Optimization-Based Valuation Methodology of Distributed Energy Resource Portfolios

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PV Systems Symposium

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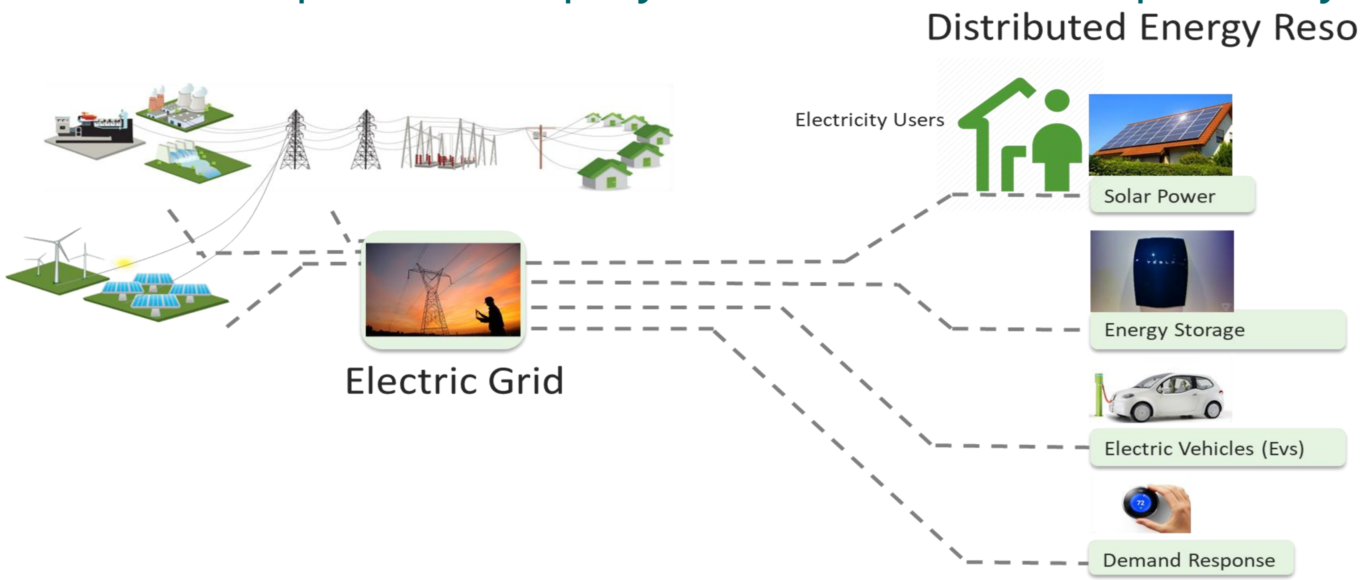
Agenda

Overview of ProsumerGrid Planning Studio
Optimization-based DER Portfolios Valuation Methodology
Use Case Example

ProsumerGrid Integrated Grid&DER Planning Studio

Context

- The electric industry is moving towards a model based on more active customers and Distributed Energy Resources (DERs).
- After 100 interviews with Electric Utilities stakeholders, we confirmed that new software tools were needed to adequately simulate, and plan the deployment of DER-based power systems.



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- **ProsumerGrid, in collaboration with NYSSGC, SCE, NRECA, and Newport Consulting** has been working on an ambitious project under DOE ARPA-E to develop a transformational tool for simulation and planning of DER-based distribution grids.
  - Project is part of the ARPA-E OPEN 2015 Portfolio
  - Project runs from June 2016 to November 2018.
  - Extended to August 2019.
- There is a void in the industry's capability to simulate and optimally plan DER-based distribution & transmission systems.
- Our utility partners confirmed that it is difficult to simulate:
  - Simulate the physical impact of multiple DERs
  - Determine the optimal operation of DERs
  - Assess the value and determine optimal investments in DERs portfolios
  - Simulate market/DSO use cases.

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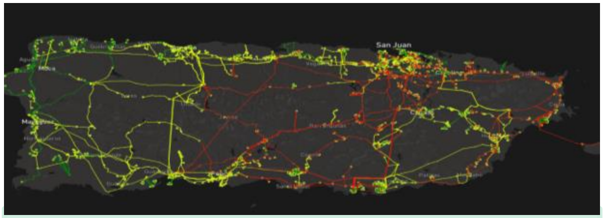
ProsumerGrid *Integrated GRID + DER Planning* Studio

Is a software tool that combines Transmission and Distribution Analysis Capabilities and DER models with Advanced Optimization Algorithms to solve urgent questions:

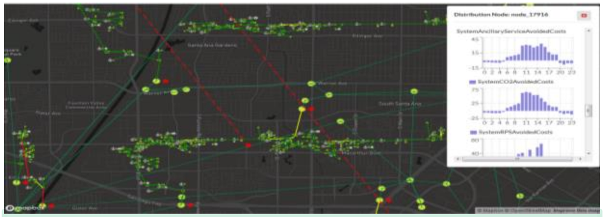


QSTS Integrated T&D&DER Power Flow Model: Impact of DERs (PV, storage, DR, and DG) on distribution and transmission systems.

- Thermal Violations
- Voltage Violations
- Back Power Flow

DER Project Assessment:

- **DER Hosting Capacity**
- **DER Locational Net Benefit Analysis**
- **DER as Non-Wires Alternatives Assessment.**



Optimal DER Scheduling: Optimal operation of distribution systems with large amounts of DERs.

- DERs Managed to Shape Feeder Load
- Optimization of Utility-Controlled Energy Storage Systems and Value Stacking
- DERs Managed to Minimize Operational Cost

