Town Center DER Microgrid Feasibility Study

Prepared for:

Township of Middletown, New Jersey
New Jersey Board of Public Utilities

Prepared by:

Leidos Engineering, LLC
Brody Business Development, LLC
Businovation, LLC

December 2018

List of Acronyms

AI	artificial intelligence
AMI	advanced metering infrastructure
BCR	benefit/cost ratio
BEMS	building energy management system
BESS	battery energy storage system
BPU	Board of Public Utilities
BTM	behind-the-meter
C&I	commercial and industrial
CHP	combined heat and power
CNG	compressed natural gas
CO_2	carbon dioxide
COTS	commercial-off-the-shelf
DER	distributed energy resources
DER-CAM	Distributed Energy Resources Customer Adoption Model
DERMS	distributed energy resource management system
DG	distributed generation
DoD	Department of Defense
DSM	demand side management
DSO	Distribution System Operator
EDC	electric distribution company
EDECA	Electric Discount and Energy Competition Act
EMP	energy master plan
EPRI	Electric Power Research Institute, Inc.
ES	energy storage
ESP	emergency standby power
EV	electric vehicle
FC	fuel cell
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
HVAC	heating, ventilation, and air conditioning
ICE	Interruption Cost Estimation
IEEE	Institute of Electrical and Electronics Engineers
IIoT	Industrial Internet of Things
in^3	cubic inch
IRP	Integrated Resource Plan
IT	information technology
JCP&L	Jersey Central Power & Light
kW	kilowatt
kWh	kilowatt-hour
LMP	locational marginal pricing
MEMS	micro-electro-mechanical systems
MOU	memorandum of understanding
MW	megawatt
NG	natural gas
NJNG	New Jersey Natural Gas
NREL	National Renewable Energy Lab
NWA	non-wires alternatives
NWS	Naval Weapons Station
O&M	operations and maintenance
P3	public-private-partnership

PCC	point of common coupling
PEM	proton exchange membrane
PPA	power purchase agreement
PV	photovoltaic
R&D	research and development
ROW	right-of-way
SAIDI	System Average Interruption Duration Index
SCADA	supervisory control and data acquisition
SEPA	Smart Electric Power Alliance
TC DER	Town Center DER
TOMSA	Township of Middletown Sewerage Authority
TOU	time-of-use
USDOE	U.S. Department of Energy
VPP	virtual power plant

Executive Summary

The Middletown Town Center Distributed Energy Resources (TC DER) microgrid represents a unique opportunity for a multi-jurisdictional collaboration between federal, state, county, and local government agencies in strengthening power system resilience to rising coastal threats along the New Jersey shore. As defined in the New Jersey Energy Master Plan Update (December 2015), “A Town Center DER microgrid would have a cluster of critical facilities within the municipality that could include multifamily buildings, hospitals and local and state government critical operations in a small radius and connected to a series of DER technologies that can operate isolated and islanded from the grid when the power is down.” Freeing up siting for hosting distributed energy resources (DER), which can then operate in an orchestrated manner to achieve cleaner and more efficient generation, smarter load consumption, and efficient service delivery, can benefit both the community and the electric distribution company.

As New Jersey proactively updates its 2019 Energy Master Plan under a new administration, preparing for an aggressive adoption of clean power, energy storage, electric transportation, and large energy efficiency gains – all while minimizing impact to ratepayers and dramatically improving community resilience – the answer is clear: microgrid is not only feasible but is a technology whose time has come for Middletown, New Jersey.

This Study pulls together detailed information on existing energy use patterns and facility operational profiles, the relevant latest technology capabilities and trends for DER, and current regulatory boundaries and codes and standards requirements to provide a more cohesive picture on the “playing field” that exists for enabling a functional Middletown TC DER microgrid to realize these benefits. The discussion of microgrid feasibility cannot be fully treated without a word on risk and its corresponding adjusted rate of return expressed as a net benefit calculation. While the Distributed Energy Resources Customer Adoption Model (DER-CAM) has been employed as required to properly baseline anticipated costs, what is not fully reflected, nor can it be, are the less tangible but relevant positive benefits. These benefits include community development such as local jobs and shared destiny. Also included in these less quantifiable benefits are grid hardening through improved storm resilience, and environmental benefits such as reduced greenhouse gas and particulate emissions. Of particular interest in future grid operations is the concept of flexibility through a transactive response to priority shifts via the creation of a distribution-based energy marketplace, of which microgrids can be a significant enabler.

Various configurations are proposed for designing and operating the microgrid, which reflect fundamentally different architectural approaches, ownership options, and business models. These choices are largely dictated by the functionality desired by the Middletown community, as well as the degree of collaboration and synergies achieved with the local distribution utility Jersey Central Power & Light (JCP&L) and, as this Study identifies, may require significant regulatory “relief” to align with the more progressive policies that are promulgated from the new administration. Changes of this nature are presently well underway in other states such as

California, New York, and Massachusetts, and in Europe, where a far more aggressive adoption of carbon-free energy and related economic models have been promoted.

As much of the current literature clearly identifies, the electric power industry, in particular the distribution segment, is at a crossroads where slowing load growth, long neglected infrastructure, rapidly changing technological capabilities, and rigid regulatory models meet to create a high degree of uncertainty and risk. This circumstance is constraining investment decisions, resulting in sub-optimal outcomes, and exposing ratepayers to the moral hazard of stranded asset investment. Additionally, there are significant changes underway at the wholesale market level as the Federal Energy Regulatory Commission (FERC) wrestles with individual state mandates, such as those in New Jersey, that are seeking a more cost effective, secure, and carbon-free energy market. These are becoming manifest in Orders such as FERC 745 (Demand Response) and FERC 841 (Energy Storage), which attempt to break down barriers to aggregate DER participation so that the inherent flexibility of these resources can be correctly valued, exposed, and captured through wholesale energy, capacity, and ancillary service opportunity. Added to these drivers are the voices of increasingly sophisticated and demanding end users who are now, in many regions, becoming both producers and consumers of energy. These "prosumers" are demanding reduced uncertainty and risk in their energy generation investments, and fairly compensated value from the marketplace that enhances their returns. As required by the New Jersey Board of Public Utilities (BPU), the DER-CAM platform was used to establish a comparative standard in the valuation of distributed energy investment and the expected benefits from such investments in a microgrid deployment. Unsurprisingly, this modeling determined overwhelmingly positive net benefit for placing DER on-premise to support critical load that can be islanded and served for emergency operations.

In this era of rapid changes to a previously stable technical and regulatory environment, there is now a major shift underway to create improved transparency, risk allocation, grid resilience, environmental responsibility, and economic participation for communities in their energy services. The feasibility of high-penetration distributed generation and storage is leading to an acceleration of adoption for these technologies, and forcing the business models of legacy utility franchises to adapt, albeit with a significant time lag. The findings of this Study point to the path forward in adopting initial amounts of highly localized generation and storage, allowing this local critical load islanding, as a precursor to enabling more advanced peer-to-peer interoperability and coordination of these resources as regulatory barriers fall. This Study provides both qualitative and quantitative analytical support for this recommended approach, but leaves the detailed design of the microgrid and its evolutionary roadmap to the next phase.

Finally, this Study contains a rather unvarnished identification and classification of the current regulatory barriers into two distinct notional groupings: *copper bound* and *data bound* constraints. Both of these currently work together to dissuade new technologies and operating models that the advanced microgrid will require to be most efficiently implemented. The pressure on these constraints is mounting as the electric power industry struggles to evolve to its new business model and role as a trusted energy service network provider – and a multi-step recommended path forward toward this resolution is offered at the conclusion of this Study.

Table of Contents

List of Figures

List of Tables

Introduction

The 2015 New Jersey Energy Master Plan Update established a new overarching goal to "Improve Energy Infrastructure Resiliency & Emergency Preparedness and Response" in response to several extreme weather events that left many people and businesses without power for extended periods of time. These new policy recommendations included:

1. Increase the use of microgrid technologies and applications for distributed energy resources (DER) to improve the grid's resiliency and reliability in the event of a major storm.
2. The State should continue its work with the U.S. Department of Energy (USDOE), the utilities, local and state governments and other strategic partners to identify, design, and implement Town Center DER (TC DER) microgrids to power critical facilities and services across the State.

At its November 30, 2016 agenda meeting, the New Jersey Board of Public Utilities (BPU) authorized the release of staff's Microgrid Report. The following recommendations in the Microgrid Report specifically addressed the development of a TC DER microgrid feasibility study incentive program and pilot:

1. Develop and implement a TC DER microgrid feasibility study incentive program as part of the current New Jersey Clean Energy Program budget. This TC DER microgrid feasibility study incentive program should provide funding for the upfront feasibility and engineering evaluation project development costs of a TC DER microgrid at the local level. This incentive should be a phased approach beginning with an initial feasibility study, followed by detailed engineering design phase.
2. Initiate a TC DER microgrid pilot within each electric distribution company service territory. This should initially be limited to the municipalities within the nine Federal Emergency Management Agency (FEMA) designated counties or municipalities that meet the same criteria identified in the New Jersey Institute of Technology report. These pilots should include, at a minimum, an initial feasibility study of the TC DER microgrid. This process should assist in the development of a TC DER microgrid tariff.

In accordance with the study grant application rules set forth, a TC DER Microgrid Feasibility Study (Study) was submitted by the Township of Middletown to the BPU in fall 2017. The Study core stakeholder organizations include the Township of Middletown; the Middletown School District; Middletown Sewage Authority; Monmouth County; NY Waterway; and Earle Waterfront. The Study critical facilities include Naval Weapons Station (NWS) Earle Waterfront Administrative Area; Township of Middletown Sewage Authority; NY Waterways Ferry Terminal; Middletown Public Works and Compressed Natural Gas (CNG) Fueling Facilities; Middletown Municipal Complex; Bayshore Middle School; Leonardo Elementary School; Bayview Elementary School; Monmouth County Highway Department; Middletown Fire Stations 3, 4 and 7; and Monmouth County Bayshore Outfall Authority.

Based on the list of core stakeholders and proposed critical facilities, there are seven FEMA Category IV designated facilities and six FEMA Category III facilities that can provide shelter or services in an emergency. There are no existing DER facilities in the proposed Study buildings. The Study was chartered to evaluate new power capacity which is estimated to be between 30 MW and 50 MW. The electric utility, Jersey Central Power & Light (JCP&L), and the gas utility, New Jersey Natural Gas (NJNG), for the Township of Middletown both provided letters of support to participate in the Study.

After review of the application, BPU staff recommended that the Board approve the Township of Middletown application for the total incentive amount of $150,000.00 and authorized President Mroz to execute the memorandum of understanding (MOU) with the Township of Middletown which sets forth the terms and conditions of the commitment of these funds.

The USDOE Microgrid Exchange Group in 2012 developed a generally accepted definition of a microgrid as:

> *A group of interconnected loads and distributed energy resources (DER) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.*

The above definition for microgrids covers a broad array of systems, technologies, customer types, and interconnection types. Currently there is no definitive or universally accepted classification system for the different types of microgrid configurations.

The microgrid can be a more efficient and effective way to provide emergency power for the specific set of critical facilities mentioned above, without relying solely on standby emergency generators. The proposed microgrid will be designed so it can operate 24/7 and supply electrical power both under blue-sky conditions as well as during and after an emergency.

This Study will examine whether a microgrid can operate in a manner that provides improved resiliency and additional reliability for the identified critical facilities better than, or similar to, the current central generator/transmission/distribution grid system, while saving the microgrid customers, owners, and operators energy costs. The Study will explore whether the microgrid can operate in a more environmentally effective manner to lower air emissions and other impacts. The Study will also describe benefits and costs of the microgrid in relation to the distribution grid overall.

Middletown is the largest municipality in Monmouth County with over 66,000 residents. Flooding caused by Superstorm Sandy disrupted the electrical distribution grid and power supply to Township customers for between 7 and 14 days. With three storm evacuation routes, regional wastewater facilities, emergency shelters, transportation hubs, and police/fire stations located in Middletown, uninterruptable electric power for critical facilities is a vital community need.

Unique among the BPU microgrid studies conducted under the TC DER microgrid feasibility study incentive program is the inclusion of NWS Earle in the list of Middletown participant sites. In 1943, the NWS Earle Pier Complex became the principal port of embarkation for the ammunition used in the liberation of Axis-occupied Europe. Today, NWS Earle serves as the main ammunition loading point for the Carrier and Expeditionary Strike Groups of the U.S. Navy's Atlantic Fleet. Although most of the 12,000-acre facility is located in the center of Monmouth County, uninterrupted operations at the Earle Pier Complex is of strategic importance to the defense of the nation. The unique physical and operating characteristics of NWS Earle, and the critical importance of the facility to national interests provide a compelling requirement for resilient and reliable power infrastructure in Middletown.

This Study addresses the following requirements pertaining to the proposed Middletown TC DER microgrid, as set forth by the BPU:

- Details on the energy use
- Microgrid boundaries and rights of way (ROW)
- Identification of emergency shelters
- Ownership/business model
- Issues pertaining to DER technologies/communication systems, interconnection, and tariffs
- Cost and financing options
- Community benefits

This list of requirements forms a set of building blocks for a recommendation that will describe a path forward for a feasible microgrid which can then be considered by the BPU and other interested parties for detailed design and implementation.

Project Overview

Applicant

As described previously, Middletown is the largest municipality in Monmouth County with over 66,000 residents and is home to essential agencies, installations, and services. Flooding caused by Superstorm Sandy disrupted the electrical distribution grid and power supply to Township customers for between 7 and 14 days, causing significant impact to the ability to provide emergency services and to sustain critical operations. With U.S. Navy facilities, three storm evacuation routes, regional wastewater facilities, emergency shelters, transportation hubs, and police/fire stations located in Middletown, uninterruptable electric power for critical facilities is a vital community need for the region, state, and nation.

Unique among the BPU microgrid studies conducted under the previously identified program is the inclusion of NWS Earle in the list of Middletown participant sites. The unique physical and operating characteristics of the NWS, and the critical importance of the facility to national interests, provide a compelling requirement for resilient and reliable power infrastructure in Middletown.

The Township of Middletown is the primary applicant and grant recipient. Township leaders are motivated by the need to improve the safety and security of its citizens through improved electrical system reliability and the resilient fortification of critical sites.

Project Core Stakeholders

The following entities are proposed core stakeholders in the Middletown TC DER microgrid. Each proposed stakeholder may play a crucial and active role in the analysis, design, construction, and operation of the microgrid.

- U.S. Navy – NWS Earle
  - The Navy facilities fulfill a critical national security mission while at the same time acting as an anchor tenant in the operation of the microgrid.
- Jersey Central Power and Light (JCP&L)
  - The utility is the local electric distribution company (EDC) for the Township, operating and maintaining the electrical transmission and distribution systems that serve all Township premises including the participating sites in this Study.
- New Jersey Natural Gas (NJNG)
  - The local natural gas distribution company operates natural gas transmission and distribution systems that supply gas to all Township premises including the participating sites in this Study.
- Township of Middletown Sewerage Authority (TOMSA)
  - TOMSA is responsible for the operation of sewage processing and disposal facilities serving the Township of Middletown.

- NY Waterways Ferry Terminal
    - The Ferry Terminal is a critical transportation hub serving the Township of Middletown and surrounding regions with efficient passenger transportation capacity.
- Middletown Board of Education
    - The Board of Education oversees the operation of schools within the Township that form a set of critical facilities in support of emergency services.
- County of Monmouth
    - Monmouth County, New Jersey, is where Middletown is located. The county provides services and administrative support in conjunction with Township authorities.
- State of New Jersey Department of Transportation
    - The Department of Transportation oversees the maintenance and operation of critical roadways and signals necessary to maintain access through the Township during normal and emergency circumstances.
- Leidos Engineering, LLC – Project Lead
    - Leidos provides engineering, technical, and strategic consulting services to utilities, developers, energy asset owners, equipment manufacturers, lenders, governments, and other participants in the energy industry. Leidos is functioning as the project lead for this Study.
- Brody Business Development, LLC – Stakeholder Engagement
    - Brody BD builds and fosters relationships with federal, state, county, and municipal officials, high-level department heads, regulators, and legislators in New Jersey. Brody BD is functioning as the stakeholder engagement expert for this Study.
- Businovation, LLC – Technology Solutions Development
    - Businovation specializes in improving the resilience of the electric system through intelligent, DER solutions that combine energy storage, electric transportation, and local generation with advanced control and communication. Businovation serves as a local expert engineering resource for this Study.

Project Location

The Middletown TC DER microgrid encompasses an area contained entirely within the Township of Middletown and includes the following proposed premise facilities that are currently metered and served individually by JCP&L. Each facility carries a FEMA designation by category. The proposed microgrid project encompasses an area that is home to 19 public facilities, 16 which are considered critical according to FEMA Categorical Classification Standards. The diameter of the project area is roughly 3.5 miles spanning from the

NY Waterways Ferry Terminal to the Middletown Public Works and Fast Fill Natural Gas Station. The average distance between all 18 individual facilities is 0.49 miles. A map of the project area which shows the location of all critical facilities is provided below. The facilities, including latitude and longitude, are as follows:

- NWS Earle Waterfront and Administrative Area (proposed locations) – Category IV
    - The mission of the weapons station is to store and transport large quantities of ordnance for the Atlantic Fleet. Security of those shipments requires perimeter security as well as entry control. The Station is the main ordnance shipment point for the Navy and Marine Corps in this half of the world.
- Township of Middletown Sewage Authority (TOMSA) – Category III (40.428605, -74.081748)
    - TOMSA provides wastewater treatment services for Middletown, Atlantic Highlands, and The Highlands. Failure would make most of these areas unlivable while posing a public health risk from the release of raw sewage.
- NY Waterways Ferry Terminal – Category III

  (40.433974, -74.078801)
    - Provides a means of rapidly transporting people in and out of the flood zone (the ships hold up to 500 people each). This is a Monmouth County Owned facility which resides on the same site as the former Monmouth County Landfill. Future uses are under currently being considered in close proximity to the ferry terminal.
- Middletown Public Works Facility and CNG Fueling Station – Category IV

  (40.389171, -74.086209)
    - Provides disaster recovery services with its own fuel supply with direct access to the restricted access federal highway, Normandy Road. The Emergency Management Office is collocated at this facility.
- Middletown Municipal Complex (Town Hall and PD) – Category IV

  (40.394531, -74.104062)
    - Township of Middletown police headquarters and municipal administration.
- Bayshore Middle School – Category III

  (40.412560, -74.058574)
    - Public School responsible for educating 643 students grades 6–8. Potential evacuation and triage center.

- Leonardo Elementary School – Category III

  (40.411515, -74.059000)

  - Public School responsible for educating 233 students grades K–5. Potential evacuation and triage center.
- Bayview Elementary School – Category III

  (40.413873, -74.084452)

  - Public School responsible for educating 404 students grades K–5. Potential evacuation and triage center.
- Middletown North High School – Category III

  (40.402341, -74.099952)

  - Public School responsible for educating 1,488 students grades 9–12. Potential evacuation and triage center.
- Monmouth County Highway Department, District #1 – Category IV

  (40.422457, -74.087891)

  - Provides snow plowing and emergency highway repair.
- Middletown Fire Department Stations 3, 4, and 7 – Category IV

  (40.422218, -74.089187) | (40.414904, -74.066230) | (40.420211, -74.092435)

  - Provides primary-response fire suppression services for the project area.
- Monmouth County Bayshore Outfall Authority – Category IV
  - Facility that pumps treated effluent to the Atlantic Ocean that is collected from two regional sewerage authorities, Bayshore Regional Sewerage Authority and TOMSA, which serve the majority of communities along the Bayshore.
- Traffic lights along Routes 36, 35, and Leonardville Road – Category IV
  - As ancillary structures allowing the safe and rapid evacuation of people during a major flood event as well as allowing emergency and relief vehicles to operate.

The following map illustrates the location of the proposed microgrid participating sites as originally submitted in the grant application to the BPU.

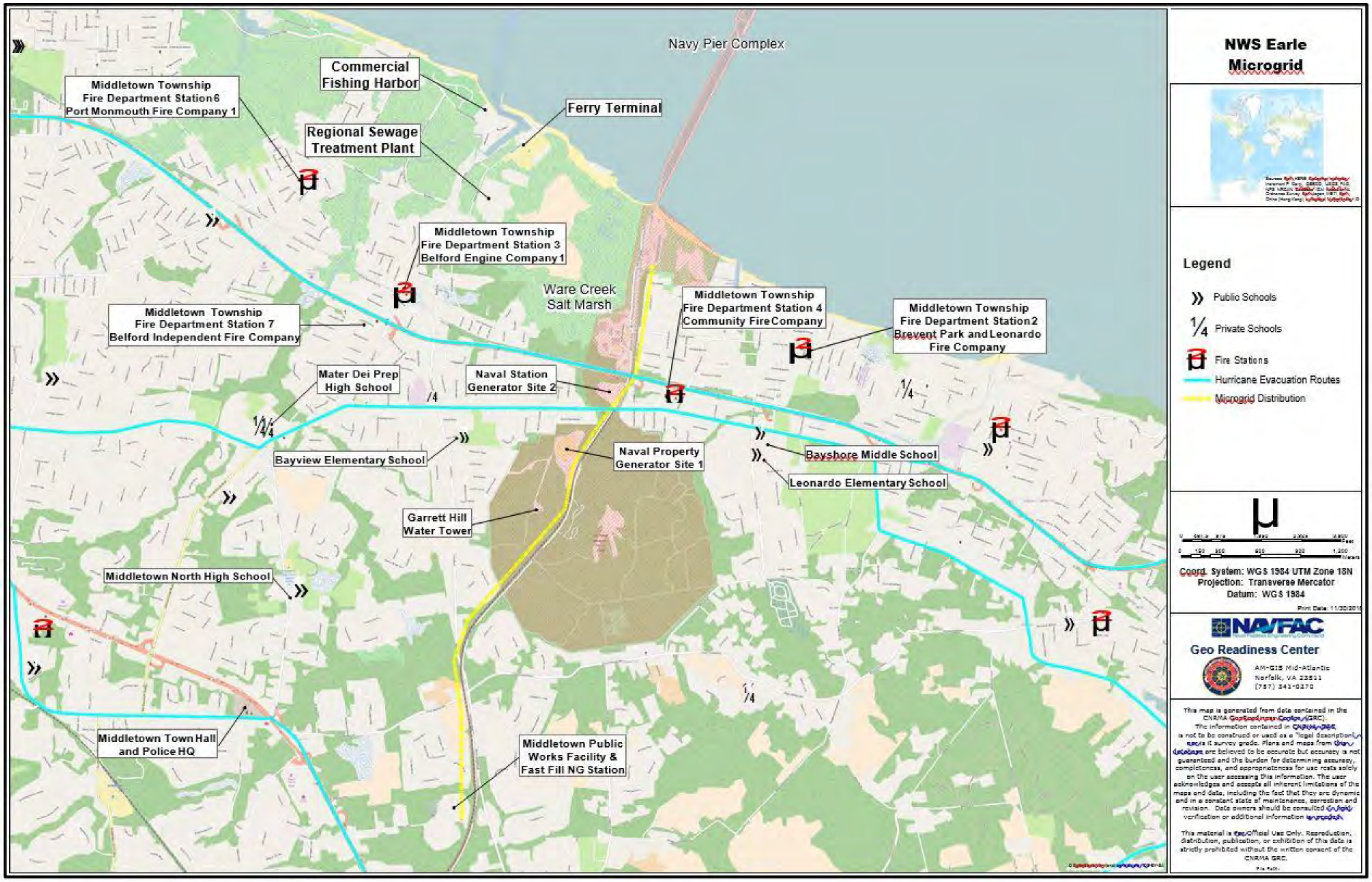


Figure 1. Locations of Proposed Microgrid Participating Sites

Project Description and Benefits

Furthermore, the grant application for the Middletown TC DER Microgrid Feasibility Study set forth the following general descriptions:

General Description of the Technology to be Developed:

Five major components exist in a utility-connected microgrid: generation, controls (both for local stability control and economic dispatch of generation), monitoring and switches for islanding.

We endeavor to use the maximum amount of commercial-off-the-shelf (COTS) products to minimize microgrid integration risk. Generation, automated switching and monitoring are completely mature components and are essentially commodities. Generation can include solar, natural gas modular reciprocating CHPs [combined heat and power], waste to energy and energy storage. Switching includes standard utility automated switches, such as VBMs, reclosers and automatic padmount switchgear. Monitoring includes standard meters, SCADA and potential wireless applications.

Microgrid controls break into two realms: control for local electrical grid stability when islanded from JCP&L and controls for economic dispatch when paralleled and connected to JCP&L. Again, these controls are COTS. That said, the development of the control realm is how to efficiently, safety and reliably connect and interface with the JCP&L SCADA and local utility control schema. The team will work with JCP&L to ensure the microgrid operates as a benefit to the broader utility supply, with respect to safety, economics, reliability and customer satisfaction.

General Description of the Benefits and Need of the Project:

The project was for the development of a feasibility study in an area of Middletown Township which is home to many critical facilities. The study was chartered to identify whether or not a microgrid is possible for a project area which includes tens of thousands of residents as well as private, municipal, county, state and federal resources.

The project engaged public and private stakeholders, and developed new working relationships in the interest of reaching the following goals:

- *Improve Local Energy Delivery for the Project Area's population*
- *Provide for Local and Regional Reliability During Emergency Response Scenarios*
- *Save Money in the Long-Term Due to Increased Efficiency*
- *Support Economic Growth in the Project Area*
- *Generate Revenue by Supporting a Wider Grid Over Time*

The project presents a plan that will help to protect the following public services during emergencies situations:

- *Water Distribution*
- *Flood Control Infrastructure*
- *Transportation Evacuation Routes*
- *Local and Regional Emergency Response (Police, Fire, OEM)*
- *Marine Transportation*
- *Federal Defense Infrastructure*
- *Public Shelters*
- *Emergency Communications*
- *Public Sewer System*

Project Approach

The following approach was utilized in the completion of this Study.

Define Critical Loads and Participation Scenarios

This process involved the acquisition of all critical-facility-specific energy consumption information, as well as the prioritization of facility operational characteristics. Scenarios were developed to describe the anticipated participation level of the load center in terms of critical load management and adjacent load coordination.

Key activities included:

1. Defining the size of the project in terms of electrical and thermal energy.
2. Defining the electric load for each critical facility.
3. Defining the square footage of the overall project.

Technology Evaluation

The technology evaluation process consisted of a comprehensive review of components suitable for incorporation into the microgrid design. Based on the load and functionality requirements, suitable technology components were researched and evaluated based on a set of technical and economic criteria. This component-level review was incorporated into a system-level review to evaluate the system level impacts of component technology choices.

Key activities included:

1. Determine general microgrid system-level architecture based upon the load and functionality requirements.
2. Research applicable technology components including different DER technology types that can be incorporated into the system architecture.

3. Determine the economic attributes of these components to support business model development.
4. Evaluate the impacts to system-level architecture of these components in a system-level analysis.

Codes and Standards Evaluation

Fully understanding the environment that governs the specification, configuration, interconnection, and operation of microgrid-embedded DER is critical to developing the most effective (i.e., most feasible) program for the Middletown TC DER microgrid solution.

Codes and standards evaluation included thorough research on all pertinent requirements that govern the design, build, and operation of the microgrid and its underlying DER, including; municipal land use ordinance, building and construction codes, State permit processes (site, environmental), National Electric Code, industry standards and certifications, and utility interconnection agreements.

The goals of the codes and standards evaluation are:

1. Present the context and sequence of all related approval/compliance processes that permit construction and operation of the Middletown TC DER microgrid.
2. Create an "inventory" of applicable codes and standards.

This information will be used to identify potential barriers to microgrid adoption, and provide recommendations for State agency staff consideration in developing possible mitigation approaches.

Stakeholder and Community Involvement

Engaging the key stakeholders and community was an important function of this Study. Stakeholders consisted of utilities, off-takers, special interest groups, residents, and organizations that would have interest or use of the possible microgrid.

The stakeholder/community involvement meetings were communicated through e-mail, newspapers, and the Township's website. These notices included dates, times, and locations. Agendas, sign-in sheets, project information handouts, and comment forms were developed.

Soon after the grant was awarded a meeting was convened with Middletown Township officials to organize an initial "kick-off" meeting that was held on January 31, 2018. Since this first meeting the elected officials and key players such as JCP&L and NWS Earle have been engaged on a continuing and frequent basis. Site visits were made at NWS Earle as well as TOMSA and NY Waterway Ferry Terminal. Two separate meetings were held at the JCP&L office in Holmdel, as well.

The stakeholders and community were engaged at the first Public Information Session on May 17 at the Poricy Park Nature Center. The second Public Information Session was held on September 27 at the Township Library. Both of these meetings were preceded by a "pre-meeting" with Township officials and key stakeholders in order to review the material that would be presented and solicit their input. It was clear that engaging the community, stakeholders, and public officials would help identify problems and/or concerns and help assess and develop solutions with their input. It would also create improved transparency.

Figure 2. Public Information Sessions Were Held May 17 and September 27

Of particular concern was the participation of a community advocacy group called RAGE (Residents Against Giant Electric). RAGE is a group of concerned citizens who had come together to fight JCP&L's plan to install 10 miles of new high voltage power lines along the NJ Transit rail line from Matawan-Aberdeen train station to Red Bank train station. Since offering them a chance to participate in the Study and a channel for their input, RAGE has now become a very important supporter of the Study and the potential for a microgrid in the Township. The RAGE website link is as follows:

http://www.rage2016.com

The stakeholder and community involvement plan included strategies for communicating the project information and soliciting feedback. The presentation material from each Community Information Session appeared on the Township's website after each meeting and a feedback link was developed and appears on the Township's webpage. The feedback e-mail link is:

microgrid@middletownnj.org

Middletown Township Mayor Kevin Settembrino appeared on a Comcast Newsmakers interview on October 4 to promote the microgrid project:

https://www.youtube.com/watch?v=7JYkH_HEjsA

A feature of each community presentation included the following heat map of proposed microgrid locations showing the relative energy usage at each site.

