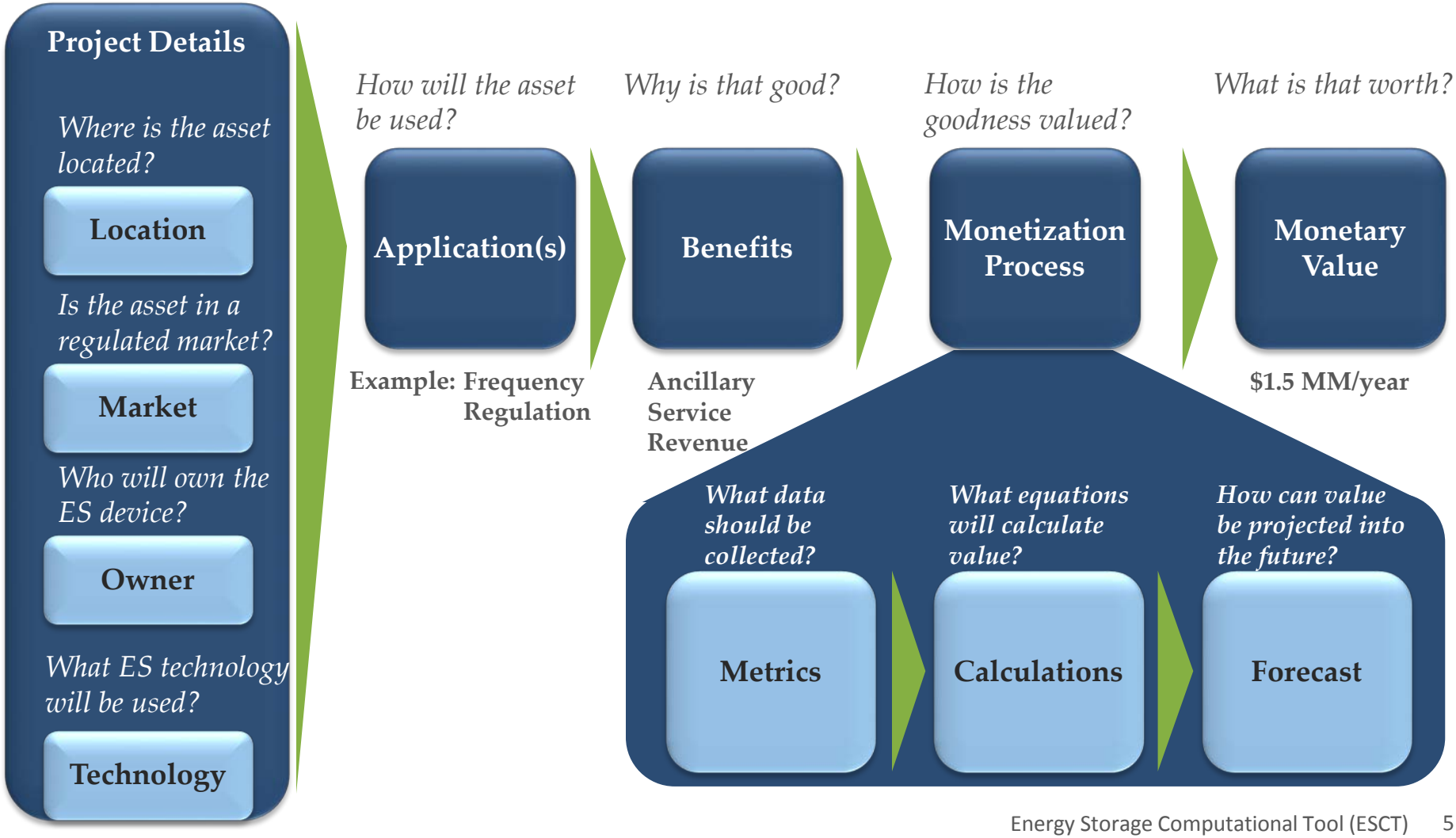
Achievable benefits may vary depending on the location of the ES on the grid, the regulatory structure, the owner, and the type of technology selected.

Project Details		
Category	**Options**	**Definition**
Location	Generation	This location describes any point between the generator and the transmission lines.
	Transmission	This location describes any point between the beginning of the transmission lines and the step-down distribution substation.
	Distribution	This location describes any place starting downstream of the power transformer at a step-down distribution substation, until the customer meter.
	End-User	This location describes any place on the customer-side of the customer meter.
Regulatory Structure	Regulated	A market in which utilities are vertically integrated, incorporating most elements of electric delivery and service into a single company.
	Deregulated	A market in which vertical integration at utilities has been broken up, allowing for independent power producers and merchant generators.
Owner	Utility	An asset owner that maintains and operates a local transmission and or distribution grid, such as an investor-owned utility, municipal utility, or electricity cooperative.
	Non-Utility Merchant/IPP	An asset owner that can independently deploy generation and ES assets for wholesale market participation or contracts with utilities or end users.
	End-User	An asset owner that is primarily an end-user of electricity.