DER Production Costing

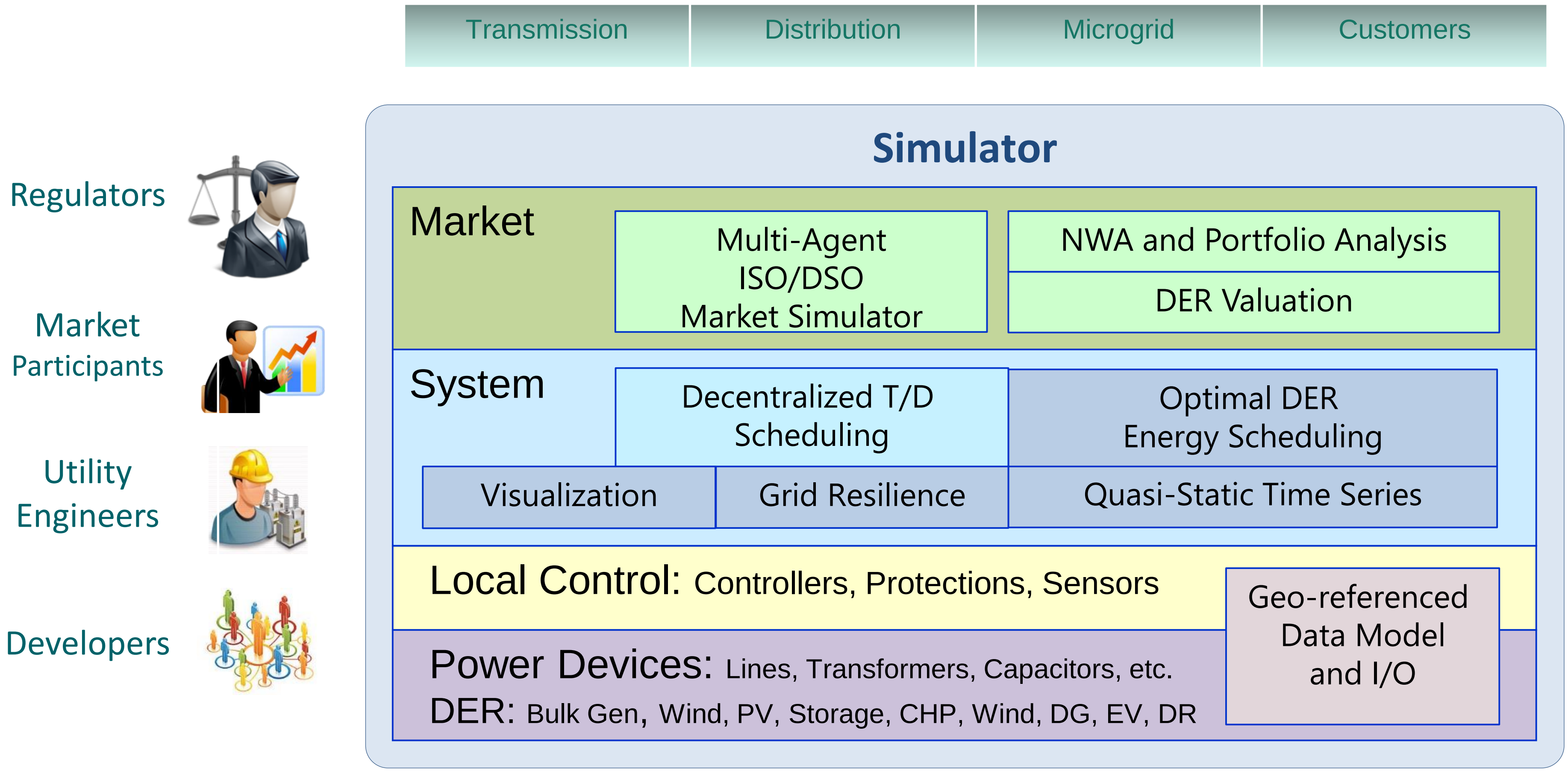
- Estimates power produced by DERs and its costs.

Optimal DER Portfolio Design: Determines the optimal combination of a set of DER options (DER type, capacity and location) for a grid subsystem (with both transmission and distribution components)
Optimal type, sizing, sitting of solar PV, energy storage and distributed generation

Integrated T&D&DER Planning:
Optimal DER Portfolio Design for T/Sub-T/D/Distribution Feeders/Microgrids/Critical Facilities

PROSUMERGRID INTEGRATED GRID+DER PLANNING STUDIO

ProsumerGrid Integrated Grid&DER Planning Studio



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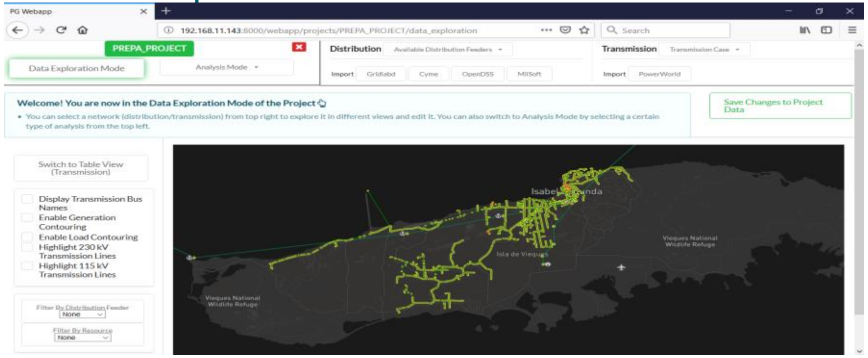
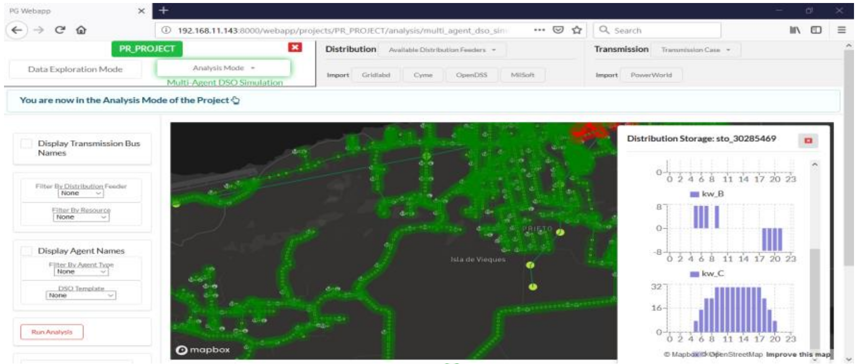
Existing Simulation	Capability
Separate T, D Models No DER Modeling Capability	**Integrated T+D+DER Modeling, Simulation & Planning**
No Consideration of Uncertainty or Risk	**Risk Adverse, Stochastic Optimization**
No Optimization	**Optimization-based DER Planning**
“Spreadsheet” B/C analysis Average System-level Assumptions	**Integrated Physical Grid, DER Costs and Financial Optimization Modeling**
Worst Case Scenario Only	**Multiple-Scenario (Demand, Prices, PV Forecasts) Probabilistic Planning**
Single Machine, Non-scalable Computing	**High Performance Computing Native, Scalable Computing (cloud-based)**
Command Prompt	**Interactive Web-based, GIS-based Visualization**
Mostly for PV Some Energy Storage (ES)	**All Relevant DERs (PV, ES, DR, EV, DG), combinations of DERs**

1. Methodology Core: DER Energy Scheduling Proxy for Distribution-level DER Production Costing

- Advanced optimization **determines optimal schedule of arbitrary sets of DERs based on desired objectives**
- The approach considers unbalanced 3-phase power flow, and DER (renewables (PV), storage, demand response and generators) locational and temporal constraints
- Combines power system modeling with financial optimization