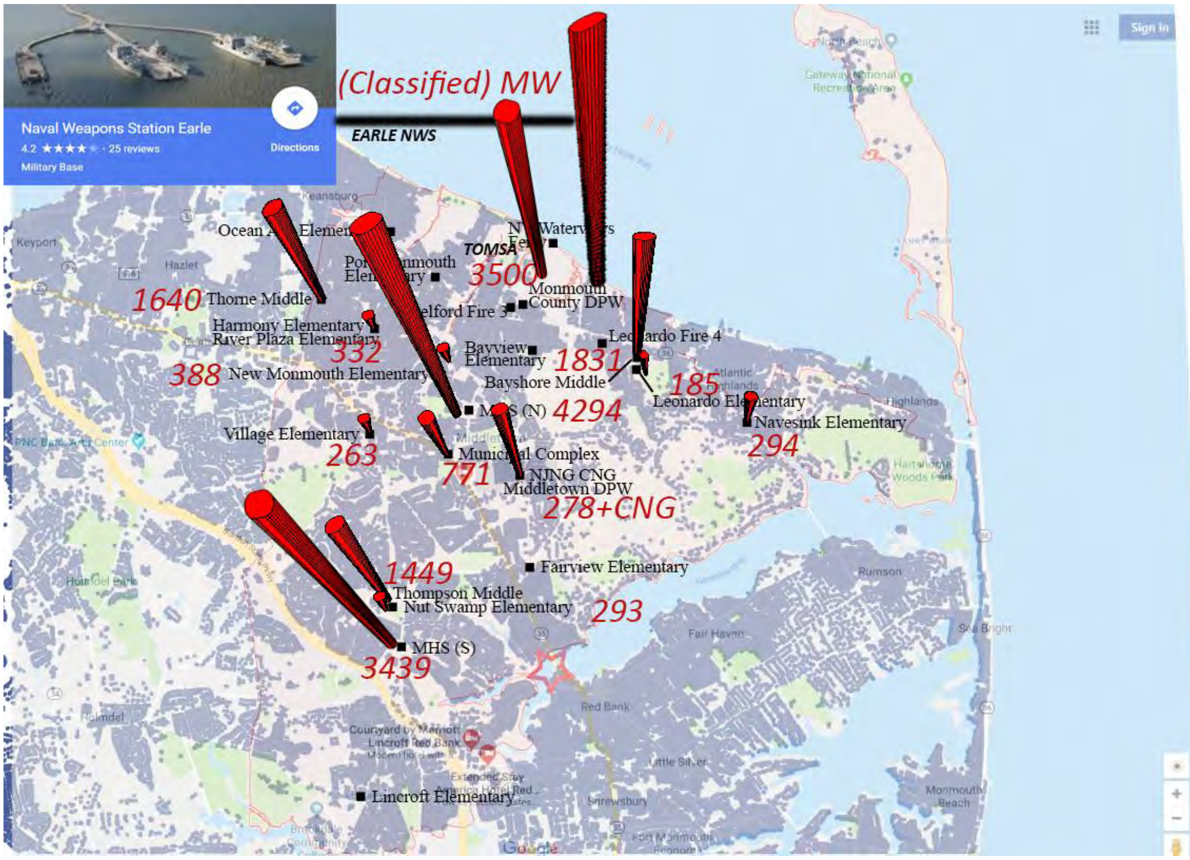


Figure 3. Heat Map of Proposed Microgrid Locations

Microgrid Design Approach and Financial Analysis

The microgrid design approach and financial analysis task leveraged the requirements and technology evaluation to determine up to three microgrid design approaches that achieve differing degrees of the following capabilities:

1. Grid Reliability
2. Load Site Resiliency
3. Flexible Energy Economics

Business models were developed to provide both a technical and economic view of potential microgrid implementations for the service territory.

Key activities included:

- Translating business and operational requirements, as well as business and operational opportunities into up to three microgrid design approaches with requirements detailing the aspects of grid and customer integration.
- Creating system architecture documentation providing an overview of the hardware, software, networking, engineering, procurement, and other requirements of the system, along with information aligning the business drivers to their respective system components.
- Using the DER-CAM software platform to develop business models around the microgrid design approaches.
- Developing a concept-of-operations for various stakeholders, outlining how business drivers and the system architecture will be mapped against operational procedures, including evolutions tied to resource adjustments, and other key changes to operational procedures to ensure that grid operational plans align to achieve the strategy goals, timelines, risk profiles, and economic model.
- Documenting any major gaps, variances, or other potential issues related to anticipated plan deliverables vs. business/technical requirements.

Report Preparation and Presentation

This task involved the organization, compilation, and documentation of all research, as well as the evaluation of the Study results in coordination with the core stakeholders. Key activities will include:

1. Providing recommendations and potential paths for proceeding with future work.
2. Presenting findings through the submission of interim and final Study reports.

Research

This section summarizes research conducted in response to BPU requested dimensions pertaining to microgrid implementation and operation; microgrid technology; codes and standards; regulatory impacts; and financing.

Microgrid Implementation and Operational Environments

Given that environmental safety standards are not violated, and barring political barriers, the optimization decision for design, build, and operation of microgrid-based energy solutions will, in the long run, always be driven by raw efficiency metrics, specifically those being financial, operational, and asset utilization. These three efficiency dimensions apply to any solution, independent of its technology assets, funding source, or their configuration and ownership structures.

Having said that, and for the purposes of framing this Study, there are four potential microgrid configuration approaches being examined for effectiveness, complexity, cost, etc., to determine their feasibility. These are contrasted in the figure below.

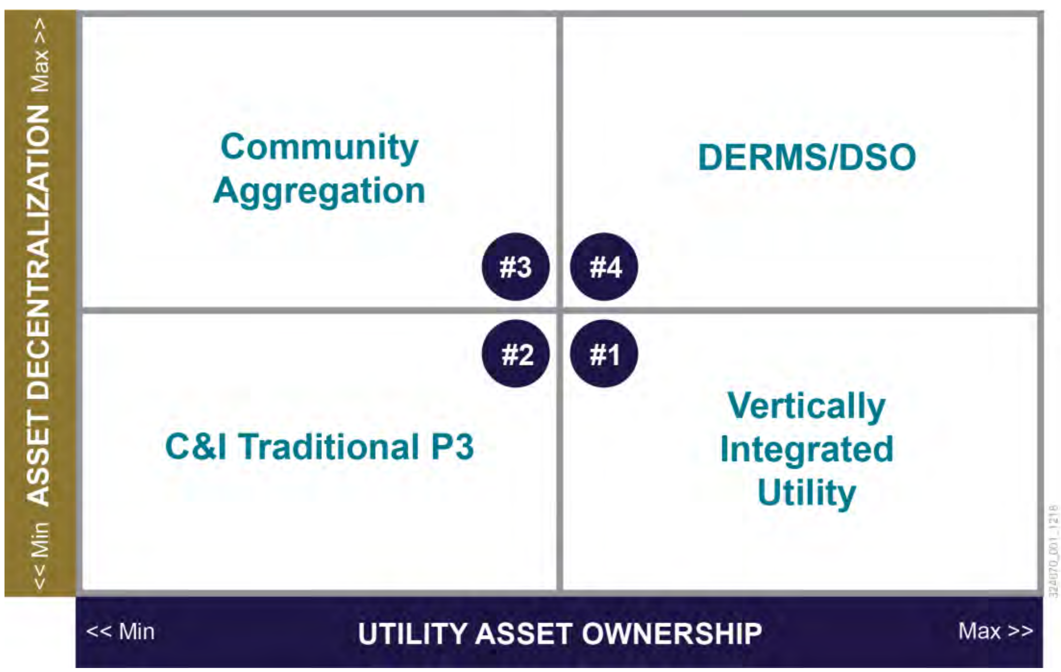


Figure 4. Four Potential Microgrid Configuration Approaches

Implementing any of the above within the context of an advanced microgrid brings challenges in maintaining the safe and reliable circuit operation that connects load to source and coincidentally allows islanding from the main utility distribution system when required for economic or emergency operation. The quadrant approach to classifying potential microgrid solutions allows for the consideration of impacts to the financing, implementation, ownership, and operation of the particular approach.

These comparative dimensions illustrate the possibilities for DER to be deployed as either highly distributed or more concentrated against a public vs. private asset ownership. The four balancing scenarios are described below to illustrate these specific arrangements. Specific examples are provided under each scenario, labeled as "'So What' for Middletown," in order to better convey practical implementation and operation as it might be realized within a Middletown TC DER microgrid, operating under the conditions described in Appendix A.

Appendix A is included to provide an explicit description of specific operating conditions that the microgrid will be facing, and this reference information should be used qualitatively within the Study to highlight certain capabilities or configuration impacts. The three conditions described represent storm disruption (grey sky), normal grid-connected operation (blue sky), and a future state of high DER penetration (green sky).

Any of these scenarios could be dynamically operated using either traditional "hard wire" direct control systems or by implementing "soft wired" transactive pricing signal response, which is explained further under the subheading "Innovation" later in this section.

Balancing Scenario #1: Vertically Integrated Utility – Rate Based

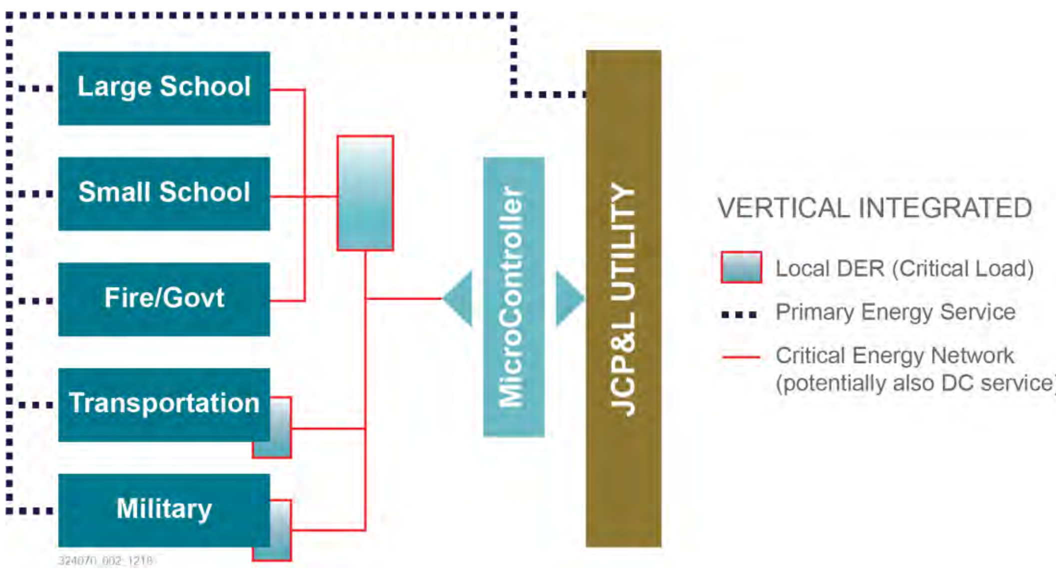


Figure 5. Scenario #1: Vertically Integrated Utility – Rate Based

This is a more traditional legacy approach that has been used by utilities in states which, unlike New Jersey, have not decoupled generation from distribution. The EDC, in this case JCP&L, would invest in, own, and operate a relatively large, likely thermal generation source that is located closer to the load centers described herein. Some utilities are experimenting with behind-the-meter (BTM) asset ownership as well. A very forward-looking approach being explored by Electric Power Research Institute, Inc. (EPRI) through public working groups is known as "DC as a Service" and might be utilized for this balancing scenario as well – particularly if there were large electric vehicle (EV) fast-charging loads associated. This recognizes the inherent value of economic scale, capital efficiency, and improved community resilience while also facing barriers of siting opposition and legality under current State law.

Were such an alternative legal under State regulatory policy, the solution would essentially be a reliability play through a "Non-Wires Alternative" for the utility that would defer more expensive long haul wires and distribution upgrades, and thus would offer net benefit for the ratepayer classes. The investments necessary to develop, connect, and control the local generation would be borne by the utility and passed on to the ratepayers through typical rate basing methods. Financial returns would accrue to the utility under traditional structures, timescales, and percentages based on capital employment.

"So what" for Middletown: Were such investments available under New Jersey law, the utility could rapidly deploy the necessary generation and control investments to deliver the community benefits under a microgrid model. The localized nature of the Middletown TC DER microgrid investments would pose an interesting context in that all utility ratepayers would bear the costs of investments that a highly locally targeted. The perception of one set of ratepayers subsidizing the benefits to another would be difficult to avoid, though this is not unlike other localized distribution system investments, albeit more expensive. Skepticism amongst the ranks of customers is likely to be a challenge for the utility to overcome in the process of public hearings and approval.

Balancing Scenario #2: Traditional C&I with P3 Structure

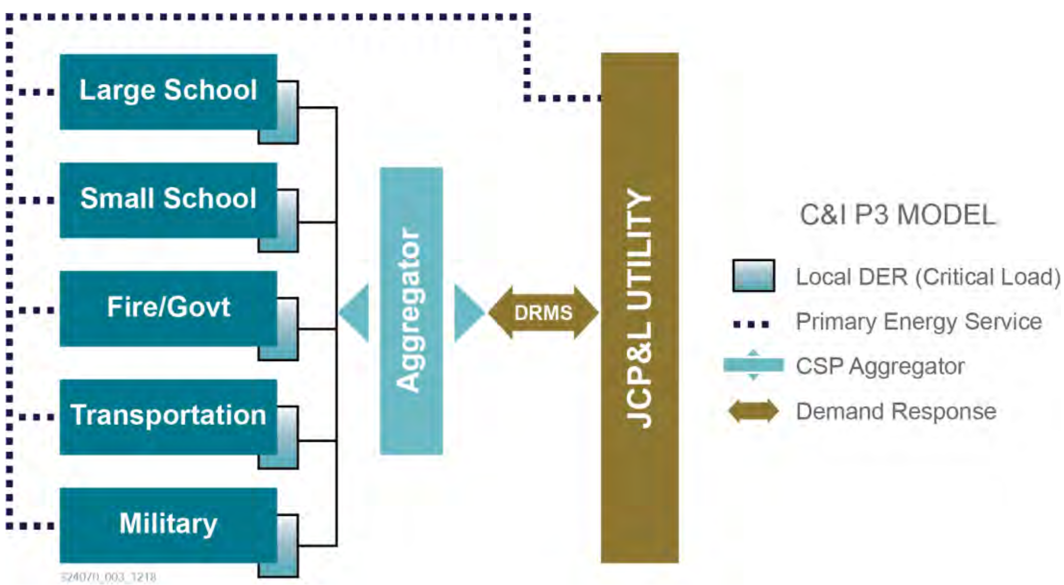


Figure 6. Scenario #2: Traditional C&I with P3 Structure

A large commercial or industrial (C&I) entity within a public-private partnership (P3) structure would invest in, own, and operate a relatively large, likely thermal generation source that is closer to the load centers described herein. A cogeneration option may be employed where suitable to utilize the heat and raise overall plant efficiency. This approach would be akin to a "campus microgrid" model where the financing, implementation, and ownership are centralized under a single private entity. The needs of a single participating site would be met, with the potential of including other sites based upon physical and electrical proximity within the distribution system.

This approach does not incur the legal limitations placed upon utility ownership of generation within the State of New Jersey. The business case necessary to attract such an investment from a large commercial entity would constitute a narrowly framed P3 scenario and the terms would need to be sufficiently beneficial to the investing party based upon their perception of operating risk and the benefits associated with improved reliability and resilience on a very specific scale. The returns on such an investment would likely be captured through a traditional power purchase agreement (PPA) with the EDC.

"So what" for Middletown: The outcomes of a microgrid investment in this scenario would have relatively limited benefit to Middletown or other JCP&L customers. The motivating needs and realized benefits from a campus microgrid are typically aligned with the interests of a single commercial or industrial consumer. The opportunity to leverage the benefits of the DER from such a scenario beyond the specific site would be highly dependent upon the ability to site the generation and interconnect it for use at other sites, as well as the opportunity for the investing party to capture these incremental returns. In a Town Center DER, or advanced microgrid scenario, investments of this type would not typically accrue benefits beyond those realized by the investing entity.

Balancing Scenario #3: Community Critical Load

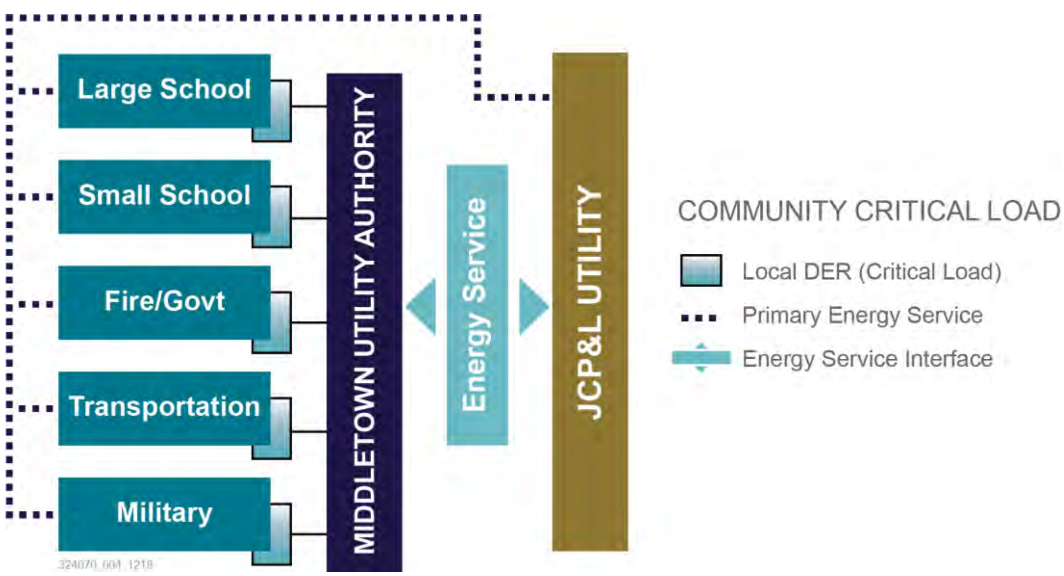


Figure 7. Scenario #3: Community Critical Load

This approach would place highly decentralized, premise-based, generation and storage that is either individually or collectively owned by the microgrid participants and enable these assets to provide economic utility service during normal grid paralleled operation (blue sky), while preserving islanding and full self-service (with graceful degradation) of the designated critical load at each premise during emergency conditions (grey sky). This form does not necessarily require a conductor wired coupling between the individual microgrid locations during islanded operation (i.e., the traditional campus microgrid) as the premise-based generation and storage would be sized to meet the minimum critical load and duration individually. An Energy Service interface would govern the coordination and economic signaling from JCP&L that would drive the operation of the aggregate "virtual microgrid."

DERs enable cleaner and more reliable local energy networks, and offer opportunity for communities to take more control of their power sourcing and consumption. The EDC still needs to maintain balance for the feeder circuits that are "hosting" this local production, so the DER operation must at least be monitored to identify the grid services that are needed precisely when and where they are needed. In the balanced Community Critical Load approach, therefore, the flexibility of the local generation and storage can be harnessed into a valuable grid service during blue sky operation.

"So what" for Middletown: An example of this operational scenario could be the Township of Middletown forming an Energy Service Cooperative that would commission a third-party designed and built local generation network embedding the recommended mix of local photovoltaic (PV), gas generation, and battery storage assets to each participant site within the community. The local generation would be sized to normally serve the designated critical load. The cooperative would then have the ability to aggregate and coordinate the local generation and storage for achieving optimal efficiency, while allowing islanding and self-sufficiency of each site for emergency or economic reasons.

Balancing Scenario #4: DSO/DERMS

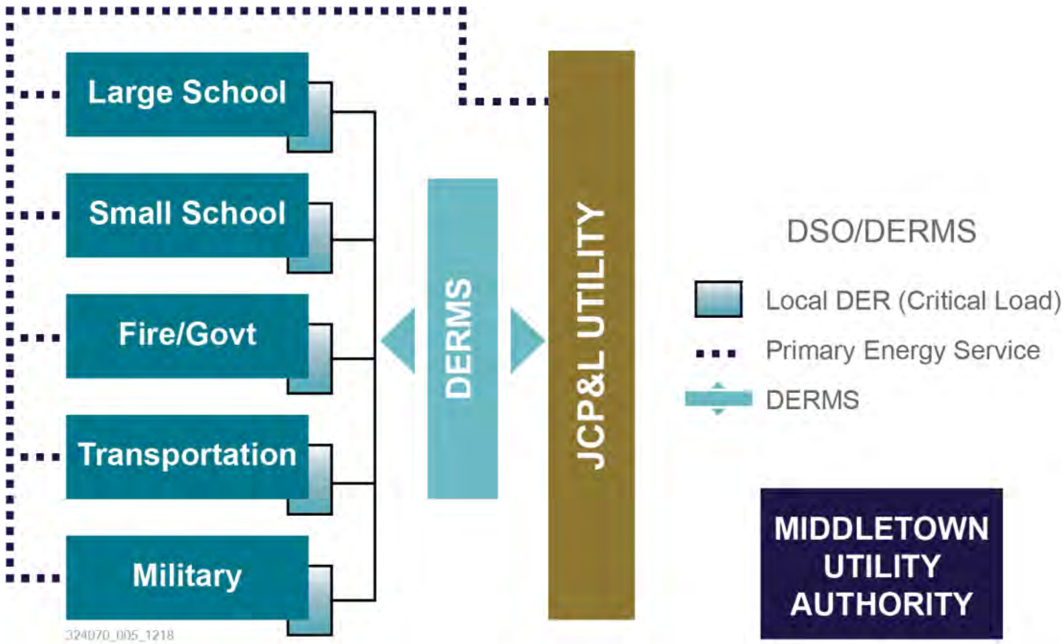


Figure 8. Scenario #4: DSO/DERMS

The EDC, in this case, JCP&L, would invest in, own, and operate a highly disaggregated virtual power plant (VPP) that is enabled through on-premise DER. There are several emerging models demonstrating the feasibility of this, particularly through the aggregation of energy storage assets in jurisdictions where vertically integrated utility generation ownership and operation is allowed. This scenario would capitalize on the systems that the utility needs to invest in for continued reliable balancing of the distribution grid, as well as their increasingly defined role as the Distribution System Operator (DSO) – providing network services to a *variety* of prosumer-operated DER connected through the grid edge wiring.

The platforms for achieving this orchestration encompass both VPPs and distributed energy resource management systems (DERMS). Although the utility would own and operate significant infrastructure needed to create the virtual aggregation, some of the individual DERs could still be privately owned and interconnect with the system operating under defined control strategies as coordinated by the DERMS.

"So what" for Middletown: An example of this operational scenario could be JCP&L implementing its management system and building a local generation network embedding the recommended mix of local PV, gas generation, and battery storage assets to each participant site within the community. The local generation would be sized to normally serve the designated critical load. A local authority would then have the ability to aggregate and coordinate the local generation and storage for achieving optimal efficiency, while allowing islanding and self-sufficiency of each site for emergency or economic reasons.

Microgrid Technology

The following discussion provides an overview of the technology alternatives pertaining to generation, storage, and controls, and the innovation and limitations applicable to each of these in the context of a microgrid application. Appendix B provides illustrations of representative technologies, using examples of actual commercial products or concept diagrams, in order to provide a visual depiction which corresponds to the descriptions within this section.

Generation

Electric power generation may be produced from both exhaustible and renewable “fuel” sources. Within the State of New Jersey the following classification furthermore applies to the underlying renewable energy technologies that generate the energy:

"**Class I** renewable energy" means electric energy produced from solar technologies, PV technologies, wind energy, fuel cells, geothermal technologies, wave or tidal action, and methane gas from landfills or a biomass facility, provided that the biomass is cultivated and harvested in a sustainable manner;

"**Class II** renewable energy" means electric energy produced at a resource recovery facility or hydropower facility, provided that such facility is located where retail competition is permitted and provided further that the Commissioner of Environmental Protection has determined that such facility meets the highest environmental standards and minimizes any impacts to the environment and local communities.

Within the context of powering the microgrid, these generation sources may be of relatively larger nameplate capacity and concentrated within specific designated sites, or relatively smaller and more highly distributed at the local facilities.

Energy storage technology is increasingly utilized in conjunction with these generation technologies in order to improve the asset utilization factor and the resilience contribution to the overall system. The technical domain for energy storage is discussed later in this section of the Study.

In the residential sector, common distributed generation systems include:

- Solar PV panels
- Small wind turbines
- Natural-gas-fired fuel cells
- Emergency backup generators, usually fueled by gasoline or diesel fuel

In the larger commercial and industrial sectors, distributed generation can include resources such as:

- Combined heat and power (CHP) systems, gas-fired
- Fuel cells fired by natural gas or biomass

- Wind turbines
- Hydropower
- Biomass combustion or co-firing
- Municipal solid waste incineration
- Reciprocating combustion engines driving emergency backup generators, which may be fueled by oil or natural gas
- Energy storage systems
- Small-scale nuclear

The following table summarizes electric power generation technologies.

Table 1.
Electric Power Generation Technologies

Generation Type	Sub Type	Notable Characteristics	Comment/Applicability for this Location
Solar PV Panels	Residential/ Commercial	• Highly scalable • Maximum resource dispersion • Moderate per-kW installation cost (and falling) • Long asset life • Minimal maintenance cost • Ease of financing • No fuel cost	Highly feasible for school and other rooftops or ground mount where appropriate, including parking canopies
	Utility Scale	• Lowest per-kW cost • Highly scalable • Limited resource dispersion	Feasible for limited parts of the NWS Earle property and potentially TOMSA
Natural Gas Generation	Emergency Standby Power (ESP) or (Non) Emergency Generator	• Spark ignited gensets generally yield low thermal efficiency • Tier IV classification can run clean but still produce CO_2 • Higher capital and operating cost than solar PV, but dispatchable with fuel security • Environmental impact, restricted to limited geographies	Feasible for replacing large current diesel gensets at TOMSA, North High School Smaller units recommended at all facilities in conjunction with energy storage
	Fuel Cell	• Very flexible for small amounts of local power; high resource dispersion potential with 200 kW incremental sizing • Higher capital cost than basic generator, but dispatchable with fuel security • Lower environmental impact, quiet, more flexible siting options	https://www.bloomenergy.com/sites/default/files/bloom-energy-microgrid-overview.pdf This technology is not recommended for consideration due to high initial cost Cost offset potential exists with the use of incentive funds from various sources with BPU approval
	Cogeneration	• Utilizes combustion waste heat for building or process thermal services • Requires expensive retrofit for heat district piping	With possible exception of TOMSA, not suitable for adaptive retrofit at facilities due to lack of heat demand and cost of infrastructure
Solar Thermal	Steam Turbine Generation	• Potentially large capacities but tied to large generation plant footprint • High capital cost, limited geographies • Minimal resource dispersion	Unfeasible for location due to seasonal variation, siting restrictions

Generation Type	Sub Type	Notable Characteristics	Comment/Applicability for this Location
Wind	Onshore	• Relatively low per-kW capital costs • Low operating costs • No fuel costs • Extremely limited resource dispersion	Not suitable at most participant sites due to siting limitations
	Offshore	• High capital cost • Low operating costs • No fuel costs	Not Suitable Offshore wind will be large capacity wholesale
Geothermal		• Reasonably efficient source, with minimal operating costs • High capital cost • Significant development/siting costs • No fuel cost	Not Suitable – except perhaps for the newly constructed municipal complex Cost effectiveness will require specific locational analysis
Small Modular Nuclear		• Potentially large capacities with moderate operating costs • High capital cost, environmental/siting impact • Extremely limited dispersion	Not Suitable Extremely immature technology that faces very long adoption cycles http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx
Hydropower	Large	• Potentially large capacities • High capital cost, environmental impact, limited geographies • Very low operating costs	Not Suitable
	Microturbine	• Very flexible for small amounts of local power • Difficult geographic siting	Not Suitable
	Tidal	• Potential large amounts of consistent power • Very immature technology • Difficult geographic siting	Not Suitable, although NWS Earle might offer an ideal location for experimental research and development (R&D) in the future

Storage

There are a diverse set of alternate technology choices for storing and releasing energy which all feature strengths and weaknesses in terms of their elemental functional characteristics. Relative to interaction with the microgrid system, the conventional terms of power *supply* and power *withdrawal* will be substituted for discharge and charge. When paired with other generation within a microgrid, energy storage has the potential to firm a variable renewable generation source, cover for temporary planned and unplanned maintenance events, and improve the overall efficiency and effectiveness of the microgrid. Specific application of energy storage requires certain level of control *system integration*. Although technological innovation continues to rapidly advance, and combinations of these elements may be designed to optimize performance at the system level, there are basic elemental characteristics are generally understood as rough comparative descriptors. This is shown the following table.

A more comprehensive and fuller comparison must take into account system-level packaging differences along with the following elemental characteristics.

Table 2. Elemental Characteristics of Technology Choices

Physical Configuration	**Electrical Characteristics**
• Energy density (kWh per in^3) • Volumetric efficiency • Form factor flexibility • Toxic/hazard/environmental impact	• C Rate (ratio of power transfer capacity to energy/duration) • Charge/discharge round trip efficiency
System Performance	**Cost Metrics**
• Life cycle • Application range of selected technology • Operating stability and precision • Thermal resistive operating profile • Nominal state of charge • Other	• Up front capital cost per kWh capacity • Operating cost per kWh • Forward pricing curve • Capacity replenishment requirements

A generally accepted categorization of the energy storage by underlying physical mechanism is shown in the following diagram.

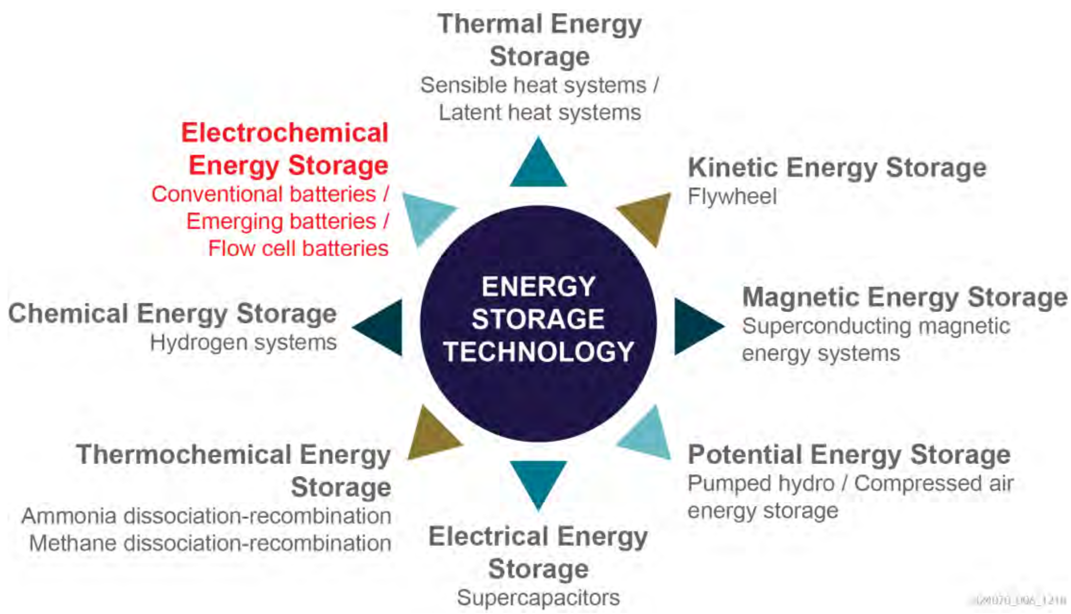


Figure 9. Categorization of Energy Storage

The following table summarizes energy storage technologies.

