Microgrids in Madison

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Agenda

- Project Overview
- GIS Data, Analysis & Results
- Economic Analysis & Results
- Microgrids in Other States
- Conclusions & Further Research
- Questions & Comments

Project Overview

The goal of this project is to determine whether microgrids with distributed energy resources (DER) can be used to meet a portion of Madison Gas & Electric's (MGE) electricity demand without reducing the utility's profitability.

- **Step 1:** GIS Analysis of Solar Potential and Electricity Use
- **Step 2:** Economic Analysis using EMT and MyPower
- **Step 3:** Policy Considerations and Conclusions

GIS Data & Methodology

GIS software (ESRI ArcMap) was used to develop estimates for solar photovoltaic (PV) potential within the City of Madison and to map electricity use in order to identify the best locations for microgrid deployment.

- **Data:** Tax Assessor data for 2013 and building footprint data from the Dane County Land Information Office
- **PV Potential:** Building footprint area is divided by 100 kW/ft^2 and reduced by 50% to account for shading, improper orientation and HVAC equipment on rooftops
- **Electricity Density:** Total electricity consumption (kWh) divided by building footprint area to produce kWh/ft^2 for residential, commercial and industrial properties

GIS Data Analysis

- **Electricity Density (kWh/ft^2):**

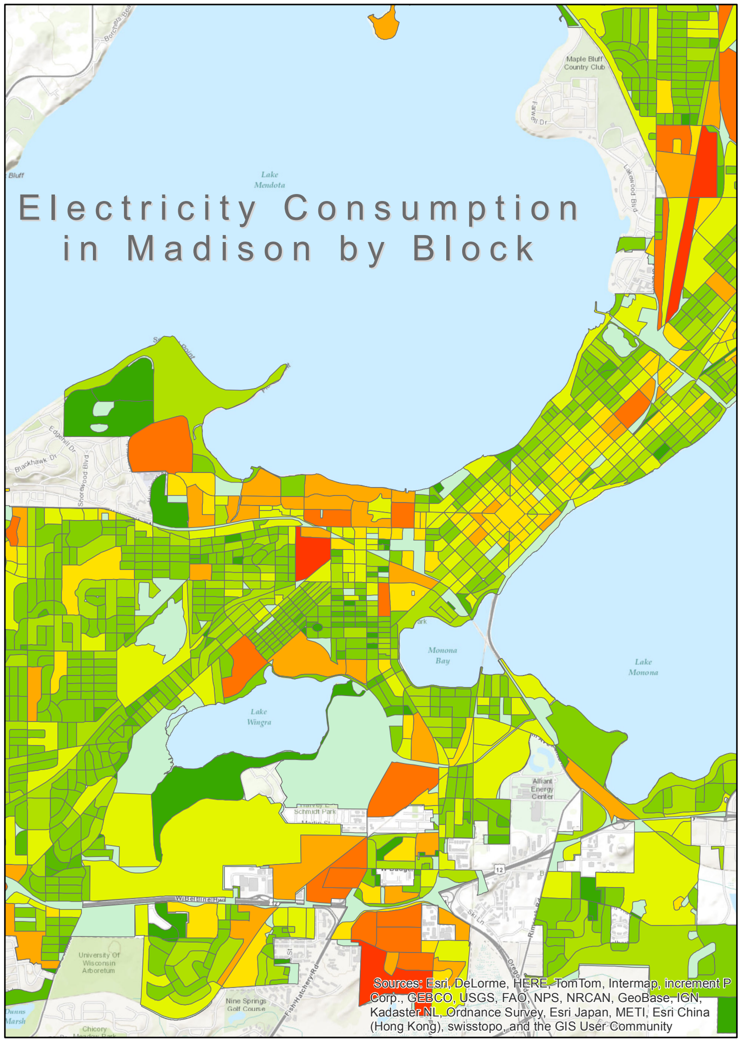
  Residential = 8.4 kWh/ft^2
  Commercial = 47.3 kWh/ft^2
  Industrial = 152.9 kWh/ft^2

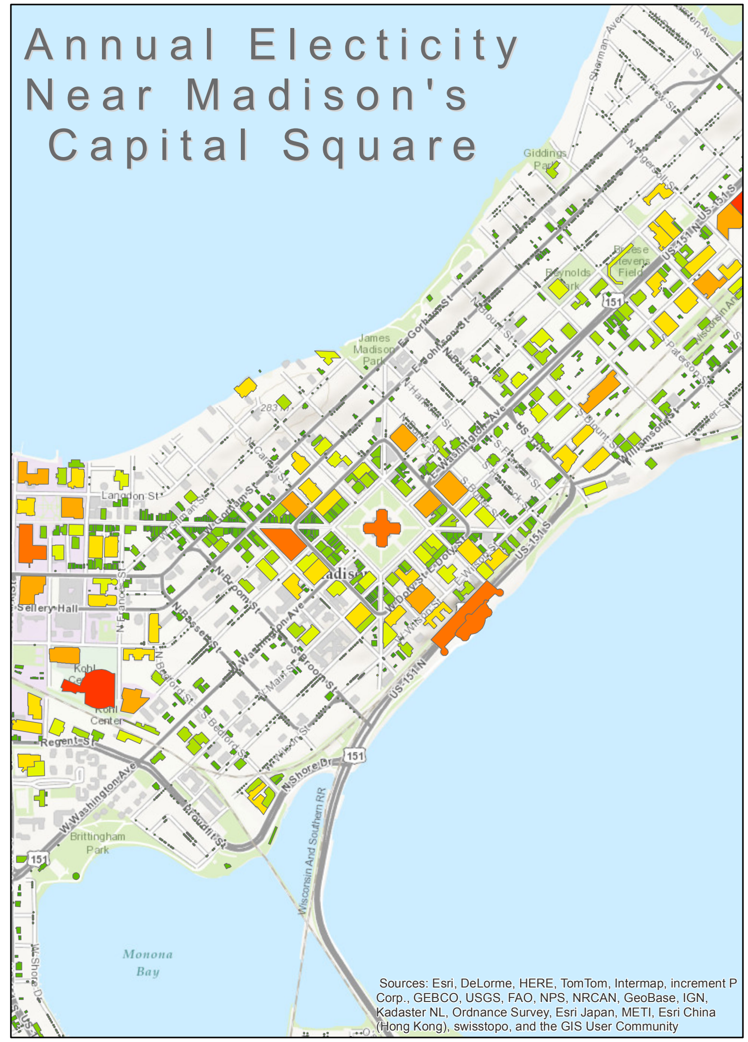
  - Only 184 of Madison's Census Blocks consume more than 5 million kWh of electricity per year, accounting for 55.9% of total annual demand. Those same Census Blocks can support 244MW of solar PV

