New Hampshire Public Utilities Commission
Comments Pursuant to Case # IR 15-296
Submitted September 17, 2015

Comments Regarding Electric Grid Modernization in New Hampshire

The Importance of Including Analysis of Microgrids as a Key Technology for Improving Grid Resiliency, Reliability & Integration of Distributed Energy Resources

Submitted By

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General Comments

The dramatic decrease in the cost of solar photovoltaics (PV), coupled with the steady increase of retail electricity rates and price volatility of fossil fuels, has led to a surge of solar development in states like Arizona, California, Colorado, New Jersey and North Carolina. Minnesota, despite its low solar potential during the state's long winters, is pushing forward with aggressive plans to increase solar generation over the next decade (Farrell, 2014). These trends indicate that stand-alone solar PV is reaching grid parity for many residential and commercial customers across the nation (Shah, 2014). Coupling solar PV with microturbines, battery storage and advanced power electronics in a microgrid configuration can help utilities integrate intermittent renewables while offering a variety of other benefits that should be analyzed in IR 15-296.

Microgrids can produce additional benefits beyond energy and fuel cost savings that must be accounted for in regulatory proceedings and utility resource planning. If the value of increased power quality and reliability (PQ&R), reduced emissions, deferred investment in traditional generating capacity, and fuel price hedging are included in cost-effectiveness calculations, then microgrids may represent a viable alternative to traditional services offered by utility distribution companies (UDC). Microgrids may well represent a desirable pathway for utilities operating in regulated markets to incorporate disruptive technologies as a new source of revenue, rather than a threat, which industry analysts expect to induce a major restructuring of the U.S. electricity sector over the coming decades (Farrell, 2015).

Historically, many utilities have opposed the deployment of distributed energy resources (DER), efficiency programs, and demand side management (DSM), which reduce electricity consumption and sales revenue for utilities operating in most regulated markets. As solar PV, battery storage, electric vehicles and microgrids continue to gain popularity and market share, utilities must consider innovative business solutions to incorporate these disruptive technologies in ways that maximizes cost savings for ratepayers without reducing long-term profitability, or shifting costs to customers receiving basic electricity services. I have conducted extensive research in the area of microgrid cost-benefit analysis and the application of traditional regulatory cost-effectiveness tests to evaluate microgrids against traditional generation and electric grid investments. The New Hampshire PUC should consider an in-depth analysis of microgrids as part of the IR 15-296 "Grid Modernization" including the following study areas:

- **Regulation & Policy**
- **Interconnection Standards**
- **Contracting Risk**
- **Prospective Microgrid Capacity**
- **Renewable Microgrid Prospects**
- **Development of a Microgrid Policy Roadmap**

These study areas are discussed in greater detail on the following page, and a summary of my own microgrid study results are included as an addendum.

New Hampshire Microgrid Feasibility Study Framework

The New Hampshire PUC should commission a study as part of the IR 15-296 "Grid Modernization" proceedings to identify regulatory barriers to and opportunities for microgrid development that can provide improved power quality and reliability, reduced emissions, integration of renewables, and increased customer control over energy consumption. The study should also provide recommendations to address barriers and identify pathways to facilitate microgrid development.

Regulation & Policy: Review applicable State, Federal, and regional laws, regulations, rules, incentives, siting and permitting requirements, and practices affecting microgrid development, ownership, and operation. Analyze policies and policy gaps, and discuss how they prohibit or discourage microgrids, or, conversely, how they support microgrids.

Interconnection Standards & Practices: Identify New Hampshire standards and practices involving interconnection, interoperability, and control of distributed energy resources. Compare and contrast these policies with the most current federal and industry standards. Identify differences affecting microgrid development and optimization in utility systems.

Contracting, Risk Assessment, and Financing: Discuss how traditional contracting, risk assessment, and financing practices apply to microgrids. Analyze New Hampshire policies that affect microgrid development, valuation, and access to third-party capital.

Prospective Microgrid Capacity: Research and model potential electric load available to microgrids within the state of New Hampshire. Segment potential load by user groups. Discuss assumptions and limiting factors affecting derived potential capacity, as well as such factors as fuel supply and access to infrastructure.

Renewable Microgrid Prospects: Identify renewable resources in Minnesota potentially available for use in microgrid applications. Discuss relevant trends in technologies and resource options, and examine economic and operational factors influencing prospects for renewable microgrids in New Hampshire.

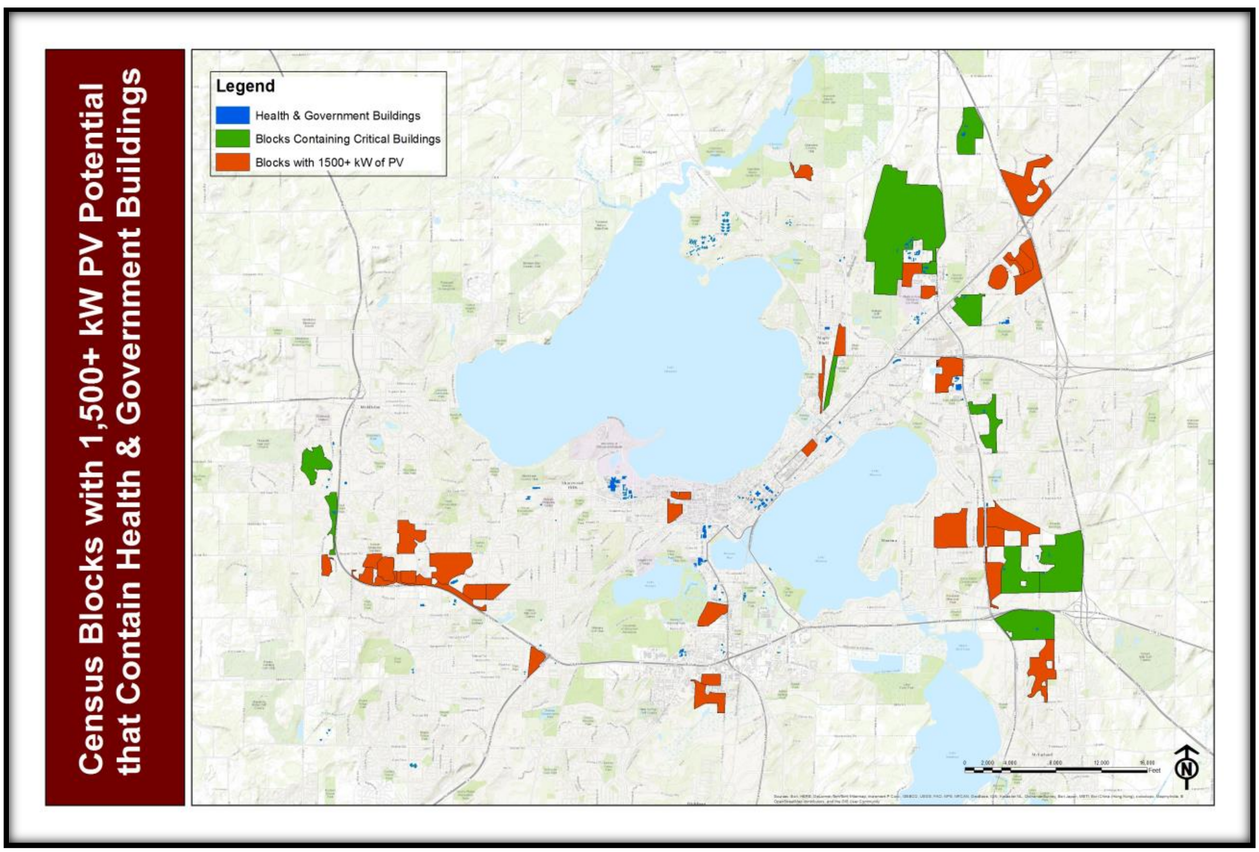
Microgrid Policy Roadmap: Recommend and explain policy steps that would help capture the benefits of microgrid development for Minnesota residents, and assist in their safe, cost-effective implementation and integration into the utility system.