Table 3.
Energy Storage Technologies

Storage Type	Sub Type	Notable Characteristics	Example/Comment
Electro-chemical	Conventional Batteries	• Moderate to high power transfer rates but for relatively short duration (< 6 hours) • Highly scalable and modular for strong resource dispersion • Capacity degradation must be considered in application design • Potential hazardous material may restrict available installation locations	Lithium-ion, NiCd, NiMH, lead-acid, advanced lead (carbon)
	Flow Batteries	• Moderate power transfer rates • Suitable for long duration storage (2–12 hours) • Easily scalable capacity at the system level • Minimal resource dispersion (requires concentration) • Chemical containment requirements need to be considered • Early in commercialization process	Redox, Vanadium, Zn bromide

Storage Type	Sub Type	Notable Characteristics	Example/Comment
Electrostatic	Ultra-Capacitor	• Extremely high power transfer rates • Potentially deep duty cycle and long lifetime • Rapidly evolving technology that is used in hybrid storage systems • Energy and power based on international standard IEC 62391-2	Harvest power from regenerative braking systems and release power to help hybrid buses accelerate. Provide energy storage for firming the output of renewable installations and increasing grid www.maxwell.com/products/ultracapacitors http://www.zapgo.com
Thermal	Hot Water Heater	• Moderate power transfer rates – power withdrawal *only* • Highly scalable and modular, with maximum resource dispersion • High efficiency • Long cycle life	Thermal storage relies on a vessel (liquid) or structure (solid) where excess combustion heat or surplus grid electric power through resistance may be stored for later drawdown to offset future building or process heating load. Explanation: https://www.researchgate.net/figure/Hot-water-thermal-energy-storage_fig6_272179312
	Ice Storage	• Moderate power transfer rates – power withdrawal *only* • Highly scalable and modular, with good resource dispersion • 60%–70% efficient • Long cycle life	During off-peak hours, ice is made and stored inside energy storage tanks. The stored ice is then used to cool the building occupants the next day. https://www.ice-energy.com/ http://www.calmac.com/how-energy-storage-works

Storage Type	Sub Type	Notable Characteristics	Example/Comment
Mechanical (Static)	Pumped Hydro	• Potentially large capacities with low operating costs • Suitable for very long duration storage (>8 hours) • Very high capital cost, limited geographic applicability • Can be emissions-heavy based on pump motor energy source • Long cycle life	Not suitable for geography of contemplated project
	Mechanical Weight	• Potentially large capacity • Highly scalable but extreme lack of resource dispersion • High round-trip efficiency • Long cycle life	Explanation and Sample Vendor Solution: https://qz.com/1355672/stacking-concrete-blocks-is-a-surprisingly-efficient-way-to-store-energy/ Not suitable for geography of contemplated project
	Compressed Gas	• High capital cost • Expensive to develop/site • Low efficiency • Appropriate for long duration storage	Not appropriate for a project of this size
Mechanical (Kinetic)	Flywheels	• Potentially large capacity • Highly modular and scalable with moderate resource dispersion • Lower round-trip efficiency than electrochemical products • Long cycle life • Suitable for shorter discharge duration applications	http://beaconpower.com/modular-design/
Chemical Fuel	Hydrogen	• Alkaline electrolysis is a mature technology for large systems, whereas PEM (Proton Exchange Membrane) electrolyzers are more flexible and can be used for small decentralized solutions • The conversion efficiency for both technologies is about 65%–70% (lower heating value); round-trip efficiency back to electric production is very low (~40%) • Some development occurring using nanotechnology for higher energy storage densities	Small-scale vessel storage of compressed hydrogen would be the most likely use for this application, but generally this technology is not sufficiently mature or cost effective for this program.

The following graphic depicts the typical application space of various energy storage technologies. In this view, discharge time and scale are plotted against one another. With this perspective, the value of energy management can be more readily compared.

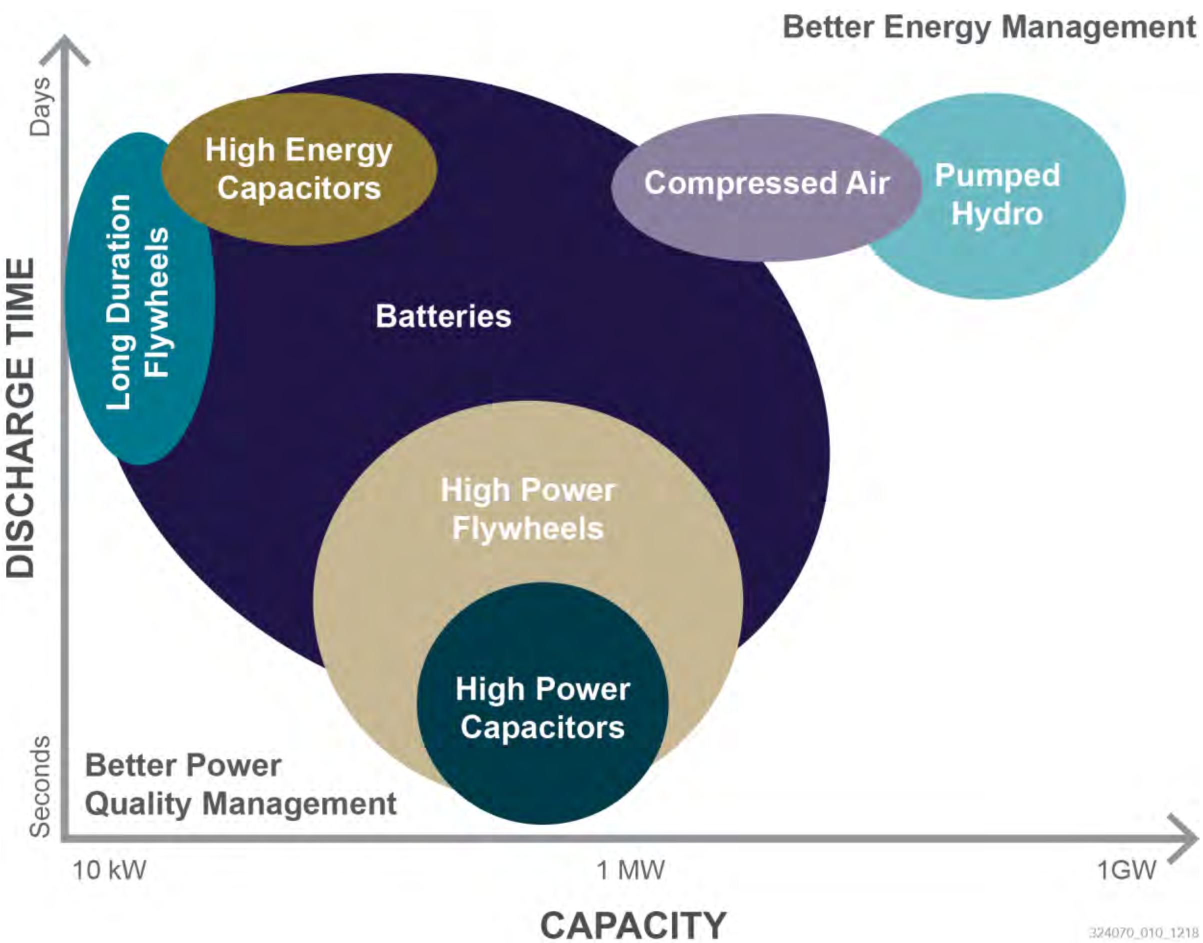


Figure 10. Discharge Time and Scale of Energy Storage Technologies

Controls

The microcontroller is the heart of the microgrid system and is responsible for energy management that includes the control functions defining the microgrid as a system that can manage itself, operate autonomously (islanded) or grid connected, and seamlessly connect to and disconnect from the main distribution grid for the exchange of power and the supply of ancillary services. The Institute of Electrical and Electronics Engineers (IEEE) 2030.7 standard has been developed and is currently active to define the functions above the component control level associated with the proper operation of the Micro-Electro-Mechanical Systems (MEMS) that are common to all microgrids, regardless of topology, configuration, or jurisdiction. Below is a pictorial representation of a microgrid segment that features several of the generation and storage elements described above, with the representative microcontroller that provides these management functions.

The key microcontroller functions are:

- Energy supply and demand balancing
- DER asset registration and authentication
- Network security establishment
- Operating performance monitoring and boundary enforcement
- Primary connection state management (in compliance with IEEE 1547)

The underlying IEEE 1547 interconnection standard governs the compliant operation of power inverters that are tied to the electric grid. The latest release of this standard addresses the communication protocols and remote monitoring and control options that allow for modifying the generation profile of connected power sources.

Control Systems and Sensors

A primary innovation coming from the industrial controls segment is the rapid advancement of IIoT (Industrial Internet of Things). These provide important (and increasingly near real time) sensing and monitoring instrument data that is critical to understanding the grid state and therefore the issue of control/balancing signals. These IIoT devices are also increasingly capable of receiving and executing control instructions.

These sensors are being rapidly incorporated within a variety of long-standing building energy management systems (BEMS) provided by traditional controls vendors such as Honeywell, Siemens, ABB, and others. New entrants to this solution space include some of the consumer electronics giants like Google and Apple, bringing even more advanced control technology such as artificial intelligence (AI), edge computing power, and standardized communication protocols. The capabilities to harness these building-centric innovations is being developed through equally advanced management systems collectively known as DERMS that are being adopted by utilities as part of their grid control platforms.

From the Center Out: The Smart Electric Power Alliance (SEPA) has facilitated an industry-led initiative to identify and define the requirements for a DERMS. This will define requirements of a standard DERMS interface and how it should be configured, parameters for control, establishing business rules, managing constraints, information technology (IT) requirements, integration requirements, cybersecurity requirements, maintainability, and more. As a result of this initiative, and with the advancement of several leading control solution vendor platforms, the utility sector is beginning to deploy these systems which provide for a common approach to monitoring and management of a proliferating set of DER assets tied to the distribution system.

From the Edge In: Increasingly, advances within edge computing are leveraging the ubiquity of data that is being provided by distributed sensors connected into a network fabric. These IIoT these data streams are also increasingly being carried within standard protocols that permit integration of disparate systems through a “cloud connection.” Lastly, the use of blockchain distributed ledger technology is permitting a cyber secure method for allowing participation by non-traditional prosumers and third-party aggregators.

Innovation

Transactive Energy

Lastly, there is another dimension of operational innovation that can be applied (at least in part, and to greater or lesser extent) over three of the four configuration scenarios described above: known as *transactive energy*. The primary aspect of this innovation is the allowance of private asset investment in the DER resources, assurance of its full interconnection safety and security certification, and the commitment and operation of the resource as part of a compensated arrangement that is cleared within a *market* construct.

Technologies that are enabling transactive control include:

- **IIoT,** which permits granular sensing and control functionality, enabling verification and compensation mechanisms.
- **AI and machine learning,** which allow for continual optimizing and behavior prediction within control loops to drive system stability.
- **Advanced communication networks (5G),** which remove latency and cost from high-volume data processing.
- **Blockchain distributed ledger,** which permits trusted and secure transaction clearing without a central authority.
- Adoption by utilities of **advanced metering infrastructure (AMI)** and **grid management systems (DERMS).**

Regulations and policies that are enabling transactive control include:

- Move toward an AMI interval metering infrastructure
- Relaxation of regulatory restrictions on local power generation and storage
- Drive toward transforming EDC roles into more Distribution System Operator roles that earn on their energy transfer and DER hosting services.

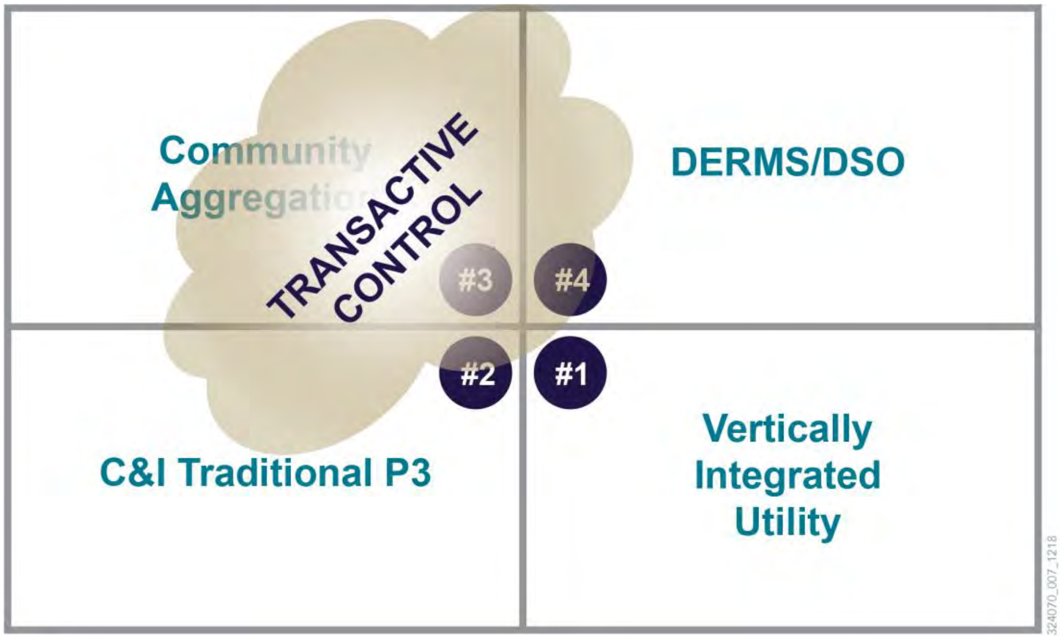


Figure 11. Conceptual Weighted Applicable Areas of Transactive Energy Control

The transactive operation of these microgrid systems would require that some authorized entity take the role of market creation and management so that accurate price signals are available to the DER owner (or their aggregation agent) at the point of common coupling (PCC) to the distribution grid. Although potentially useful as an internal control technique within a vertically integrated utility **(Case #1)**, this is unlikely as the utility would simply "hard wire" using legacy vendor solutions that manage end-to-end control for optimizing traditional economic and reliability metrics. Therefore, in practical terms there are three remaining scenarios to which transactive energy control schemes could apply.

Case #4 offers more opportunity for the progressive utility that is adopting a DERMS system and moving into a role of the Distribution System Operator, and allows a new class of customer services to be offered by the utility. Transactions here can be implemented through the DERMS as it generates the pricing signals for needed grid services, and also validates the response and clearing the compensation to close the transaction. Although this scenario involves a higher level of utility ownership for some of the DER assets and control infrastructure, incremental generation may still be acquired (or leased) through private investment to avoid additional capital expense being placed on general ratepayers.

Case #2 opens up a vibrant financial basis to encourage more commercial investment through public-private partnerships, as the access to incremental revenue streams will improve the risk profile for the investors. Transactions here could still be implemented through the utility DSO generating the pricing signals for needed grid services while minimizing the utility ownership of much of the DER assets and control infrastructure. The DSO utility simply deploys and manages the "hosting network" which creates access for these private assets to participate in the market. Ratepayer costs are minimized while network participants achieve a fair risk/reward profile.

Case #3 provides the foundation for true distributed energy peer-to-peer trading networks, although it correspondingly imparts the highest degree of legacy utility disintermediation. Transactions here can be triggered by the locational marginal pricing (LMP) signals for energy as obtained from grid operators, as well as for needed grid services to maintain balanced generation and load. This scenario involves minimal utility ownership and operational control over a highly disaggregated DER asset mix and leaves the control function to nimble aggregators who maintain optimal asset utilization. Again, there is a restructuring of the risk/reward profile to level the playing field and allow optimal participation in the local community energy network.

To summarize, the applicability of transactive energy methods is presented here as an overlay to consider how the new Middletown TC DER microgrid structure may be operated using market pricing signals as opposed to conventional command and control means. The technique is being explored in many research labs, and is beginning its commercial deployment in limited areas around the world.

Below are two reference examples of solutions that are being utilized for developing and building optimized microgrids. The IES solution is software-based and allows accurate modeling of grid and facility details with impact assessment for various levels and positions of deployed DER into the community energy system. Detailed models and simulations were run for densely populated areas within Scotland and other parts of the United Kingdom. The PXiSE solution is an outgrowth from a San Diego Gas & Electric providing real-world design and operational management integration capabilities leading toward standards-based microgrid implementation.

CASE STUDY: IES	**CASE STUDY: PXiSE**
Integrated Environmental Solutions (IES) developed an Intelligent Virtual Network (iVN) mapping and analysis tool capable of modeling electrical distribution networks of a community, with the inclusion of all energy consumers and producers on that network. The iVN can create a model of a community in its existing state, and analyze the impact that various scenarios (addition of EVs, PV, wind, etc.) would have on the overall community in terms of impact to the grid, as well as the welfare of the individual members within the community. This enables the iVN to be used as a decision making tool, helping to determine optimum scenarios at both building level and community level. The iVN can also be used to forecast both demand and generation, enabling the prosumer or community to engage in energy trading. KEY FINDINGS FROM TEST APPLICATION ON SCOTTISH COMMUNITIES (Eday, Glasgow, Penilee) • Community battery more financially viable than domestic storage • EVs in place of traditional petrol/diesel • Vehicles can reduce transport running costs by up to 30% • Flexible appliance can reduce peak load by 10% in the home • Addition of renewable assets and flexibility increases trading potential ***Link:*** *http://www.iesve.com/*	The PXiSE Active Control Technology (ACT) is a development of Sempra Energy via its majority-owned subsidiary PXiSE Energy Solutions, LLC (Mitsui and Co., Ltd. is minority owner) and has been deployed at a Napa Valley winery and a corporate office building in downtown San Diego, California, along with utility-scale renewables sites and a Hawaiian renewables plus storage site. It's also being deployed in Australia as part of the PXiSE DERMS solution for Horizon Power in Western Australia. It works with any mix of energy resources and empowers microgrids of all sizes to quickly and easily adapt to changing conditions. Designed to handle complex microgrid operations: • Operates at 50Hz to 60Hz, depending on grid frequency • Over 400 protocols, allowing for integration with any mix of technology and infrastructure • Blinkless disconnect and connect for complete stability, even in the event of an outage (IEEE 2030.7 compliant) • Deploys in weeks, not months • Scales to meet the needs of each individual microgrid now and in the future • Maintains a stable grid using energy storage in coordination with other energy resources ***Link:*** http://www.pxise.com/wp-content/uploads/2018/09/SempraPXiSE_AdvMicroGrid09.20.2018_v2.pdf

Codes and Standards

As articulated in the New Jersey Board of Public Utilities Microgrid Report, dated November 30, 2016, the following statutes and regulations bear upon the status of microgrids in New Jersey. The inventory of impactful standards drawn from this earlier report forms a sound basis against which to offer comments on the impact of regulations of the feasibility of a microgrid for Middletown.

The State of New Jersey has just commenced the development of a revised energy master plan (EMP) to be completed and released in 2019. The opportunity for input to the updated plan has recently commenced. Impacts to microgrid development opportunities under the new EMP are likely to be significant and are, as yet, undetermined

New Jersey Statutes Applicable to Microgrids

Title 48 in the New Jersey statute does not specifically define a microgrid or DER. Key provisions in the amendments of the Electric Discount and Energy Competition Act (EDECA) N.J.S.A. 48:3-51 et seq., relate to microgrids. These provisions are contained in Appendix A [of the 2016 Microgrid Report]*. There is a limited definition of DG in EDECA related to the Standby Charge Review Law and the net metering regulations at N.J.A.C. 14:8-4.1.*

The key provisions in EDECA as they relate to microgrids are summarized as follows:

N.J.S.A. 48:3-51 - Definitions

Off-site end use thermal energy services customer

"Off-site end use thermal energy services customer" means an end use customer that purchases thermal energy services from an on-site generation facility, combined heat and power facility, or co-generation facility, and that is located on property that is separated from the property on which the on-site generation facility, combined heat and power facility, or co-generation facility is located by more than one easement, public thoroughfare, or transportation or utility-owned right-of-way.

Impact: This definition is potentially relevant, though unlikely to be so, within the context of the proposed microgrid for Middletown. In the context of anticipated reliability needs, off-site generation poses risks, costs, and burdens associated with new or existing power distribution infrastructure.

On-site generation facility

"On-site generation facility" means a generation facility, including, but not limited to, a generation facility that produces Class I or Class II renewable energy, and equipment and services appurtenant to electric sales by such facility to the end use customer located on the

property or on property contiguous to the property on which the end user is located. An on-site generation facility shall not be considered a public utility. The property of the end use customer and the property on which the on-site generation facility is located shall be considered contiguous if they are geographically located next to each other, but may be otherwise separated by an easement, public thoroughfare, transportation or utility-owned right-of-way, or if the end use customer is purchasing thermal energy services produced by the on-site generation facility, for use for heating or cooling, or both, regardless of whether the customer is located on property that is separated from the property on which the on-site generation facility is located by more than one easement, public thoroughfare, or transportation or utility-owned right-of-way.

Impact: This definition is relevant to the proposed microgrid for Middletown. Each participating site is expected to require a unique mix of generation and storage to meet reliability assumptions. In order to minimize risk and cost, on-site generation is likely to be a preferred approach.

Class I Renewable Energy

"Class I renewable energy" means as electric energy produced from solar technologies, photovoltaic technologies, wind energy, fuel cells, geothermal technologies, wave or tidal action, small scale hydropower facilities with a capacity of three megawatts or less and put into service after July 27, 2012, and methane gas from landfills or a biomass facility, provided that the biomass is cultivated and harvested in a sustainable manner.

Impact: This definition is relevant to the proposed microgrid for Middletown. A generation mix including Class I renewable energy, as defined, is anticipated for the majority of the participating sites.

Class II Renewable Energy

"Class II renewable energy" means electric energy produced at a hydropower facility with a capacity of greater than three megawatts or a resource recovery facility, provided that such facility is located where retail competition is permitted and provided further that the Commissioner of Environmental Protection has determined that such facility meets the highest environmental standards and minimizes any impacts to the environment and local communities.

Impact: This definition is not relevant to the proposed microgrid for Middletown. No Class II renewable energy resources are anticipated.

N.J.S.A. 48:3-77.1

Utilization of locally franchised public utility electric distribution infrastructure

In order to avoid duplication of existing public utility electric distribution infrastructure, and to maximize economic efficiency and electrical safety, delivery of electric power from an on-site generation facility to an off-site end use thermal energy services customer as defined in section 3 of P.L.1999, c.23 (N.J.S.A. 48:3-51), shall utilize the existing locally franchised public utility electric distribution infrastructure. The New Jersey electric public utility having franchise rights to provide electric delivery services within the municipality shall provide electric delivery services at the standard prevailing tariff rate that is normally applicable to the individual off-site end use thermal energy services customer.

Impact: This statute has the potential to impact the proposed microgrid for Middletown. While the goal of this Study and eventual design for the microgrid seeks to minimize the risk and cost of relying upon existing electrical distribution infrastructure, the potential exists for such a reliance to be incorporated as a part of the final design. For the purposes of this Study, while explored as an alternative, the recommended design will not require the use of existing utility distribution infrastructure.

N.J.S.A. 48:2-21.37

Distributed Generation (DG)

"Distributed Generation" means energy generated from a district energy system or a combined heat and power (CHP) as that term is defined in section 3 of P.L.1999, c. 23 (C.48:3-51), the simultaneous production in one facility of electric power and other forms of useful energy such as heating or process steam, and energy generated from other forms of clean energy efficient generation systems.

Impact: This definition is unlikely to be relevant to the proposed microgrid for Middletown. Thermal offtake from local generation was not considered as a requirement. For the purposes of this Study, distributed generation was taken to include all forms of locally sited generation including natural gas and photovoltaic.

New Jersey Examples of the On-Site Statute Provisions

Currently [as of the November 2016 BPU Microgrid Report]*, there are thirty-eight (38) level 1 microgrids and twelve (12) level 2 microgrids operating in New Jersey. There are no advanced microgrids or level 3 microgrids that provide electricity to multiple customers across multiple ROW. The Trenton District Energy Company facility and the Atlantic City Mid-Town Thermal*

Energy facility are defined as on-site generators that provide thermal energy to multiple commercial customers and cross multiple rights of ways (ROW). The customers of these on-site generators are defined as off-site end use thermal energy service customers. These districts thermal energy on-site facilities are not classified as advanced microgrids, because the USDOE definition of an advanced microgrid, noted in Section 2 [of the Microgrid Report]*, focuses on electrical boundaries and electric loads interconnected with DER. The BPU, as set forth in N.J.S.A. 48:3-51 does not regulate an onsite thermal facility that has multiple off-site end use thermal energy service commercial and industrial customers that cross multiple ROW as a public utility.*

Several advanced microgrid projects are in the process of being developed, including the New Jersey Transit Grid and Hoboken Microgrid. These projects are working in partnership with BPU and other agencies to evaluate how these provisions will be implemented within an advanced microgrid.

As currently set forth in N.J.S.A. 48:3-51 and 48:3-77.1, a district thermal energy facility that expands to supply electric service, or an advanced microgrid, can only serve the on-site electric end-use customer that is geographically contiguous and only cross one ROW. To connect multiple electric commercial customers that cross multiple ROW, the expanded district thermal energy facility, or advanced microgrid, must use the existing electric distribution system. Several level 2 campus wide microgrids, which were developed prior to the amendments in N.J.S.A 48:3-77.1, cross multiple public ROWs that transect their campus.

Impact: This discussion is relevant to the proposed microgrid for Middletown. The proposed design is unlikely to require the supply of electric service beyond the needs of the participating site; therefore, the definition of the resulting project may not meet the strict terms of a level 3 system where power is delivered from a single generation source to multiple sites across multiple rights of way. In the case of the Middletown system, reliance on extended distribution infrastructure is seen as a risk to operation and reliability, and therefore has been avoided. This does not take into account the need for coordination and control of the various participating sites or the opportunity for local distribution energy market concepts to be applied in the oversight and operation of a distributed, virtual microgrid.

Issues with the Existing On-Site Statutes Related to Enhanced Reliability and Resiliency of Advanced Microgrids

As noted…in Section 1 [of the Microgrid Report]*, it was the above ground existing distribution grid that failed after Sandy and other major storms. They fail because wind, trees or flooding take down above ground power lines and utilities poles. The majority of the electric distribution and transmission grid system is above ground. One response to this failure is to strengthen the utility poles and implement vegetation management which is on-going in the State.*

An option to address this failure is to underground all utility services but that option is not cost effective and presents other operation difficulties. Undergrounding of the distribution system is a potential solution to grid outages which is raised in every state after every statewide emergency. Undergrounding electric system wires is extremely costly. Recent reports by Florida, North Carolina, Oklahoma, Virginia and Maryland did not find undergrounding wires was not cost efficient, and did not recommend it as an option to respond to recent system-wide grid power outages caused by severe weather. A recent Edison Electric Institute study found the cost for overhead lines was between $136,000 to $197,000 per mile, and the cost for undergrounding wires was at a range of $409,000 to $559,000 per mile without the same level of benefits. (http://www.eei.org/issuesandpolicy/electricreliability/undergrounding/documents/undergroundreport.pdf)

While EDCs may underground some critical customers, the transmission and distribution infrastructure would remain exposed to extreme weather. An option that could address this issue is to connect critical customers in an advanced microgrid to provide emergency power in an effective manner with utilities underground connecting multiple critical customers. However, N.J.S.A. 48:3-77.1 requires multiple electric commercial customers that cross multiple ROW that want to be served by an on-site generated must connect to the existing electric distribution system because of economic efficiency.

The provisions in N.J.S.A. 48:3-77.1 do not address the need for improvement and advancement of resiliency and reliability given that the majority of the distribution grid system is above ground.

Some of the current level 2 or campus-wide microgrids are able to provide emergency services to their buildings during the grid outage. The eight New Jersey Campus microgrids found undergrounding to be cost effective in their CHP projects due to underground construction of the thermal pipes. Adding in the electric wire does not substantively increase this cost. It was the below ground pipes and wires of the level 2 or campus-wide microgrids that allowed for isolation from the distribution grid and the continuation of both thermal energy and electricity to their on-site buildings.

Below is a summary of a survey performed by the USDOE National Renewable Energy Lab (NREL) for the State as part of the HMGP Energy Allocation Initiative and Lifeline funding grants. The HMGP Energy Allocation Initiative and Lifeline grants were available to local and state governments to assist in the procurement of alternate energy systems or emergency back-up/standby generators. There were over 500 grantees that responded to the survey.

One of the questions NREL asked was which energy sources failed after Superstorm Sandy. The below survey data documents that the underground natural gas distribution system had less outages and failures than diesel.

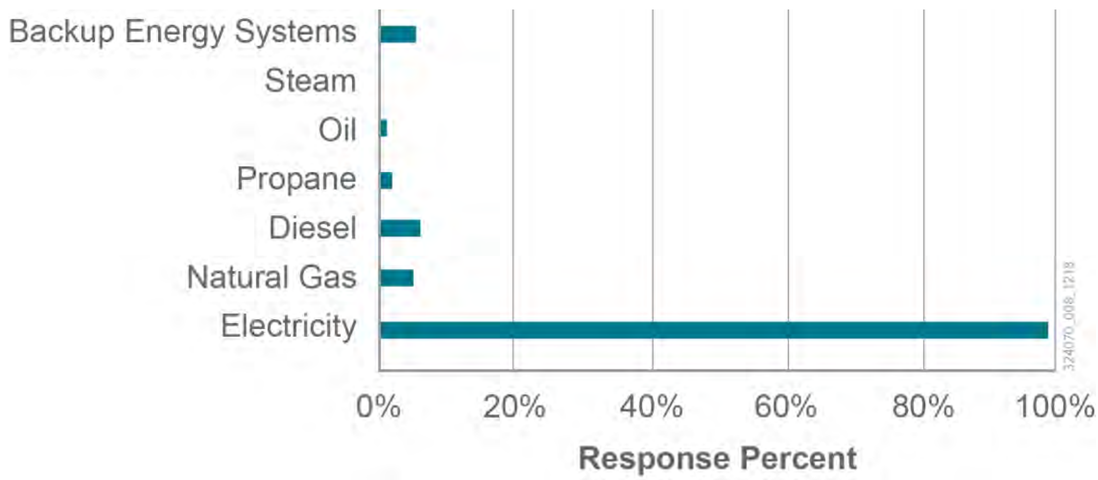


Figure 12. Energy Source Failures

Source: NREL (https://www.nrel.gov/docs/fy14osti/60631.pdf)

Impact: This discussion is relevant to the proposed microgrid for Middletown. As noted in prior impact summaries, the cost and risk associated with the enhancement and use of existing electrical distribution infrastructure is neither desirable, nor conducive to meeting the reliability objectives of the participating sites. Also, natural gas energy sources offer higher reliability than alternative local generation options during an emergency. This is a fact to be taken into account when specifying proposed local generation mix for microgrid participating sites.

Other Codes and Regulations Related to Microgrids

There are several other requirements, regulations, standards and codes related to the development of advanced microgrids and several key requirements are listed below.

Building Energy Construction Codes

An advanced microgrid must meet all building code requirements. The New Jersey Department of Community Affairs – Division of Construction Code Enforcement regulates the fire and life safety aspects of emergency energy systems and will review any plan related to the systems that connect multiple DER technologies to multiple critical customers across multiple ROWs. As the DER systems get smaller and more cost effective, how they are addressed in the state, national and international building energy construction codes, and the classification of facilities with micro-CHP, both commercial and residential, will be important to the development of advanced microgrids.