The ESCT identifies different benefits depending on the application selected.

Applications	Economic										Reliability		Env.	
	Market Revenue			Asset Utilization					Efficiency	Cost	Interruptions		Air	
	Arbitrage Revenue	Capacity Revenue	Ancillary Service Revenue	Optimized Generator Operation	Reduced Congestion Cost	Deferred Generation Capacity Investments	Deferred Transmission Capacity Investments	Deferred Distribution Capacity Investments	Reduced Electricity Losses	Reduced Electricity Cost	Reduced Outages	Improved Power Quality	Reduced CO_2 Emissions	Reduced SO_X, NO_X, and Particulate Emissions
Electric Energy Time Shift	X			X		X	X	X	X	X			X	X
Electric Supply Capacity		X				X								
Load Following			X	X		X							X	X
Area Regulation			X	X		X							X	X
Electric Supply Reserve Capacity			X	X		X							X	X
Voltage Support			X									X		
Transmission Support							X				X			
Transmission Congestion Support					X		X							
T&D Upgrade Deferral				X		X	X	X	X				X	X
Time of Use Energy Cost Management				X		X	X	X	X	X			X	X
Demand Charge Management				X		X	X	X	X	X			X	X
Electric Service Reliability											X			
Electric Service Power Quality												X		
Renewables Energy Time Shift	X			X		X	X	X	X	X			X	X
Renewables Capacity Firming		X				X							X	X
Wind Generation – Short		X				X							X	X
Wind Generation – Long	X			X		X	X	X	X	X			X	X

The user enters data collected during operation of the ES system in order to monetize the benefits and conduct a cost/benefit analysis over time.



ESCT modules reflect the framework developed to assess the value of an energy storage project.

The ESCT is composed of three modules.

1. Asset Characterization Module
2. Data Input Module
3. Computational Module

	1 Asset Characterization Module	2 Data Input Module	3 Computational Module
Purpose	Determine the list of project benefits.	Filter irrelevant metrics. Guide and assist data entry.	Calculation and present results.
Inputs	Project Details, Applications	List of Benefits	Calculation Dataset, Sensitivity Ranges
Outputs	List of Benefits	Calculation Dataset	Tabular and Graphic Presentation of Monetized Benefits
Key Methodologies	Application-to-Benefit Relational Models	Benefit-to-Input Relational Model	ES Benefit Calculations, Benefit Forecast Methodology

The ESCT User Guide includes detailed explanations of the methodology as well as step-by-step use instructions.

- The first half of the User Guide is dedicated to:
  - Providing context for the tool and explaining its purpose;
  - Explaining the general methodology for assessing the benefits of an energy storage project; and
  - Defining each Application and Benefit.
- The second half of the User Guide is dedicated to:
  - Explaining the general Architecture of the ESCT; and
  - Providing a step-by-step instruction manual for using the ESCT.
- The Appendix of the User Guide documents and explains:
  - The detailed cost and benefit calculations used in the tool; and
  - Key concepts and assumptions (ex. inputs, default values, escalation techniques).

The ESCT, an overview presentation, and a users guide are publicly available for download at no cost at www.SmartGrid.gov.

- The ESCT and related documents can be downloaded at:

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

- DOE will hold webinars to demonstrate the tool to Smart Grid Demonstration Program recipients before the end of the year.

QUESTIONS??

Key Contacts

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Asset Characterization Module Screen Shots

Location, Market, Owner, Energy Storage Technology

On this form please indicate the following:
1) The physical location of the energy storage deployment project,
2) The regulatory structure in which the storage deployment will operate in,
3) The owner of the storage device,
4) The type of storage technology the deployment utilizes.

Location

- (•) Generation and Transmission — Definition
- ( ) Distribution — Definition
- ( ) End-User — Definition

Market

- ( ) Regulated — Definition
- (•) Deregulated — Definition

Owner

- ( ) Utility — Definition
- (•) Non-Utility Merchant/Independent Power Producer — Definition
- ( ) End-User — Definition

What type of storage technology does the deployment utilize? Battery, Lithium Ion

Exit | Next

Asset Characterization Module Screen Shots

Parameters

Please enter all of the system parameters for the energy storage deployment.