This suggested framework is based on a study commissioned by the Minnesota Department of Commerce in 2013 (link). Completing a comprehensive study of microgrid opportunities, barriers, and economic conditions in New Hampshire will help the state keep pace with regional neighbors like Connecticut and New York who have already implemented microgrid development programs. The New Hampshire PUC can facilitate the microgrid study process by promoting collaboration between regulated utilities, ratepayer advocacy groups, and consulting firms selected through a competitive bidding process.

Summary of Wisconsin Microgrid Research

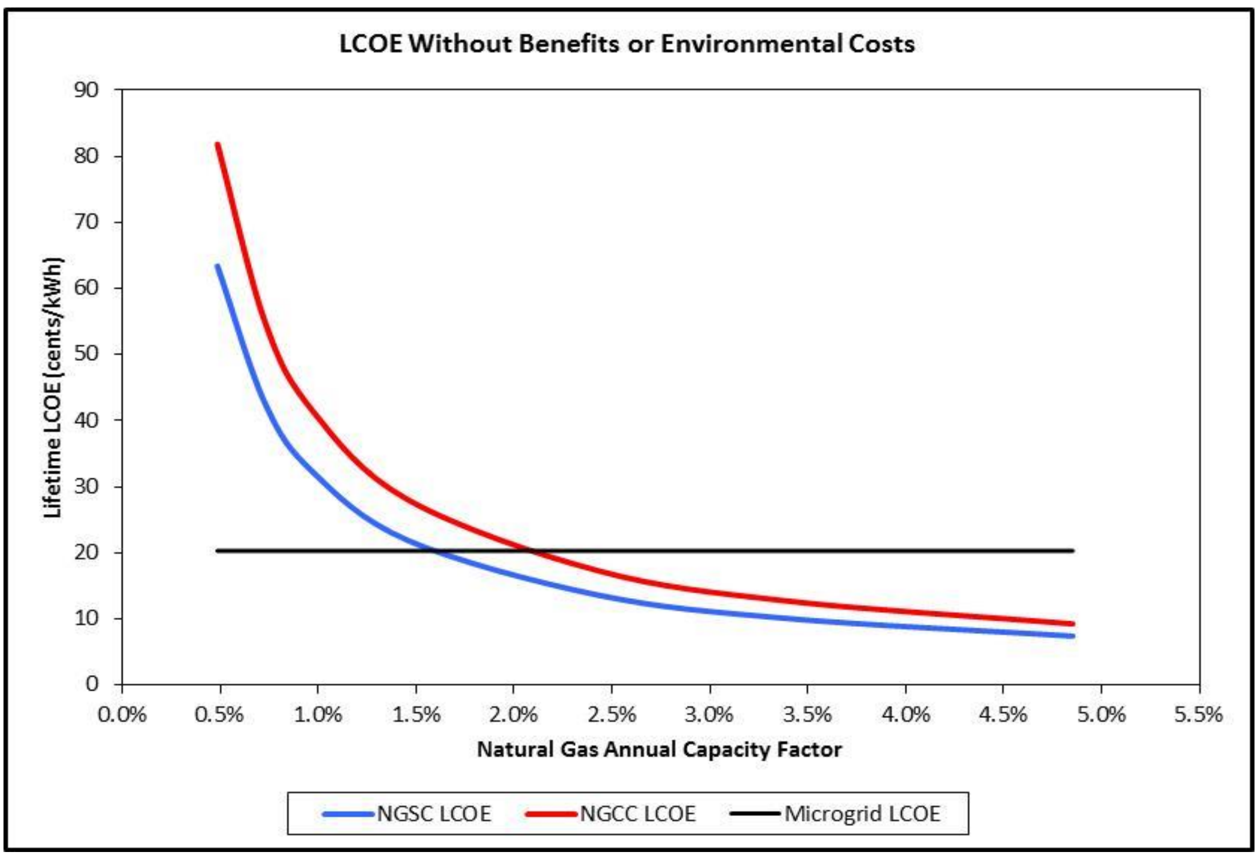
Research completed at UW-Madison with support from the Wisconsin Distributed Resources Collaborative (WIDRC), and the Wisconsin Energy Institute (WEI) shows that microgrids can deliver positive net benefits to electricity customers, the host electric utility, and society at large, under certain scenarios.

The study quantifies the costs and benefits associated with using microgrids as the main technology to promote distributed renewable electricity generation in Madison. A multi-stakeholder analytical process was employed to evaluate cost-effectiveness from the perspective of electric ratepayers served by microgrids, the local electric utility, ratepayers not served by microgrids, and electric utility regulators. The cost-effectiveness methodology combines the use of existing geographic information systems (GIS) software, and the Model for Distributed Energy Resource Networks (MoDERN), which was developed specifically for analyzing utility distribution microgrids. GIS analysis determined that there were 45 locations in Madison capable of supporting at least 1,500kW of rooftop solar PV capacity, while 11 of those locations also contain critical facilities (health and government buildings) that would benefits from improved power quality and reliability offered by microgrids. The map below shows the location of these potential microgrid development sites (green areas are sites that contain health and government buildings).