IEEE 1547 Interconnection and IEEE 2030 Interoperability
(http://www.nrel.gov/docs/fy15osti/63157.pdf)

The Institute for Electrical and Electronic Engineers (IEEE) has several codes and guides related to microgrids and DER operation to and within the grid. Specifically IEEE 1547 series of standards addresses the interconnection of DER to the distribution grid. IEEE 1547.4 addresses the standard related to islanding of DER microgrids. These standards are in the process of being upgraded and expanded given the recent interest in enhancing the development of microgrids, especially advanced microgrids. It will be important for the Board and staff to stay abreast of these standards and how they should be incorporated into any EDC interconnection guidance, requirements and tariffs. [Notably, the revised standard opens the potential for "smart inverters" to communicate with, and respond to utility or other market signals that request grid management services. The missing element here is the requirement (and mechanism) for the utility to *compensate* asset owners or their aggregation agents for these services.]

Another related IEEE standard is the interoperability standards at IEEE 2030 Guide for Smart [Grid] Interoperability of Energy Technology and Information Technology Operation with the Electric Power Systems and End-Use Applications and Loads. The guide provides standard in understanding and defining smart grid interoperability of the electric power system with end-use applications and loads. Smart grid is a key in expanding and implementing DER advanced microgrids and IEEE 2030 is a key standard to expanding and implementing Smart Grid. [Specifically, IEEE 2030.7 is the segment that governs the standard operation of the microcontroller which forms and manages the microgrid.]

Impact: The identified codes and standards are relevant to the proposed microgrid for Middletown. It is both recommended and expected that current and emerging IEEE standards be employed and observed in the design and implementation of the system. Such an approach will ensure safety, efficiency, interoperability, and predictable performance.

BPU Class I Renewable Energy Net Metering and Interconnection Requirements

As set forth in EDECA, N.J.S.A. 48:3-87(e) provides for the interconnection and net metering of Class I renewable energy sources.

Class I Renewable Energy Net Metering

EDECA allows for net metering of any capacity generating size Class I renewable energy facility for residential, commercial or industrial customers on the customer's side of the meter at the avoided retail rate provided that the generating capacity does not exceed the amount of electricity supplied to the customer over an historical 12-month period. The objective of net metering is to net out a customer's electric bill to zero over an annual period. The objective of net metering is not to intentionally design a system to consistently generate excess electricity from the Class I renewable energy facility. (EDECA allows a customer to choose to be credited *on a real-time basis or a customer may execute a bilateral agreement for the sale and purchase of the customer's excess generation.) The requirements for Class I renewable energy net metering are set forth at N.J.A.C 14:8-7.*

Impact: This statute is expected to be relevant to the proposed microgrid for Middletown. While net metering is unlikely to be employed for the participating sites with local generation of the type and scale described in this Study, it is likely that a bilateral power purchase agreement(s) will be established to extract value from the investment required to develop the generation resources. Such bilateral agreements will be necessary to justify the financing necessary to construct and operate the microgrid sites.

Class I renewable energy generated on the customer's side of the meter

Class I renewable energy generation facility that meet the criteria at N.J.A.C. 14:8-4.1 are deemed to be generated on the customer's side of the meter. In this case the renewable energy generation facility must be within the legal boundaries of a property, as set forth within the official tax map, on which the energy is consumed or that is contiguous to the property on which the energy is consumed.

The property on which the energy is consumed and the property on which the renewable energy generation facility is located shall be considered contiguous if they are geographically located next to each other, but may be otherwise separated by an existing easement, public thoroughfare, or transportation or utility-owned right-of-way and, but for that separation, would share a common boundary. The fact that a public thoroughfare may be encumbered by third-party easements does not alter a determination as to whether two properties would be considered contiguous.

Impact: This definition is expected to be relevant to the proposed microgrid for Middletown. Locally sited Class I renewable energy and other generation alternatives are anticipated for the participating sites in order to meet reliability and economic requirements.

Class I Renewable Energy Aggregated Net Metering

The EDECA provisions in N.J.S.A. 48:3-87(e)(4) provide for net metering aggregation to a single EDC customer that operates a solar electric power generation system installed at one of the customer's facilities or on a property owned by the customer, provided that the customer is a State entity, school district, county, county agency, county authority, municipality, municipal agency or municipal authority. However, aggregated net metering is not available to an on-site generation facility. The requirements for aggregated net metering are set forth at N.J.A.C. 14:8-7.

Impact: This statute is not expected to be relevant to the proposed microgrid for Middletown. On-site generation is anticipated for the participating sites which will include, but not be limited to solar electric generation and will therefore obviate this provision.

BPU Class I Renewable Energy Interconnection Requirements

The EDECA provisions in N.J.S.A. 48:3-87(e)(2) provide for the interconnection of customer generators that are eligible for net metering. The interconnection regulations at N.J.A.C. 14:8-5, direct the EDC to provide three review procedures for applications for interconnection of customer-generator facilities as follows:

> *Level 1, for customer-generator facilities of 10kW or less, provided a facility meets certification requirements for these systems;*
>
> *Level 2, for applications to connect customer-generator facilities with a power rating of two MW or less, which meet the certification requirements of this sized system; and*
>
> *Level 3, for applications to connect customer-generator facilities that do not qualify for either the level 1 or level 2 interconnection review procedures*

As set forth at N.J.A.C. 14:8.7 there is no process fee for Level 1 inverter based Class I renewable of 10 kW or less. The processing fee for Level 2 and 3 systems are listed in the regulations and in part depend on the complexity of the system and the requirement evaluations. Each EDC has a specific interconnection tariff and information on each EDC tariff can be found at http://www.njcleanenergy.com/renewable-energy/programs/net-metering-and-interconnection/interconnection-forms on the BPU's Clean Energy website. (The Tariff are typically termed Non-Utility Generator [NUG] tariffs.)

One of the specific provisions that may impact the amount of variable DER that can be interconnected to the distribution system is the provision related to the 15% peak load screen. Screens are the tests the EDC system engineers review to insure the variable DER system can be safely connected to the distribution system for both the DER customer and the EDC system. The screen limits the capacity of variable DER on a distribution line to 15% of the line's peak load. For a twelve (12) kilovolt (kV) line this is approximately three (3) MW. A twelve (12) kV line is a typical line on all the EDC's distribution systems throughout the State in residential areas.

Another key issue is the interconnection and use of more than one type of DER technology on the same site. This is especially the case in combining CHP and solar PV or solar PV and storage because a conflict arises in regard to net metering. EDECA does not provide for net metering for non-renewables and limits net metering to Class I renewables. The system developed by advanced microgrids with multiple DER technologies needs to be able to accurately meter, record and report Class I renewable net metered electricity separately from the other components in the DER microgrid system that are not net metered.

Impact: This set of statutes is expected to be relevant to the proposed microgrid for Middletown. The provisions will impact interconnection planning, approval, and costs, as well as potential bilateral power purchase agreements. The sizing and mix of local generation is expected to vary significantly by participating site. While these provisions will require detailed planning in the project design phase, they are not seen as prohibitive to the successful implementation of the system.

FERC Qualified Facilities (QF) Interconnection

The Public Utility Regulatory Policies Act of 1978 (PURPA) established a new class of generating facilities which would receive special rate and regulatory treatment. Generating facilities in this group are known as qualifying facilities (QFs), and fall into two categories:

1. *Qualifying small power production facilities; and*
2. *Qualifying cogeneration facilities.*

A small power production facility is a generating facility of 80 MW or less whose primary energy source is renewable (hydro, wind or solar), biomass, waste, or geothermal resources. A cogeneration facility is a CHP facility that produces electricity and another form of useful thermal energy.in a manner *that is more efficient than the separate production of both forms of energy. There is no size limitation for qualifying cogeneration facilities. QFs have the right to sell energy and capacity to a utility. However, the utility is relieved of this requirement if the QF has access to the wholesale market such as in a competitive state like New Jersey. (Detailed information on QF can be found at http://www.ferc.gov/industries/electric/gen-info/qual-fac.asp.)*

All DER systems that want to sell or provide their excess energy and capacity to the wholesale market must be interconnected per PJM requirements. The PJM interconnection requirements are listed in their Manual 14A Generation and Interconnection Process. System 20 MW or less can follow the small generator interconnection process listed in Chapter 3 of the Manual. (Detail of the PJM Interconnection Process can be found at https://www.pjm.com/~/media/documents/manuals/m14a.ashx.)

The PJM small generator procedures follow the small generator interconnection procedures and agreement promulgated by FERC in FERC Order 792. (Detail of FERC SGIP and SGIA can be found at http://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp.)

PJM, consistent with FERC Order 792, there is an expedited queue process for small generators. However, for a 10 kW inverter based system to access the PJM market as an energy or capacity resource there is a $300 nonrefundable fee to determine if the point of interconnection is FERC jurisdictional and then a $500 nonrefundable fee for the interconnection review. The fee for larger DER is scaled up from this level. The BPU fee for an EDC review of a 10 kW inverter based Class I renewable system is $0.00.

All the DER list is section 6 [of the Microgrid Report] have been interconnected and the majority of the DER systems can export power to the distribution grid and some can export energy to the wholesale markets. The EDC tariffs include all FERC classified QF and all Class I renewables. The EDC's provide this same process for the interconnection of a fossil fuel system which is not a QF or a class I renewable and are in the process of expanding this process for interconnecting battery storage systems.

The Interstate Renewable Energy Council (IREC) publishes an annual report that ranks the states in terms of their overall net metering and interconnection statutes, regulations, policies and procedures. Since 2007 through 2015 New Jersey has achieved a ranking of A for interconnection procedures and B for net metering policies. (Detail of State rank for IX/NM can be found at http://freeingthegrid.org/.)

Impact: This set of requirements are not expected to be relevant to the proposed microgrid for Middletown. It is unlikely that the locally sited generation proposed for the participating sites will be planned for access to wholesale energy markets (PJM) directly. Power production and bilateral power purchase agreements are anticipated to impact the local distribution utility.

New Jersey's Clean Energy Program – Statutory Provisions

As set forth in N.J.S.A. 48:3-59 the Clean Energy portion of the societal benefits charge (SBC) can be used to support demand side management programs, energy efficiency and Class I renewable energy.

N.J.S.A. 48:3-51 defines demand side management [DSM] as the management of customer demand for energy service through the implementation of cost-effective energy efficiency technologies, including, but not limited to, installed conservation, load management and energy efficiency measures on and in the residential, commercial, industrial, institutional and governmental premises and facilities in this State.

The BPU through New Jersey's Clean Energy Program (NJCEP) provides incentives to develop renewable energy and DSM energy efficiency DER technologies and projects. DER microgrid technologies promoted through the NJCEP includes but is not limited to solar, wind, sustainable biomass, CHP powered by renewable fuel such as landfill gas or biomass gas, CHP powered by fossil fuel and fuel cells. The CHP and fuel cells powered by fossil fuel must be defined as DSM energy efficiency. One of the criteria to evaluate a DSM EE DER technology or project is a cost effectiveness test that is part of the Rutgers' DER CBA model.

Impact: This statute is expected to be relevant to the proposed microgrid for Middletown. The opportunity for DSM as part of a final solution specific to each site may provide the opportunity for added benefits realization and an improvement of the financial case. This was not specifically quantified in the analysis so any added outcomes in this regard would represent an improvement of an already positive set of scenarios. No CHP resources are being considered as a part of the proposed generation mix at the participating sites as there is no thermal offtake requirement. The Rutgers CHP Cost Benefit Analysis tool was not utilized.

Linkage to the New Jersey Energy Master Plan Update - December 2015

The initial policy directive set by the Board for this Report was to address the comment and the response as noted in the Summary Section above. However, there are additional policy, regulatory, technical, and financial reasons for developing a statewide microgrid policy that can operate 24/7 under both blue skies and black sky conditions. These reasons are referenced in the 2015 New Jersey Energy Master Plan (EMP) Update.

The BPU as Chair of the EMP Committee issued the 2011 EMP Update in December 2015. The EMP Update notes that the production and distribution of clean, reliable, safe, and sufficient supplies of energy is essential to New Jersey's economy and way of life. Energy is a vital tool of economic growth and job creation across New Jersey's entire economy. Economic growth depends on abundant, affordable supplies of energy. When considering where to locate or expand businesses often identify energy costs as second only to labor costs in their decision-making process. The energy costs must be balanced with the benefits provided by energy policies.

The 2011 EMP Update contains five overarching goals:

1. *Drive Down the Cost of Energy For All Customers*
2. *Promote a Diverse Portfolio of New, Clean, In-State Generation*
3. *Reward Energy Efficiency and Energy Conservation/Reduce Peak Demand*
4. *Capitalize on Emerging Technologies for Transportation and Power Production*
5. *Maintain Support for the Renewable Energy Portfolio Standard*

A Statewide microgrid policy and development of microgrids at the local level addresses all of the five overarching goals of the EMP Update. The microgrid can assist the local government in controlling its energy costs. The technologies in a microgrid helps to promote diverse clean instate generation as well as promoting emerging technologies and renewable energy. The operations of a microgrid can enhance the energy efficiency of the local government and other facilities as well as reduce the impacts of peak energy demand on the grid.

The EMP Update set forth a Plan for Action that grouped 31 policy recommendations into four general sections listed below. A microgrid developed at a local level touches on a majority of these policy areas. It should be noted that the Energy Storage segment has advanced considerably since the 2015 EMP revision in terms of functional performance and cost economics, and therefore looks to become of much more central significance to the feasibility of

DER based microgrids. This is reflected in the recent legislation moved to accelerate adoption of substantial amounts of storage in NJ, and will likely feature prominently in the 2019 EMP update.

- *Expand In-State Electricity Resources*
    - *Build new in-state generation*
    - *Develop 1500 MW of CHP and DG*
    - *Promote expansion of gas pipelines*
    - *Clean energy to be 70% of supply by 2050*
- *Cost Effective Renewable Resources*
    - *Extend the EDC's solar programs*
    - *Evaluate solar incentives*
    - *Promote certain solar photovoltaic (PV) installations*
    - *Reduce the cost of solar panels*
    - *Promote effective use of biomass*
    - *Support other renewable technologies*
- *Promote Cost Effective Conservation and Energy Efficiency*
    - *Monitor EE effect on solar*
    - *Promote EE and Demand Response (DR) in State buildings*
    - *Monitor PJM's DR programs*
    - *Apply cost benefits test to EE programs*
    - *Evaluate dynamic pricing and metering*
    - *Add aggressive EE building codes*
    - *Increase natural gas EE*
    - *Expand education and outreach*
    - *Monitor energy storage developments*
- *Support the Development of Innovative Energy Technologies*
    - *Improve vehicle efficiency and funding*
    - *Support emerging technologies*

This EMP Update adds a new section, "Improve Energy Infrastructure Resiliency & Emergency Preparedness and Response," based upon New Jersey's Plan for Action in the aftermath of Superstorm Sandy. A statewide microgrid policy can addresses each of these new policy areas in the EMP Update

- *Improve Energy Infrastructure Resiliency & Emergency Preparedness and Response*
    - *Protect the State's critical energy infrastructure*
    - *Improve EDC emergency preparedness and response*

- *Increase the use of microgrid technologies and applications for distributed energy resources (DER)*
- *Create long-term financing for local energy resiliency measures through the ERB and other financing mechanisms*
- *Specially the EMP Updated highlighted several action items and recommendations related to microgrids and DER:*
    - *The increase in in-state electricity generation to maintain the progress on controlling energy costs must also include newer, more efficient distributed generation such as combined heat and power, fuel cells and solar. Interest in local generation is growing alongside interest in DG. Distributed generation technologies can also improve and enhance the State's energy resiliency at the local level through the development and implementation of microgrids.*
    - *The State will continue to encourage new DG of all forms and keep a focus on expanding use of CHP by reducing financial, regulatory and technical barriers and identifying opportunities for new entries. The BPU should initiate a stakeholder process to determine how to reduce these barriers and increase the development of DG with a focus on CHP, fuel cells within a microgrid. This should include evaluating revisions to the CHP and fuel cell incentives to promote local energy resiliency.*
    - *The State should continue its work with the USDOE, the utilities, local and state governments and other strategic partners to identify, design and implement TCDER microgrids to power critical facilities and services across the State.*

Impact: This EMP is expected to be relevant to the proposed microgrid for Middletown. The proposed system is expected to support the fulfillment of the promises set forth in the EMP, as well as additional statewide goals such as aggregate deployed energy storage. An updated EMP is under development for 2019 and is expected to provide guidance and support for the Middletown system in a variety of ways yet to be determined.

For reference, in the consideration of impacts to rights of way that may arise from the local siting of generation for the Middletown TC DER microgrid, the current utility ROW authorization procedure is noted at the following link:

https://www.firstenergycorp.com/content/customer/help/safety/real-estate-power-lines/transmission-right-of-way.html

Regulatory Impacts

There are multiple areas of friction from existing regulatory restrictions that are exposed by the implementation of a Middletown TC DER microgrid and the attempt to have it configured for advanced microgrid functionality. The impact of these restrictions is highly dependent on the specific ownership and operation of the microgrid DER assets. The current regulatory framework has been established in conformance with statutory law that confers monopoly franchise rights to electric distribution companies operating as regulated public entities within New Jersey. This construct dates back to the early years when this fast-growing industry began to expand and consolidate shortly after the invention of the electric light bulb by Thomas Edison.

Figure 13. Samuel Insull, Founder of the Regulated Utility Franchise Model

On June 7, 1898, Samuel Insull in his role as President of the National Electric Light Association (predecessor of today's Edison Electric Institute) outlined in the following, what would become the model for the adoption of state regulation of electric power monopolies:

> *While it is not supposed to be popular to speak of exclusive franchises, it should be recognized that the best service at the lowest possible price can only be obtained, certainly in connection with the industry with which we are identified, by exclusive control of a given territory being placed in the hands of one undertaking.*

This theory was sound and worked well as load growth grew, circuit connections expanded to bring electric power to suburban and then rural areas, and fuel prices remained low with minimal environmental externalities attributed to the production and distribution of electric power. Now, however, set against the currently intensifying dynamics of diminishing load growth (even load destruction), increasing environmental cost accountability, dramatic reduction in DER cost barriers, growing grid operating flexibility needs, and the overhead burden of a less effective centralized system model, the central tenets supporting Samuel Insull's justifications have essentially been superseded.

Yet the model persists.

More than a century of established and tested case law, cemented by judicial opinions and legislative reinforcement, along with a strong investor stake in capital preservation and guaranteed profitability quest has led this construct to become a highly defensive and restrictive bulwark for the electric utility sector to preserve their former rent-seeking power through guaranteed capital investment return and cost of service recovery, even while offloading much of their performance risk and financial exposure to the public ratepayers. At the same time, the public has also become much more knowledgeable about these intensifying dynamics and are expressing strong desire for a more transparent, equitable, cleaner, and more participatory energy system that is not bound by this outdated regulatory construct.

The other edge of the "progressive regulation sword" cuts beneficially *for* the utilities – microgrids open up the potential for these utilities to support platforms that can level the playing field to private participation and return to a more balanced and less extractive risk/reward profile as a true public service. This alternative also brings tangible and shared economic benefits through a far more resilient and flexible system, opening up new sources of business revenue (and the corresponding need for careful risk management and investment governance) to the innovative utility of the future. To achieve this requires support for regulatory reform that acknowledges the disparities and contention described above. The Middletown TC DER microgrid program can serve as the catalyst to these changes. Specifically, the following actions should be pursued which can lower the barriers to microgrid adoption within New Jersey.

STEP #1: Work Around the **Two Primary Constraints** Blocking Effective Competitive Solutions

The utility has the franchise right to serve load within their defined service territory exclusively through their wire asset based infrastructure which earns a substantial investor profit. Alternatives to this have historically been impractical, expensive, and illegal. We call this the ***copper bound*** constraint. Secondly, the utility is remunerated through authorized rate recovery on an operating-cost-plus recovery basis that strongly discourages transparency on detailed operational performance and customer behavior data, which therefore precludes innovative third-party solutions from being surfaced and considered as non-wires alternatives (NWA). We call this the ***data bound*** constraint. These constraints effectively mask operating inefficiencies, and also distort true locational marginal pricing signals and corresponding DER hosting capacities that could stimulate truly innovative and cost efficient third-party edge generation, storage, and load management solutions.

There is no practical way for immediately removing these constraints to support a true advanced microgrid solution to the initial Middletown TC DER microgrid needs – *yet* the basic positive economics of justifying *some* minimum level of self-hosted generation and storage (sized for the critical load) remain compelling, especially given the ongoing dramatic cost decrease for these technologies. Barring municipal zoning restrictions or other non-utility imposed constraints, the non-exporting DER should therefore be placed in Step #1 at all sites (deployed in a prioritized order) from highest to lowest cost-benefit ratio. Despite the fact that this represents a sub-optimal microgrid configuration, it establishes these flexible resources which can be more efficiently interoperated in the future as regulatory barriers to prosumer energy production and exchange fall.

STEP #2: Unlock the **Data Vault Securely** to Third-Party Access

The experience resulting from energy-data collection attempts for the Study team to baseline facility energy use and load profiles for this Study clearly illustrates some of the barriers that are present to information access which could enable effective third-party NWA solutions.

- Users are not familiar with, nor do they have easy access to, consistent and standardized billing and consumption data, and the data itself is not provided in a timely and electronically usable format.
- No interval data is available (or at least was offered) upon request, which limits the potential for introducing smart energy load management solutions.
- Difficult and opaque enterprise legal hurdles are presented to the authorization of third-party access and use of customer and system data, creating large lag time and injecting costly business process inertia.
- System operational data is deemed as competitive with restricted access, and is not made available.

Many regulatory jurisdictions across the country recognize this barrier and have taken action to encourage (even mandate) the utility release of this data in secure and usable formats for purposes *other* than reinforcing their franchise investment rate-recovery requests. The USDOE has developed a potentially powerful protocol and access method through its Green Button initiative (https://www.energy.gov/data/green-button), which should be advanced by the BPU in this step.

STEP #3: Establish a "**Value of DER" Framework** that is Reflected in Utility Integrated Resource Plan (IRP) Filings

This step will guide interaction between the IRP and DER-focused proceedings – ensuring that overall procurement planning incorporates DER.

Resources should be evaluated and compensated based on their ability to provide a service, not on some arbitrary boundary like on which side of a customer meter they are located.

The following actions are recommended as a model for New Jersey to consider in addressing a more effective and efficient DER ownership and valuation structure. These are drawn from an existing plan developed by the California Public Utilities Commission that is currently in progress, and are presented for consideration.

- Consider the use of integration capacity analysis to streamline utility interconnection processes to accelerate DER deployment.
- Consider developing guidelines to clarify the circumstances in which utility or affiliate ownership of DERs is appropriate.

- Fully operationalize advanced smart inverter functionalities to enhance the integration of DERs into the grid.
- Consider the role of DERMS to enhance grid management and maximize the value of DER deployment.

In essence, this "Value of DER" framework should address the current lack of structured methodologies for fully valuing the net benefit of allowing (even encouraging) a wider dispersion of generation and storage assets that are able to coordinate their operation through an advanced microgrid structure that exists within the evolving distribution system. The methodology should also strive to expose the risk/reward decoupling between energy ecosystem participants that is forced by the current monopoly franchise constraints, and look for alternate models that can unlock the full potential of DER by:

- Providing *measurable* value for both resilience and flexibility
- Enabling accurate data-driven market signals to third-party DER solution providers
- More fully justifying the business case for AMI interval metering and related IIoT sensor instrumentation
- Removing barriers to DER/microgrid participation in capacity and energy markets

As there is still a need to systematically identify the full set of data categories (Step #2) and in creating a non-biased methodology for determining the true value of DER/microgrids (Step #3) that would facilitate non-wires solutions to grid needs, it is recommended that these steps include convening a dedicated and diverse working group under the auspices of the New Jersey 2019 Energy Master Plan that can be focused clearly on this task. Some of the guiding work from other states and jurisdictions could be used to inform the work here, such as that being pursued in the Washington, D.C. legislative arena on potentially forming a DER authority with an energy data stewardship role.

STEP #4: Create a **Regulatory Sandbox Framework** that Permits Experimentation and Critical Data Collection

A critical step toward evaluating the feasibility of the advanced microgrid is clearly establishing a more level playing field that can validate its practical interconnected operation, and thereby yield valuable data on its robustness, security, effectiveness, and scalability. The primary barriers presented by the ***copper bound*** and the ***data bound*** constraints should be removed within a limited segment of the Middletown TC DER microgrid – we call this a "regulatory sandbox" – and relevant stakeholder groups should be encouraged to work together to design a demonstration within that sandbox that will accomplish the following:

- Permit a larger third-party owned and operated load-serving distributed generation source, along with commensurately sized energy storage, to be hosted on one of the more critical facility sites that is central to proximate satellite facilities located along a JCP&L common circuit.

- Develop a streamlined and efficient process for the creation of a municipal energy authority to open up avenues to federal and/or private financing and ownership of distributed generation resources.
- Enable and establish protocol compliant data access using the Green Button *Connect* tools.
- Allow JCP&L to upgrade their circuit with sufficient features and capacity to permit power exchange between this local facility and its satellites. This might include energy storage facilities acting as a "buffer" to smooth this power flow.
- Remove ROW restrictions for transferring energy between the generation and storage facility, and for delivering energy to the broader JCP&L-served community.
- Provide a market pricing signal that can be used for modifying participation levels in delivered grid services, and to effectively and seamlessly "island" the advanced microgrid as a demand response call from JCP&L and/or PJM to play in the capacity market.

The regulatory sandbox framework should also be developed as a template along with a repeatable process within the reformulated 2019 Energy Master Plan, and this Middletown implementation be used as a first proof-of-concept for its application.

Financing of Implementation and Operation

A number of financing, implementation, and operation alternatives are available to support the proposed Middletown TC DER microgrid. As described in this Study, the costs associated with a microgrid can be significant. The capital and operating costs are considerable for each participating site, and to realize the aggregate benefits of a TC DER microgrid system, substantial investment will be required.

Therefore, identifying the most efficient and effective access to resources is essential to success. In this case, success is defined as the implementation of the microgrid system in manner that is timely and meets the financial, reliability, and operating requirements set forth. A project that takes too long to implement, or that is not completed in such a way that it supports the reliability objectives within financial constraints, is unlikely to be approved or completed.

For the purposes of this Study, three financing options are considered. These options include the following:

- Option 1: Utility and/or publicly funded projects
- Projects funded using public-private-partnership (P3) including bilateral power purchase agreements, of which there are two models to consider:
    - Option 2: The Township acts as the contracting entity with the private partner
    - Option 3: The utility acts as the contracting entity with the private partner

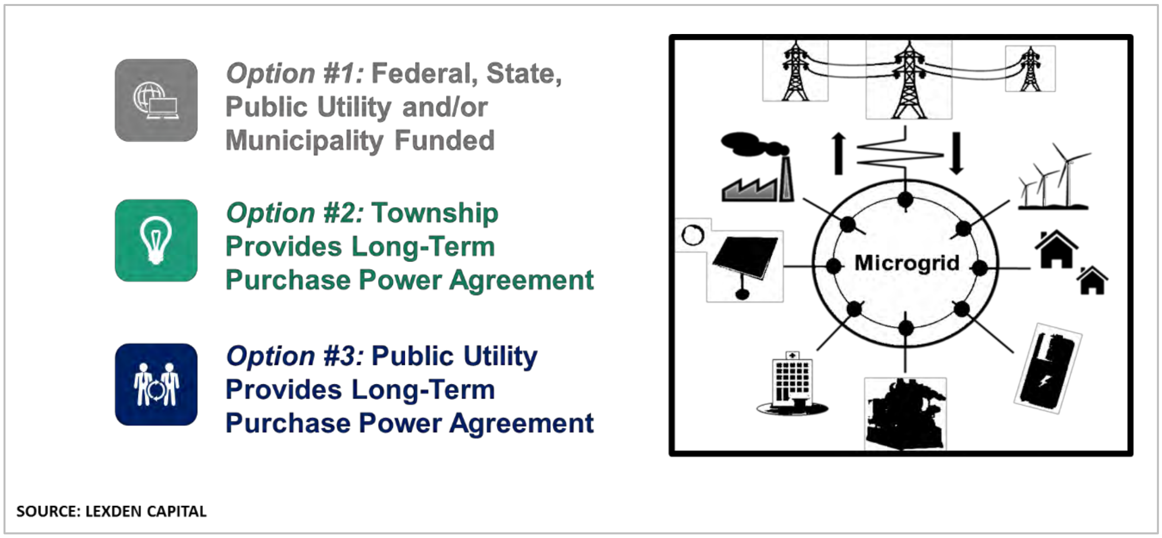


Figure 14. Financing Options for Municipality Microgrid Projects

Each option will be described in detail with a consideration of the pros and cons, as follows:

Option 1 is best described as the traditional manner in which public projects, in this case, utility projects, are accomplished. A source of public monies is allocated to fund the cost of implementation. This funding source might include bond financing, or budgeting through traditional capital budgeting processes. In the case of a public utility, the opportunity to seek approval for inclusion of the capital costs as a part of the rate making process is also a possibility, though in the case of New Jersey, EDCs are prohibited from owning generation by regulation, and would not ordinarily be allowed to finance, implement, operate a project such as a microgrid. The cost of capital for public entities is generally favorable, though the recapture of returns from the investment is not typically measured other than through budgetary means. In case of public utility financing via rate basing, the returns on capital employed are well understood. In the case of Option 1, with respect to the Middletown TC DER microgrid, the opportunity for Department of Defense (DoD) funding of generation and storage at NWS Earle must be explored in order to meet base requirements.

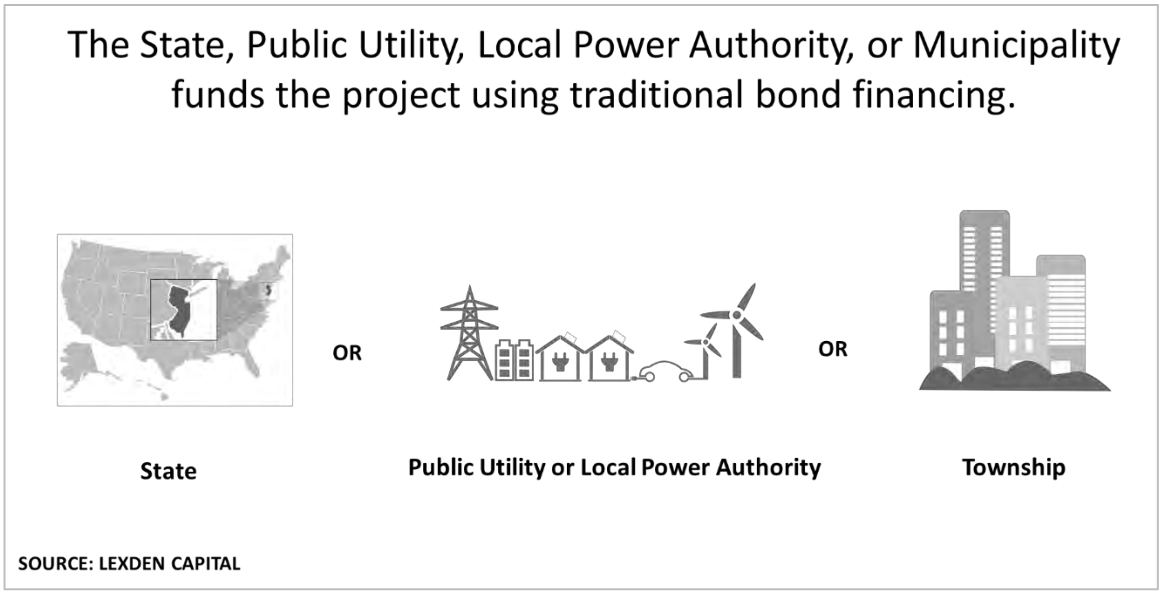


Figure 15. Option #1: Traditional Financing

While the pros of a publicly financed microgrid include low cost of capital, traditional control and management, and relatively simple, well-understood execution, the cons are also significant. Public projects are not typically efficiently completed. Cost overruns are common and execution can be a challenge to control given the limited incentives for effectiveness.