What is the total nameplate power output (kW)?	20,000	kW	Use Default Value	Definition
What is the total nameplate energy storage capacity (kWh)?	40,000	kWh	Use Default Value	Definition
What is the response time of the energy storage device(s) deployed?	0.001	seconds	Use Default Value	
What is the nameplate round-trip efficiency of the energy storage device(s) deployed?	92	%	Use Default Value	
What is the nameplate cycle life (cycles) of the energy storage device(s) deployed?	1	cycles	Use Default Value	Definition
What is the average or expected year over year demand growth of the electric system?	2	%	Use Default Value	
Does the energy storage device(s) deployed have reactive power capabilities?	Yes		Use Default Value	
Please indicate the NERC Region in which the energy storage deployment is located.	NPCC Upstate NY			

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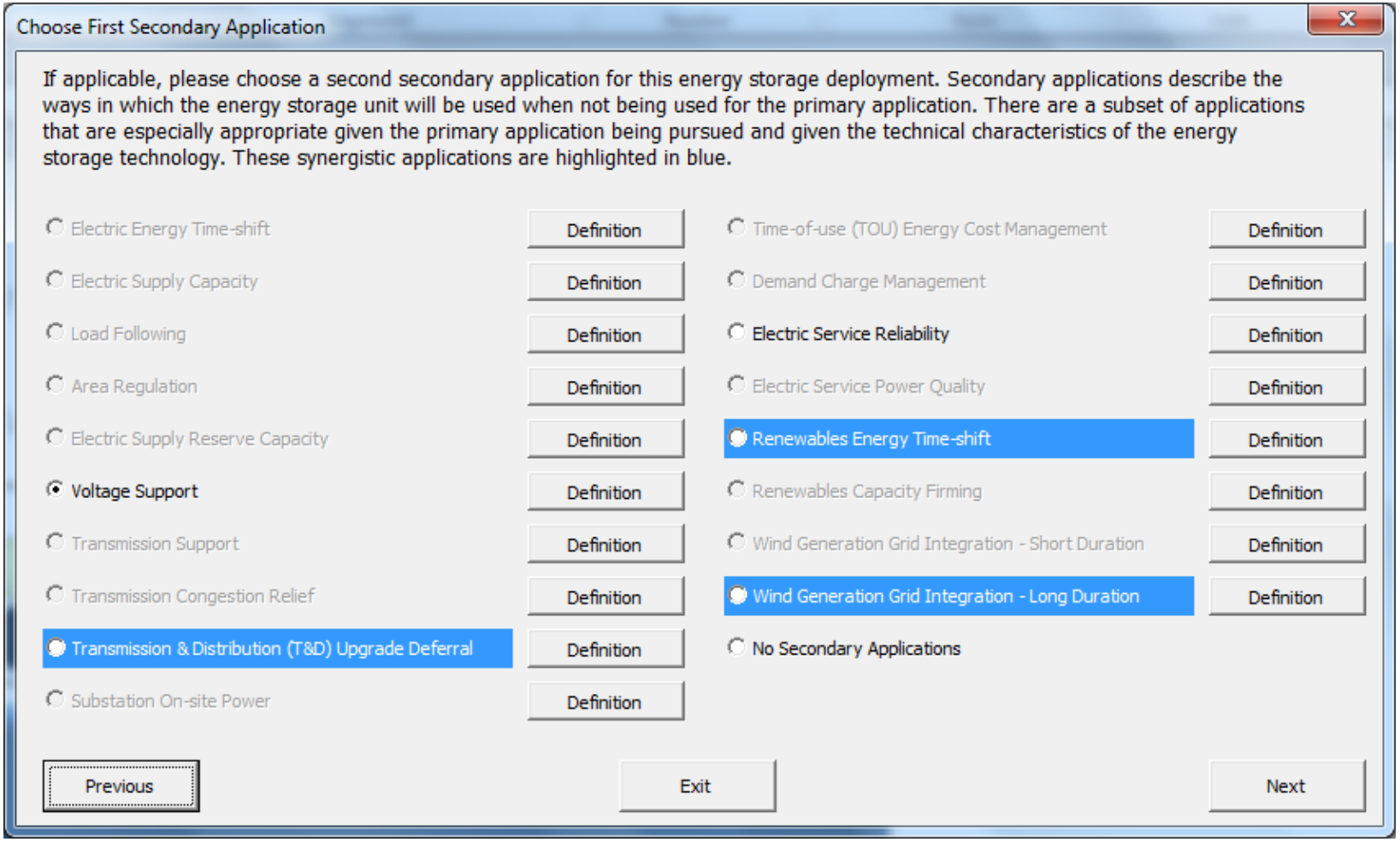
Asset Characterization Module Screen Shots