- **Solar PV Potential:**

  83 Census Blocks can support at least 1,000kW of solar PV with a total potential of 160MW

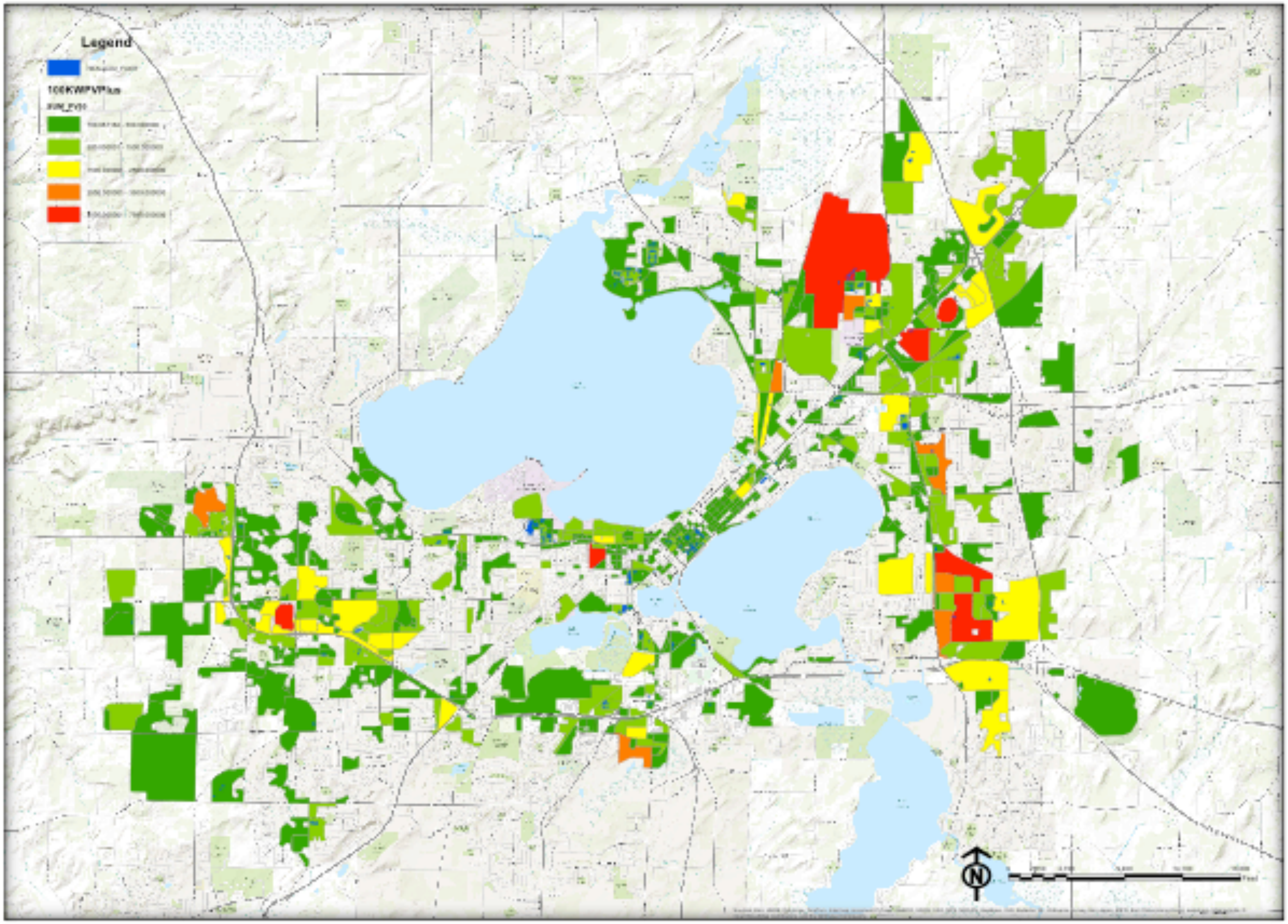
  21 of those Census Blocks can meet up to 25% of their annual demand with solar generation, and 10 can supply at least 50% of their annual demand





These maps show the variation in electricity consumption across Census Blocks (left) and building footprints (right). Variations are largely dependent on building size because MGE could not provide customer specific data.

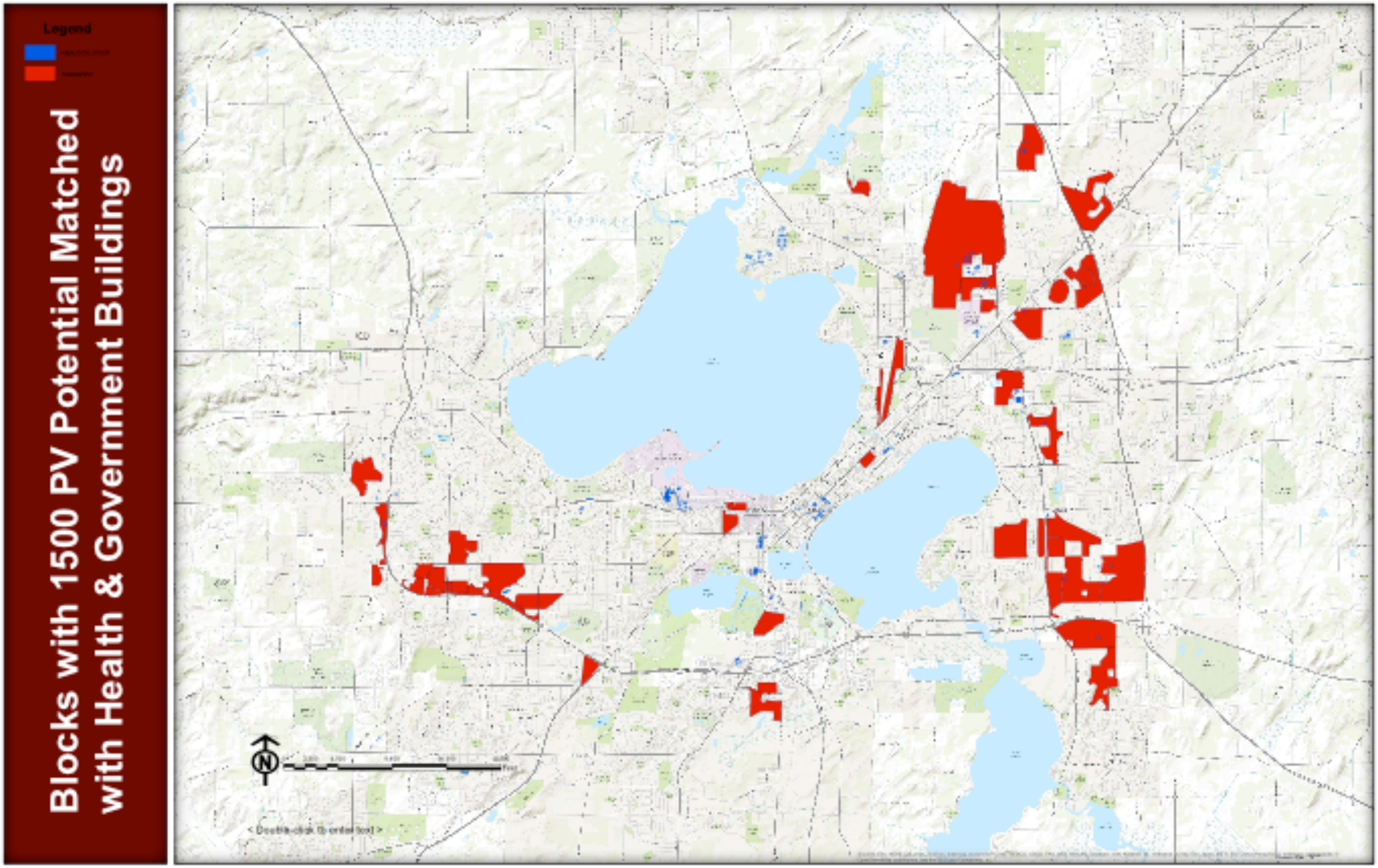
Blocks with 100+ PV Potential Matched with Health & Government Buildings



There are ***600 Census Blocks*** capable of supporting at least 100kW of solar PV within the City of Madison. ***Total rooftop potential in these Census Blocks is estimated to be 330MW.***

Selecting Microgrid Sites

- **Step 1:** Buildings with less than 20kW of PV potential were given zero values and total rooftop potential was summed across each Census Block
- **Step 2:** Census Blocks capable of supporting at least 1,500kW (1.5MW) of solar PV were selected **<u>(45 of 12,888)</u>**
- **Step 3:** Census Blocks that contain "critical buildings" in the health care or government sectors were selected so that the public benefits of increased reliability is maximized **<u>(11 of 45 shown on following slide)</u>**