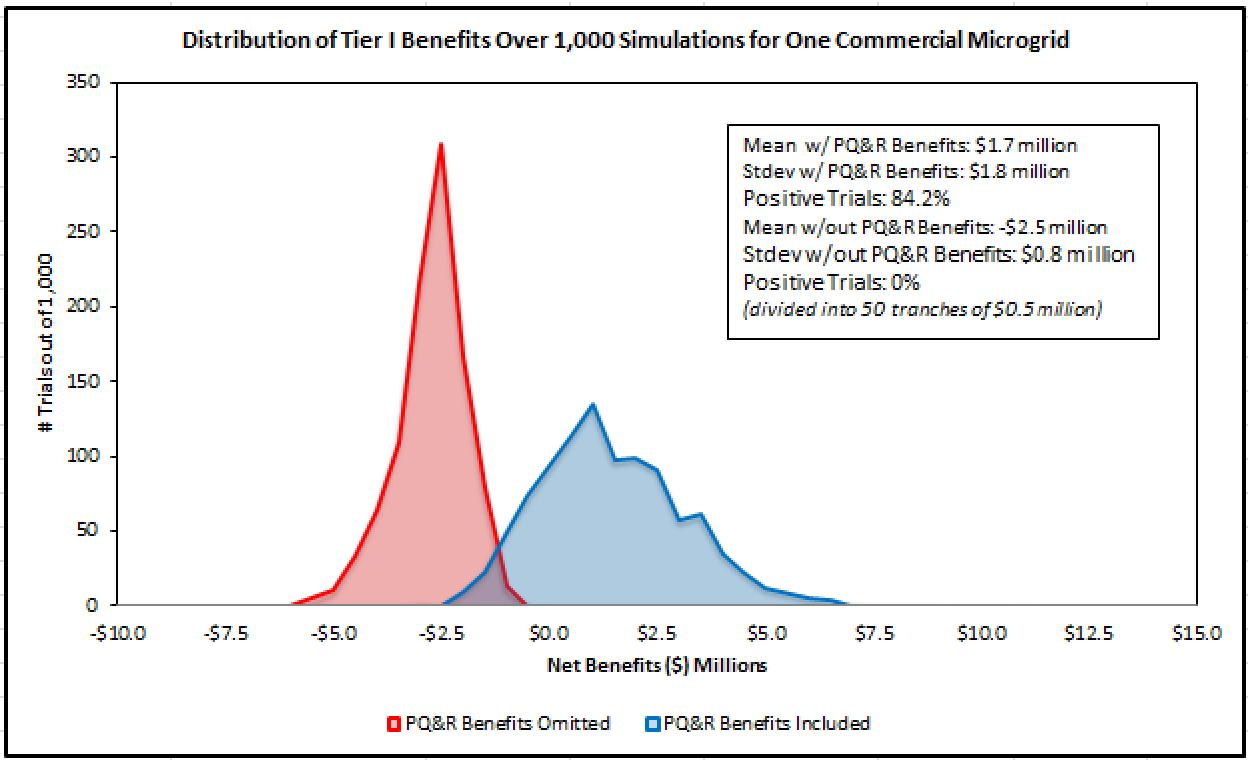


The study evaluated six microgrid deployment scenarios using widely accepted cost-effectiveness metrics developed by the California Public Utilities Commission (CPUC). The six deployment scenarios are; 1.5% and 3% of annual electricity demand in the residential, commercial and industrial sectors based on 2012 data obtained from the U.S. Energy Information Administration (EIA). Using a standard microgrid configuration consisting of 750kW of rooftop solar PV and one 1,000kW natural gas microturbine, it was determined that the 45 potential microgrid sites with at least 1,500kW of solar PV potential could support each of the microgrid deployment scenarios. Each microgrid system was estimated to cost $8.5 million with annual operations and maintenance costs of $250,000-$350,000.

Over a 25-year analysis period, the levelized cost of electricity (LCOE) for one hypothetical microgrid system was found to be 17-19 cents/kWh, compared to 30-40 cents/kWh for a natural gas-fired peaking unit operating at an annual average capacity factor of 1% (based on a comparison with a 25MW unit that operates roughly 50 hours each year to meet extreme peak demand). This comparison does not account for the added benefit of increased power quality and reliability delivered to microgrid customers, which would decrease the microgrid's lifetime LCOE. This analysis shows that microgrids represent a lower cost, and less emissions intensive, alternative to building traditional power plants. However, baseload power plants that operate at much higher capacity factors are still cheaper than microgrid systems, with LCOE's ranging from 4-8 cents/kWh (Utah University, link).