Asset Characterization Module Screen Shots

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Benefits

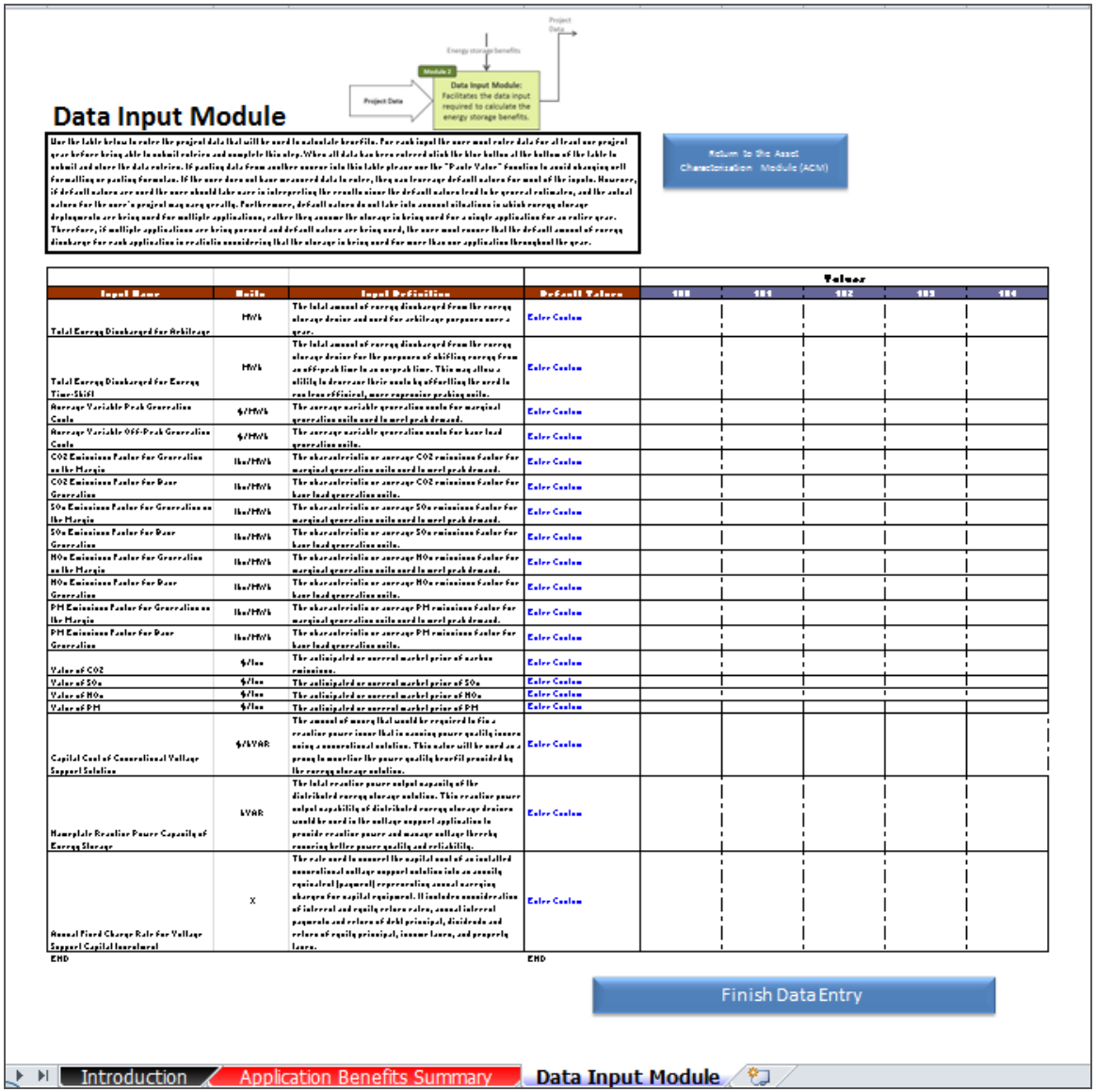
The benefits highlighted in blue below represent the benefits that your energy storage project will yeild based on primary and secondary applications that are being pursued. For further explanation of a benefit click the button to the right of the benefit.