There are ***11 Census Blocks*** capable of supporting at least 1,500kW of solar PV that contain 29 critical buildings. ***Total rooftop potential in these Census Blocks is estimated to be 32.7MW.***

Microgrid Deployment

Standard Microgrid: Comprised of 1,500kW of solar PV, two Capstone 200kW microturbines, smart switch and smart metering equipment/software

- **3% Deployment:** Microgrids offset 3% of total demand in each customer segment for a total of three possible deployment scenarios (residential, commercial, industrial)
- **1.5% Deployment:** Microgrids offset 1.5% of total demand in each customer segment for a total of three possible deployment scenarios (residential, commercial, industrial)

Microgrid Deployment Costs

Customer Segment	Replace 3% of Retail Sales	Replace 1.5% of Retail Sales
Residential	9	5
Commercial	24	12
Industrial	3	2
Total	36	19

Microgrid Costs	**Capacity (kw)**	**Capacity Factor (%)**	**Generation (kWh)**	**O&M Cost**	**Capital Cost**
Solar PV	1500	14.61%	1,921,338	-$30,000	-$3,750,000
Microturbines	400	27.66%	969,942	-$108,331	-$964,000
600 Amp Static Switch					-$75,092
Other System Components					-$1,732,500
Construction Costs ($/ft3)					-$1,500,000
Total Costs			**2,891,280**	**-$138,331**	**-$8,021,592**

Microgrid Deployment

Scenario A: MGE builds, owns and operates all microgrid equipment. Customers served by microgrids pay higher off/on-peak rates listed below:

- **Residential:** 7.5 - 8.25 cents/kWh, 24.6 – 27.1 cents/kWh
- **Commercial:** 5.5 - 14.25 cents/kWh, 11.4 - 32.7 cents/kWh
- **Industrial:** 5.5 – 6 cents/kWh, 8.4 – 9.1 cents/kWh
- **Microgrid Rates:** 21.1 – 21.5 cents/kWh (50-70% above LCOE)

Scenario B: A third party developer owns/operates the microgrids

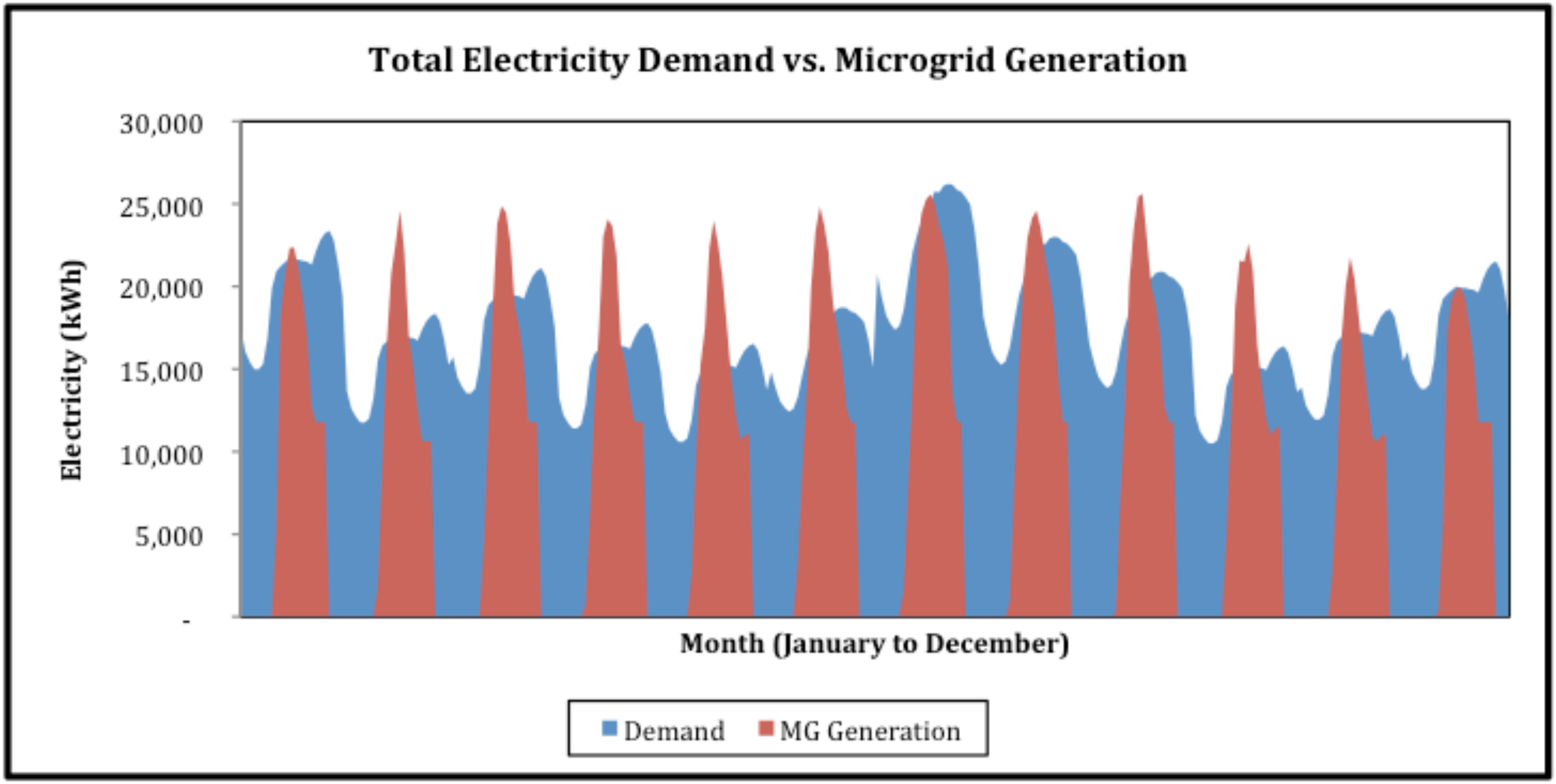
- **Residential:** 7.5 cents/kWh, 23.9 cents/kWh
- **Commercial:** 5.5 – 6.5 cents/kWh, 11.4 – 13.5 cents/kWh
- **Industrial:** 5.3 cents/kWh, 8.4 cents/kWh
- **Microgrid Rates:** 22.2 – 25.8 cents/kWh

Microgrid Key Assumptions

- Installed cost of solar PV is set at $2,500/kW and panels operate at an annual average capacity factor of 14.6% based on NREL's PVWatts data for Madison, Wisconsin
- All microgrid customers pay MGE's time-of-use rates that vary during off-peak and three on-peak periods
- Microturbines only operate during on-peak periods to meet demand not matched by solar PV. Excess generation is sold back to MGE at 5 cents/kWh.
- Microgrids serve 20 residential customers, 5 commercial customers, or 2 industrial customers