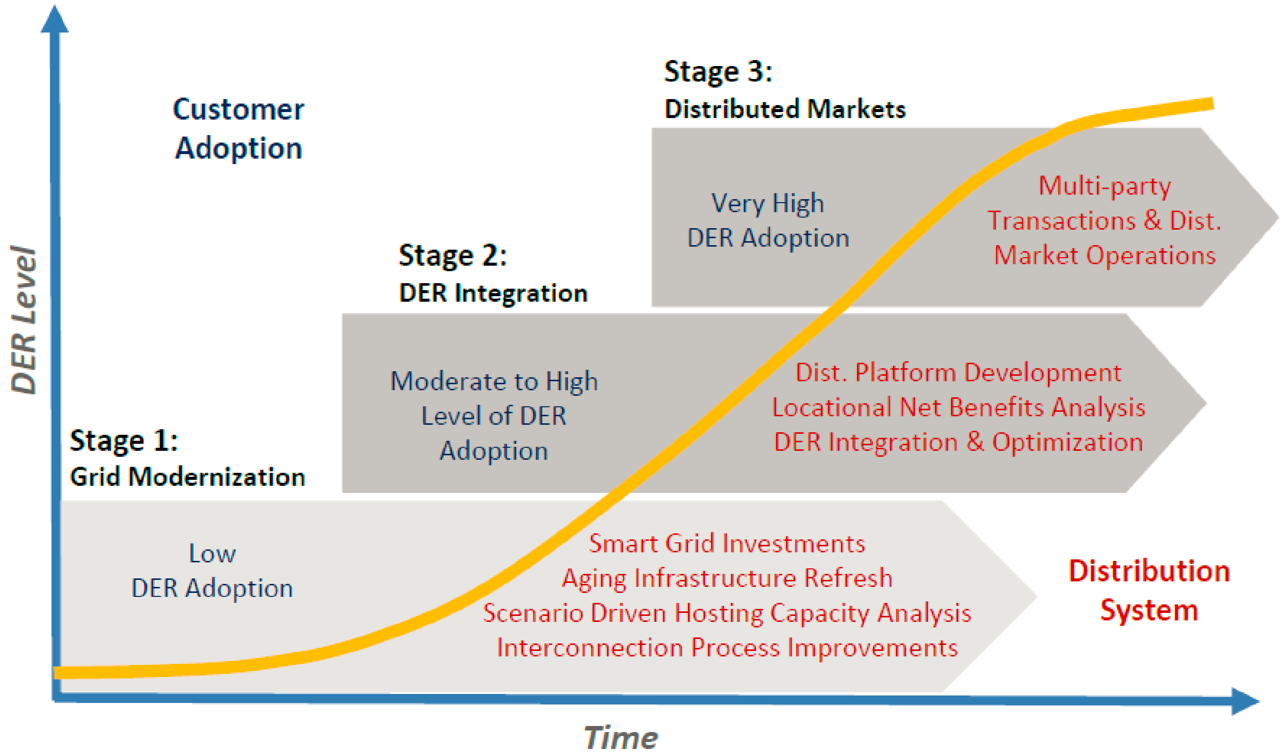
- DER Decision-Variables
  - Curtailable PV
  - Schedulable Storage
  - Flexible Demand
- Output:
  - Optimal Schedules for all DERs
  - Time Vector, Per Phase, Distribution Locational Marginal Prices (DLMP)
- Supports various types of impact analysis
  - DERs managed to shape feeder load
  - Optimization of Utility Controlled Distributed Energy Storage
  - Scheduling of flexible demand, others





1. Methodology: Identify DER Level

- Integrated Grid&DER Planning Studio seeks to address the questions & issues in a manageable, logical sequence that considers different levels of DER penetration.*



* De Martini, P. Kristov L. "Distribution Systems in a High Distributed Energy Resources Future"

1. Methodology: Identify Distribution Functions

Distribution Functions by Evolutionary Stage*

Distribution Functions	Stage 1	Stage2	Stage 3
1. Planning			
A. Scenario based, distribution engineering analysis	✓	✓	✓
B. DER Interconnection studies and procedures	✓	✓	✓
C. DER Hosting capacity analysis	✓	✓	✓
D. DER locational value analysis		✓	✓
E. Integrated T&D Planning		✓	✓
2. Operations			
A. Design-build and ownership of distribution grid	✓	✓	✓
B. Switching, outage restoration & distribution maintenance	✓	✓	✓
C. Physical coordination of DER schedules		✓	✓
D. Coordination with ISO at T-D interface		✓	✓
3. Market			
A. Sourcing distribution grid services		✓	✓
B. Optimally dispatch DER provided distribution grid services		✓	✓
C. Aggregation of DER for wholesale market participation		✓	✓
D. Creation & operation of distribution level energy markets; transactions among DER			✓
E. Clearing and settlements for inter-DER transactions			✓
F. Market facilitation services			✓

* De Martini, P. Kristov L. "Distribution Systems in a High Distributed Energy Resources Future"

1. Methodology: Identify Architecture & Agents

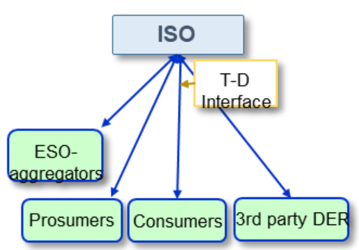
Conceptual ISO-DSO-DER Models*

A → **B** → **C1** → **C2**

Total ISO (A)

ISO **models & optimizes the whole system**, from BAA level down to distribution circuits, with visibility to distribution grid conditions & all DER

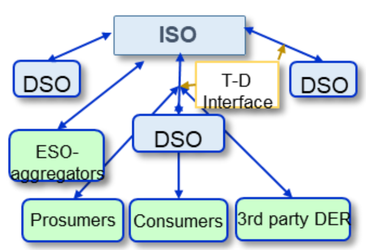
DSO has minimal new functions, only to ensure safety & reliability



Minimal DSO (B)

ISO optimizes whole system, including large numbers of small DERs, but **models DERs at the T-D interface** with little or no visibility into the distribution system

DSO has significant coordination role, to manage DER responses to ISO dispatches as well as DER services provided to distribution grid



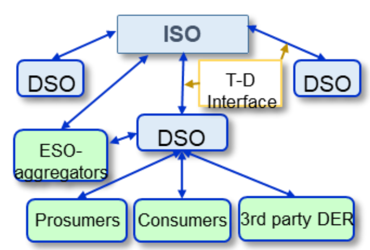
Market DSO (C1)

Market DSO (C2)

Maximizes DSO role in operational coordination, to minimize the complexity for the ISO optimization

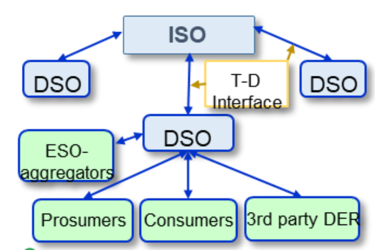
C1: ISO sees only a small number of aggregate DERs at each T-D interface