Arbitrage Revenue	Definition
Capacity Market Revenue	Definition
Ancillary Services Revenue	Definition
Reduced Electricity Cost (Consumer)	Definition
Reduced Electricity Cost (Utility/Ratepayer)	Definition
Reduced Congestion Costs (Non-Utility Merchant)	Definition
Reduced Congestion Costs (Utility/Ratepayer)	Definition
Optimized Generator Operation (Non-Utility Merchant)	Definition
Optimized Generator Operation (Utility/Ratepayer)	Definition
Reduced Electricity Losses	Definition
Deferred Transmission Investments	Definition
Deferred Distribution Investments	Definition
Deferred Generation Capacity Investments	Definition
Reduced Outages (Consumer)	Definition
Reduced Outages (Utility/Ratepayer)	Definition
Improved Power Quality	Definition
Reduced CO2 Emissions	Definition
Reduced SOx Emissions	Definition
Reduced NOx Emissions	Definition
Reduced PM Emissions	Definition

Previous

Finish

Data Input Module Screen Shots



Data Input Module

Use the table below to enter the project data that will be used to calculate benefits. For each input the user must enter data for at least one project year before being able to submit entries and complete this step. When all data has been entered click the blue button at the bottom of the table to submit and store the data entries. If pasting data from another source into this table please use the "Paste Value" function to avoid changing cell formatting or pasting formulas. If the user does not have measured data to enter, they can leave any default values for most of the inputs. However, if default values are used the user should take care in interpreting the results since the default values lead to be general estimates, and the actual values for the user's project may vary greatly. Furthermore, default values do not take into account situations in which energy storage deployments are being used for multiple applications, rather they assume the storage is being used for a single application for an entire year. Therefore, if multiple applications are being pursued and default values are being used, the user must ensure that the default amount of energy discharge for each application is realistic considering that the storage is being used for more than one application throughout the year.

Return to the Asset Characterization Module (ACM)

Input Name	Units	Input Definition	Default Values	Values				
				180	181	182	183	184
Total Energy Discharged for Arbitrage	MWh	The total amount of energy discharged from the energy storage device and used for arbitrage purposes over a year.	Enter Custom					
Total Energy Discharged for Energy Time-Shift	MWh	The total amount of energy discharged from the energy storage device for the purpose of shifting energy from an off-peak time to an on-peak time. This may allow a utility to decrease their costs by offsetting the need to run less efficient, more expensive peaking units.	Enter Custom					
Average Variable Peak Generation Costs	$/MWh	The average variable generation costs for marginal generation units used to meet peak demand.	Enter Custom					
Average Variable Off-Peak Generation Costs	$/MWh	The average variable generation costs for base load generation units.	Enter Custom					
CO2 Emissions Factor for Generation on the Margin	lbs/MWh	The characteristic or average CO2 emissions factor for marginal generation units used to meet peak demand.	Enter Custom					
CO2 Emissions Factor for Base Generation	lbs/MWh	The characteristic or average CO2 emissions factor for base load generation units.	Enter Custom					
SOx Emissions Factor for Generation on the Margin	lbs/MWh	The characteristic or average SOx emissions factor for marginal generation units used to meet peak demand.	Enter Custom					
SOx Emissions Factor for Base Generation	lbs/MWh	The characteristic or average SOx emissions factor for base load generation units.	Enter Custom					
NOx Emissions Factor for Generation on the Margin	lbs/MWh	The characteristic or average NOx emissions factor for marginal generation units used to meet peak demand.	Enter Custom					
NOx Emissions Factor for Base Generation	lbs/MWh	The characteristic or average NOx emissions factor for base load generation units.	Enter Custom					
PM Emissions Factor for Generation on the Margin	lbs/MWh	The characteristic or average PM emissions factor for marginal generation units used to meet peak demand.	Enter Custom					
PM Emissions Factor for Base Generation	lbs/MWh	The characteristic or average PM emissions factor for base load generation units.	Enter Custom					
Value of CO2	$/lbs	The anticipated or current market price of carbon emissions.	Enter Custom					
Value of SOx	$/lbs	The anticipated or current market price of SOx	Enter Custom					
Value of NOx	$/lbs	The anticipated or current market price of NOx	Enter Custom					
Value of PM	$/lbs	The anticipated or current market price of PM	Enter Custom					
Capital Cost of Conventional Voltage Support Solution	$/kVAR	The amount of money that would be required to fix a reactive power issue that is causing power quality issues using a conventional solution. This value will be used as a proxy to monetize the power quality benefit provided by the energy storage solution.	Enter Custom					
Nameplate Reactive Power Capacity of Energy Storage	kVAR	The total reactive power output capacity of the distributed energy storage solution. This reactive power output capability of distributed energy storage devices would be used in the voltage support application to provide reactive power and manage voltage thereby ensuring better power quality and reliability.	Enter Custom					
Annual Fixed Charge Rate for Voltage Support Capital Investment	X	The rate used to convert the capital cost of an installed conventional voltage support solution into an annuity equivalent (payment) representing annual carrying charges for capital equipment. It includes consideration of interest and equity return rates, annual interest payments and return of debt principal, dividends and return of equity principal, income taxes, and property taxes.	Enter Custom					
END			END					

Finish Data Entry

Introduction | Application Benefits Summary | Data Input Module

Data Input Module Screen Shots

Back

Data Input Module

Project Data

Energy storage benefits

Module 2

Data Input Module: Facilitates the data input required to calculate the energy storage benefits.