Once completed, the operation of a complex system such as the proposed Middletown TC DER microgrid will require new resources, processes, and utility partnership models. While such a microgrid may not be inherently complex, most public entities suffer from inertia and organizational effectiveness challenges when implementing change. These circumstances often lead to inefficiency and unanticipated costs in operation. The regulatory limits on EDC ownership of generation would call for unique partnerships, potentially with other utilities such as natural gas, or an agency such as the Township to operate and oversee the microgrid. This complexity introduces operational risk for a publicly funded project.

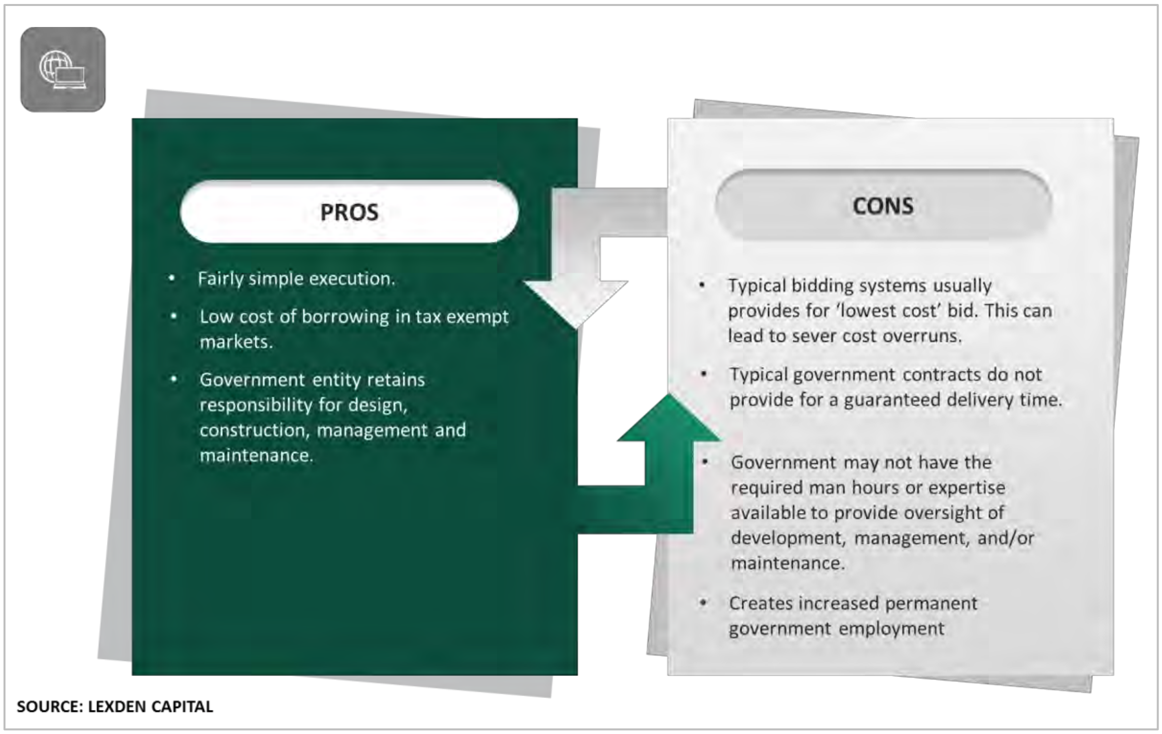


Figure 16. Option #1: Pros and Cons

Option 2 is the first of two P3 options to consider. In this case, an intermediary agency would be utilized as the public partner. The private financing would be justified and repaid based upon a bilateral power purchase agreement between the private entity and the public entity. In the case of Middletown, the possibility of establishing a municipal utility authority has been receptively considered, though the details of the formation and operation of such an entity are not fully described. Such an agency authority may be a requirement in order to engage the DoD and Navy in a request for funding and implementing the system needs for NWS Earle.

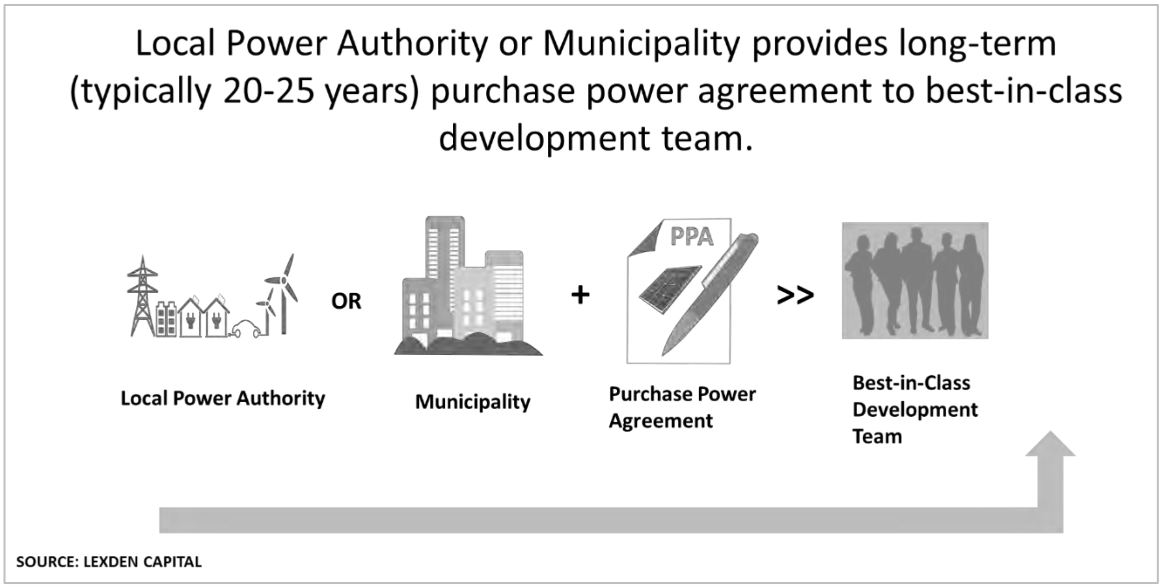


Figure 17. Option #2: Public-Private Partnership Model A

The pros of an arrangement such as Option 2 are considerable. The inherent execution efficiencies of a private partner will support rapid project completion and efficient operation, while alleviating the risk and inefficiency of a publicly funded and managed project. Additionally, procurement burdens may be simplified and the opportunity to select and rapidly implement leading technologies is improved. The risk transfer to a private entity provides for speed of implementation and long-term clarity and efficiency in the operation of the system, with strong performance incentives to be built into the agreement from the outset. Long-term economic development via jobs and local management are significant as well.

The cons, in summary, are relatively limited. There is the potential for slightly higher costs in the project overall, but these would be mitigated for the public interest via the private financing mechanisms. Some public entities find it challenging to conceive of or enter into long-term agreements such as a 20+ year power purchase agreement. Such an agreement will be required to attract the private capital necessary for the project and ensure the compelling returns.

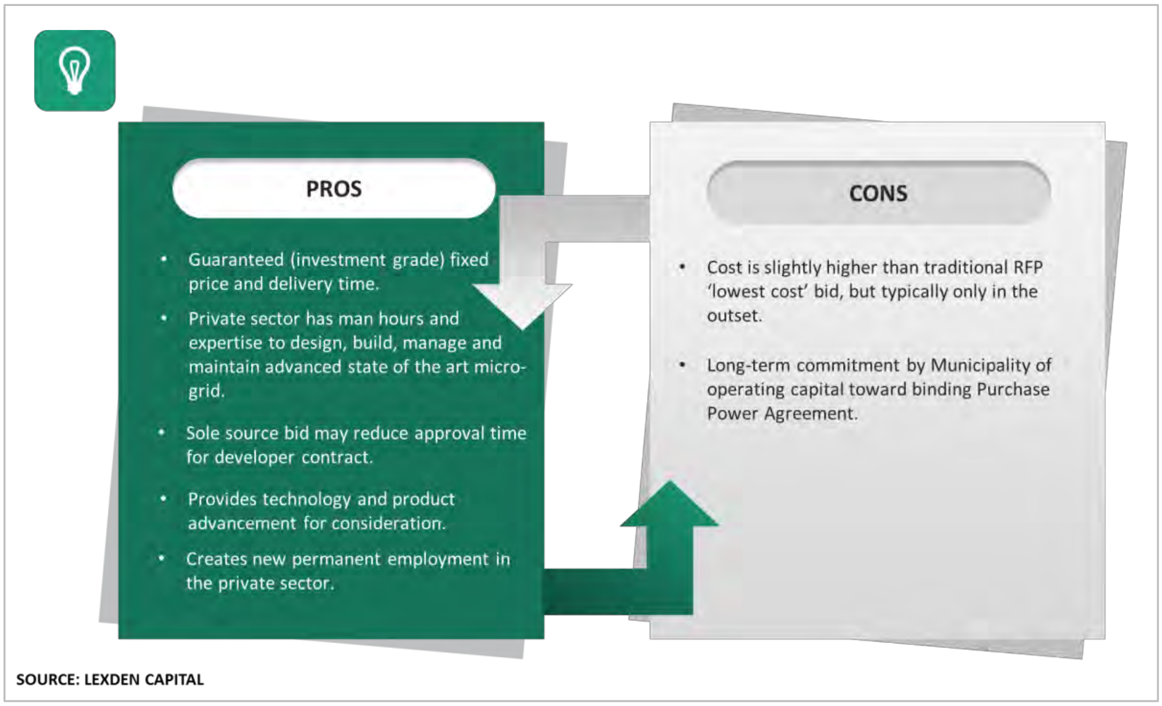


Figure 18. Option #2: Pros and Cons

Finally, **Option 3** provides for a streamlined P3 arrangement that simplifies the number of agencies involved, and offers benefits to all parties in alignment with their expectations. In this case, the public utility is the agency engaged in the bilateral power purchase agreement, which helps to overcome the current regulatory barriers and offers financial benefits to both the private financiers as well as the utility, while ensuring that the Township receives the reliable and efficient power provided by the microgrid system.

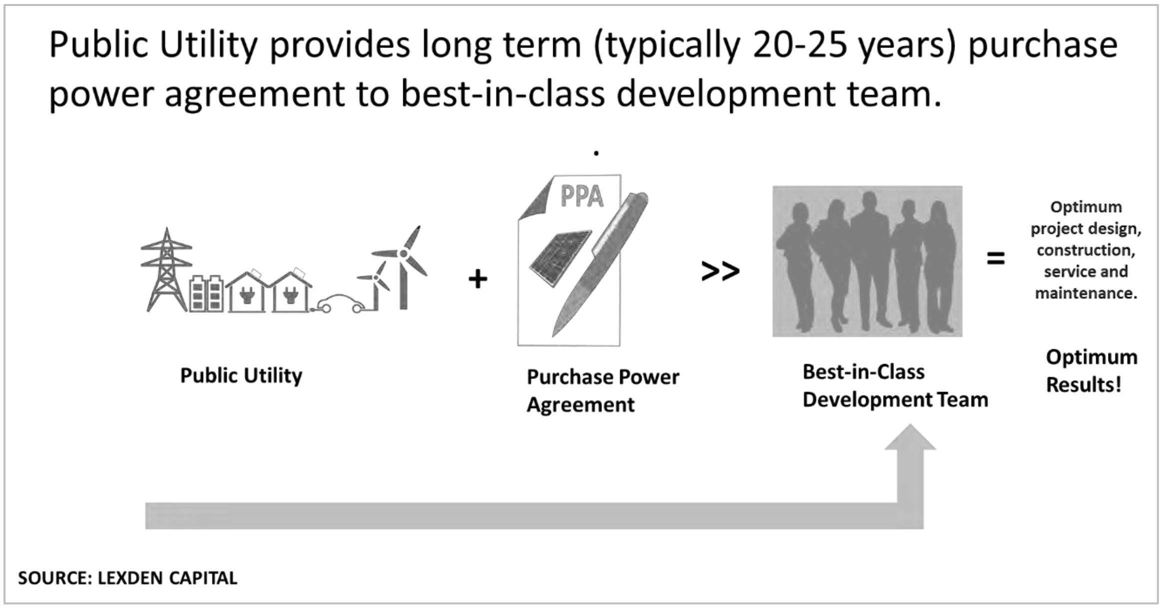


Figure 19. Option #3: Public-Private Partnership Model B

Similar to Option 2, the pros for Option 3 include private-sector efficiency and execution, risk transfer, and economic development. Conversely, by avoiding the intermediary public agency and contracting with the public utility directly, a clarified long-term relationship can be established between two entities that understand the trajectory of long-term agreements. Operation of the microgrid facilities, in the case of Options 2 and 3, can be flexibly determined based upon the interests of the utility and financing entity. Either a best-in-class operational team can be assembled, or the utility can be asked to operate the microgrid generation and storage under an operating agreement that leaves ownership under the control of the financier. In the case of Options 2 and 3, the ability to coordinate financing and construction of generation and storage to meet NWS Earle requirements can be carved out, if desired, from the overall project. While each site is shown to be economically feasible, the opportunity to select the most opportune sites is available without affecting the feasibility of other locations in the participant list.

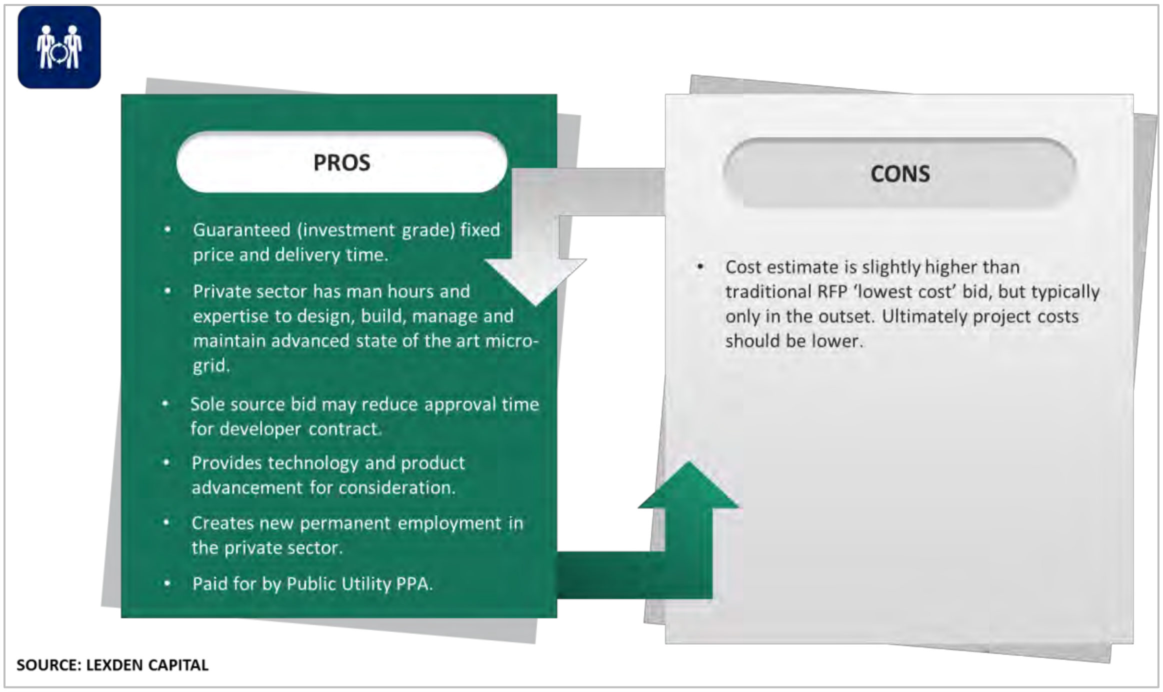


Figure 20. Option #3: Pros and Cons

The following image provides a summary of the pros, cons, and optimal solution when considering the three options for finance and implementation of a microgrid for Middletown.

This chart below shows the pros and cons for each option. Option 3 is the optimal for project design, construction, service, maintenance and financing.

Option #1: Federal, State, Public Utility and/or Municipality Funded			Option #2: Township Provides Long-Term Purchase Power Agreement			Option #3: Public Utility Provides Long-Term Purchase Power Agreement		
ATTRIBUTES	PROS	CONS	ATTRIBUTES	PROS	CONS	ATTRIBUTES	PROS	CONS
Fairly simple execution.	X		Guaranteed (investment grade) fixed price and delivery time.	X		Guaranteed (investment grade) fixed price and delivery time.	X	
Low cost of borrowing in tax exempt markets.	X		Private sector has man hours and expertise to design, build, manage and maintain advanced state of the art micro-grid.	X		Private sector has man hours and expertise to design, build, manage and maintain advanced state of the art micro-grid.	X	
Government entity retains responsibility for design, construction, management and maintenance.	X		Sole source bid may reduce approval time for developer contract.	X		Sole source bid may reduce approval time for developer contract.	X	
Typical bidding systems usually provides for 'lowest cost' bid. This can lead to sever cost overruns.		X	Provides technology and product advancement for consideration.	X		Provides technology and product advancement for consideration.	X	
Typical government contracts do not provide for a guaranteed delivery time.		X	Creates new permanent employment in the private sector.	X		Creates new permanent employment in the private sector.	X	
Creates increased permanent government employment.		X	Cost is slightly higher than traditional RFP 'lowest cost' bid, but typically only in the outset.		X	Paid for by Public Utility PPA.	X	
Government may not have the required man hours or expertise available to provide oversight of development, management, and/or maintenance.		X	Long-term commitment by Municipality of operating capital toward binding Purchase Power Agreement.		X	Cost estimate is slightly higher than traditional RFP 'lowest cost' bid, but typically only in the outset. Ultimately project costs should be lower.		X

SOURCE: LEXDEN CAPITAL

Figure 21. Summary of Microgrid Financing Options

Data Gathering and Analytical Approach

Data Gathering

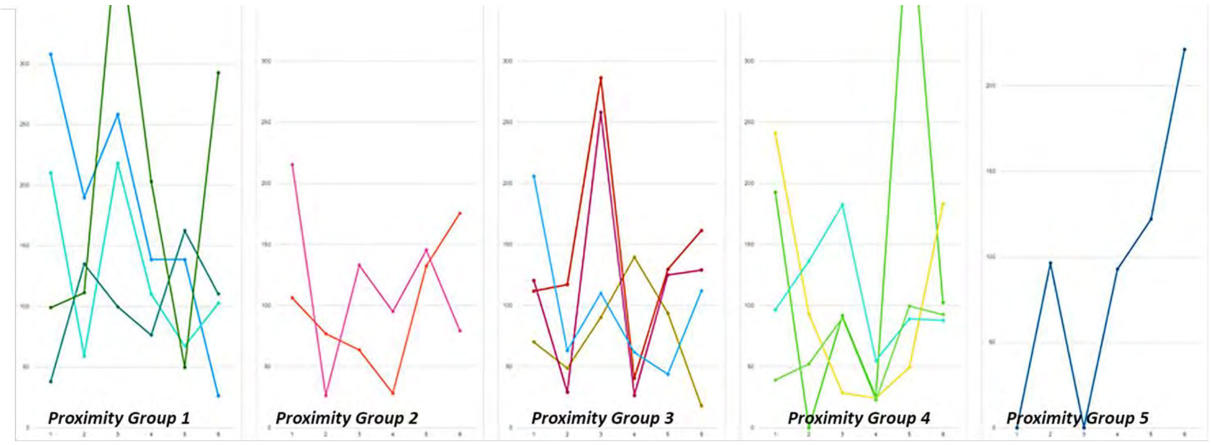
The fundamental starting point for the Study was to gather data to describe the historical utility usage at each of the participating sites. This data included electrical and gas consumption derived directly from utility bills. This data provided insights into usage, demand, and rates, all of which were critical to the analysis.

Challenges arose because JCP&L has not deployed advanced metering; therefore, no interval data was available. Interval data is highly valuable in determining the load profile for a given location, and the absence of this data requires inference and estimation. In addition, as the original data request was made of individual site managers, a variety of gaps were evident in the data provided. This was primarily due to the various natures of the responsible organizations and facilities management in place, as well as other restrictions such as security concerns.

After considerable effort with each participating site, a consolidated data request was issued to JCP&L to obtain the missing site-specific data. Additional information was requested, which included circuit reliability and system one-line diagrams, all of which supported the analysis of need and how best to consider alternatives based upon the existing distribution feeder and substation affinity of each site.

Overall, the data gathering effort was considerably more difficult and protracted than originally anticipated. The variety of responsible parties and their respective constraints contributed to lengthy response times following requests. When data was requested from JCP&L, disclosure constraints were required prior to receiving the required information. For this reason, actual data will not be catalogued or presented in this Study. Data anonymity is a requirement that must be respected. If detailed data is desired, it may be provided upon request, and under non-disclosure.

What can be shared, and what was presented at community meetings, is anonymized circuit reliability data. It is felt that this data is a crucial way in which the driving need for the proposed Middletown TC DER microgrid can be demonstrated. As shown in the following diagram, key circuits in the Middletown regional electric distribution system exhibit highly variable reliability, based upon their System Average Interruption Duration Index (SAIDI), which measures the total duration of an interruption for the average customer given a defined time period. This variability demonstrates electrical availability issues on a given circuit and correlates to system outages. These outages, the variability, and their commensurate value, as measured by the critical load at each site, are a key factor in the economic analysis. It was noted that limited investments for remediation or improvement have been made in the electric distribution system within the Study area in recent years. This represents the value to be achieved under grey sky scenarios as outlined in Appendix A.



System Average Interruption Duration Index (**SAIDI**) measures the total duration of an interruption for the average customer given a defined time period.

- Proximity groups organized by circuits to nearby premises served by common substations.
- High variability observed on most circuits year over year.
- Root cause needed for better understanding of failure mechanisms – but downed wires are typical.

Figure 22. SAIDI 6-year History by Middletown Circuit Proximity Groups

Analytical Methodology

Electrical and gas usage data was requested from each of the participating sites, and, when data could not be gathered directly, from the local utilities. While interval data would have been the ideal objective, such data was not available as AMI has not been deployed. Therefore, monthly consumption data was used and load curves estimated based upon knowledge of the site operation, or standard curves available in the modeling tool.

The central tool used to conduct the feasibility analysis for the proposed microgrid for Middletown was the Distributed Energy Resources Customer Adoption Model (DER-CAM). This is a USDOE-developed tool that provides a standardized mechanism by which the BPU can evaluate and compare feasibility study results across projects. The DER-CAM tool is staged with data for participating sites and a set of assumptions and factors which are then processed to produce an output that includes:

- The cost-optimized mix of DER necessary to meet specified objectives
- An analysis of economic and greenhouse gas impacts or benefits
- The associated costs and a cash flow analysis over successive years

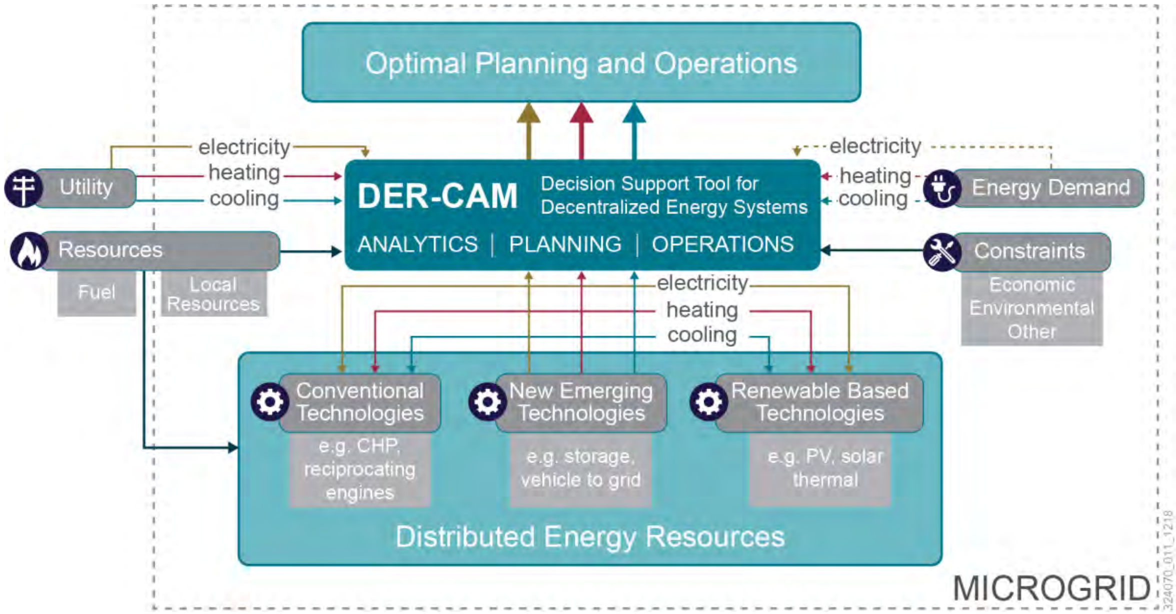


Figure 23. DER-CAM Schematic

The DER-CAM tool can be allowed to run its optimization routines naturally, or it can be forced to consider alternative generation mix constraints, which can then be optimized to understand the impacts to the costs and benefits.

The approach taken with DER-CAM was to develop a model for each individual participating site in order to understand the specific generation requirements for those locations. Then the collection of sites was considered in aggregate to understand overall feasibility and to explore microgrid configuration alternatives. These alternatives were then evaluated in order to arrive at a recommended configuration.

The first step was to take the entire list of participating sites and look for opportunities for efficiency in the analytical process. It became apparent that the participating sites could be grouped by classification. The following table illustrates the entire list of sites considered, along with their type and proposed classification:

The classifications, or sites identified, were as follows:

- Elementary Schools
- Middle and High Schools
- Municipal Buildings
- Fire Stations
- The TOMSA Facility
- The NY Waterways Ferry Terminal
- NWS Earle
- NJNG CNG Station

Except where some of these sites are individually defined, the operating characteristics, energy consumption, and load profiles for the identified groups were assumed to be approximately similar within their particular classification. In the case of a particular classification, electric usage was assumed to be an effective scaling factor to support the analysis of an individual case within a class. By using this approach, a full DER-CAM analysis of a single site per class could be conducted, then extended to the balance of sites within the class by applying the electric usage scaling factor. The following table shows all participating sites, with the green highlighted site entries denoting the class designations for the subsequent sites. These green sites were treated as proxies for the analysis of their class.

Table 4.
Participating Sites Grouped by Class

	MG Cluster ID#	Substation Name	Substation Transformer Rating	Participant
1	MG Middletown	Middletown	12 MVA 34.4 kV/13.2 kV	Middletown North High School
2	MG TaylorLane	Taylor Lane	12 MVA 34.4 kV/13.2 kV	Thorne Middle
3	MG Lincroft	Lincroft	12 MVA 34.4 kV/13.2 kV	Middletown South High School
4	MG Lincroft	Lincroft	12 MVA 34.4 kV/13.2 kV	Thompson Middle School
5	MG Middletown	Middletown	12 MVA 34.4 kV/13.2 kV	Bayshore Middle
6	MG Belford	Belford	7.5 MVA 34.4 kV/4.3 kV	Bayview Elementary
7	MG Keansburg	Keansburg	7.5 MVA 34.4 kV/13.2 kV	Ocean Ave Elementary
8	MG Belford	Belford	12 MVA 34.4 kV/13.2 kV	Port Monmouth Elementary
9	MG TaylorLane	Taylor Lane	12 MVA 34.4 kV/13.2 kV	Harmony Elementary
10	MG TaylorLane	Taylor Lane	12 MVA 34.4 kV/13.2 kV	River Plaza Elementary
11	MG Lincroft	Lincroft	12 MVA 34.4 kV/13.2 kV	Nut Swamp Elementary
12	MG Lincroft	Lincroft	12 MVA 34.4 kV/13.2 kV	Lincroft Elementary
13	MG StoneChurch	Stone Church	12 MVA 34.4 kV/13.2 kV	Navesink Elementary
14	MG Fairview	Fairview	7.5 MVA 34.4 kV/13.2 kV	Fairview Elementary
15	MG Middletown	Middletown	12 MVA 34.4 kV/13.2 kV	New Monmouth Elementary
16	MG Middletown	Middletown	12 MVA 34.4 kV/13.2 kV	Leonardo Elementary
17	MG Middletown	Middletown	12 MVA 34.4 kV/13.2 kV	Middletown Village Elementary

	MG Cluster ID#	Substation Name	Substation Transformer Rating	Participant
18	MG Middletown	Middletown	12 MVA 34.4 kV/13.2 kV	Middletown Municipal Complex
19	MG Belford	Belford	12 MVA 34.4 kV/13.2 kV	Monmouth County Highway Dept. Building &
20	MG Fairview	Fairview	15 MVA 34.4 kV/13.2 kV	Middletown DPW
21	MG Belford	Belford	12 MVA 34.4 kV/13.2 kV	NY Waterways
22	MG Fairview	Fairview	15 MVA 34.4 kV/13.2 kV	NJNG CNG Station
23	MG Belford	Belford	12 MVA 34.4 kV/13.2 kV	TOMSA
24	MG Belford	Belford	7.5 MVA 34.4 kV/4.3 kV	Middletown Fire Station 4
25	MG Belford	Belford	12 MVA 34.4 kV/13.2 kV	Middletown Fire Station 3
26	MG Belford	Belford	12 MVA 34.4 kV/13.2 kV	Middletown Fire Station 7
27	MG Belford	Belford	7.5 MVA 34.4 kV/4.3 kV	EARLE NWS (Admin)
28	MG Belford	Belford	7.5 MVA 34.4 kV/4.3 kV	EARLE NWS (Water Front)

In order to develop a structured set of DER-CAM analytical outcomes for comparison, a set of optimization scenarios was defined for each participating site. These scenarios were chosen as follows.

The following three "Normal Case" scenarios assumed no grid outage and no critical load or outage costs:

- 1.A: A reference case assuming no distributed generation – the optimization was run to validate that utility energy costs were appropriately modeled given the estimated load curve for the site.
- 1.B: A case run unconstrained in order to allow DER-CAM to optimize a mix of distributed generation, regardless of type, that would maximize the 20-year overall return on investment including initial capital costs and annual operating expense.
- 1.C: A case with forced constraints to require a minimum utilization level of PV generation and energy storage. Once again, the DER-CAM tool optimizes the final mix of generation in order to maximize the 20-year overall return on investment including capital costs and annual operating expense.

The following three scenarios assumed certain percentages of critical load and outage cost assumptions based upon site or site class. In this manner, the value of interruptions to electrical service could be factored into the optimization routines in the tool. The outage duration assumed was 12 hours for the following, which is minimum threshold of reliability that the team felt was reasonable for consideration. These are termed “Low Resiliency” scenarios.