DSO is the coordinator of the aggregators



C2: ISO sees only one resource at each T-D interface

DSO is the aggregator for all DERs below that interface



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* De Martini, P. Kristov L. “Distribution Systems in a High Distributed Energy Resources Future”

1. Methodology: Identify Local Regulatory B/C Categories

- E3 – Net benefits of NEM in California
- California – Distribution Resources Plans (June 2016)
- New York – Benefit costs handbooks (2015)
- EPRI – Cost Benefit Framework (2014)

E3 DERAC Components
Energy
Losses
Generation Capacity
Ancillary Services
Environment
Avoided RPS
T-D Capacity

Color Code
Generation
Transmission
T-D
Distribution
Externalities

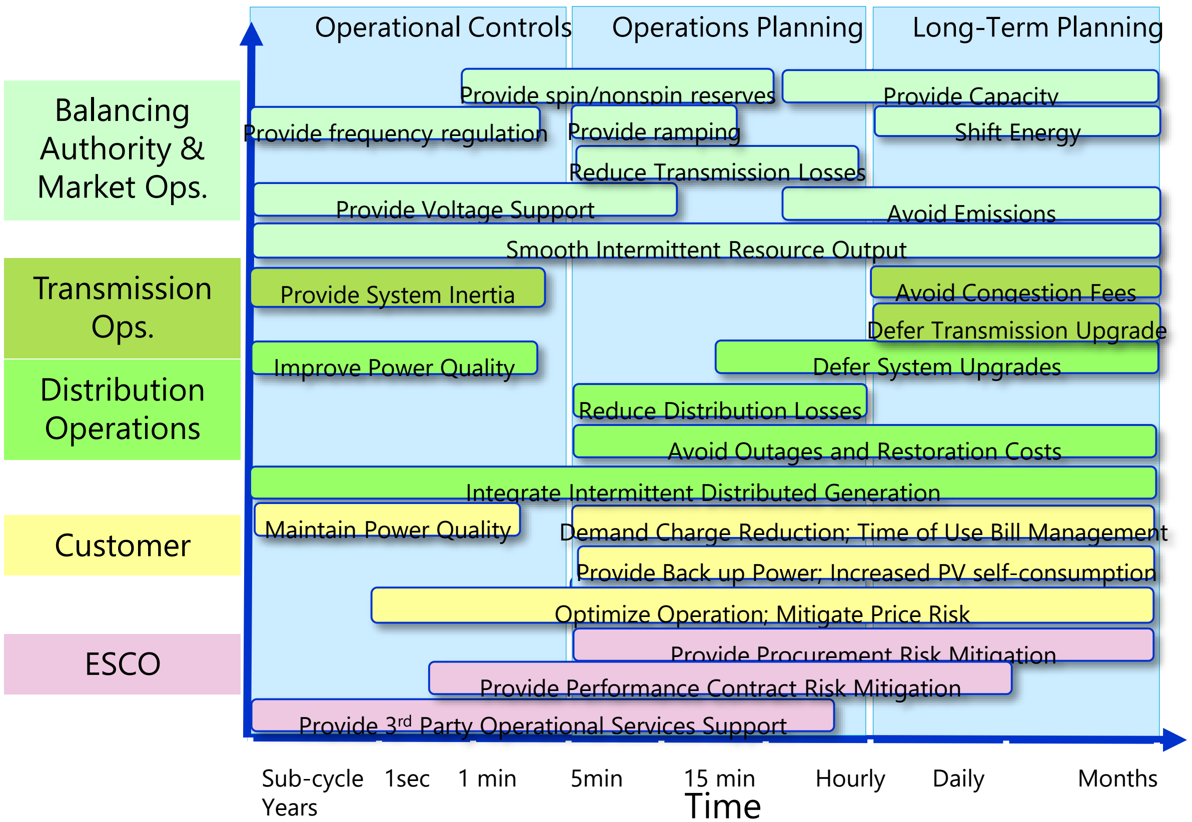
CPUC Components
Avoided Energy
Avoided Environmental GHG
T-D Losses
RA Capacity
Avoided Ancillary Services
Avoided RPS Expenditures
Avoided Renewable Integration Costs
T-D Capacity Expansion Deferral
Distribution P, Q Capital and O&M
Distribution Reliability & Resiliency Capital and O&M
Societal
Public Safety Avoided Costs

NYPUC Components
Avoided Energy
Avoided Gen Capacity
Avoided Transmission Losses
Avoided Ancillary Services
Wholesale Market Impact (attenuation)
Avoided Trans Cap Infrastructure & O&M
Avoided Distribution Cap Infrastructure
Avoided Distribution O&M
Avoided Distribution Losses
Costs (program admin costs, lost utility revenue)
Avoided GHG
Net Non Energy Benefits

*NY Business Cost Handbooks, E3 Avoided Cost Tool, CA DRP Proceedings

1. Methodology: Identify Services

- Steps in BCA framework analysis:
  - 1) Identify value categories in value chain /value network
  - 2) Identify services exchanged
  - 3) Allocate service benefits to stakeholders
  - 4) Classify them as benefit or costs
  - 5) Identify monetization mechanism



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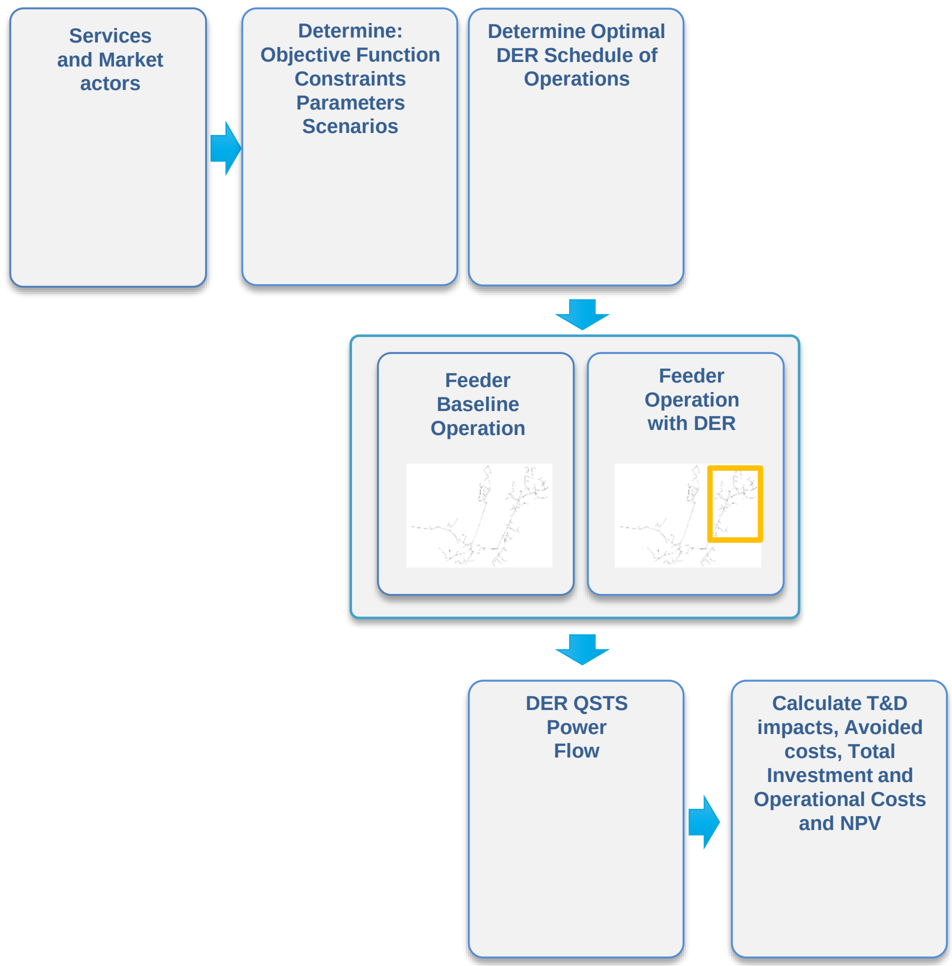
1. Methodology: Calculate Impacts