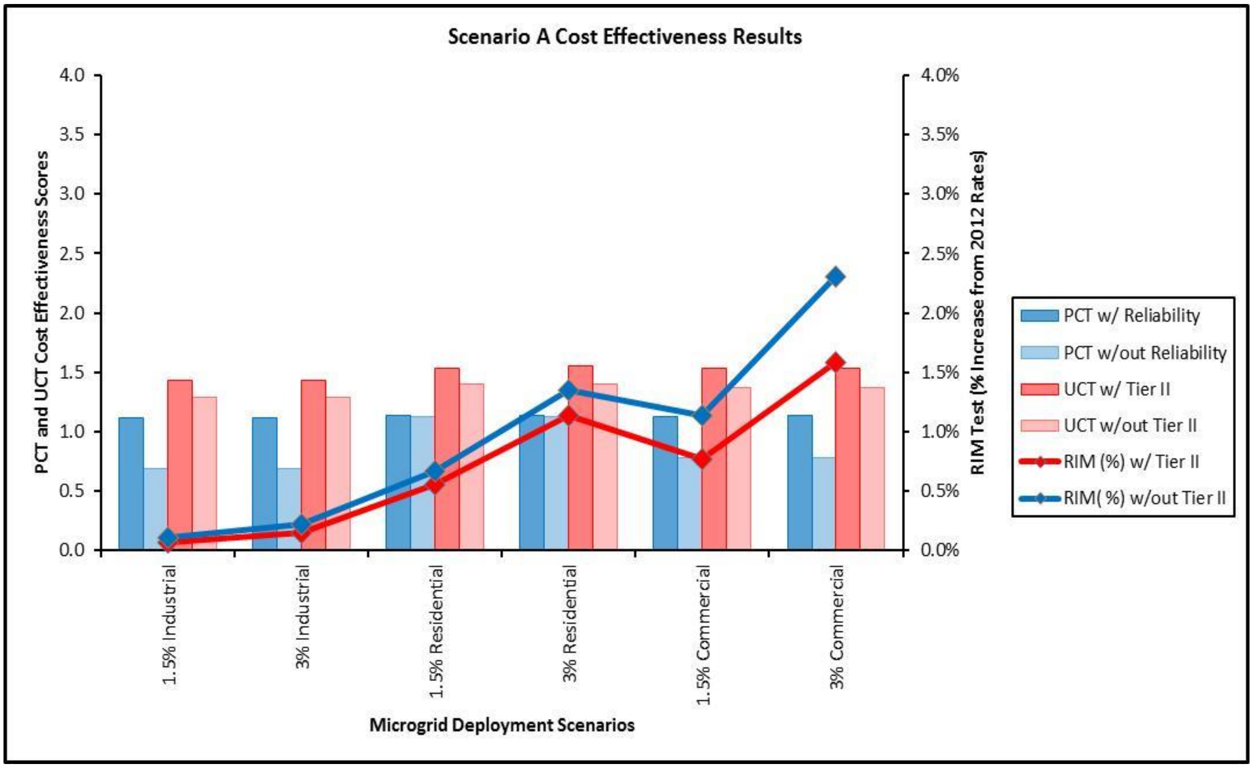


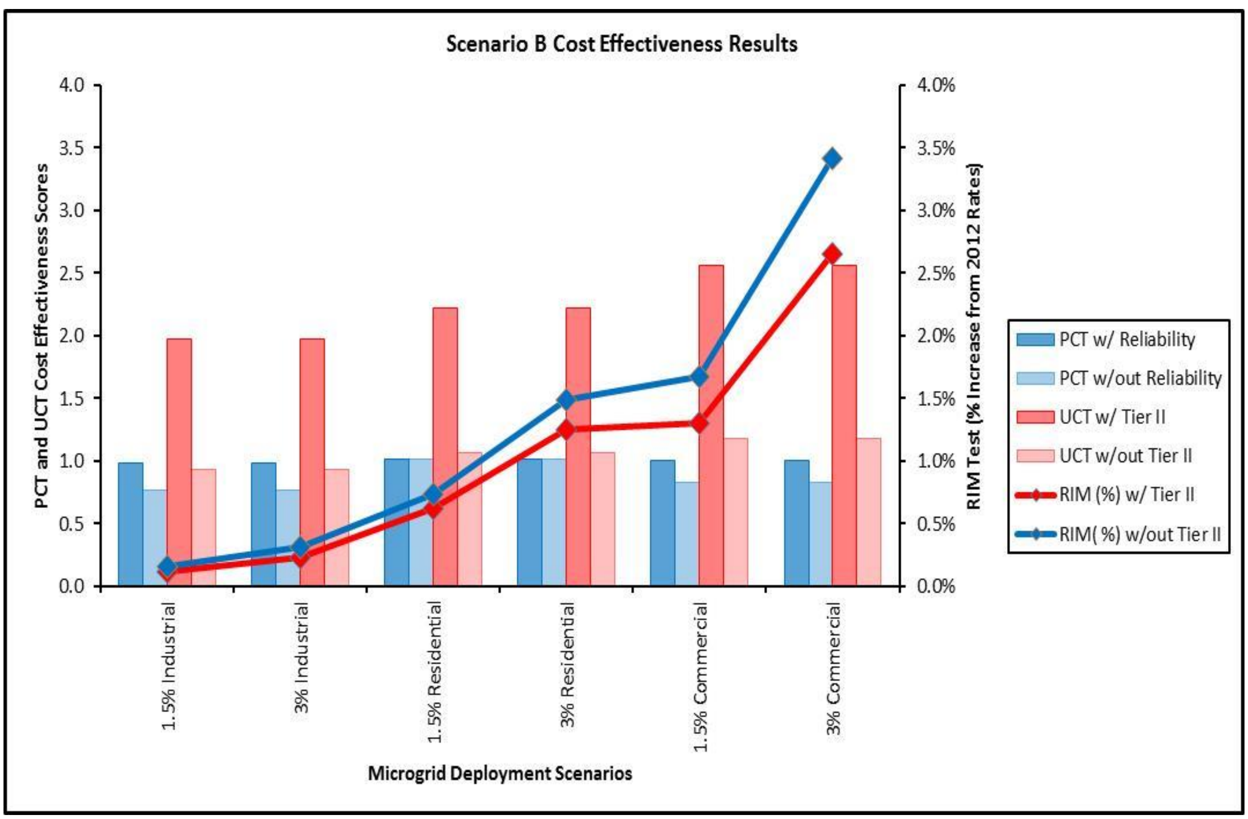
The results of the cost-effectiveness analysis found that solar PV-based microgrids capable of meeting 1.5% of annual electricity demand in each customer segment pass all three cost-effectiveness tests when built, owned and financed by the local electric utility (termed Scenario A in the study). Microgrids built and operated by a third party developer (termed Scenario B in the study) were not cost-effective under test case assumptions, but may provide positive benefits to customers who place a high value on power quality and reliability. The graph below shows the distribution of 1,000 Monte Carlo simulations that compares the lifetime net benefits received by commercial microgrid customers when the value of power quality and reliability is included, or excluded, in their lifetime net benefit calculations. Clearly, a customer who does not place a high value on power quality and reliability would not be interested in paying higher electricity rates for microgrid services, but the value of increased reliability can be significant and should not be ignored by the utility or industry regulators.



Analysis of microgrid deployment at the city-level found that 12 of the 24 scenarios tested under Scenario A passed all three cost-effectiveness tests, while none of the 24 scenarios tested under Scenario B passed all three tests (Scenarios must have a PCT and UCT (participant and utility cost test) score of at least 1.1 and a RIM (ratepayer impact measure) score lower than 1.5% to be considered cost-effective). These results show that microgrid deployment in Madison can be cost-effective for all major stakeholders at low penetration levels. Third party microgrids are only cost-effective in niche markets serving customers who place high values on power quality and reliability. However, as the cost of solar PV and microgrid power electronics continues to decline, third party microgrids may be able to offer services that are cost competitive with traditional grid services.

Cost Effectiveness Test Results under Scenario A & B





In the figures on the previous page, the blue and red bars display the PCT and UCT scores for each microgrid deployment scenario using the numerical scale on the left vertical axis. The red and blue line graphs display the RIM test results for each microgrid deployment scenario using the percentage scale on the right vertical axis. The results clearly show that microgrid deployment under Scenario A produces higher lifetime net benefits for microgrid customers with lower rate increases on non-microgrid customers. The following tables provide a complete summary of the cost-effectiveness results under Scenario A and Scenario B. Green cells show the microgrid deployment scenarios that passed all three cost-effectiveness tests, while red cells highlight the failed cost-effectiveness tests for each microgrid deployment scenario.

Cost Effectiveness Results under Scenario A

Tier II & Reliability	PCT	UCT	RIM (%)
1.5% Residential	1.135	1.531	0.56%
3% Residential	1.135	1.558	1.13%
1.5% Commercial	1.122	1.531	0.78%
3% Commercial	1.133	1.531	1.58%
1.5% Industrial	1.12	1.436	0.07%
3% Industrial	1.12	1.436	0.15%
Tier II, No Reliability			
1.5% Residential	1.124	1.531	0.56%
3% Residential	1.124	1.558	1.13%
1.5% Commercial	0.776	1.531	0.78%
3% Commercial	0.776	1.531	1.58%
1.5% Industrial	0.688	1.436	0.07%
3% Industrial	0.688	1.436	0.15%
No Tier II & Reliability			
1.5% Residential	1.135	1.401	0.67%
3% Residential	1.135	1.401	1.36%
1.5% Commercial	1.122	1.366	1.13%
3% Commercial	1.122	1.366	2.31%
1.5% Industrial	1.12	1.289	0.11%
3% Industrial	1.12	1.289	0.23%
No Tier II, No Reliability			
1.5% Residential	1.124	1.401	0.67%
3% Residential	1.124	1.401	1.36%
1.5% Commercial	0.776	1.366	1.13%
3% Commercial	0.776	1.366	2.31%
1.5% Industrial	0.688	1.289	0.11%
3% Industrial	0.688	1.289	0.23%

Cost Effectiveness Results under Scenario B

Tier II & Reliability	PCT	UCT	RIM (%)
1.5% Residential	1.017	2.221	0.62%
3% Residential	1.017	2.221	1.25%
1.5% Commercial	1.005	2.557	1.30%
3% Commercial	1.005	2.557	2.65%
1.5% Industrial	0.988	1.977	0.11%
3% Industrial	0.988	1.977	0.23%
Tier II, No Reliability			
1.5% Residential	1.011	2.221	0.62%
3% Residential	1.011	2.221	1.25%
1.5% Commercial	0.833	2.557	1.30%
3% Commercial	0.833	2.557	2.65%
1.5% Industrial	0.769	1.977	0.11%
3% Industrial	0.769	1.977	0.23%
No Tier II & Reliability			
1.5% Residential	1.017	1.064	0.74%
3% Residential	1.017	1.064	1.49%
1.5% Commercial	1.005	1.185	1.68%
3% Commercial	1.005	1.185	3.42%
1.5% Industrial	0.988	0.929	0.16%
3% Industrial	0.988	0.929	0.31%
No Tier II, No Reliability			
1.5% Residential	1.011	1.064	0.74%
3% Residential	1.011	1.064	1.49%
1.5% Commercial	0.833	1.185	1.68%
3% Commercial	0.833	1.185	3.42%
1.5% Industrial	0.769	0.929	0.16%
3% Industrial	0.769	0.929	0.31%