- 2.A: A reference case assuming no distributed generation – the optimization was run to validate that utility energy costs were appropriately modeled given the estimated load curve for the site.
- 2.B: A case run unconstrained in order to allow DER-CAM to optimize a mix of distributed generation, regardless of type, that would maximize the 20-year overall return on investment including initial capital costs and annual operating expense.
- 2.C: A case with forced constraints to require minimum a utilization level of PV generation and energy storage. Once again, the DER-CAM tool optimizes the final mix of generation in order to maximize the 20-year overall return on investment including capital costs and annual operating expense.

The following three scenarios assumed certain percentages of critical load and outage cost assumptions based upon site or site class. In this manner, the value of interruptions to electrical service could be factored into the optimization routines in the tool. The outage duration assumed was 7 days for the following, which is maximum threshold of reliability that the team felt was reasonable for consideration. These are termed “High Resiliency” scenarios.

- 3.A: A reference case assuming no distributed generation – the optimization was run to validate that utility energy costs were appropriately modeled given the estimated load curve for the site.
- 3.B: A case run unconstrained in order to allow DER-CAM to optimize a mix of distributed generation, regardless of type, that would maximize the 20-year overall return on investment including initial capital costs and annual operating expense.
- 3.C: A case with forced constraints to require minimum a utilization level of PV generation and energy storage. Once again, the DER-CAM tool optimizes the final mix of generation in order to maximize the 20-year overall return on investment including capital costs and annual operating expense.

The scenarios can be logically organized as follows in order to aid in understanding.

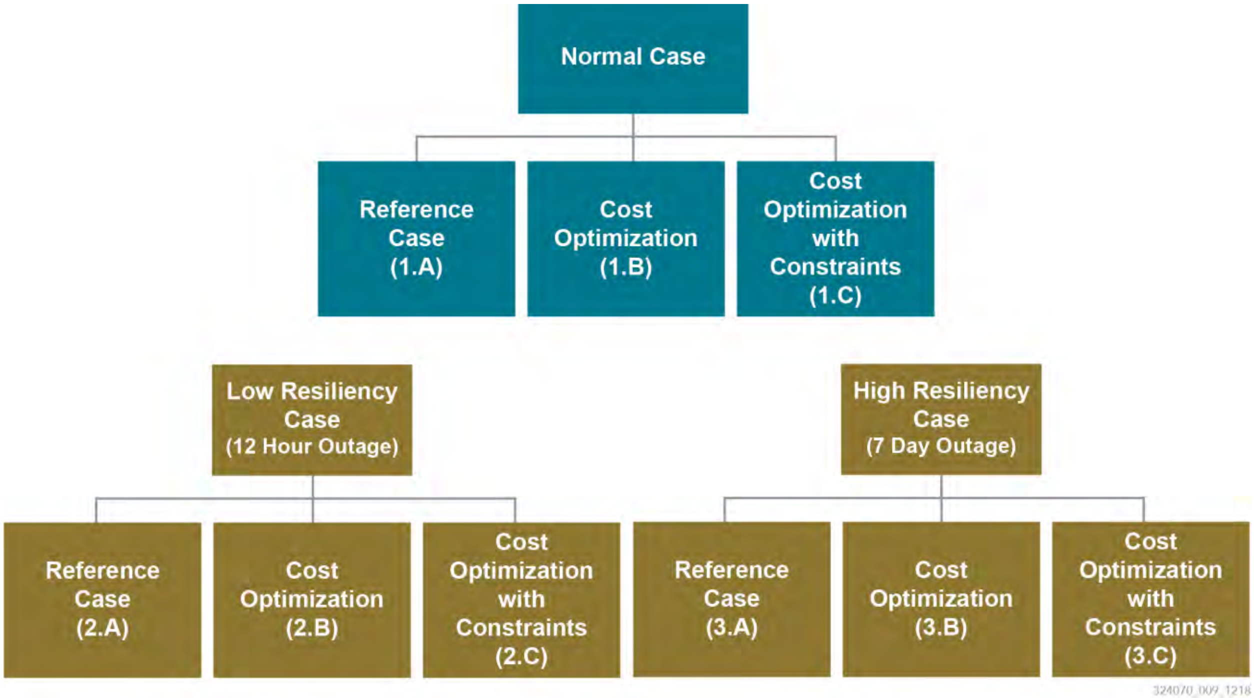


Figure 24. Optimization Scenarios

By aligning the site analysis using DER-CAM according to this structure, each site can be modeled for a variety of objectives. Accordingly, if the worst case assumption for each site or site classification proves to be economically feasible, the site, and its class peers, can also be assumed to be economically feasible. This will then lead to the consideration of a recommended overall approach for the project.

Assumptions

The relatively limited data (i.e., only electric and gas consumption data) available for this Feasibility Study required that a set of assumptions be credibly established such that the DER-CAM analysis could be completed. The following are the cost assumptions utilized. Assumptions were developed via research using established references and sources. Capital costs and operating expenses were confirmed in this manner, where necessary. Assumptions are considered accurate where drawn from reliable external sources. Leidos does not control or warrant the accuracy of assumptions drawn from external sources.

The following image depicts natural gas cost assumptions used to support fuel costs associated with distributed generation resources based upon this fuel source. This information was sourced directly from the local gas utility and applied to a range of generator configurations:

New Jersey Natural Gas
Prices per therm

General Service Large (GSL)
Commercial using greater than or equal to 5,000 therms annually

	Customer Charge	Demand Charge per HMAD	Delivery	BGSS
Nov-17	$56.16	$1.85	$0.4623	$0.3212
Dec-17	$56.16	$1.85	$0.4623	$0.4329
Jan-18	$56.03	$1.85	$0.4611	$0.4055
Feb-18	$56.03	$1.85	$0.4611	$0.4859
Mar-18	$56.03	$1.85	$0.4611	$0.3879
Apr-18	$49.93	$1.84	$0.4371	$0.3975
May-18	$49.93	$1.84	$0.4371	$0.4042
Jun-18	$50.09	$1.84	$0.4367	$0.3950
Jul-18	$50.09	$1.84	$0.4367	$0.4081
Aug-18	$50.09	$1.84	$0.4367	$0.4181
Sep-18	$50.09	$1.84	$0.4356	$0.4246
Oct-18	$52.17	$1.84	$0.4279	$0.4370

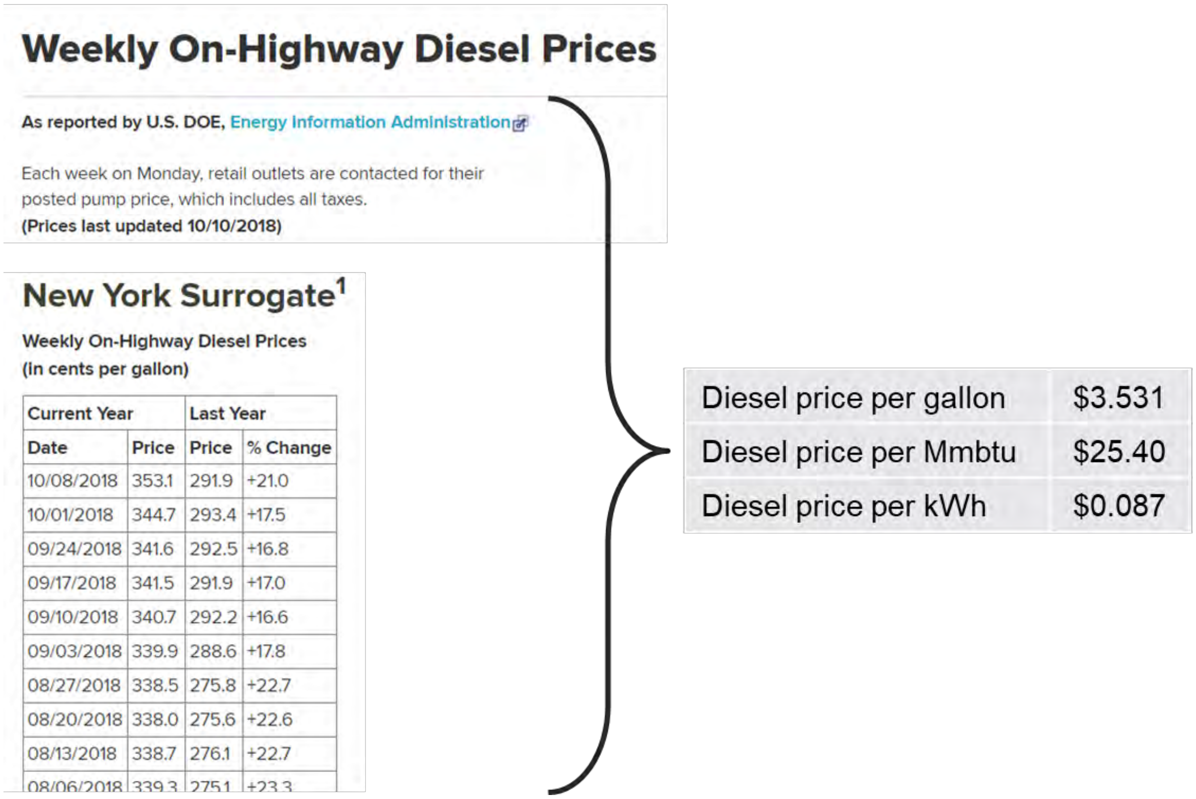
Important Notes:
The Demand Charge is applied to a customer's Highest Month Average Daily Usage (HMAD).
The HMAD represents the highest daily usage a customer could have in one month.

Gen Size (kW)	Monthly kWh Consumption	Monthly Therms Consumption	Customer Charge ($56.16)	Demand Charge ($1.85 per Highest Month Daily Usage)	Delivery Charge ($0.4623 per Therm)	Total ($)	$/kWh
50	36000	1229	$ 56.16	$ 94.71	$ 568.01	$ 718.88	$ 0.0200
100	72000	2457	$ 57.16	$ 189.42	$ 1,136.03	$ 1,382.61	$ 0.0192
250	180000	6143	$ 58.16	$ 473.55	$ 2,840.07	$ 3,371.78	$ 0.0187
500	360000	12287	$ 59.16	$ 947.10	$ 5,680.14	$ 6,686.40	$ 0.0186
1000	720000	24573	$ 60.16	$ 1,894.20	$ 11,360.27	$ 13,314.63	$ 0.0185
						Average	**$ 0.0190**

Figure 25. Natural Gas Cost Assumptions

The following image depicts diesel cost assumptions used to support fuel costs associated with distributed generation resources based upon this fuel source. Please note the almost 5-to-1 ratio of diesel price to natural gas price:

https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/On-Highway-Diesel/Weekly-Diesel-Prices



Weekly On-Highway Diesel Prices

As reported by U.S. DOE, Energy Information Administration

Each week on Monday, retail outlets are contacted for their posted pump price, which includes all taxes.
(Prices last updated 10/10/2018)

New York Surrogate[1]

Weekly On-Highway Diesel Prices
(in cents per gallon)

Current Year		Last Year	
Date	Price	Price	% Change
10/08/2018	353.1	291.9	+21.0
10/01/2018	344.7	293.4	+17.5
09/24/2018	341.6	292.5	+16.8
09/17/2018	341.5	291.9	+17.0
09/10/2018	340.7	292.2	+16.6
09/03/2018	339.9	288.6	+17.8
08/27/2018	338.5	275.8	+22.7
08/20/2018	338.0	275.6	+22.6
08/13/2018	338.7	276.1	+22.7
08/06/2018	339.3	275.1	+23.3

Diesel price per gallon	$3.531
Diesel price per Mmbtu	$25.40
Diesel price per kWh	$0.087

Figure 26. Diesel Cost Assumptions

The following image depicts gas turbine capital cost assumptions, based upon various size ratings. This information was based upon direct research with manufacturers:

Gas Turbine (NG)	kW	Cap Cost ($/kW)
GT_75	75	2014
GT_250	250	2014
GT_500	500	1623
GT_750	750	1493
GT_1000	1000	1428
GT_2500	2500	1133
GT_5000	5000	994

Figure 27. Gas Turbine Capital Cost Assumptions

The following image depicts energy storage capital cost assumptions, based upon various size ratings. This information was based upon direct research with manufacturers. A variable capital cost of $1,000 per kWh was utilized, accounting for siting, permitting, and other interconnection requirements:

Li-Ion Battery Size	Capital Cost ($/kWh of installed storage capacity)	O&M ($/kWh/yr)	Major Maintenance ($/kWh/yr)	Capacity Maintenance ($/kWh/yr)		O&M + Major = Total O&M ($/kWh/yr)
<1MWh	$700.00	$4.50	$24.00	$6.50		$28.50
1-4MWh	$525.00	$3.00	$24.00	$5.00		$27.00
4-9MWh	$475.00	$3.00	$21.00	$5.00		$24.00

Assumptions and notes:

1. CapEx is storage and balance of system equipment, install and commissioning only. It excludes siting, permitting, land or enviro.
2. The major maintenance and opex numbers assume a 25 year useful life for the asset. This will require a major rebuild of the inverters in year 15 or so.
3. The capacity maintenance line item covers replenishment of the storage capacity due to battery degradation. The primary degradation driver is usage (throughput) of the battery, and to a lesser extent shelf life. The assumption with this value is a single full cycle of the battery every weekday of the year. If the battery is cycled much less, this may not be required at all. Naturally it goes up if it is cycled more.
4. All of these values were informed by a 6 hour capacity assumption (to support outages).
5. kWh's in all cases above refer to the installed storage capacity of the project and not energy throughput.

Figure 28. Energy Storage Capital Cost Assumptions

The following depicts cost assumptions associated with solar generation. This information was derived from a national benchmarking report produced by NREL:

Executive Summary

This report benchmarks U.S. solar photovoltaic (PV) system installed costs as of the first quarter of 2017 (Q1 2017). We use a bottom-up methodology, accounting for all system and project-development costs incurred during the installation to model the costs for residential, commercial, and utility-scale systems. In general, we attempt to model the typical installation techniques and business operations from an installed-cost perspective. Costs are represented from the perspective of the developer/installer; thus, all hardware costs represent the price at which components are purchased by the developer/installer, not accounting for preexisting supply agreements or other contracts. Importantly, the benchmark also represents the sales price paid to the installer; therefore, it includes profit in the cost of the hardware,[1] along with the profit the installer/developer receives, as a separate cost category. However, it does not include any additional net profit, such as a developer fee or price gross-up, which is common in the marketplace. We adopt this approach owing to the wide variation in developer profits in all three sectors, where project pricing is highly dependent on region and project specifics such as local retail electricity rate structures, local rebate and incentive structures, competitive environment, and overall project or deal structures. Finally, our benchmarks are national averages weighted by state installed capacities. Table ES-1 summarizes the first order benchmark assumptions.

Table ES-1. Benchmark Assumptions

Unit	Description	
Values	2017 U.S. dollars (USD)	
System Sizes	In direct current (DC) terms; inverter prices are converted by DC-to-alternating current (AC) ratios.	
PV Sector	**Description**	**Size Range**
Residential	Residential rooftop systems	3–10 kW
Commercial	Commercial rooftop systems, ballasted racking	10 kW–2 MW
Utility-Scale	Ground-mounted systems, fixed-tilt and one-axis tracker	>2 MW

Based on our bottom-up modeling, the Q1 2017 PV cost benchmarks are:

- $2.80 per watt DC (Wdc) (or $3.22 per watt AC [Wac]) for residential systems
- $1.85/Wdc (or $2.13/Wac) for commercial systems
- $1.03/Wdc (or $1.34/Wac) for fixed-tilt utility-scale systems
- $1.11/Wdc (or $1.44/Wac) for one-axis-tracking utility-scale systems.[2]

[1] Profit is one of the differentiators between "cost" (aggregated expenses incurred by a developer/installer to build a system) and "price" (what the end user pays for a system).
[2] This year, we use the same DC-to-AC ratio (1.3) for both fixed-tilt and one-axis-tracking utility-scale PV systems (see Section 2.5).

Figure 29. Solar Generation Cost Assumptions

Source: NREL (https://www.nrel.gov/docs/fy17osti/68925.pdf)

The following image depicts assumptions require to establish the cost of interruption to electric service which, in turn, has a direct bearing upon valuing the total cost of energy and the value of distributed generation in addressing those costs. These assumptions were derived by using the Interruption Cost Estimation (ICE) Calculator produced by the Berkeley Lab Energy and Environment Impacts Division. The costs associated with the Residential ($1.92 per unserved kWh) and Medium and Large C&I ($36.73 per unserved kWh) load classifications are used to account for outage costs of non-critical and critical loads, respectively:

SAIFI	SAIDI	CAIDI	#Residential	#Non-Residential	
1.000	720	720	0	1	New Jersey

Interruption Cost Estimates

Sector	# of Customers	Cost Per Event (2016$)	Cost Per Average kW (2016$)	Cost Per Unserved kWh (2016$)	Total Cost (2016$)
Residential	0	$22.93	$23.09	$1.92	$0.00
Small C&I	1	$8,706.59	$2,028.45	$169.04	$8,706.59
Medium and Large C&I	0	$81,104.61	$440.80	$36.73	$0.00
All Customers	**1**	**$8,706.59**	**$2,028.45**	**$169.04**	**$8,706.59**

Figure 30. Assumptions Required to Establish the Cost of Interruption to Electric Service

DER-CAM Output by Site Class

Results by Site Class

The following results were produced using DER-CAM according to the analytical methodology and assumptions described.

Middletown North High School – Proxy Case for Class: Middle and High Schools

The Middletown North High School is used as the fully analyzed proxy case for the Middle and High Schools on the list of participating sites. This assumes that load curves and operational profiles are similar. As previously discussed, this allowed for analysis of a class of participating sites and differential analysis based upon relative electric usage as a scaling factor.

The following output from DER-CAM illustrates this proxy case exhaustively based upon the planned analytical scenarios. Each output is discussed in detail. For the subsequent proxy cases and individual sites, a truncated set of output, representing the conclusions, is presented in the interest of brevity.

The following images depict the weekday and weekend load curves inferred and utilized by the DER-CAM tool as representative of high schools and middle schools. Note that this is not based upon actual interval data as AMI is not installed in Middletown. The first set of load curves represents electricity demand, while the second set represents demand for natural gas. The data provided by the participant only allowed to model the electricity tariff in DER-CAM as a blended rate of $0.12 per kWh that includes both energy and demand rates.

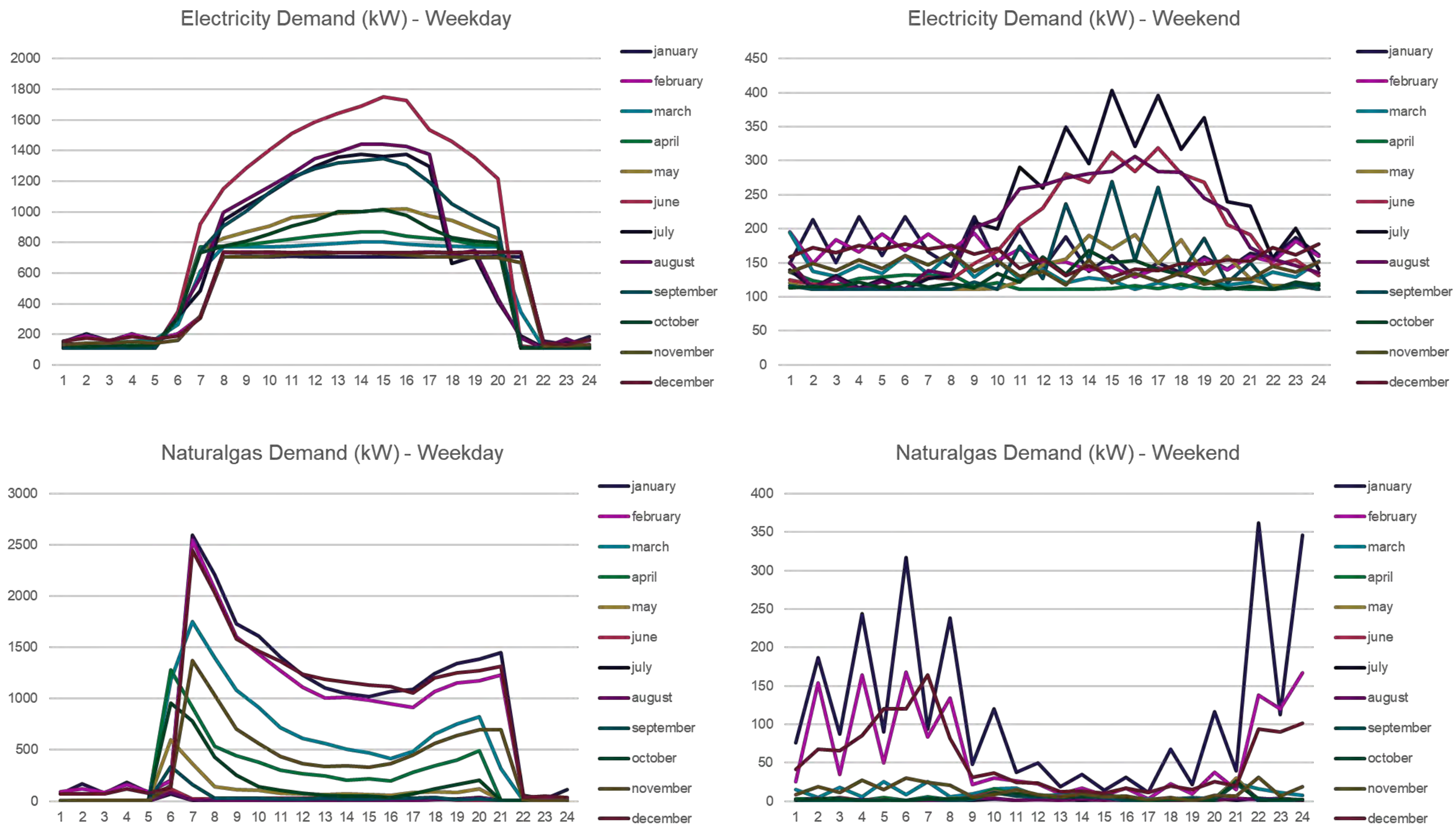


Figure 31. Middletown North High School Loads

As described in the methodology, the first scenario (1.A) to be analyzed for all participating sites was a reference case optimization depicting energy use drawn exclusively from the host utility. No DER were assumed. This was used to validate that DER-CAM was accurately simulating energy usage in line with historical billed amounts, which was the case.

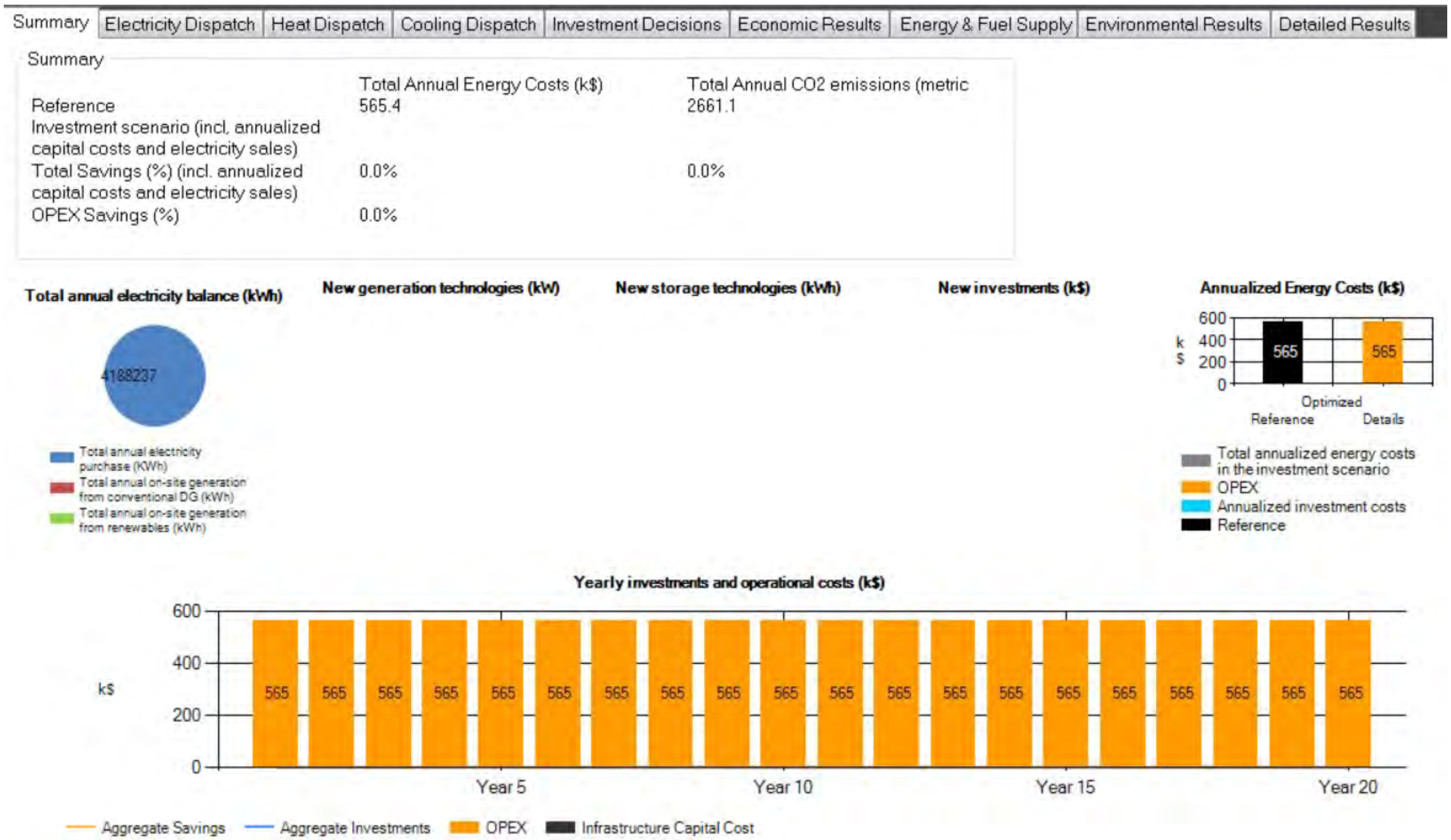


Figure 32. MNHS: Reference Case (1.A)

The second scenario (1.B), as described in the methodology, asked DER-CAM to pick an optimal mix of DER with no constraints applied, and no interruption of service valuation. Effectively, this scenario seeks an improved economic model based on DER investments measured solely against the annual electric usage. The primary test for feasibility is expressed in the total annual savings % which includes capital and operating costs, and electricity sales required to achieve the result. In this scenario, the investment is feasible. Also presented are the environment and societal benefits of reduced greenhouse gas, which DER-CAM also calculates.

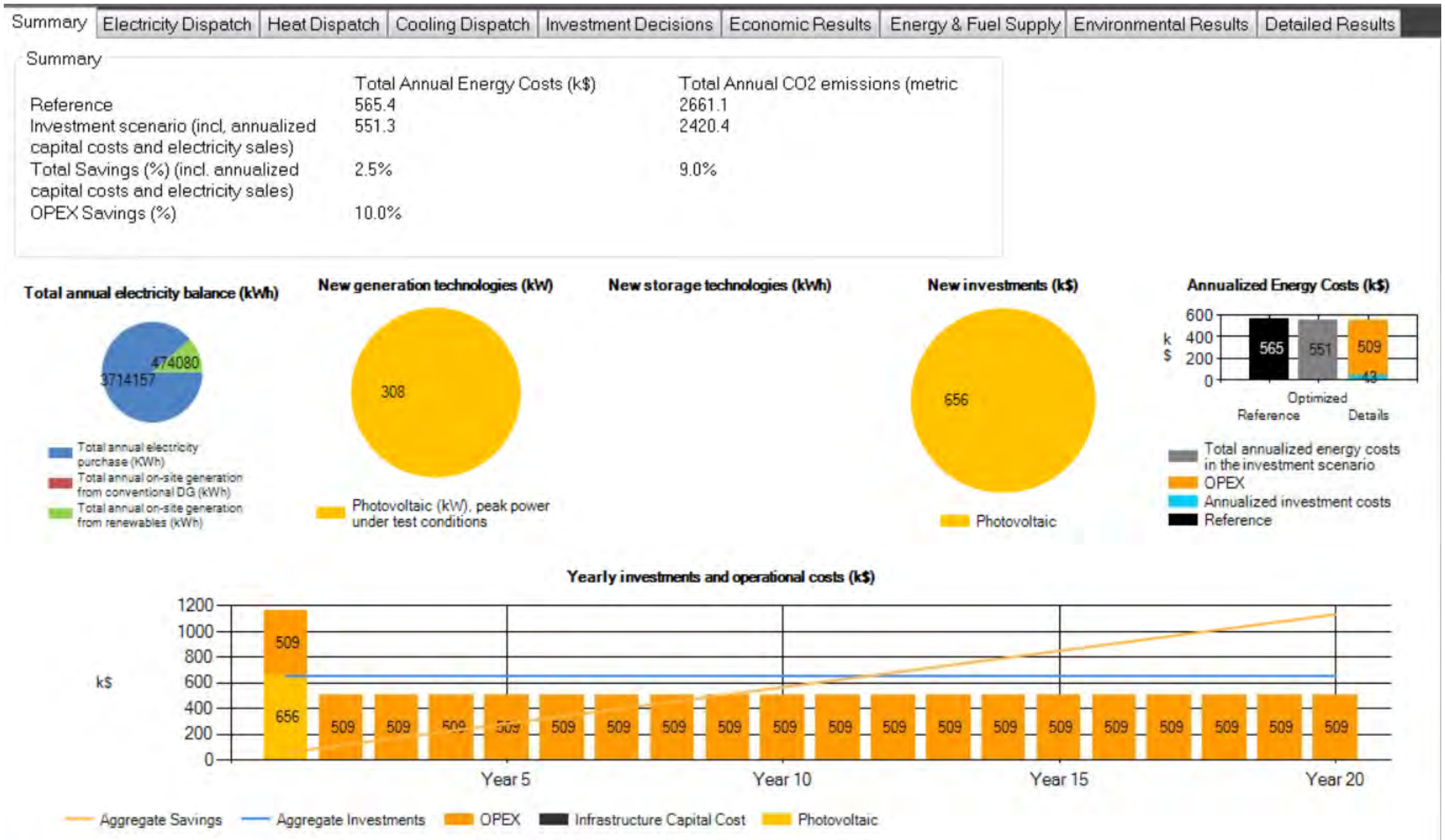


Figure 33. MNHS: Cost Optimization (1.B)

The third scenario (1.C) depicts an optimal mix of generation after applying constraints that force the inclusion of PV at 5% of site's peak load and storage at 10% of site's peak load as required options. This scenario still ignores any resiliency requirement or outage valuation. In this case, the alternative would not be feasible given the overall increase in cost. This is not surprising given the slim margin of value in the unconstrained case. For eventual determination of feasibility, this is not the ideal case and is presented for completeness only, not to illustrate a conclusion of the Study. Please refer carefully to the diagram to understand the recommended mix of generation sources including natural gas, solar, and storage.