- Steps in BCA framework analysis:
  - 5) Based on previous inputs, determine:
    - Objective Function
    - Constraints
    - Parameters
    - Scenarios
  - 6) Generate Optimal DER Schedule of Operations
  - 7) Run QSTS Power Flow and compare with Baseline Feeder Operation
  - 8) Calculate distribution, transmission impacts, & avoided costs, total investment and operational costs and NPV



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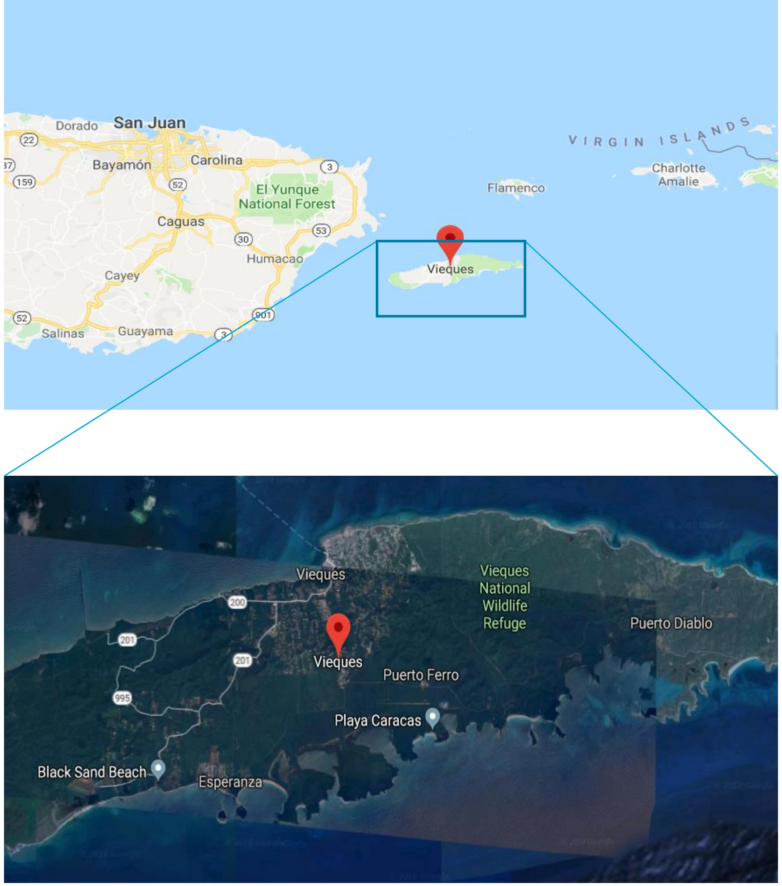
Use Case
Optimal Long-Term DER Planning & Valuation

- On Tuesday, July 24, 2018 representatives from PREPA, NYSSGC and ProsumerGrid met to discuss project progress and identify potential use case locations. PREPA identified 6 potential use-case locations.
- The team identified a Caribbean island off Puerto Rico's eastern coast.
  - Area: 134.4 mi^2
  - Population: 8,669 (2017)



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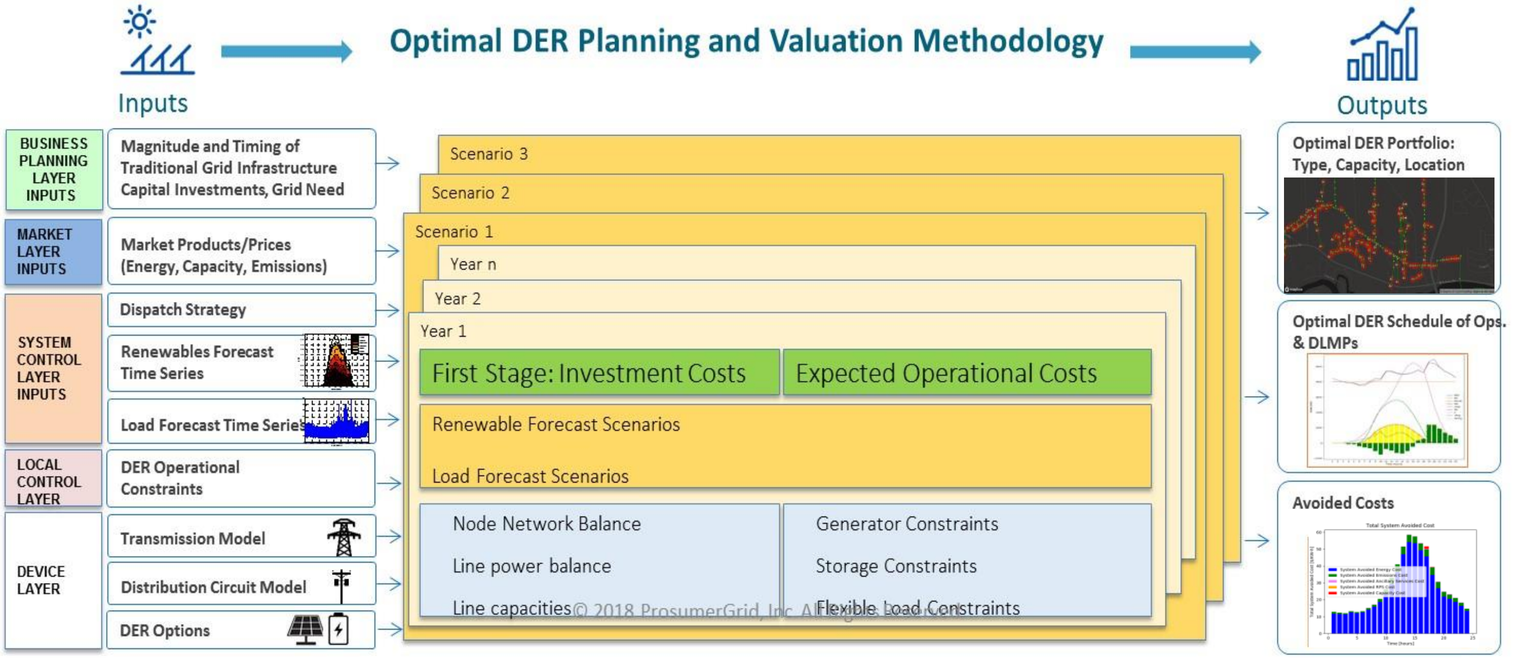
Use Case
Optimal Long-Term DER Planning & Valuation