Microgrid Benefit Categories: Scenario A

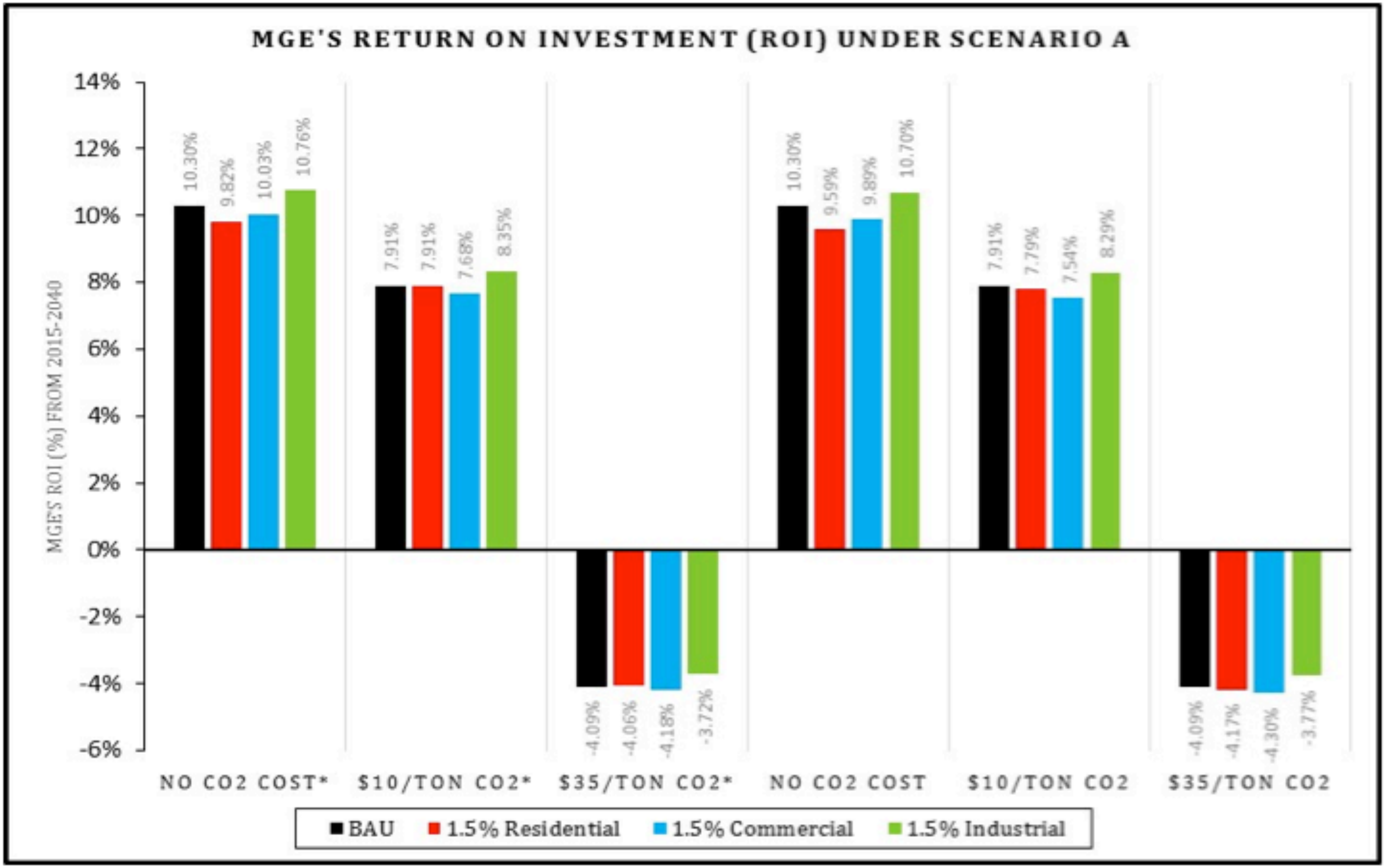
Ratepayers (Tier I)	MGE (Tier II)	Society (Tier III)
• Avoided Electricity Purchases • Avoided Economic Losses/Damage from Power Outages	• Avoided Wholesale Electricity Purchases • Avoided Fuel Costs • Avoided T&D Losses • T&D/Capacity Investment Deferral • Fuel Price Hedging • Reduced SO_2/NO_x Compliance Costs • RECs from solar generation • Greater system resiliency and black start capability (not valued)	• Reduced SO_2 Emissions & Associated Health/ Environmental Benefits • Reduced NO_x Emissions & Associated Health/ Environmental Benefits • Reduced CO_2 Emissions & Associated Health/ Environmental Benefits • Reduced water usage for power plant cooling (not valued)



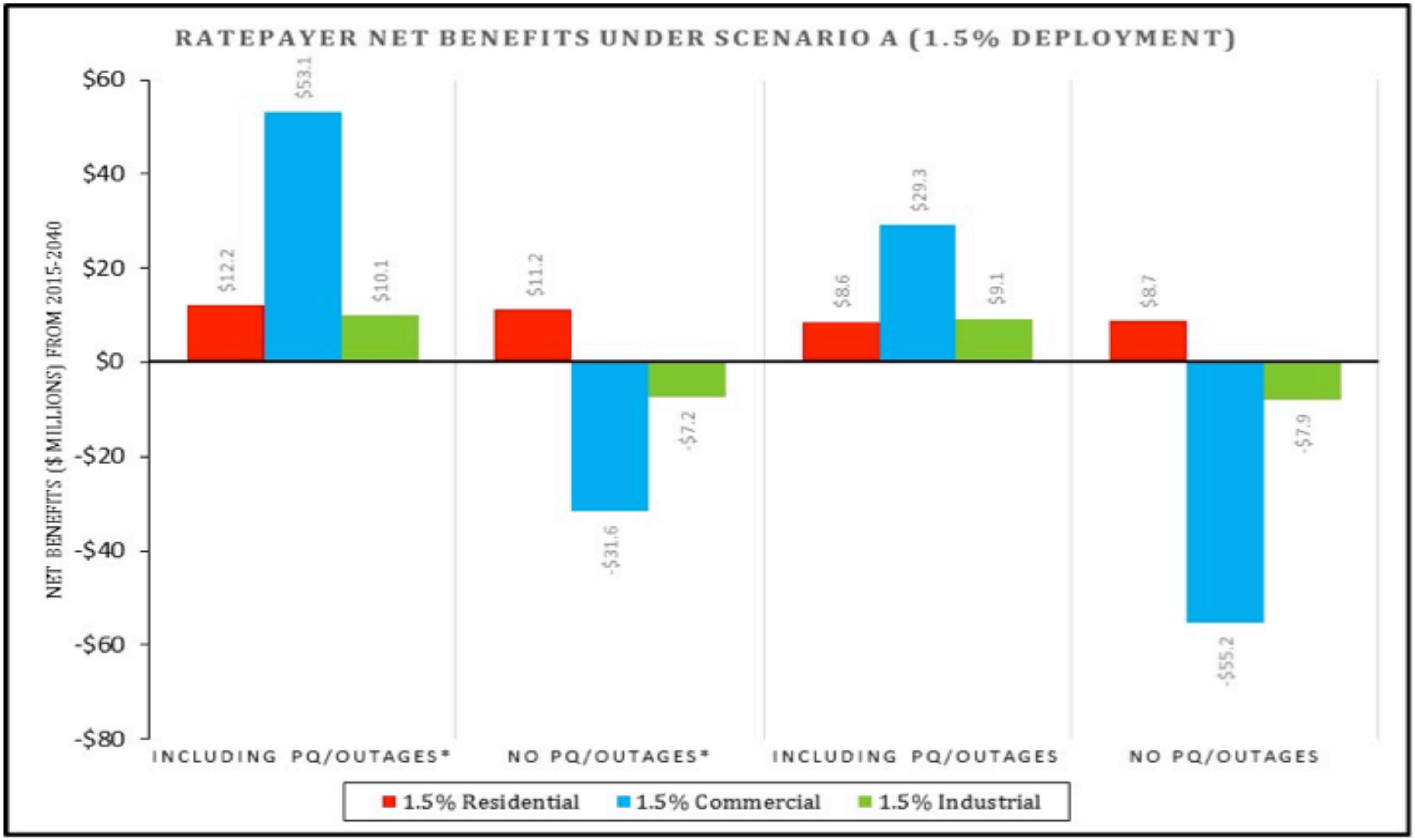
- The standard microgrid is able to offset 95% of annual on-peak demand based on the use of feeder line data provided by MGE applied to a system with annual demand of 5 million kWh
- Under MGE's time-of-use rates for residential customers, this translates into annual savings of nearly $500,000 (1.7 million kWh avoided during on-peak hours and 680,000 kWh avoided during off-peak hours)

Cost Effectiveness Measures

- **Participant Cost Test (PCT):** Scenario must score higher than 1.1 to reflect a 10% ROI for ratepayers
- **Utility Cost Test (UCT):** Scenario must score higher than 1.0 to ensure that retail sales from the microgrid exceed the NPV of lifetime costs
  At the utility level, the UCT must exceed 1.103 so that MGE maintains its 10.3 regulated ROI
- **Ratepayer Impact Measure (RIM):** Microgrid deployment cannot result in MGE raising rates for non-microgrid customers by more than 1% above the base case (taken as an average of 25 years)



- MGE's ROI dips no lower than 9.8% under the 1.5% deployment scenarios
- MGE's ROI rises above the BAU to 10.7% under industrial deployment



- All customer groups experience positive net benefits when power quality and reliability benefits are included. Only residential customers experience positive net benefits when power and reliability are not included.