Project Data

Use the table below to enter the project data that will be used to calculate benefits. For each input the user must enter data for at least one project year before being able to submit entries and complete this step. When all data has been entered click the blue button at the bottom of the table to submit and store the data entries. If pasting data from another source into this table please use the "Paste Value" function to avoid changing cell formatting or pasting formulas. If the user does not have measured data to enter, they can leave any default values for most of the inputs. However, if default values are used the user should take care in interpreting the results since the default values lead to be general estimates, and the actual values for the user's project may vary greatly. Furthermore, default values do not take into account situations in which energy storage deployments are being used for multiple applications, rather they assume the storage is being used for a single application for an entire year. Therefore, if multiple applications are being pursued and default values are being used, the user must ensure that the default amount of energy discharge for each application is realistic considering that the storage is being used for more than one application throughout the year.

Return to the Asset Characterization Module (ACM)

Input Name	Units	Input Definition	Default Values	Values				
				180	181	182	183	184
Total Energy Discharged for Arbitrage	MWh	The total amount of energy discharged from the energy storage device and used for arbitrage purposes over a year.	Enter Custom					
Total Energy Discharged for Energy Time-Shift	MWh	The total amount of energy discharged from the energy storage device for the purposes of shifting energy from						
Average Variable Peak Generation Costs	$/MWh							
Average Variable Off-Peak Generation Costs	$/MWh							
CO2 Emissions Factor for Generation on the Margin	lbs/MWh							
CO2 Emissions Factor for Base Generation	lbs/MWh							
SOx Emissions Factor for Generation on the Margin	lbs/MWh							
SOx Emissions Factor for Base Generation	lbs/MWh							
NOx Emissions Factor for Generation on the Margin	lbs/MWh							
NOx Emissions Factor for Base Generation	lbs/MWh							
PM Emissions Factor for Generation on the Margin	lbs/MWh							
PM Emissions Factor for Base Generation	lbs/MWh							
Value of CO2	$/lbs							
Value of SOx	$/lbs							
Value of NOx	$/lbs							
Value of PM	$/lbs							
Capital Cost of Conventional Voltage Support Solution	$/kVAR	the energy storage solution.						
Nameplate Reactive Power Capacity of Energy Storage	kVAR	The total reactive power output capacity of the distributed energy storage solution. This reactive power output capability of distributed energy storage devices would be used in the voltage support application to provide reactive power and manage voltage thereby ensuring better power quality and reliability.	Enter Custom					
Annual Fixed Charge Rate for Voltage Support Capital Investment	%	The rate used to convert the capital cost of an installed conventional voltage support solution into an annuity equivalent (payment) representing annual carrying charges for capital equipment. It includes consideration of interest and equity return rates, annual interest payments and return of debt principal, dividends and return of equity principal, income taxes, and property taxes.	Enter Custom					
END			END					

Finish Data Entry

Microsoft Excel

Please make sure you enter data for at least one year for all required inputs. All of the required data for the Total Energy Discharged for Arbitrage input is not entered. If the value for a particular year is zero please enter zero rather than leaving the space blank. Do not enter zero for project data beyond the first year if data is simply unavailable however.

OK

Introduction | Application Benefits Summary | Data Input Module

Computational Module Screen Shots

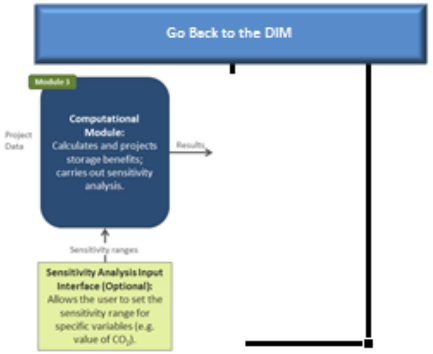
Computational Module (CM) Main Page

Instructions

Welcome to the Computational Module (CM) phase of the Energy Storage Computational Tool (ESCT). 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.

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 40 seconds to complete the analysis.