The study results show that the local UDC can develop microgrids more cost-effectively for microgrid customers than a third party developer. However, if the utility is unwilling to pursue microgrid development, there are a few scenarios where microgrids could be cost-effective for all stakeholders when built and operated by a third party developer. Third party microgrids would have to serve commercial or industrial customers who place a high value on increased power quality and reliability in order to pass the 1.1 PCT cost-effectiveness threshold. Third party microgrid deployment in the industrial sector could pass all three cost-effectiveness tests if the industrial customers served by the microgrid place a high value on power quality and reliability. The 1.5% commercial/industrial and 3% industrial deployment scenarios passed the UCT and RIM tests, while a higher value for power quality and reliability benefits would result in a PCT score of 1.1 or higher. Table 28 on the following page illustrates the values for increased power quality and reliability that would be necessary for commercial and industrial customers to see lifetime net benefits and a 25-year ROI greater than 10% (reflecting a PCT score of 1.1 or higher) under Scenario B.

An overview of the MoDERN Tool is included in the following section

MoDERN Toolkit Functionality and Summary of Features

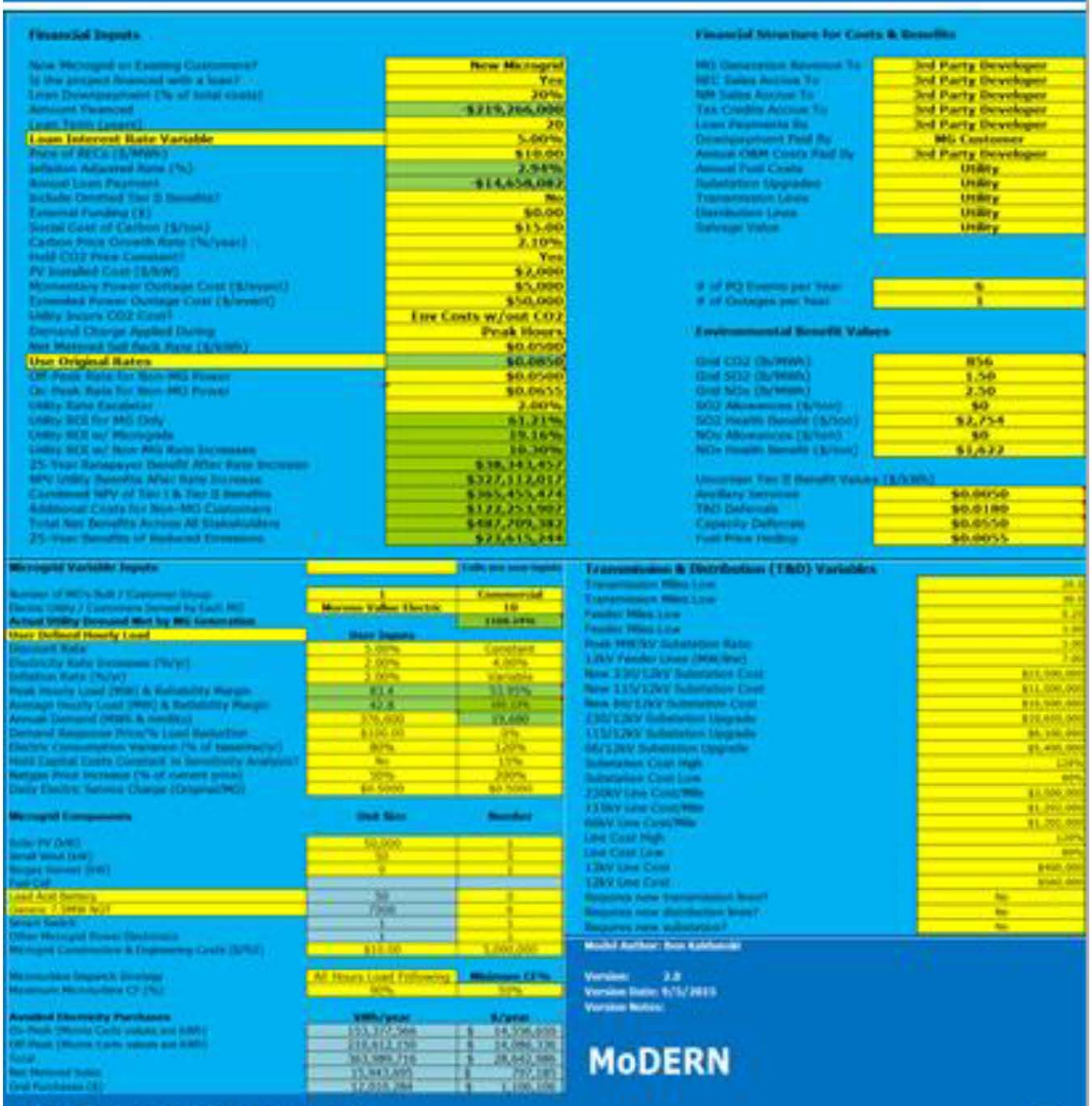
Hourly Energy & Cost Simulations
Annual Energy & Cost Simulations
Lifetime Net Benefits from Four Perspectives

- Microgrid Project Developer
- Electric Ratepayers Served by the Microgrid
- Host Electric Utility
- Environment & Societal Benefits