- **Objective:** For each distribution feeder, determine the optimal portfolio (type, capacity, location) of the least cost combination (investment operational costs) DERs (solar PV, energy storage, demand response) considering the forecasted demand and the expected time of grid disconnection.



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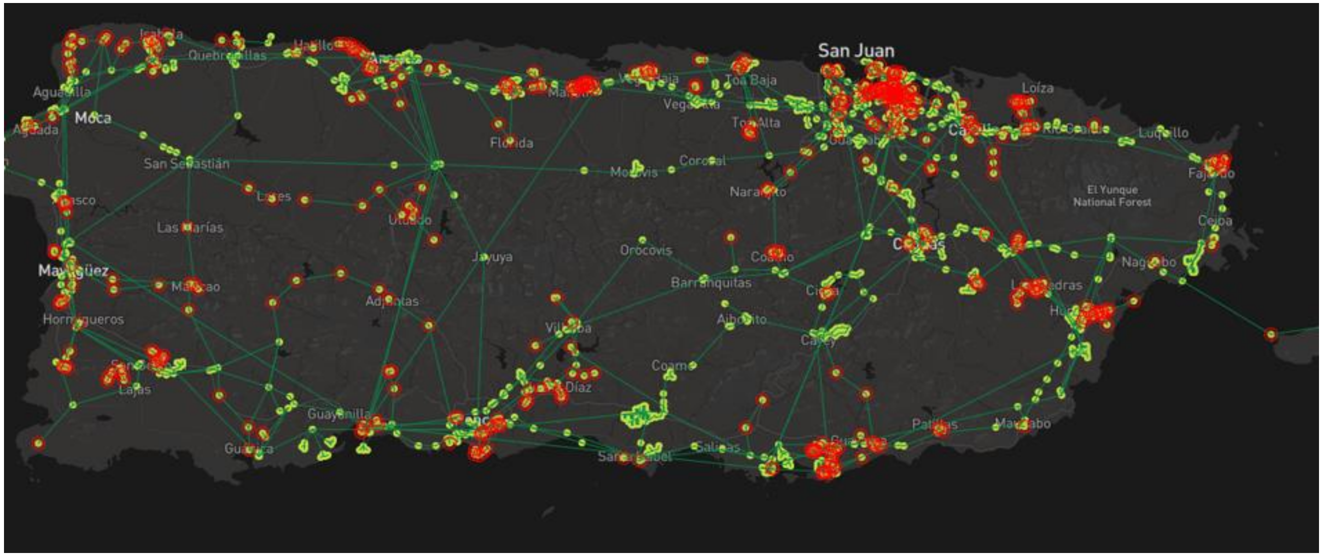
Use Case
Optimal Long-Term DER Planning & Valuation

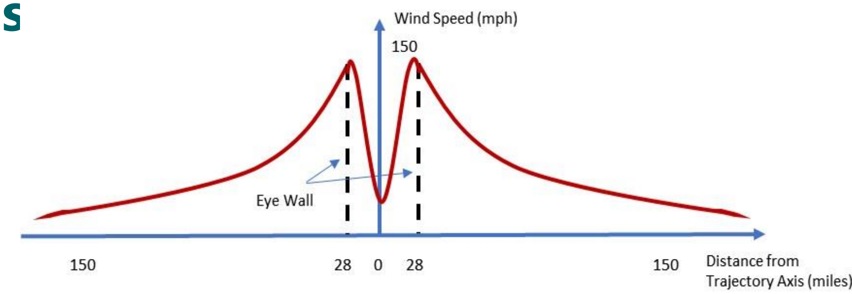
- **Transmission Resilience Simulations**
  - Baseline Reference of Transmission and Subtransmission
  - N-1 Contingency Analysis
  - N-1 Severe Contingencies and Weak Elements
  - Transmission and Subtransmission elements loading

- **Example:**
Buses Islanded by *N*-1 38KV Outages.

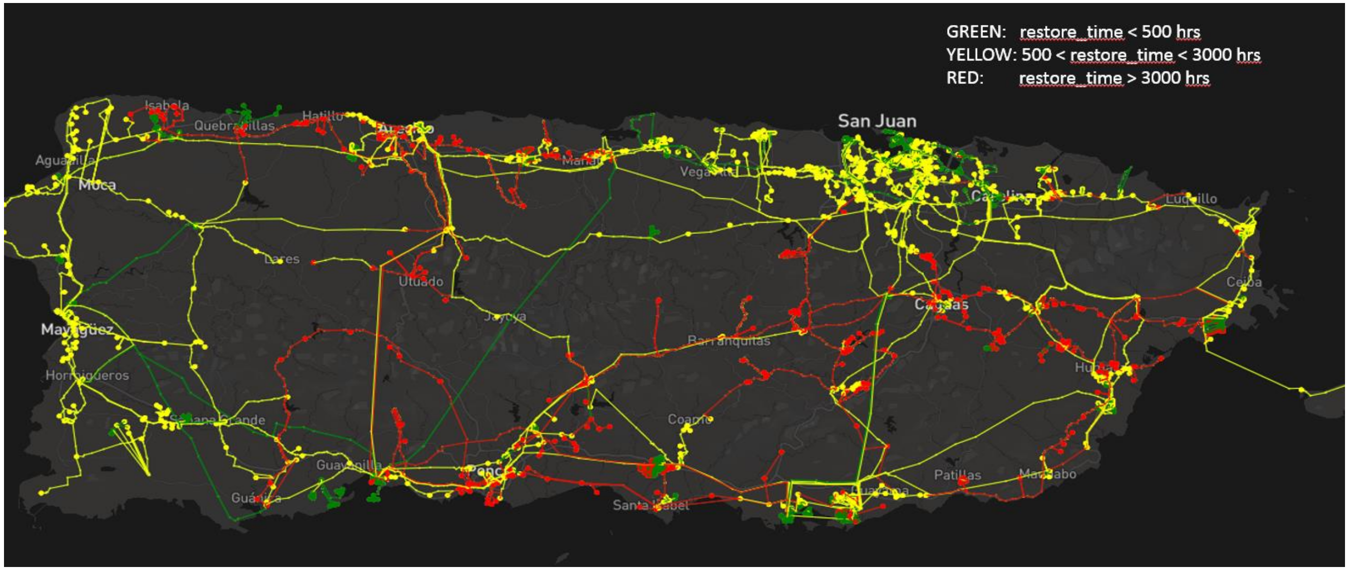


Use Case
Optimal Long-Term DER Planning & Valuation

- **Transmission Resilience Simulations**
  - Hurricane Wind Speed Model
  - Infrastructure Damage Model
  - Restoration Model
    - -> Locational Expected Restoration Times