The Value of Reliability and Power Quality

Interruption Length	Momentary	30 Minutes	1 Hour	4 Hours	8 Hours
Medium and Large Commercial & Industrial Businesses					
Agriculture	$4,382	$6,044	$8,049	$25,628	$41,250
Mining	$9,874	$12,883	$16,366	$44,708	$70,281
Construction	$27,048	$36,097	$46,733	$135,383	$214,644
Manufacturing	$22,106	$29,098	$37,238	$104,019	$164,033
Telecommunications & Utilities	$11,243	$15,249	$20,015	$60,663	$96,857
Trade & Retail	$7,625	$10,113	$13,025	$37,112	$58,694
Financial Institutions & Real Estate	$17,451	$23,573	$30,834	$92,375	$147,219
Services	$8,283	$11,254	$14,793	$45,057	$71,997
Public Administration	$9,360	$12,670	$16,601	$50,022	$79,793

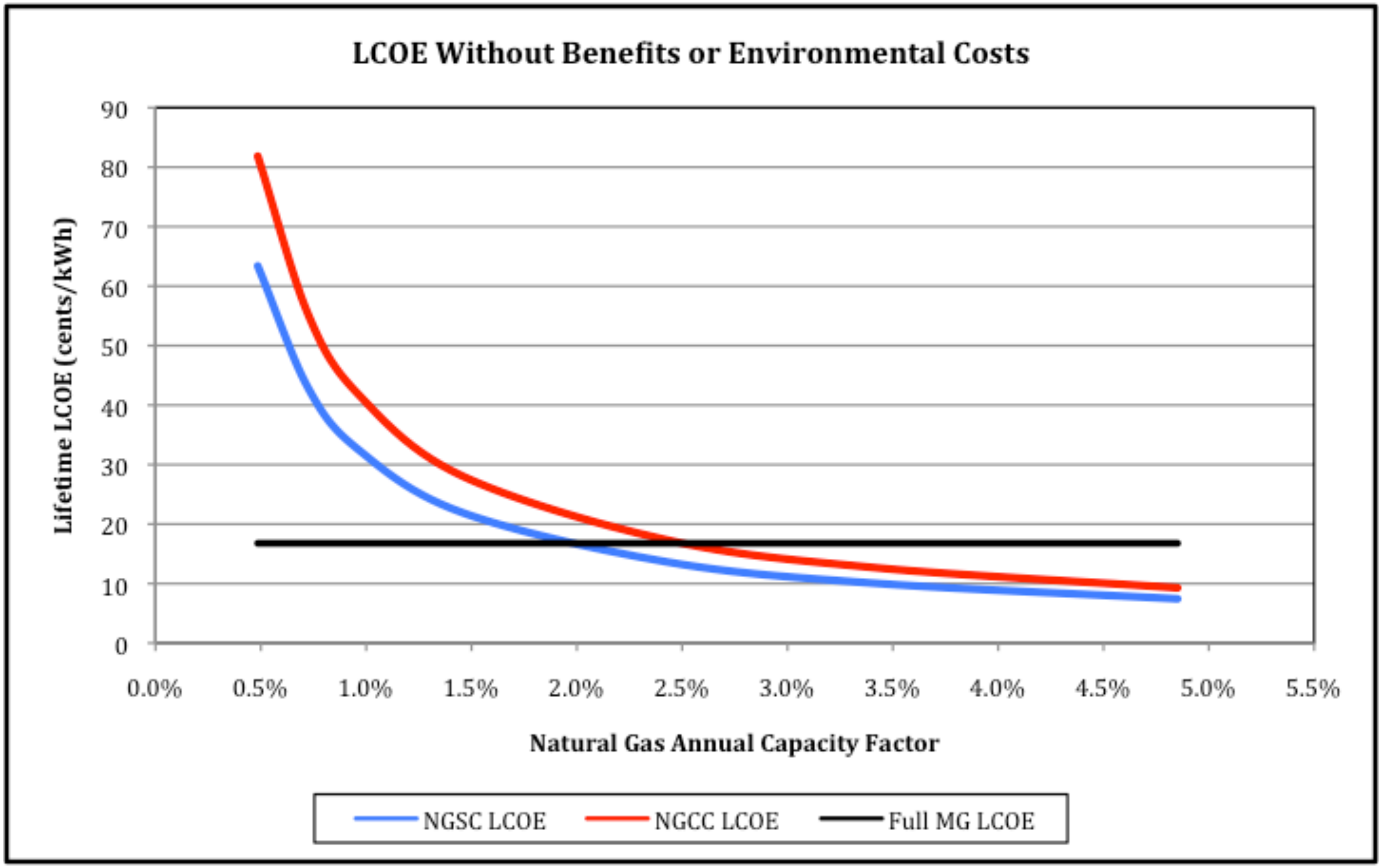
- Simulations used 0-20 momentary power quality events/year
- Simulations used 0-2 one-hour power outages/year
- Values ranged from $0/event to 150% of the value in the table above

Cost Effectiveness Results

- **15 of 24 simulations under Scenario A** passed all four cost-effectiveness tests (all residential scenarios)
- **7 of 24 simulations under Scenario B** passed all four cost-effectiveness tests (no residential scenarios)

These results show that MGE can expand distributed solar PV while developing a “smart” distribution network by self-financing microgrids in all three customer segments.

If MGE is unwilling to pursue this strategy, a third party developer could also develop microgrids, but this option is less cost-effective that Scenario A



- The LCOE of the microgrid (16 cents/kWh) is competitive against natural gas peaking plants at capacity factors lower than 2%. Only 4 of 18 NG units operated above 2.5% CF in 2012, and 11 operated at 1% or less.

Key Takeaways

- Up to 3% of demand in each customer segment can be met with solar PV-based microgrids without raising average rates for non-microgrid customers more than 1% above BAU levels
- Residential customers see positive net benefits and an ROI of at least 10% under all simulations in Scenario A, none in Scenario B
- Commercial and Industrial customers only experience positive net benefits when the value of increased power quality and reliability is included (highly dependent on each customer)
- **A cost/revenue sharing model could maximize benefits under Scenario B for MGE, ratepayers, and the third party developer,**

Microgrids in Other States

- **California:**
  Issued a $26.5 million funding notice in July 2014 for low-carbon microgrid projects that support critical facilities (Borrego Springs)

- **Connecticut's Microgrid Grant & Loan Pilot Program:**
  9 out of 36 projects were awarded $18 million in September 2013 under legislation passed in 2012

- **New Jersey's Energy Resilience Bank:**
  In the wake of Superstorm Sandy, the ERB is designed to increase the resiliency of critical facilities by financing distributed energy projects

- **New York's "NY Prize" Competition:**
  $40 million to support ten "independent, community-based electric distribution systems across the state."

Additional Research

- Conduct more detailed GIS analysis of solar PV potential using 3D mapping to account for shading and orientation
- Test more complex rate structures under Scenario A & B (i.e. fixed charges, participation in DSM programs)
- Develop techniques to test alternative business models (i.e. joint ownership, smart integrator and energy service utility)
- Analyze other DER technologies for microgrid deployment (i.e. biogas at wastewater treatment facilities and CHP)

Questions?