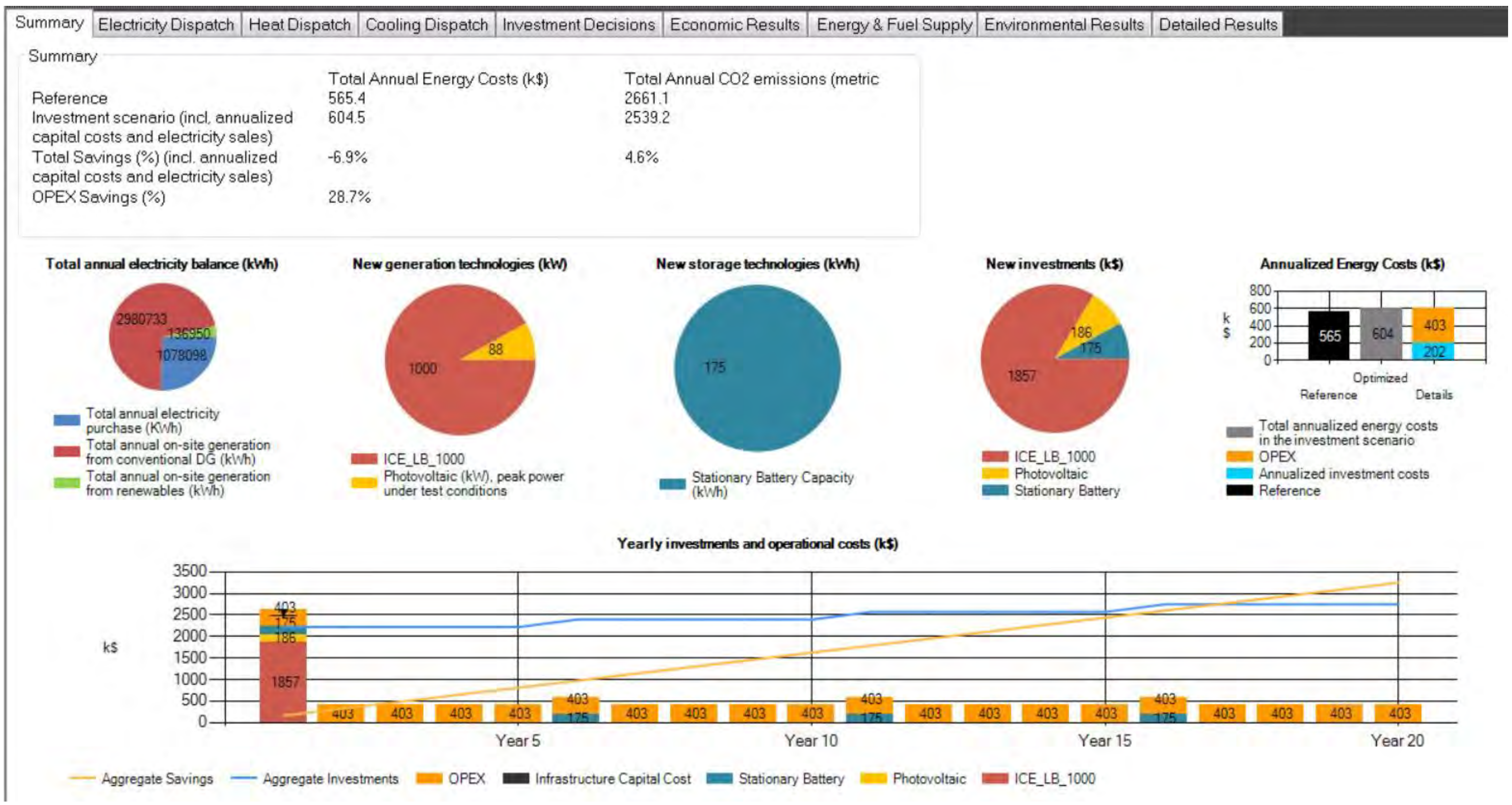


Figure 34. MNHS: Cost Optimization with 87.5 kW PV (5%) and 175 kW (10%) ES Forced (1.C)

The following table illustrates the resiliency factors applied to the DER-CAM model for the Middle and High School class of sites. This indicates that 70% of the site's load can be considered low value and non-critical with a variable cost of $1.92 per kWh. Thirty percent of the site's load is considered critical and is valued at $36.73 per kWh. This value and the critical load distribution is important as these vary by site class, and are factored into how much, and how costly time of interrupted electrical service is for these sites. This value ends up significantly impacting the overall value proposition of the generation mix investments for the site.

F1	Variable Cost ($/kWh)	Max Curtailment	Max Hours
LowCR	1.92	0.6	8760
MidCR	1.92	0.1	8760
HighCR	36.73	0.3	8760

Figure 35. Curtailment Parameters – Middle and High School Class

Taking the resiliency values into account, and valuing interrupted service accordingly, the additive cost of interruption is applied to the basic cost of the service and the comparative cost basis against which to determine the value of reliability investments necessary to mitigate the service interruption impact. DER-CAM modeled a 12-hour outage reference case scenario (2.A) as follows. One can notice that the reference annual cost of energy is increased from $565,000 based on scenario (1.A) to $773,000, as this scenario takes the cost of interruption into account.

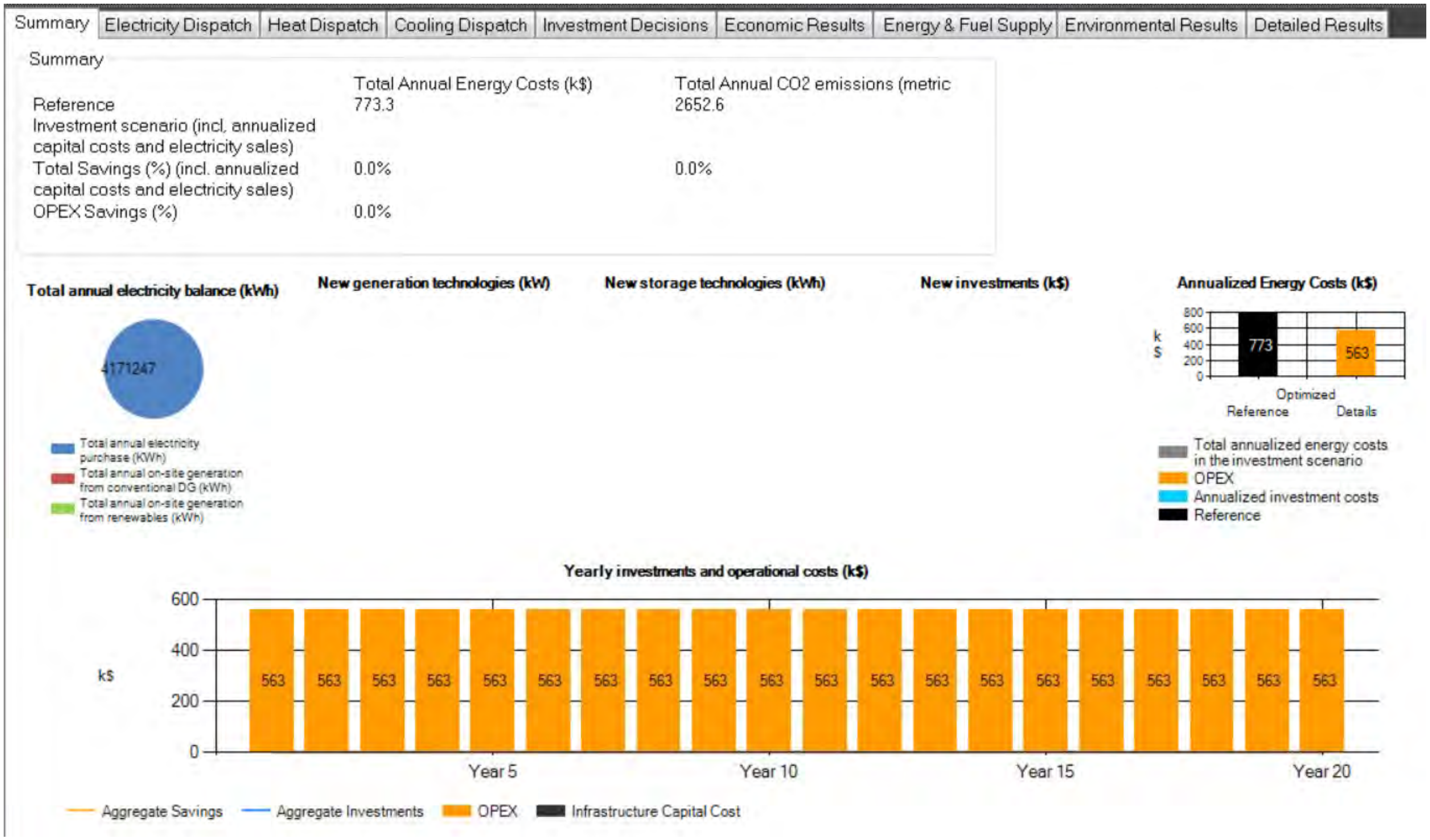


Figure 36. MNHS: Resiliency Reference Case with 12 Hr Outage (2.A)

The next scenario (2.B) depicts a 12-hour outage allowing DER-CAM to select the necessary DER mix and optimizing for a significant improvement in overall cost of 25.4%. This is the result of solving the issue of the high cost outage when critical loads are unserved.

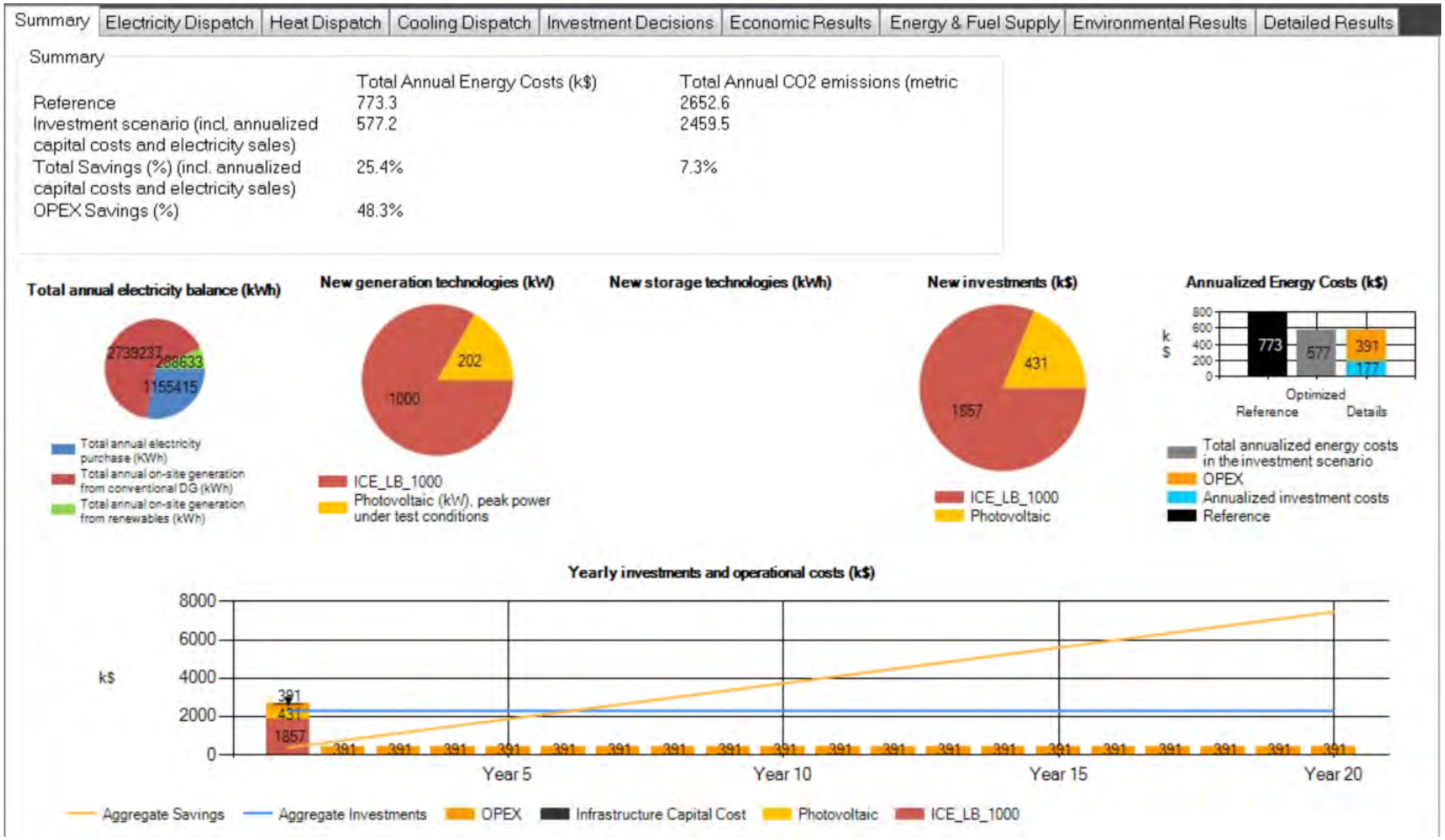


Figure 37. MNHS: Resiliency Reference Case with Cost Opt (2.B)

The following load curve is configured to show the dispatch of DER sources as a part of serving demand under the terms of scenario 2.B.

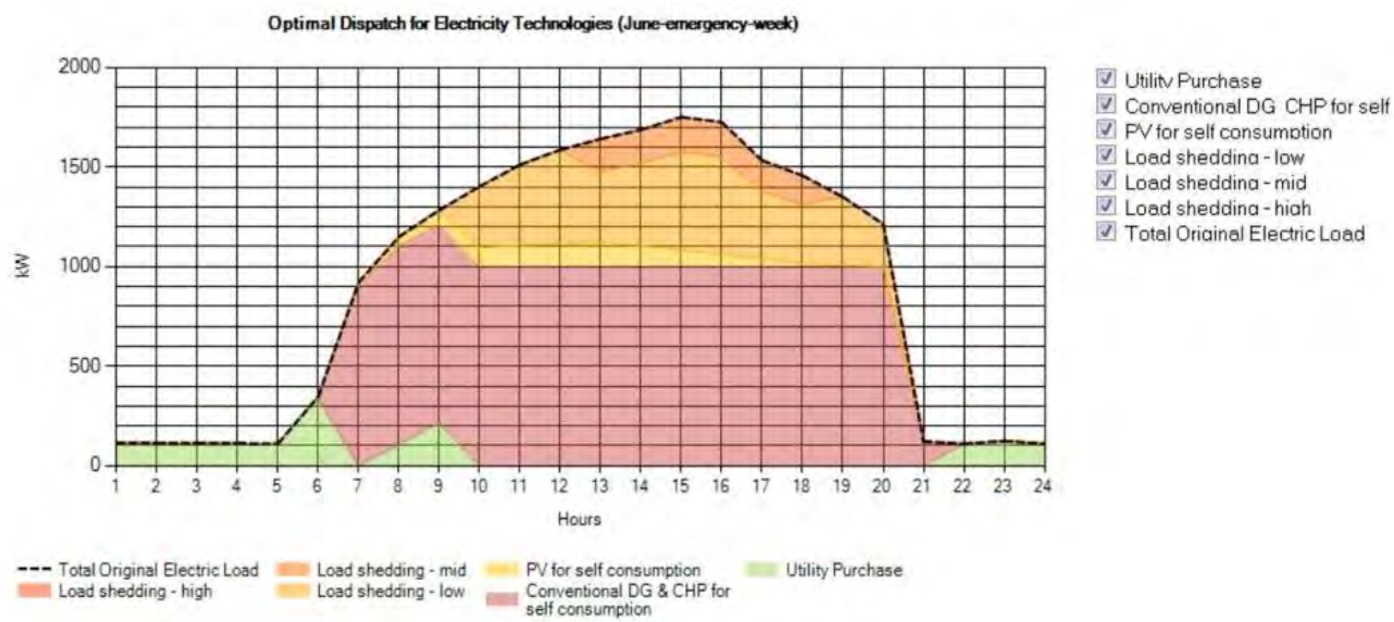


Figure 38. MNHS: DER Dispatch Curve Reference Case with Cost Opt (2.B)

The next scenario (2.C) takes the 12-hour outage and forces the application of PV at 5% of site's peak load and storage at 10% of site's peak load into the DER mix to be optimized. The business case is still positive with an annual improvement in total costs of 20.3%.

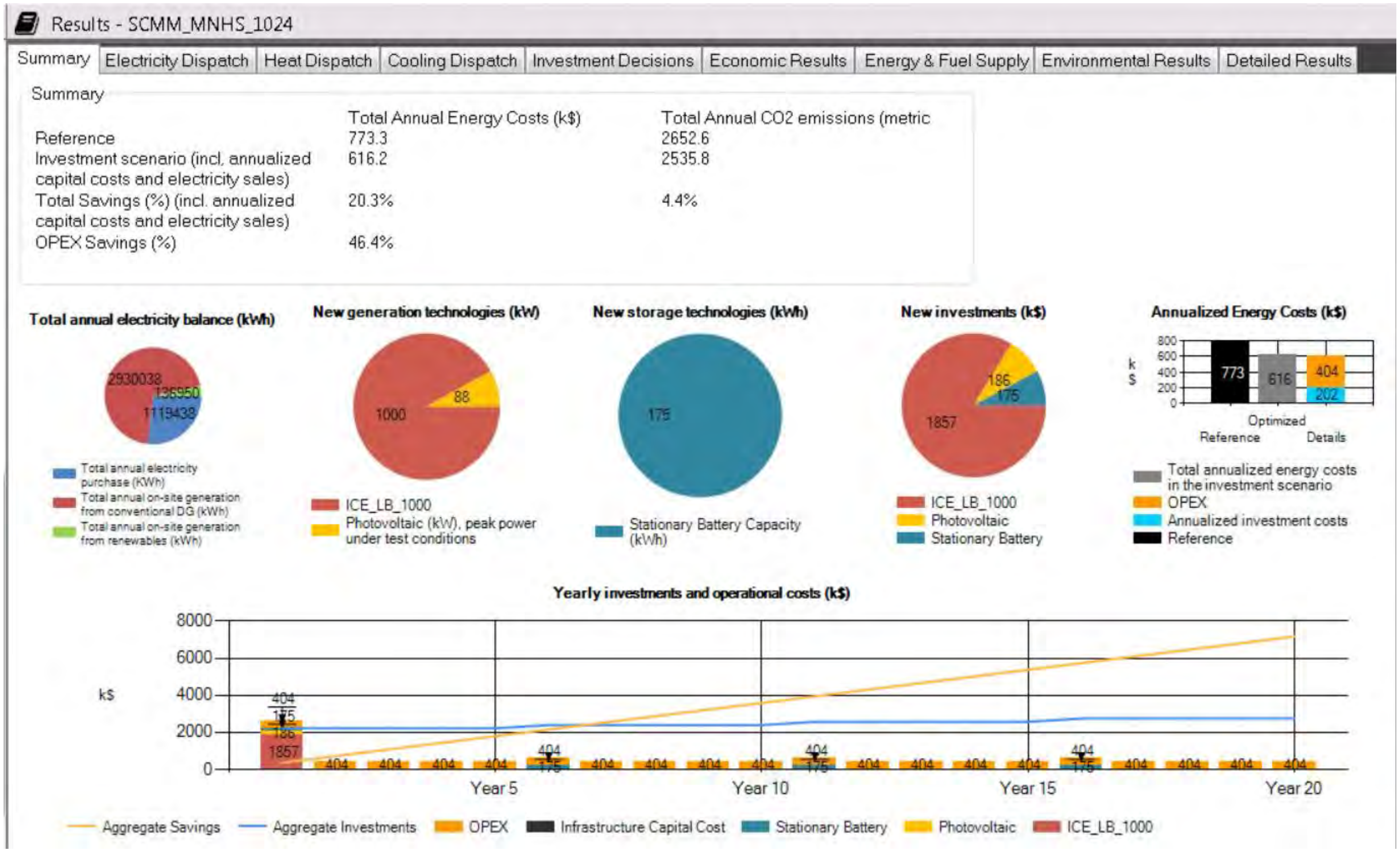


Figure 39. MNHS: Resiliency Reference Case with Cost Opt with 87.5 kW PV (5%) and 175 kW (10%) ES Forced (2.C)

The load curve for the scenario 2.C is presented below with DER dispatch, and battery state of charge.

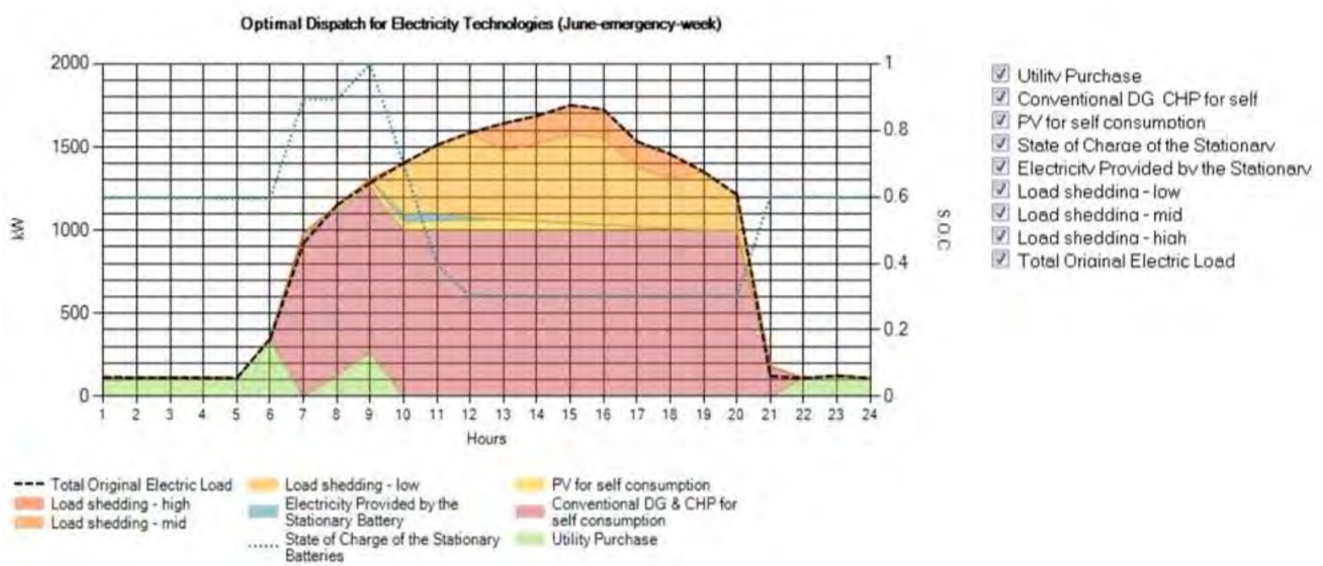


Figure 40. MNHS: Dispatch Curve for Resiliency Reference Case with Cost Opt with 87.5 kW PV (5%) and 175 kW (10%) ES Forced (2.C)

In the same manner that scenarios 2.A, 2.B, and 2.C modeled a 12-hour interruption, scenarios 3.A, 3.B, and 3.C model a worst case 7-day interruption. The goal is to allow DER-CAM to present optimized generation in support of continued operation of critical load over the identified timespan. In scenario 3.A, below, the reference of total energy requirement with no DER is presented.

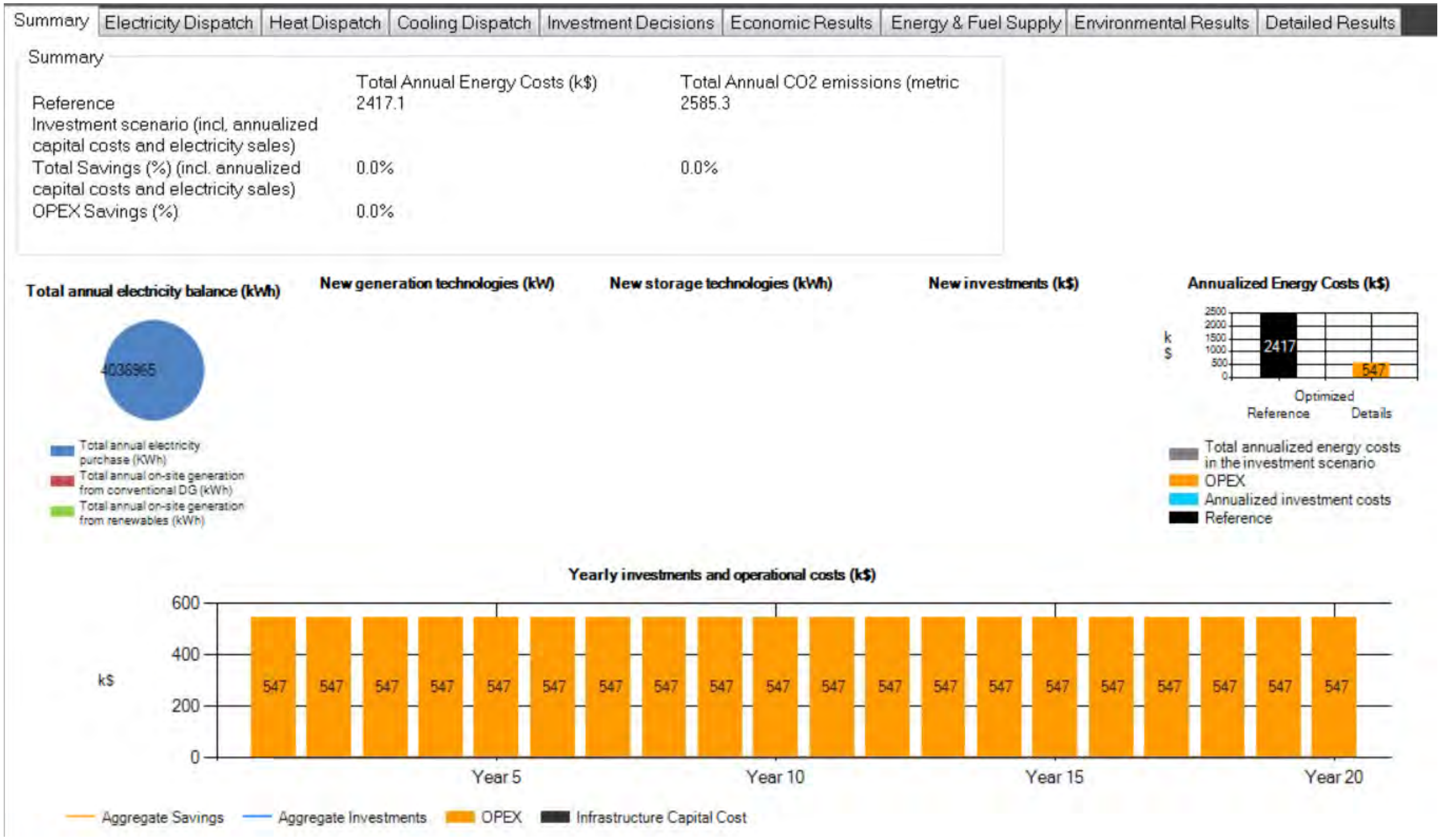


Figure 41. MNHS: Resiliency Reference Case with 7-Day Outage (3.A)

For a 7-day outage, scenario 3.B is presented to show the DER-CAM unconstrained generation mix for optimized economic value under the estimated cost of outage for critical loads. The longer duration is proven highly economically feasible based upon a 74.2% cost improvement over the base costs for such a reliability requirement.

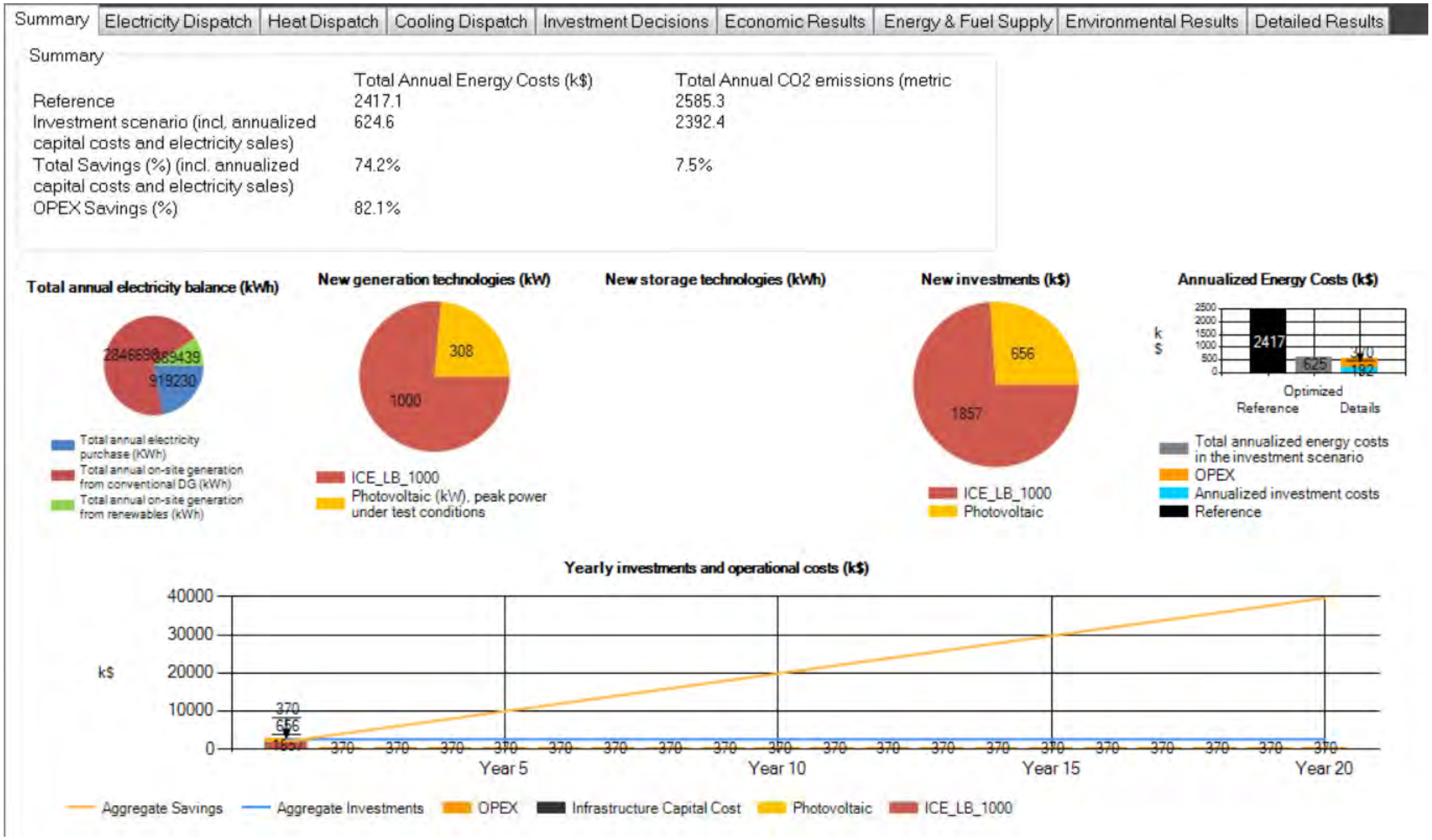


Figure 42. MNHS: DER Cost Optimized with 7-Day Outage (3.B)

Scenario 3.C depicts the primary case for determining feasibility. This case takes the worst outage valuation scenario of 7 days for critical load support, and applies a mix of DER including solar and storage. Based on the assumptions and cost estimates, such an investment would yield a 72.3% annual cost improvement and reliability that addresses critical loads for such interruptions over a 20 year time horizon.