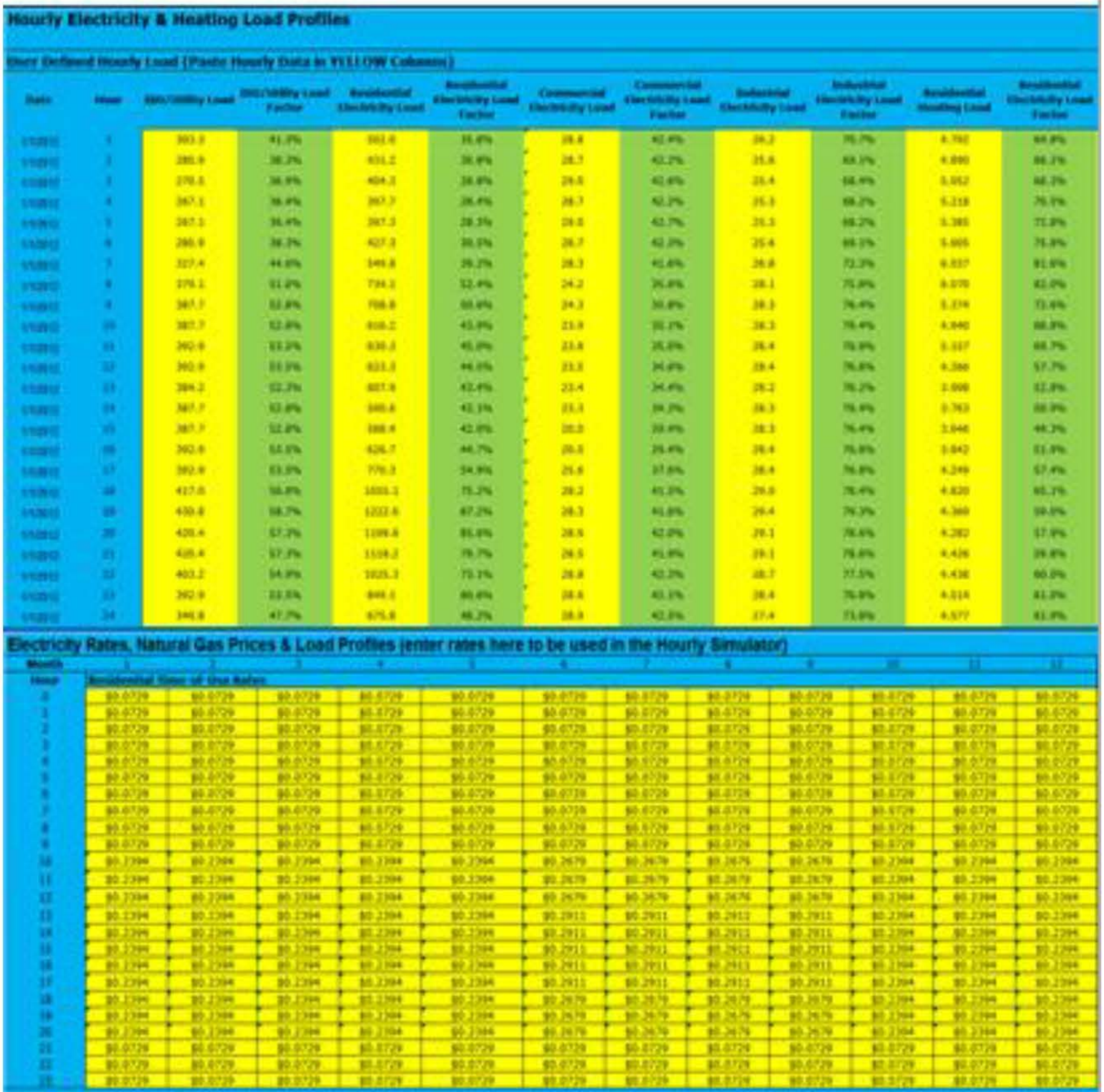
Risk Analysis Based on 1,000 Simulations
Cash Flow Analysis
Project Payback Period
Internal Rate of Return (IRR)

Technology Types	Included in MoDERN
Solar PV	✓
Wind Turbines	✓
Biogas Digesters	✓
NG Microturbines w/ CHP	✓
Diesel Gensets	✓
Battery Storage	✓
Demand Response	✓
Analytical Features	
Hourly Energy Demand & Costs	✓
Lifetime Net Benefits	✓
Cash Flow/Payback Period/ROI/IRR	✓
Regulatory Cost Effectiveness Tests	✓
Risk Analysis Using 1,000 Simulations	✓
Host Utility Financial Analysis	✓

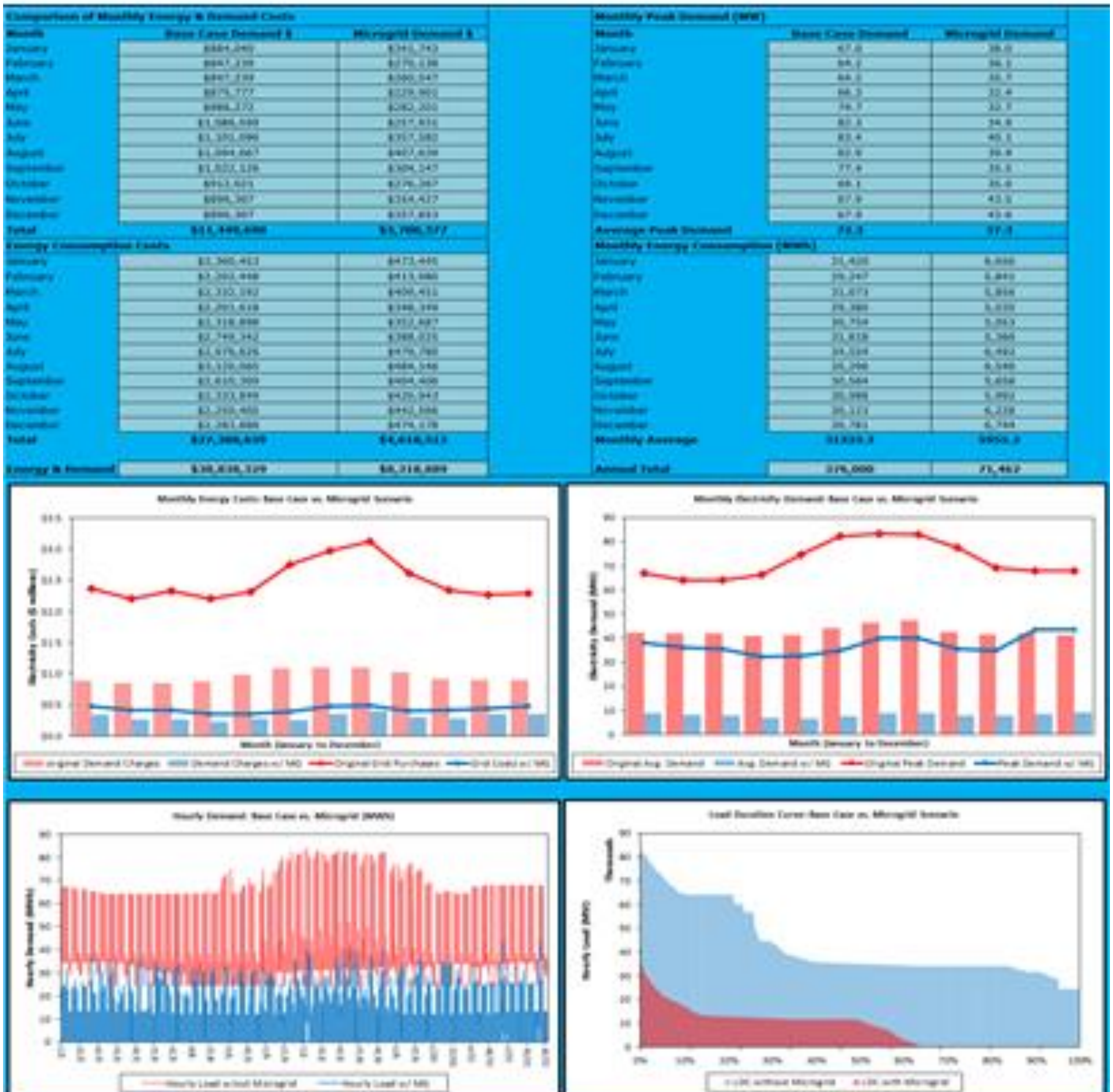
MoDERN Input Screens
Easy-to-Use User Interface