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Assumptions & Variables

Randomized Variables in Monte Carlo Analysis`				
Variable	**Min Value**	**Max Value**	**Mean**	**Distribution**
Capacity Factor - Solar	12%	16%	14%	Triangular
Capacity Factor - Biogas	62%	99%	83%	Triangular
Percent Change in Average Electricity Consumption	80%	120%	100%	Uniform
Average Electricity Growth Rate	0%	8.8%	3%	Uniform
Social Cost of Carbon	$1.90	$200	$35	Asymmetric Triangular
METB Rate	20%	30%	25%	Uniform

Fixed Variables in Monte Carlo Analysis`			
Variable	**Value**	**Variable**	**Value**
Discount Rate	3%	**REC Price ($/MWh)**	$1.00
Inflation Adjusted Interest Rate	4.90%	**WI Solar Rebate**	$2,400
Total Demand (kWh/year)	5,000,000	SO_2 **Permit Price ($/ton)**	$1.50
On-Peak Demand Purchased from Grid (%)	0%	NO_x **Permit Price ($/ton)**	$40
Off-Peak Purchases from Grid (%)	100%	SO_2 **Social Cost ($/ton)**	$2,754
Net Metered Sales Rate ($/kWh)	$0.07	NO_x **Social Cost ($/ton)**	$1,622
MISO Price ($/kWh)	$0.03	**Annual** CO_2 **Social Cost Increase (%/year)**	2.10%
Avoided Ancillary Services (% of total power purchases avoided)	1%	**Avoided Outage Cost ($/year)**	$4,750

Avoiding the Death Spiral

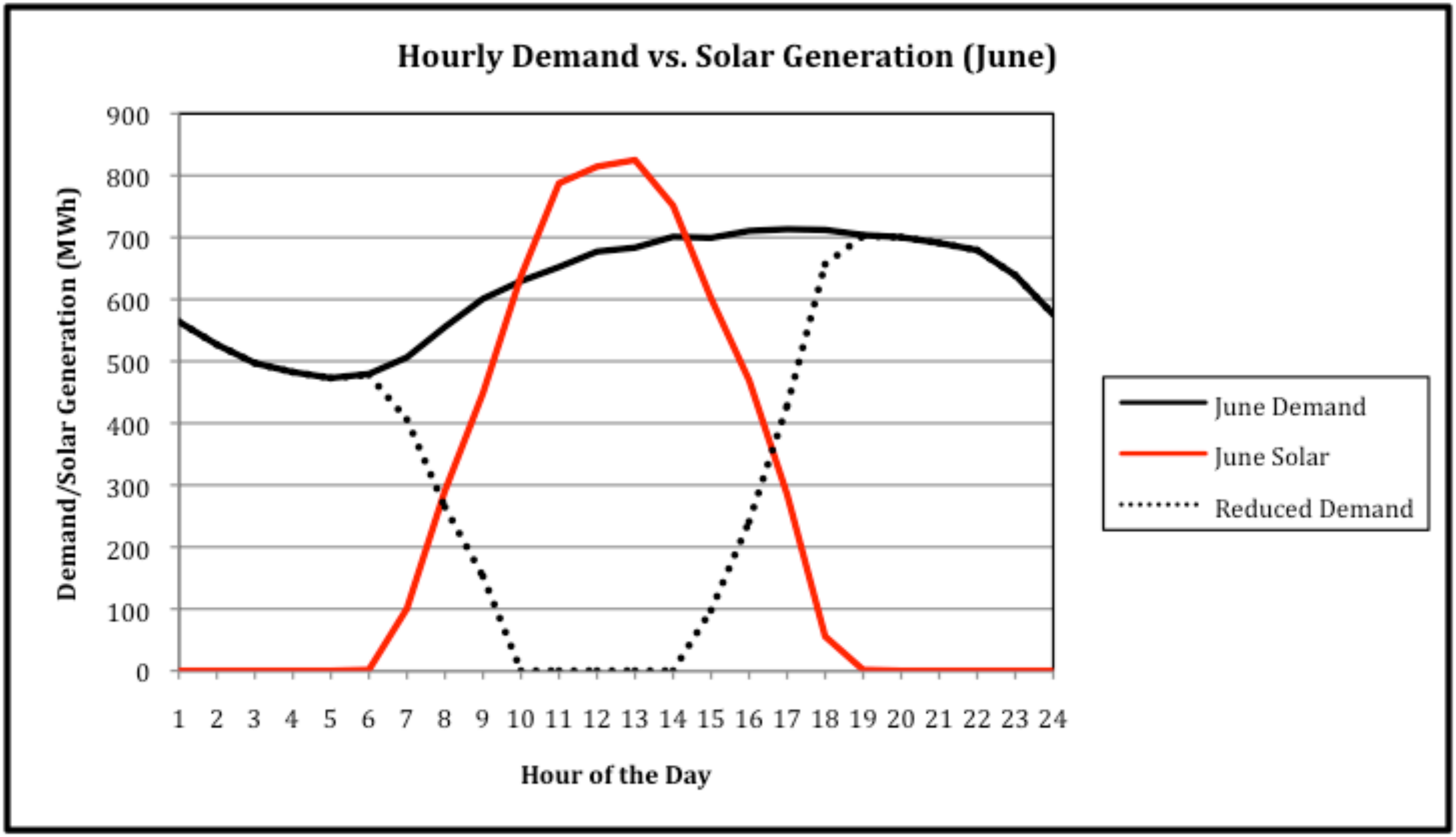
Utilities and regulators in multiple states are grappling with the problem of decreasing revenue and increasing DER

- Adopt higher fixed charges and lower volumetric rates to reduce exposure to lost revenue
- Decoupling (i.e. revenue-per-customer)
- Develop utility scale and customer sited DER projects
- Implement an alternative business model