Reference Case

Run CM with Reference Case Inputs

View Reference Case Results

Sensitivity Analysis

Run CM with Sensitivity Case Inputs

View Sensitivity Results

Reset all values to 100%

		Select % swing toggle			2011 Values		
Input Name	Unit	Low	Reference	High	Low	Reference	High
Total Energy Discharged for Arbitrage	MWh	100%	100%	100%	$ 18,000	$ 18,000	$ 18,000
Total Energy Discharged for Energy Time-Shift	MWh	100%	100%	100%	18,000	18,000	18,000
Average Variable Peak Generation Costs	$/MWh	100%	100%	100%	$ 46	$ 46	$ 46
Average Variable Off-Peak Generation Costs	$/MWh	100%	100%	100%	$ 24	$ 24	$ 24
CO2 Emissions Factor for Generation on the Margin	lbs/MWh	100%	100%	100%	845	845	845
CO2 Emissions Factor for Base Generation	lbs/MWh	100%	100%	100%	-	-	-
SOx Emissions Factor for Generation on the Margin	lbs/MWh	100%	100%	100%	0.075	0.075	0.075
SOx Emissions Factor for Base Generation	lbs/MWh	100%	100%	100%	-	-	-
NOx Emissions Factor for Generation on the Margin	lbs/MWh	100%	100%	100%	0.25	0.25	0.25
NOx Emissions Factor for Base Generation	lbs/MWh	100%	100%	100%	-	-	-
PM Emissions Factor for Generation on the Margin	lbs/MWh	100%	100%	100%	0.040	0.040	0.040
PM Emissions Factor for Base Generation	lbs/MWh	100%	100%	100%	0.200	0.200	0.200
Value of CO2	$/ton	100%	100%	100%	$ 20	$ 20	$ 20

Introduction | Application Benefits Summary | Input Review | CM Main Page

Computational Module Screen Shots

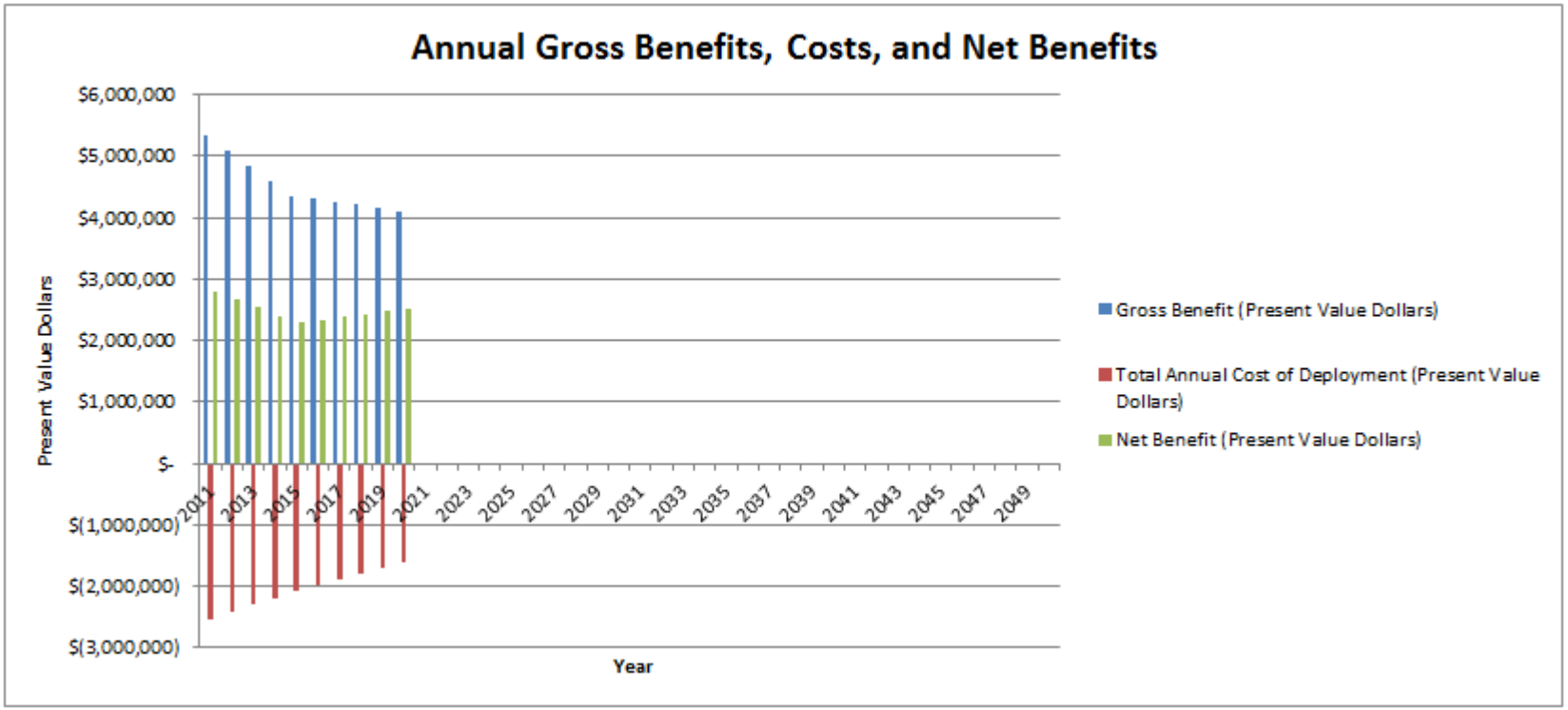
Reference Case Output: Annual and Cumulative Results Tables