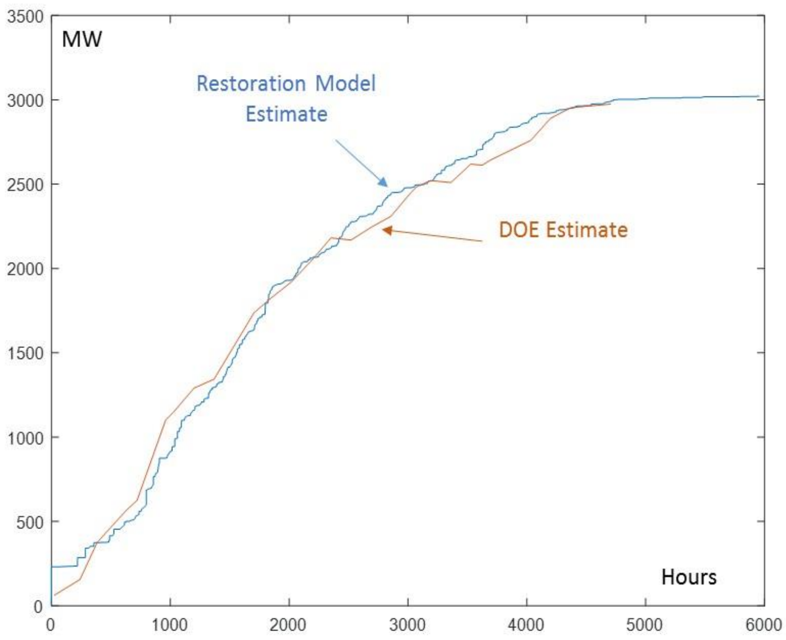


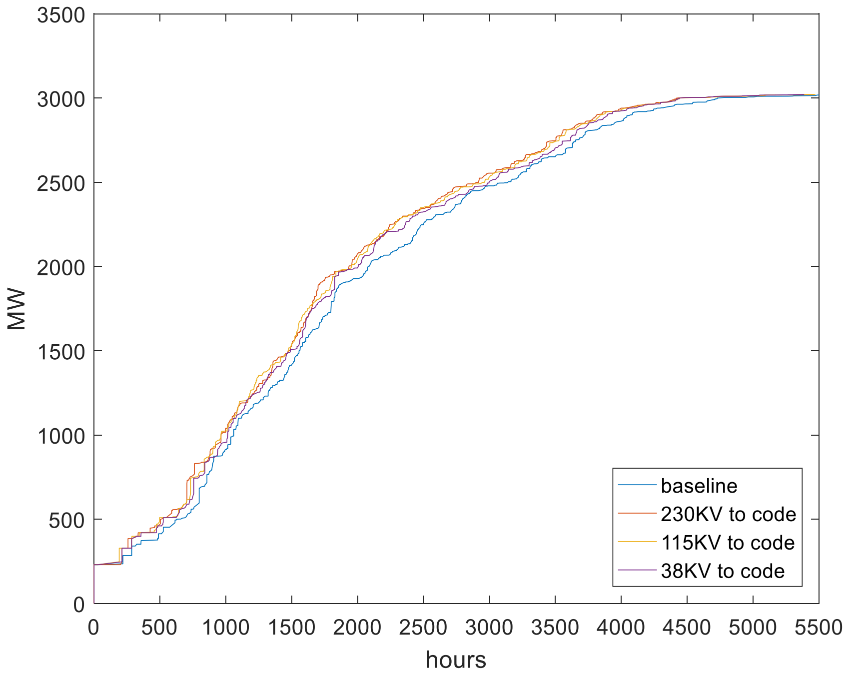
- **Example:** Expected Locational Restoration Times for a Category 4 Hurricane Scenario



Use Case
Optimal Long-Term DER Planning & Valuation

- **Transmission Resilience Simulations**
  - Grid resilience performance for CAT4 baseline using Resilience Model
  - Impact of various grid improvement options on grid resilience:
    - Undergrounding, reinforcements, etc.
  - Example: Bringing 10% of line segments to code





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Use Case
Optimal Long-Term DER Planning & Valuation

- **What is the least cost combination of investments in DERs** to meet identified distribution need (expected restoration time and local load) for the next 10 years?
- **What types and capacities of these DER** resources should be installed?
- **Where should these DER resources be installed?**
  - Need to consider all possible locations on the feeder (node and phase), distribution circuit unbalance and network constraints.
- **What are the resulting benefits, costs and NPV of the DER Portfolio selected?**
  - Benefits or avoided costs related to: energy, capacity, CO2 emissions, ancillary services, and **avoided loss of load costs**
  - Costs: total capital investment and operational costs
  - Metrics: benefit-cost ratio, and the net present value

Use Case
Optimal Long-Term DER Planning & Valuation

- **DERs Assumptions Summary and Potential Sensitivities***

Parameter Name	Baseline	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5	Sensitivity 6
		High PV/ES Cost	Decreasing Demand	Low VOLL	High CO2 Cost	Max DG Units	Max DG Units
Investment Costs							
Solar PV Investment Cost ($/kW)	960.15	1182.11					
Storage Investment Cost ($/kW)	1716.17	2043.70					
DG Investment Cost ($/kW)	2676						
Operational Costs							
Solar PV Operational Costs ($/kW-year dc)	8.51						
Storage Operational Cost ($/kWh)	0.002554						
DG Operational Cost ($/kWh)	0.16						
Other							
Demand Growth Percent (%)	0.00		-0.24%				
VOLL ($/MWh)	31,897			10,000.00			
CO2 ($/tonne)	26.9142				37.8857		
Max DER Capacity	Unrestricted	2 x load				DG=6	

- *Assumptions are based on public data form EIA, NREL, Commercial Solutions, other NWA analysis at NY and CA

Use Case
Optimal Long-Term DER Planning & Valuation

- **What is the least cost combination of investments in DERs** to meet identified distribution need (6.3 MW) for the next 10 years?