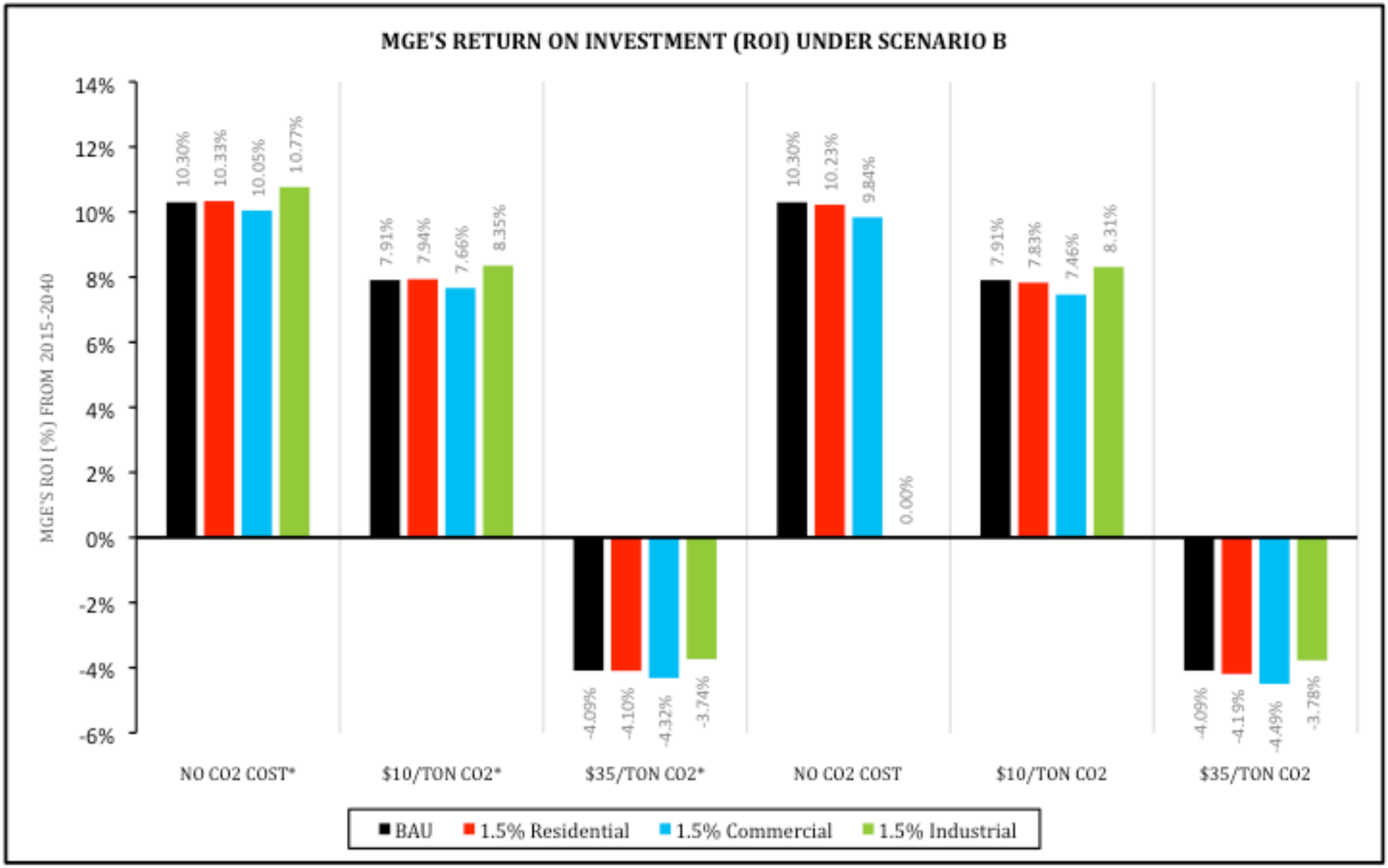
Alternative Business Models

- **Joint Ownership of DER:** Former DOE Secretary Steven Chu urges utilities to purchase and own DER, while partnering with third party installers/developers to build the projects
- **Smart Integrator:** Utility operates a regulated smart grid system and offers independent power and other services at market prices
- **Energy Service Utility:** May own and generate power or buy generation to bundle with energy service packages (i.e. different bundles like cell phone and cable/internet service providers)

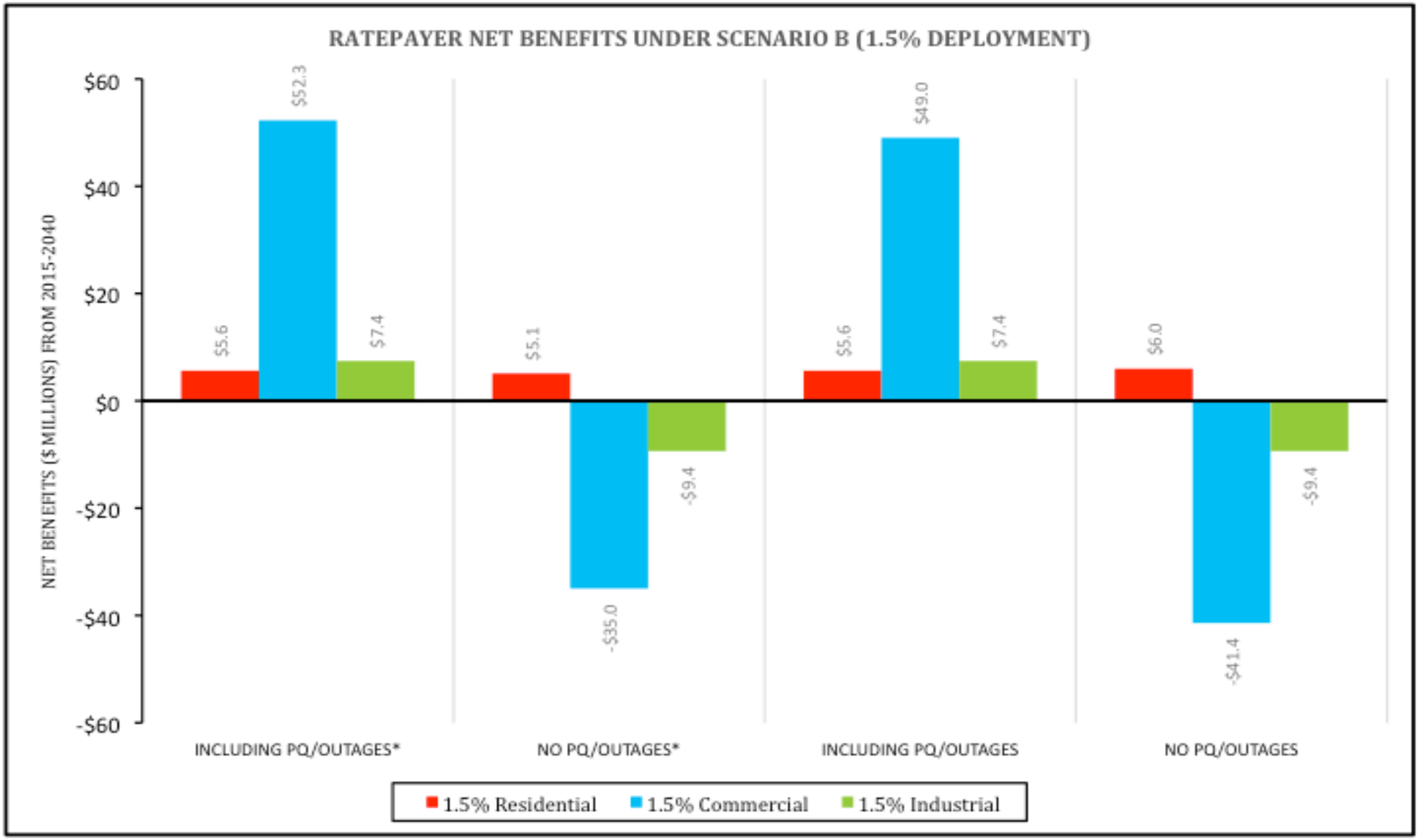
* *Requires an extensive overhaul of the regulatory framework*



- Solar PV is capable of providing all demand from 10am to 2pm based on average load curves and generation for the month of June
- The "duck head" can be mitigated by ramping up the 400kW microturbines in the late afternoon, which can supply more than 50% of load in the evening



- Results under Scenario are comparable, with slightly higher ROI for MGE because the utility does not incur the high cost of MG development. Again, the industrial scenario results in an ROI that is higher than the base case.