The tables below display the annual and cumulative project benefits and costs. The benefits are organized by category. The total gross benefit, total cost, and net benefit are also displayed at the bottom of each chart. All values are present value terms. To calculate additional benefits navigate to the additional benefits worksheets from the Additional Benefits tab.

Annual Benefit and Cost Table

	Benefits	Additional Benefits - Total Present Value over the Deployment Period	+	Primary and Secondary Benefits - Total Present Value over the Deployment Period	=	Total Benefit - Present Value over the Deployment Period	2011	2012	2013	2014	2015
Market Revenue	Arbitrage Revenue	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Capacity Market Revenue	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Ancillary Services Revenue	$ -		$ 44,855,400		$ 44,855,400	$ 5,303,900	$ 5,038,700	$ 4,786,700	$ 4,547,400	$ 4,320,000
Improved Asset Utilization	Optimized Generator Operation (Non-Utility Merchant)	$ -		$ 154,200		$ 154,200	$ 18,200	$ 17,300	$ 16,500	$ 15,600	$ 14,900
	Optimized Generator Operation (Utility/Ratepayer)	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Deferred Generation Capacity Investments	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Reduced Congestion Costs (Non-Utility	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Reduced Congestion Costs (Utility/Ratepayer)	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
T&D Capital Savings	Deferred Transmission Investments	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Deferred Distribution Investments	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
Energy Efficiency	Reduced Electricity Losses	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
Electricity Cost Savings	Reduced Electricity Cost (Consumer)	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Reduced Electricity Cost (Utility/Ratepayer)	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
Power Interruptions	Reduced Outages (Consumer)	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Reduced Outages (Utility/Ratepayer)	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
Power Quality	Improved Power Quality	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
Air Emissions	Reduced CO2 Emissions	$ -		$ 216,500		$ 216,500	$ 25,600	$ 24,300	$ 23,100	$ 21,900	$ 20,900
	Reduced SOx Emissions	$ -		$ -		$ -	$ -	$ -	$ -	$ -	$ -
	Reduced NOx Emissions	$ -		$ 27,900		$ 27,900	$ 3,300	$ 3,100	$ 3,000	$ 2,800	$ 2,700
	Reduced PM Emissions	$ -		$ 12,100		$ 12,100	$ 1,400	$ 1,400	$ 1,300	$ 1,200	$ 1,200
	Total Gross Benefit	**$ -**		**$ 45,266,100**		**$ 45,266,100**	**$ 5,352,400**	**$ 5,084,800**	**$ 4,830,600**	**$ 4,588,900**	**$ 4,359,700**
	Costs										
	Capital Cost of Deployment (fixed charge rate)					$ 19,156,400	$ 2,387,000	$ 2,267,700	$ 2,154,300	$ 2,046,600	$ 1,944,200
	Operating and maintenance costs not related to energy (labor for operation, plant maintenance, equipment wear leading to loss-of-life)					$ 1,283,900	$ 160,000	$ 152,000	$ 144,400	$ 137,200	$ 130,300
	Decommissioning and Disposal Costs					$ -	$ -	$ -	$ -	$ -	$ -
	Total Annual Cost of Deployment					**$ 20,440,300**	**$ 2,547,000**	**$ 2,419,700**	**$ 2,298,700**	**$ 2,183,700**	**$ 2,074,500**
	Total Net Benefit					**$ 24,825,800**	**$ 2,805,400**	**$ 2,665,100**	**$ 2,531,900**	**$ 2,405,200**	**$ 2,285,200**

Application Benefits Summary | Input Review | CM Main Page | **Result Tables** | Result Charts | Additional Benefits

Computational Module Screen Shots

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