MoDERN Input Screens
Rate Structures & Load Curves



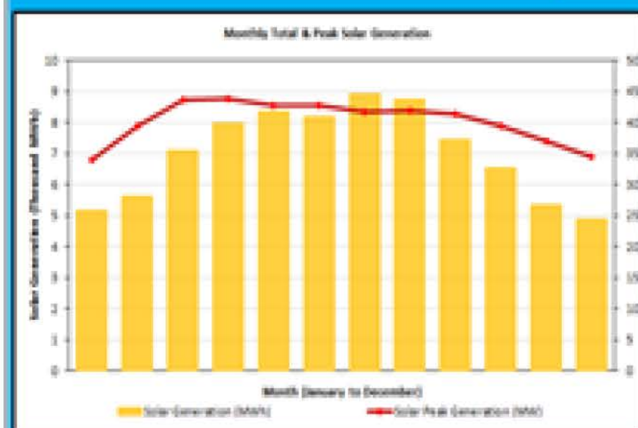
Hourly, Monthly, Annual
Energy Consumption & Cost Analysis

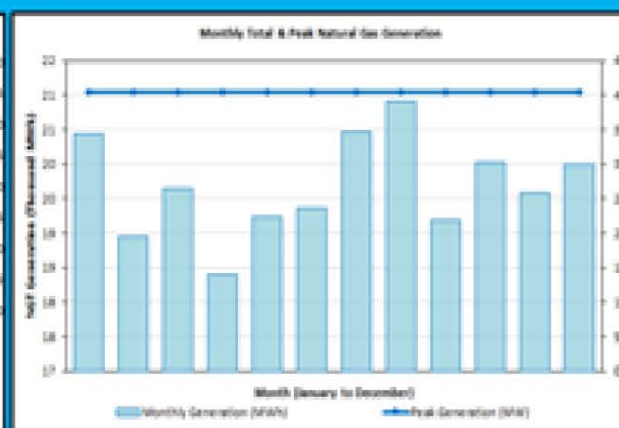


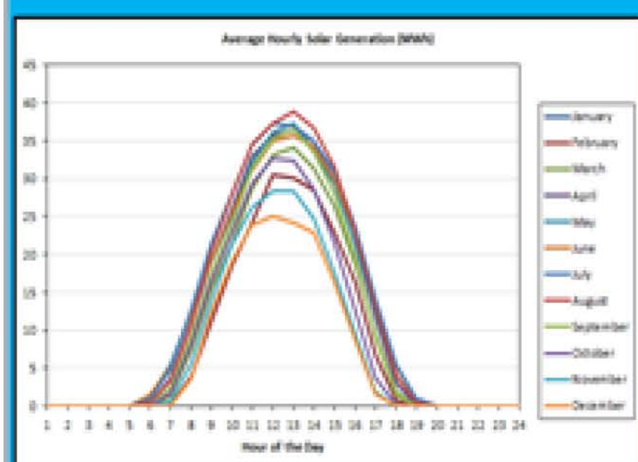
Hourly, Monthly, Annual Generation Dispatch & Cost Analysis

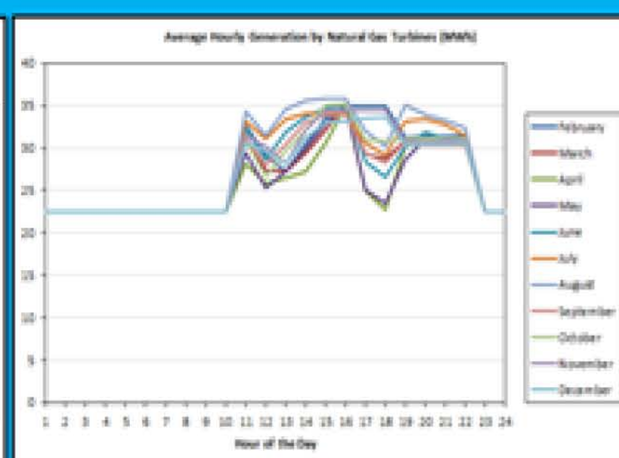
Monthly Peak (MW) & Total (MWh) Solar Generation		
Month	Monthly MWh)	Peak (MW)
January	5,155	33.9
February	5,625	39.4
March	7,107	43.7
April	7,978	43.7
May	8,371	42.8
June	8,168	42.7
July	8,906	43.7
August	8,753	41.9
September	7,440	41.3
October	6,517	39.4
November	5,340	36.9
December	4,890	34.6
Monthly Average	**7,021**	**40.2**
Annual Totals	**84,249**	

Monthly Peak (MW) & Total (MWh) Natural Gas Generation		
Month	Monthly MWh)	Peak (MW)
January	20,435	40.5
February	18,948	40.5
March	19,646	40.5
April	18,399	40.5
May	19,242	40.5
June	19,363	40.5
July	20,476	40.5
August	20,908	40.5
September	19,196	40.5
October	20,028	40.5
November	19,594	40.5
December	19,999	40.5
Monthly Average	**19,686**	**40.5**
Annual Totals	**236,232**	







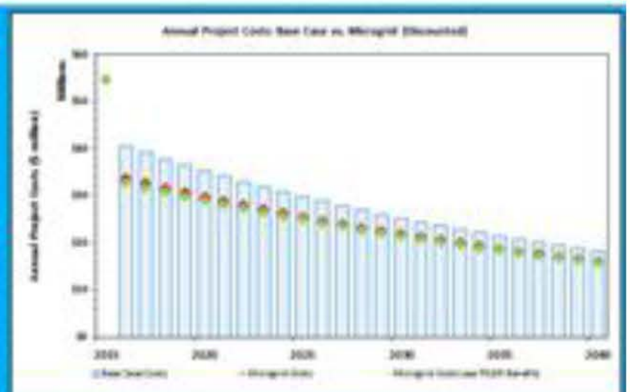


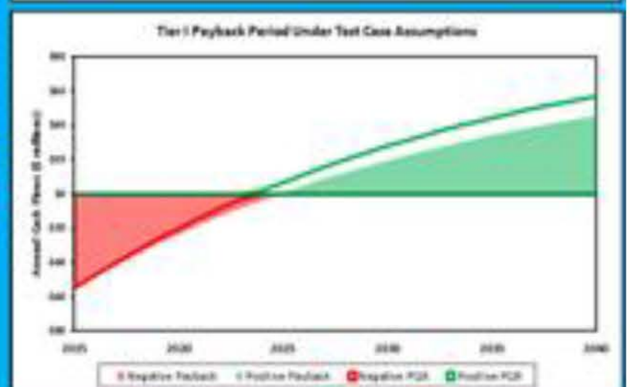
Comprehensive Financial Analysis Cash Flow, Payback Period, IRR, ROI

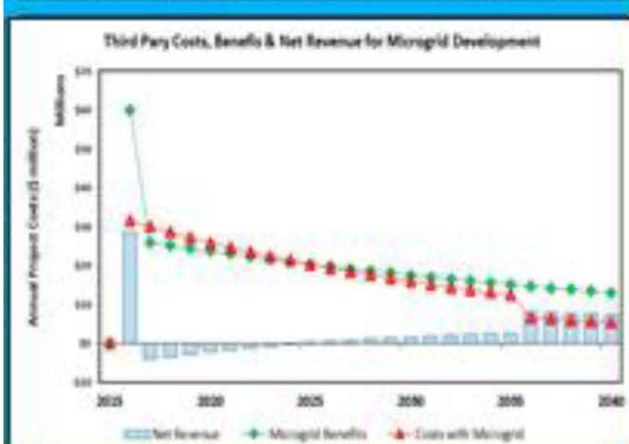
Cash Flow Analysis: Microgrid Customers (Tier I)