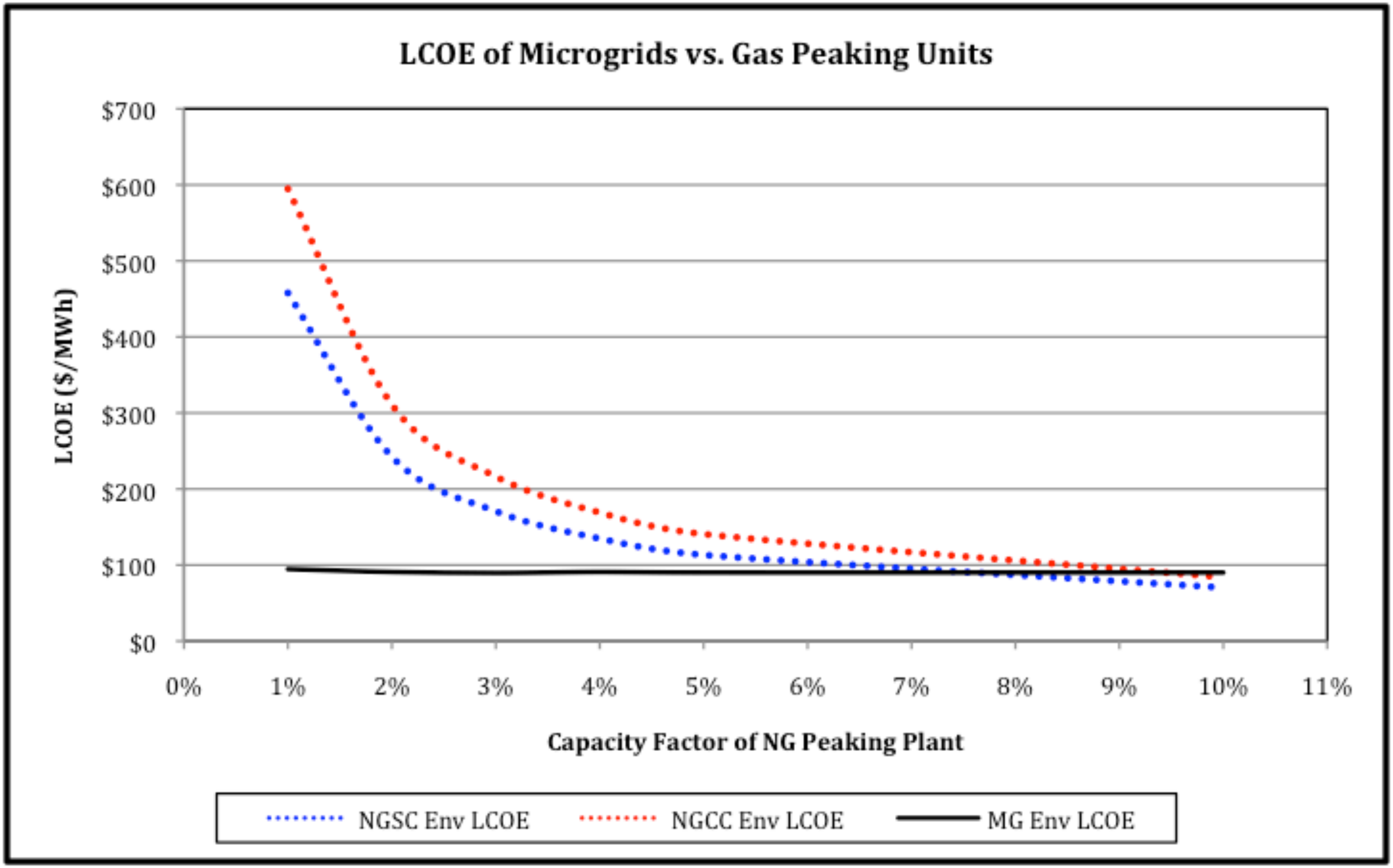
- Similar trends appear under Scenario B, but ratepayer benefits are lower than Scenario A under every scenario EXCEPT the 1.5% commercial. Residential ROI is less than 10% because the MG developer must charge higher rates than MGE to earn a minimum 15% ROI.

Policy Considerations

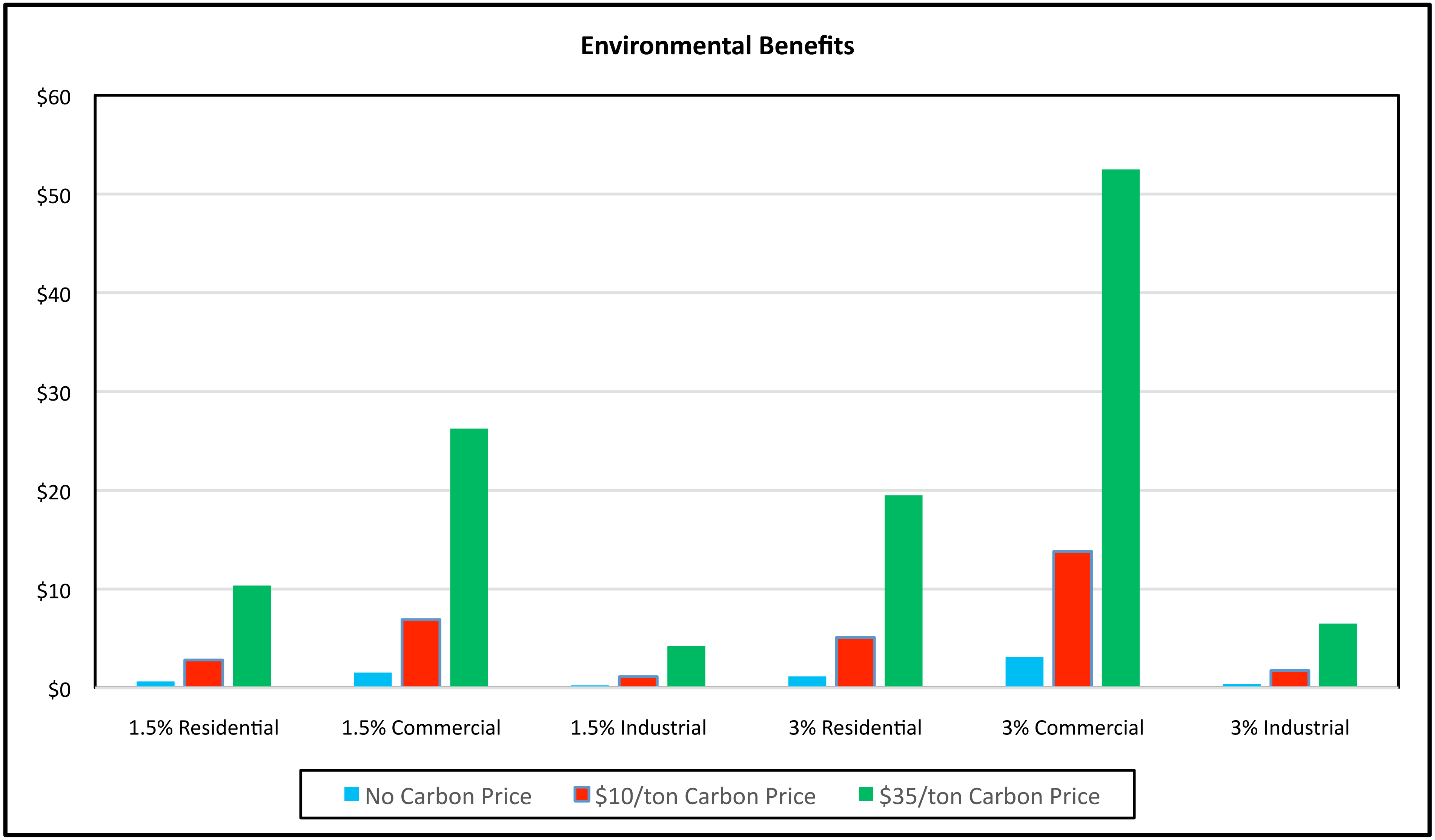
The "death spiral" defined by the Edison Electric Institute

"As DER and demand side management (DSM) programs continue to capture market share, utility revenues will be reduced. Adding the higher costs to integrate DER, increasing subsidies for DSM and direct metering of DER will result in the potential for a squeeze on profitability and credit metrics."

- **How to avoid the death spiral?**
- **Addressing net metering and DER integration costs**
- **Implement alternative/innovative utility business models**



- The LCOE of the microgrid (13 cents/kWh) is competitive against natural gas peaking plants at capacity factors lower than 4%. Only 4 of 18 NG units operated above 5% CF in 2012, and 11 operated at 1% or less.



- Under the 1.5% scenario, net social benefits range from $2.5 to 33.5 million depending on the social cost of carbon
- The benefit of reduced carbon costs could be monetized by MGE if/when the US EPA finalized regulations to limit carbon emissions from existing power plants