	Units	Baseline	Sens 1	Sens 2	Sens 3	Sens 4	Sens 5	Sens 6
Simulation Name		**Baseline**	**High PV/ES Cost**	**Decreasing Demand**	**Low VOLL**	**High CO2 Cost**	**Large DG Units**	**High CO2 Cost**
Max DER per phase	**#**	**Unrestricted**	**2 x Load**	**2 x Load**	**2 x Load**	**2 x Load**	**Max DG =6**	**Max DG =0**
Number of DERs								
Num Solar PV	**#**	6	151	151	151	151	153	164
Num Storages	**#**	9	56	55	55	55	70	76
Num Generators	**#**	5	11	11	11	10	3	0

DERs considered:




Solar Photovoltaic Systems

Energy Storage

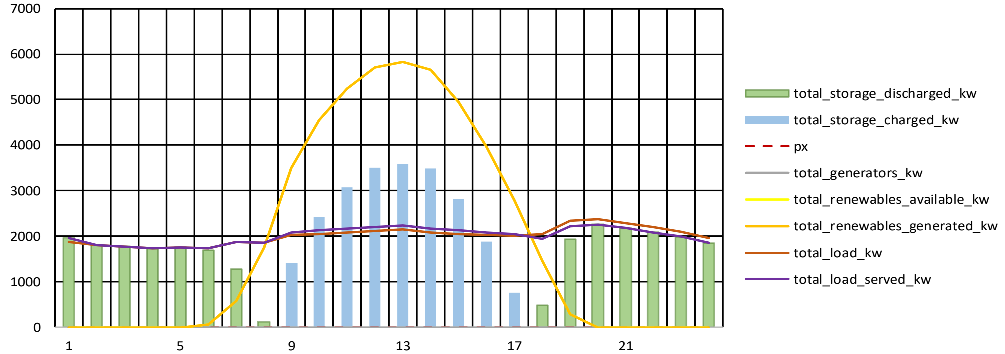
Distributed Generation

Demand Response

Use Case
Optimal Long-Term DER Planning & Valuation

- **What types and capacities of these DER** resources should be installed?

	Units	Baseline	Sens 1	Sens 2	Sens 3	Sens 4	Sens 5	Sens 6
Simulation Name		Baseline	High PV/ES Cost	Decreasing Demand	Low VOLL	High CO2 Cost	Large DG Units	High CO2 Cost
Max DER per phase	#	Unrestricted	2 x Load	2 x Load	2 x Load	2 x Load	Max DG =6	Max DG =0
DER Capacity								
Solar_PV	kW	5418.49	5418.49	5418.49	5418.49	5418.49	5418.49	5827.70
Energy_Storage	kW	3442.06	3442.06	3442.06	3442.06	3442.06	3442.06	4261.78
Demand_Response	kW	118.69	118.69	118.69	118.69	118.69	118.69	118.69
Distributed Gen	kW	368.85	368.85	368.85	368.85	368.85	368.85	0.00



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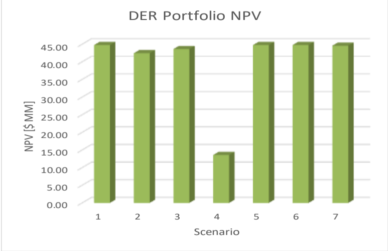
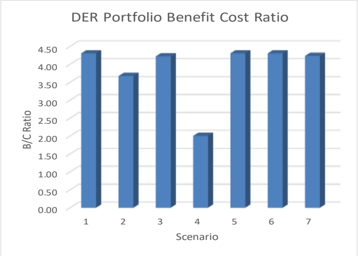
Use Case
Optimal Long-Term DER Planning & Valuation

- **What are the resulting benefits, costs and NPV of the DER Portfolio selected?**

	Units	Baseline	Sens 1	Sens 2	Sens 3	Sens 4	Sens 5	Sens 6
Simulation Name		Baseline	High PV/ES Cost	Decreasing Demand	Low VOLL	High CO2 Cost	Large DG Units	High CO2 Cost
Max DER per phase	#	Unrestricted	2 x Load	2 x Load	2 x Load	2 x Load	Max DG =6	Max DG =0
DER_Portfolio_Benefit_Costs_Results								
DER Portfolio NPV	$ MM	44.76	42.43	43.62	13.58	44.76	44.76	44.57
Benefit/Cost Ratio		4.31	3.67	4.22	2.00	4.31	4.31	4.23
DER Portfolio Benefits (Avoided Costs)								
Energy	$ MM	11.88	11.88	10.83	11.88	11.88	11.88	11.88
Gen Capacity	$ MM	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ancillary Services	$ MM	0.03	0.03	0.03	0.03	0.03	0.03	0.03
CO2 Emissions	$ MM	0.95	0.95	0.87	0.95	0.95	0.95	1.02
Loss of Load	$ MM	45.41	45.41	45.41	14.24	45.41	45.41	45.41
Distribution Capacity	$ MM	0	0	0	0	0	0	0
DER Portfolio Investment plus Operation Costs								
Total Costs	$ MM	13.53	15.86	13.53	13.53	13.53	13.53	13.78





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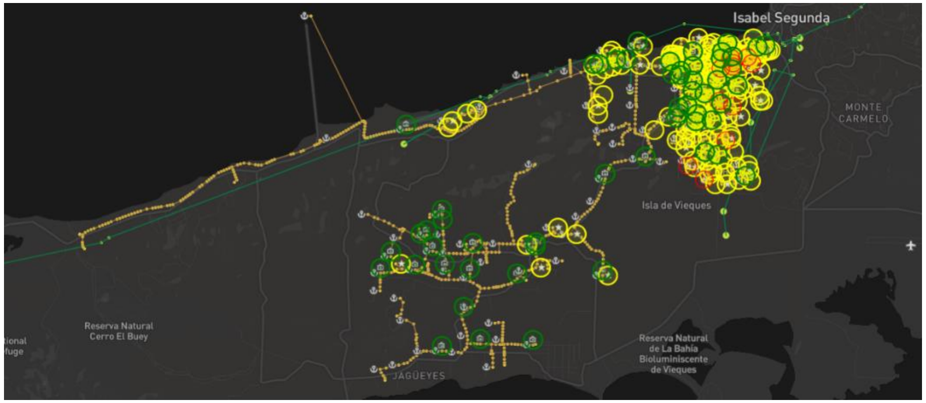
Use Case
Optimal Long-Term DER Planning & Valuation

- **Where should these DER resources be installed?**
- Baseline

- S1



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Thanks

Additional Info:

ProsumerGrid: info@prosumergrid.com

Learn more at:
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