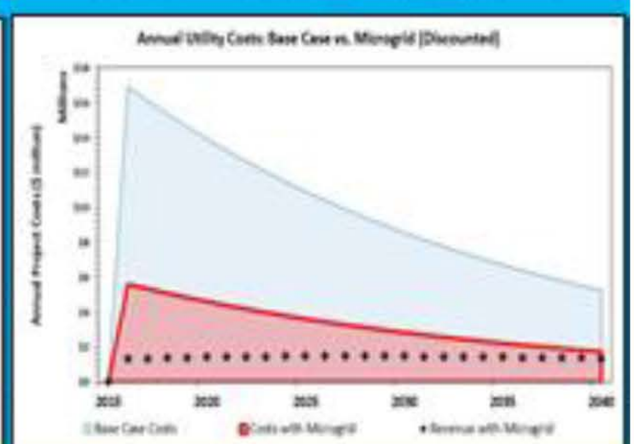
Year	Original Energy Costs	Costs w/ MG	MG Payback
2015	$0.0	$0.0	[illegible]
2016	[illegible]	[illegible]	[illegible]
2017	[illegible]	[illegible]	[illegible]
2018	[illegible]	[illegible]	[illegible]
2019	[illegible]	[illegible]	[illegible]
2020	[illegible]	[illegible]	[illegible]
2021	[illegible]	[illegible]	[illegible]
2022	[illegible]	[illegible]	[illegible]
2023	[illegible]	[illegible]	[illegible]
2024	[illegible]	[illegible]	[illegible]
2025	[illegible]	[illegible]	[illegible]
2026	[illegible]	[illegible]	[illegible]
2027	[illegible]	[illegible]	[illegible]
2028	[illegible]	[illegible]	[illegible]
2029	[illegible]	[illegible]	[illegible]
2030	[illegible]	[illegible]	[illegible]
2031	[illegible]	[illegible]	[illegible]
2032	[illegible]	[illegible]	[illegible]
2033	[illegible]	[illegible]	[illegible]
2034	[illegible]	[illegible]	[illegible]
2035	[illegible]	[illegible]	[illegible]
2036	[illegible]	[illegible]	[illegible]
2037	[illegible]	[illegible]	[illegible]
2038	[illegible]	[illegible]	[illegible]
2039	[illegible]	[illegible]	[illegible]
2040	[illegible]	[illegible]	[illegible]
25 Year totals	[illegible]	[illegible]	[illegible]

Year	[illegible]	[illegible]	[illegible]
Original Energy Costs	[illegible]	[illegible]	[illegible]
Energy Costs w/ Microgrid	[illegible]	[illegible]	[illegible]
Microgrid Development Costs	$0	$0	$0
Financial Benefits	[illegible]	[illegible]	[illegible]
Benefits w/ PQ/Reliability	[illegible]	[illegible]	[illegible]
Financial Cash Flow	[illegible]	[illegible]	[illegible]
Cash Flow w/ PQ/Reliability	[illegible]	[illegible]	[illegible]
Financial Payback Tracker	[illegible]	[illegible]	[illegible]
Payback Tracker w/ PQ/Reliability	[illegible]	[illegible]	[illegible]









Monte Carlo Risk Analysis Module
Analyze Variables Over 1,000 Trials

Monte Carlo Analysis: Tier I Results

Monte Carlo Results: Percentage Distribution

Monte Carlo Average	[illegible]
Monte Carlo Median	[illegible]
Monte Carlo Minimum	[illegible]
Monte Carlo Maximum	[illegible]
% with Positive Net Benefits	[illegible]
25th Percentile	[illegible]
50th Percentile	[illegible]
75th Percentile	[illegible]
90th Percentile	[illegible]
95th Percentile	[illegible]

User Defined Variables	Min	Max
CO2 Intensity (tons/kWh)	[illegible]	[illegible]
Solar Capacity Factor (%)	12.00%	16.00%
Wind Capacity Factor (%)	10.00%	30.00%
Biogas Capacity Factor (%)	41.64%	99.94%
NG Annual Price Change	75.00%	200.00%
Social Cost of Carbon	$1.00	$100.00
METR Tax Rate	$0.20	$0.30
Demand Growth/Decline	80%	120%
Avg Rate Growth Factor	1.00	1.0400
Annual Power Quality Events	0	12
Annual Extended Outages	0	2
Cost of PQ Events	$1,250	$10,000
Cost of Extended Outages	$12,500	$100,000
Ancillary Services	$0.0025	$0.0100
Fuel Hedging Value	$0.0000	[illegible]
T&D Deferred Costs	$0.0000	$0.0270
Capacity Deferred Costs	$0.0000	[illegible]
Battery O&M Costs	85%	115%
Discount Rate (%)	2%	10%
Inflation Rate (%)	1%	3%
Loan Interest Rate (%)	4%	8%
Salvage Value (% of Test Case)	0%	150%
Total Capital Cost	85%	115%
REC Prices ($/MWh)	$1.00	$50.00
SO2 Intensity (tons/kWh)	[illegible]	[illegible]
NOx Intensity (tons/kWh)	[illegible]	[illegible]
SO2 Allowance Price ($/ton)	$1.00	$2.00
NOx Allowance Price ($/ton)	$5.00	$100.00
SO2 Health Cost ($/ton)	$500	$4,000
NOx Health Cost ($/ton)	$500	$4,000
Integration/Admin Cost	$0.0000	[illegible]

Distribution of Variables: Normal

Monte Carlo Sensitivity Analysis: Third Party Developer

Monte Carlo Results: Percentile Distribution

Monte Carlo Average	[illegible]
Monte Carlo Median	[illegible]
Monte Carlo Minimum	[illegible]
Monte Carlo Maximum	[illegible]
% with Positive Net Benefits	[illegible]
25th Percentile	[illegible]
50th Percentile	[illegible]
75th Percentile	[illegible]
90th Percentile	[illegible]
95th Percentile	[illegible]

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Discount Rate (%)	2%	10%
Inflation Rate (%)	1%	3%
Loan Interest Rate (%)	4%	8%
Salvage Value (% of Test Case)	0%	150%
Total Capital Cost	85%	115%
REC Prices ($/MWh)	$1.00	$50.00
SO2 Intensity (tons/kWh)	[illegible]	[illegible]
NOx Intensity (tons/kWh)	[illegible]	[illegible]
SO2 Allowance Price ($/ton)	$1.00	$2.00
NOx Allowance Price ($/ton)	$5.00	$100.00
SO2 Health Cost ($/ton)	$500	$4,000
NOx Health Cost ($/ton)	$500	$4,000
Integration/Admin Cost	$0.0000	[illegible]

Distribution of Variables: Normal

Analyze Impact on Utility Revenue Electricity Rates & Lifetime Benefits