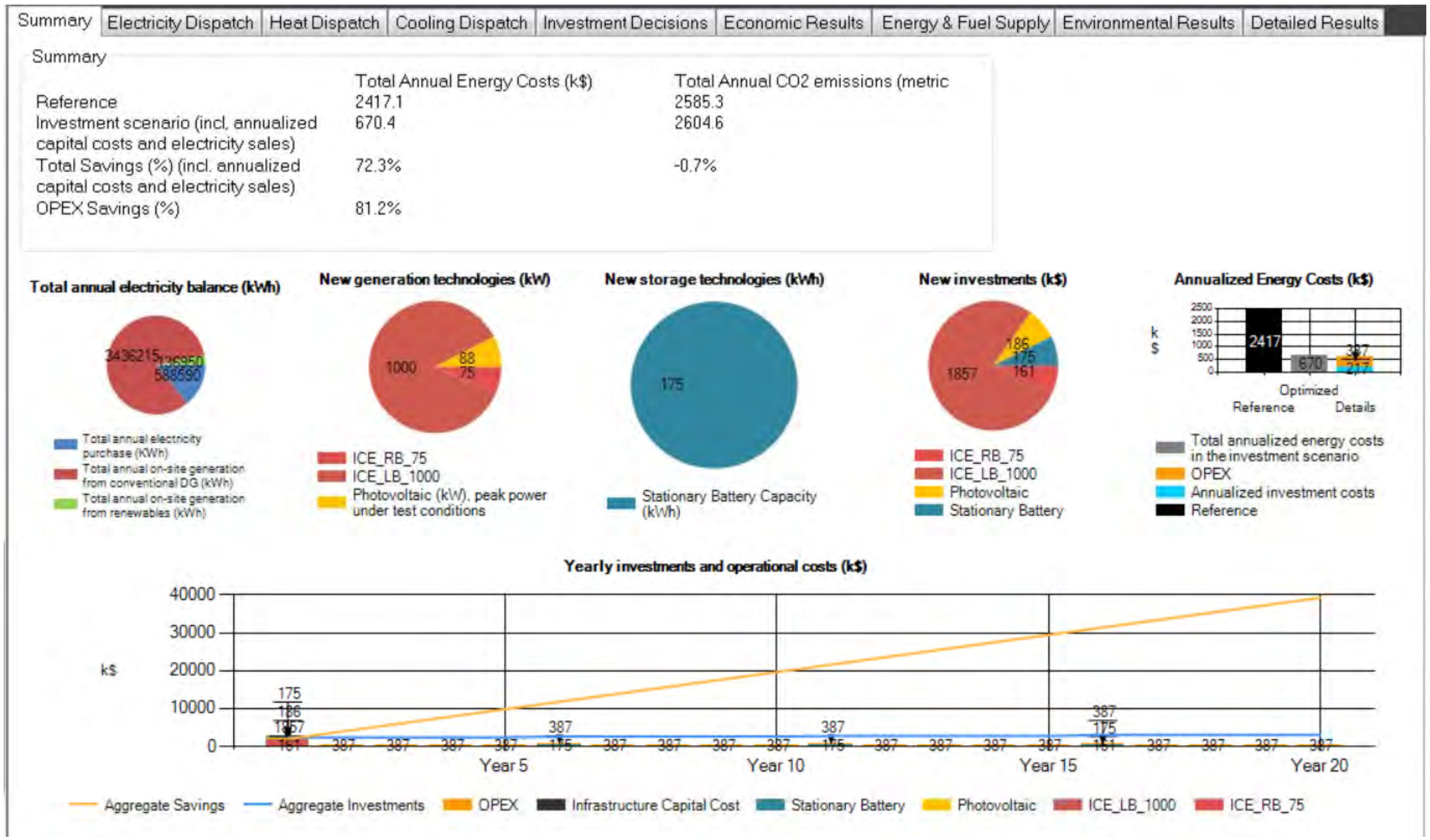


Figure 43. MNHS: DER Cost Optimized with Constraints with 7-Day Outage (3.C)

The following image depicts the load curve with DER dispatch as provided for in scenario 3.C, the feasibility confirmation case:

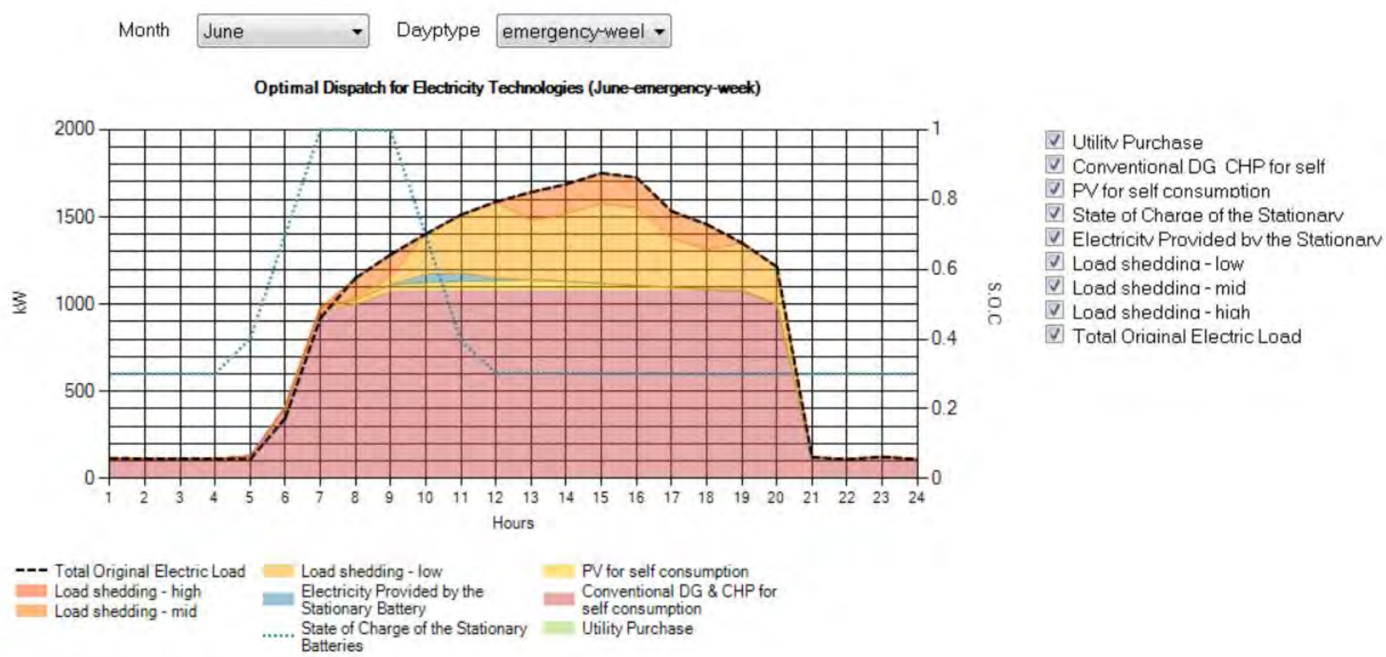


Figure 44. MNHS: DER Dispatch Curve with 7-Day Outage (3.C)

The following table summarizes the nine scenarios and their results at a glance. Scenario 3.C is the feasibility validation case, and will be treated as such for all site classes. A positive annualized cost savings for scenario 3.C supports a determination of feasibility to address worst case reliability requirements of a 7-day outage, with an optimal mix of DER including solar and storage.

Scenario #	Scenario Description	New DER Capacity (kW)	New DER Details (Type, #, kW)	Utility Purchase (MWh)	DER Generation (MWh)	Annualized Cost ($k)	Annualized Cost Savings ($k)	Annualized Cost Savings (%)	Annual CO2 emissions (metric tons)	Annual CO2 Emission Savings (metric tons)	Annual CO2 Emission Savings (%)
Normal Case											
1.A	Baseline: Normal Operation; No outages; Utility purchase only; No new and existing DER;	0	N/A	4,188	0	565	**0**	**0**	2,661	**0**	**0**
1.B	Cost optimization: No outages; New DER	308	(PV,1,308)	3,714	474	551	**14**	**2.5%**	2,420	**241**	**9.1%**
1.C	Cost optimization with constraints: No outages; New DER (PV-5% & BESS-10%)	1,263	(ICE_1000,1,1000); (PV,1,88); (BESS,1,175);	1,078	3,118	605	**-40**	**-7.1%**	2,539	**122**	**4.6%**
Low-Resiliency Case (12-Hour Outage)											
2.A	Low Resiliency Baseline: 12-Hour outages; Utility purchase only; No new and existing DER;	0	N/A	4,171	0	773	**0**	**0**	2,652	**0**	**0**
2.B	Cost optimization: 12-Hour outage; New DER	1,202	(ICE_1000,1,1000); (PV, 1, 202);	1,155	3,028	577	**196**	**25.4%**	2,460	**192**	**7.2%**
2.C	Cost optimization with constraints: 12-Hour outage; New DER (PV-5% & BESS-10%)	1,263	(ICE_1000,1,1000); (PV,1,88); (BESS,1,175);	1,119	3,067	616	**157**	**20.3%**	2,536	**116**	**4.4%**
High-Resiliency Case (7-Day Outage)											
3.A	High Resiliency Baseline: 7-Day outages; Utility purchase only; No new and existing DER;	0	N/A	4,036	0	2,417	**0**	**0**	2,585	**0**	**0**
3.B	Cost optimization: 7-Day outage; New DER	1,308	(ICE_1000,1,1000); (PV,1,308);	919	3,136	625	**1,792**	**74.1%**	2,392	**193**	**7.5%**
3.C	Cost optimization with constraints: 7-Day outage; New DER (PV-5% & BESS-10%)	1,338	(ICE_1000,1,1000); (ICE_75,1,75);(PV,1,88;) (BESS,1,175);	588	3,573	670	**1,747**	**72.3%**	2,604	**-19**	**-0.7%**

Figure 45. MNHS: Microgrid Generation Life Cycle Cost Analysis Summary

The following table provides investment cost summary necessary to achieve scenario 3.C, the feasibility case.

						Investment Cost over 20 year project life cycle ($)	**Annualized Investment Cost ($)**
Capital Costs							
New DER							
Type	*#*	*kW*	*Life (years)*	*Size of PV (m^2)*	*Unit cost ($)*		
Solar PV	1	88	30	572	$186,375	$186,375	$12,124
ICE_1000	1	1000	20	N/A	$1,857,000	$1,857,000	$149,010
ICE_75	1	75	15	N/A	$160,800	$321,600	$15,492
BESS	1	175	5	N/A	$175,000	$700,000	$40,421
		1338				**$3,064,975**	**$217,047**
Operational Costs							
Electric costs						$1,434,211	$71,711
Natural-gas Costs						$4,857,791	$242,890
Fixed O&M Costs						$105,000	$5,250
Variable O&M Costs						$1,350,280	$67,514
						$7,747,282	**$387,364**
Load curtailment costs						**$1,320,280**	**$66,014**
					Total Costs	**$12,132,537**	**$670,425**

Note: Cost Summary reflects new generation resource sizing as per scenario 3.C

Note: The Operational costs include total electric costs, fuel costs, fixed and variable O&M costs

Note: The annualized capital costs are calculated using the life span of DER and the discount rate of 5%

Note: The O&M costs only include DER specific fixed and variable O&M costs, it does not include fuel costs.

Note: Annual O&M costs are assumed to be constant across all the 20 years of project life cycle.

Note: Natural gas costs include cost to serve existing thermal loads and new DG

Figure 46. MNHS: Microgrid Generation Investment Cost Summary

The following graph depicts the annual investment and operational costs by generation source for scenario 3.C, the feasibility test case.

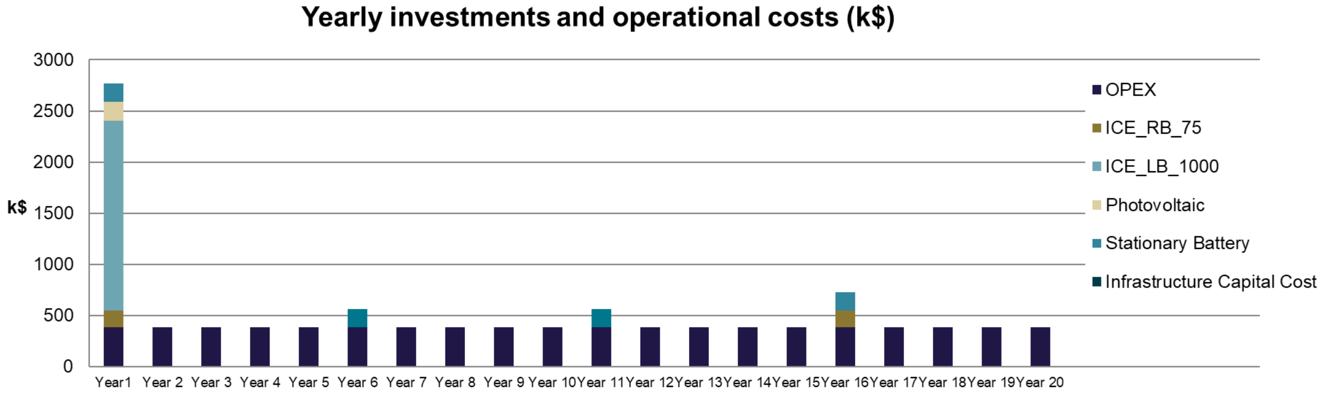


Figure 47. MNHS: Microgrid Generation Annual Investment Cost Summary

The following graph depicts annual investment and cost curves demonstrating the high value return and feasibility of scenario 3.C, the feasibility test case.

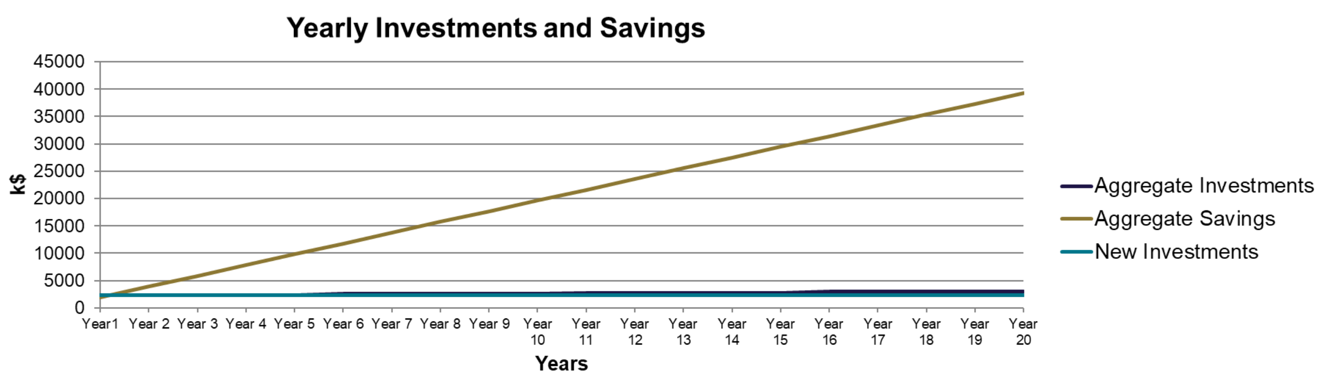


Figure 48. MNHS: Microgrid Generation Investment Cost Summary Curves

The preceding data demonstrates the feasibility of the Middletown North High School, and by extension, the entire site class pertaining to middle and high schools. While all analysis output is preserved, in order to address the remaining site classes and individual sites with brevity and clarity, a concise set of data will be presented for each site class to provide for the following:

- Inferred site load curves
- Electricity tariff modeled in DER-CAM
- Resiliency assumption – site-specific
- 7-day outage mixed DER optimization – Scenario 3.C – Feasibility Test Case
- Scenario 3.C dispatch load curve
- Analytical scenarios summary table
- Generation investment cost summary
- Yearly generation investment cost summary
- Yearly investments and savings summary

For all sites and site classes, feasibility will be determined by a positive return on overall costs over a 20-year timeframe based upon the optimal mix of DER resources necessary to meet the 7-day resiliency requirements included in analytical scenario 3.C.

Bayview Elementary School – Proxy Case for Class: Elementary Schools

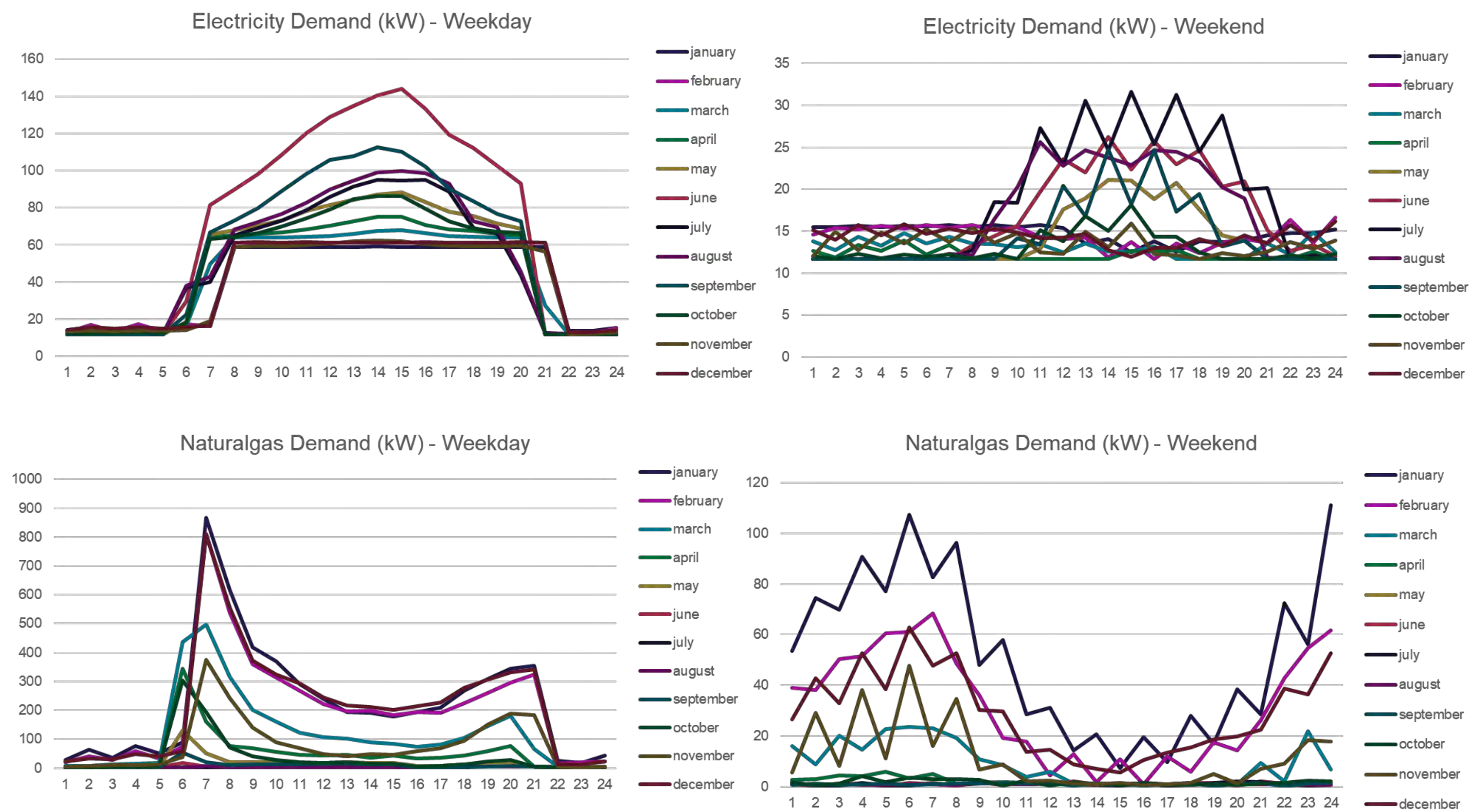


Figure 49. Bayview Elementary Loads

Curtailment Parameters

	F1	VariableCost	MaxCurtailment	MaxHours
1	LowCR	1.92	0.6	8760
2	MidCR	1.92	0.1	8760
3	HighCR	36.73	0.3	8760

Figure 50. Bayview Elementary Curtailment Parameters

The data provided by the participant only allowed modeling of the electricity tariff in DER-CAM as a blended rate of $0.12 per kWh that includes both energy and demand rates.

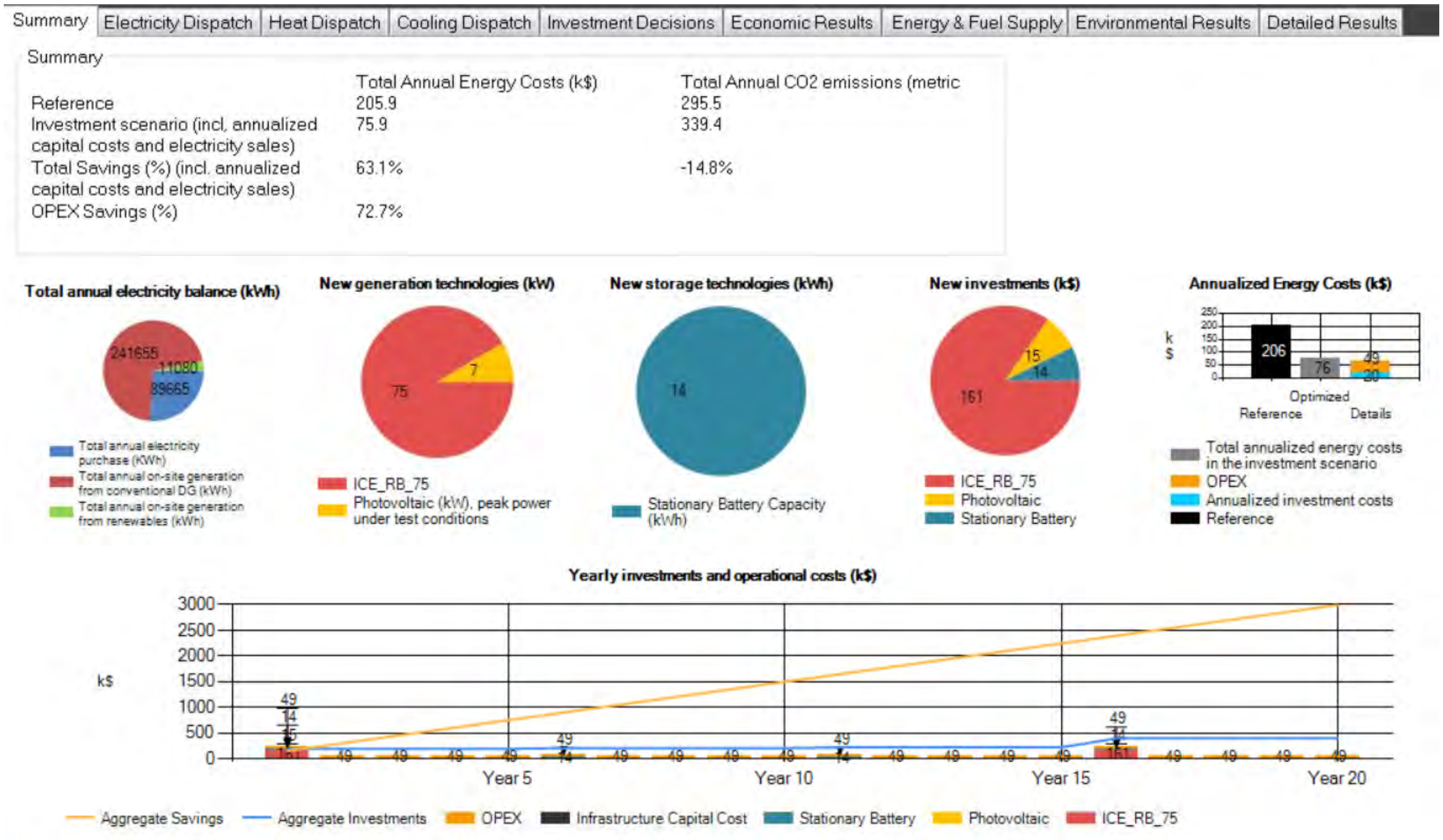


Figure 51. Bayview Elementary: 3.C (PV 5%, ES 10%)

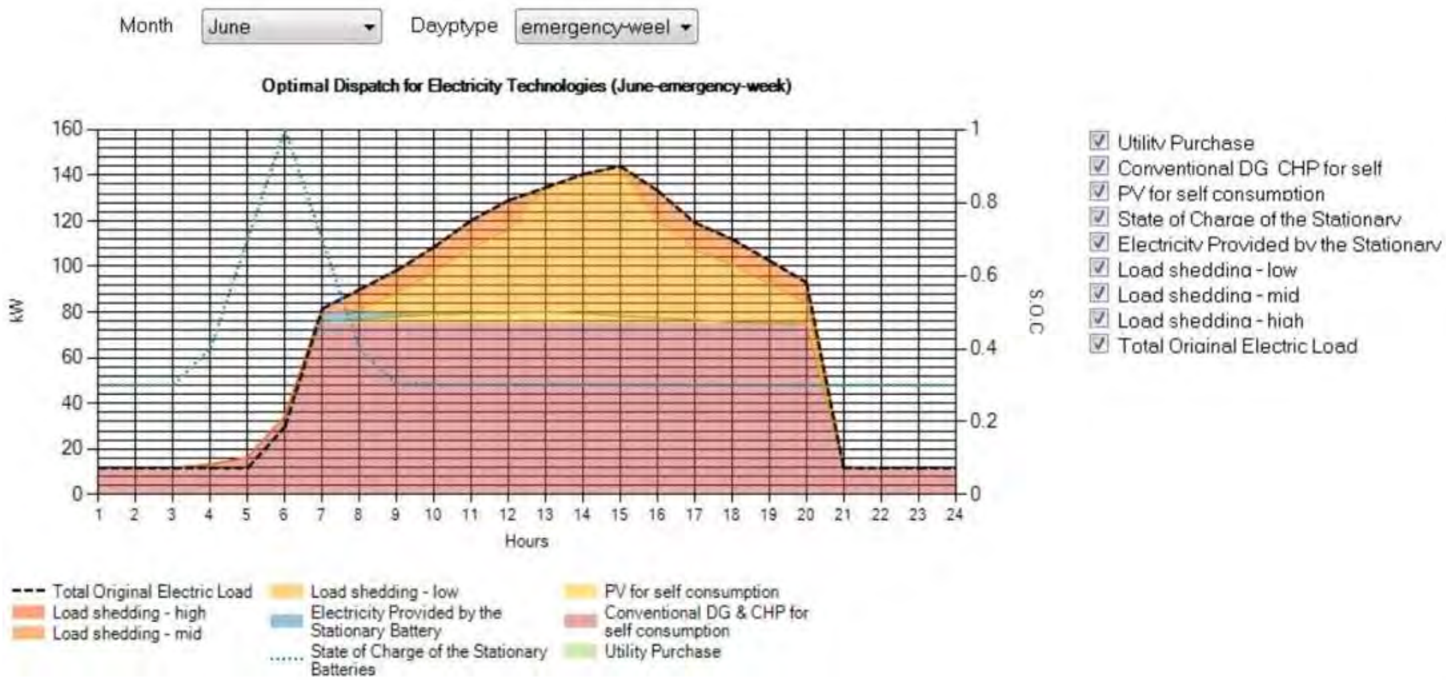


Figure 52. Bayview Elementary: 3.C (PV 5%, ES 10%)

Scenario #	Scenario Description	New DER Capacity (kW)	New DER Details (Type, #, kW)	Utility Purchase (MWh)	DER Generation (MWh)	Annualized Cost ($k)	Annualized Cost Savings ($k)	Annualized Cost Savings (%)	Annual CO2 emissions (metric tons)	Annual CO2 Emission Savings (metric tons)	Annual CO2 Emission Savings (%)
Normal Case											
1.A	Baseline: Normal Operation; No outages; Utility purchase only; No new and existing DER;	0	N/A	345	0	56.5	**0**	**0**	302	**0**	**0**
1.B	Cost optimization: No outages; New DER	80	(PV,1,80)	238	107	54.8	**1.7**	**3.0%**	247	**55**	**18.2%**
1.C	Cost optimization with constraints: No outages; New DER (PV-5% & BESS-10%)	21	(PV,1,7); (BESS,1,14);	334	11	59.8	**-3.3**	**-5.8%**	296	**6**	**2.0%**
Low-Resiliency Case (12-Hour Outage)											
2.A	Low Resiliency Baseline: 12-Hour outages; Utility purchase only; No new and existing DER;	0	N/A	344	0	73.1	**0**	**0**	301	**0**	**0**
2.B	Cost optimization: 12-Hour outage; New DER	118	(PV,1,118)	195	149	59.5	**13.6**	**18.6%**	225	**76**	**25.2%**
2.C	Cost optimization with constraints: 12-Hour outage; New DER (PV-5% & BESS-10%)	96	(ICE_75,1,75); (PV,1,7); (BESS,1,14);	93	252	70.3	**2.8**	**3.8%**	341	**-40**	**-13.3%**
High-Resiliency Case (7-Day Outage)											
3.A	High Resiliency Baseline: 7-Day outages; Utility purchase only; No new and existing DER;	0	N/A	333	0	205.9	**0**	**0**	296	**0**	**0**
3.B	Cost optimization: 7-Day outage; New DER	145	(ICE_75,1,75); (PV,1,70);	93	249	69.6	**136**	**66.2%**	285	**11**	**3.7%**
3.C	Cost optimization with constraints: 7-Day outage; New DER (PV-5% & BESS-10%)	96	(ICE_75,1,75); (PV,1,7); (BESS,1,14);	89	252	75.9	**130**	**63.1%**	339	**-43**	**-14.5%**

Figure 53. Bayview Elementary: Microgrid Generation Life Cycle Cost Analysis Summary

Type	#	kW	Life (years)	Size of PV (m^2)	Unit cost ($)	Investment Cost over 20 year project life cycle ($)	Annualized Investment Cost ($)
Capital Costs							
New DER							
Solar PV	1	7	30	46	$14,910	$14,910	$970
ICE_75	1	75	15	N/A	$160,800	$321,600	$15,492
BESS	1	14	5	N/A	$14,000	$56,000	$3,234
		96				**$392,510**	**$19,695**
Operational Costs							
Electric costs						$220,820	$11,041
Natural-gas Costs						$641,180	$32,059
Fixed O&M Costs						$8,400	$420
Variable O&M Costs						$116,000	$5,800
						$986,400	**$49,320**
Load curtailment costs						**$137,460**	**$6,873**
					Total Costs	**$1,516,370**	**$75,888**

Note: Cost Summary reflects new generation resource sizing as per scenario 3.C

Note: The Operational costs include total electric costs, fuel costs, fixed and variable O&M costs

Note: The annualized capital costs are calculated using the life span of DER and the discount rate of 5%

Note: The O&M costs only include DER specific fixed and variable O&M costs, it does not include fuel costs.

Note: Annual O&M costs are assumed to be constant across all the 20 years of project life cycle.

Note: Natural gas costs include cost to serve existing thermal loads and new DG

Figure 54. Bayview Elementary: Microgrid Life Cycle Cost Summary

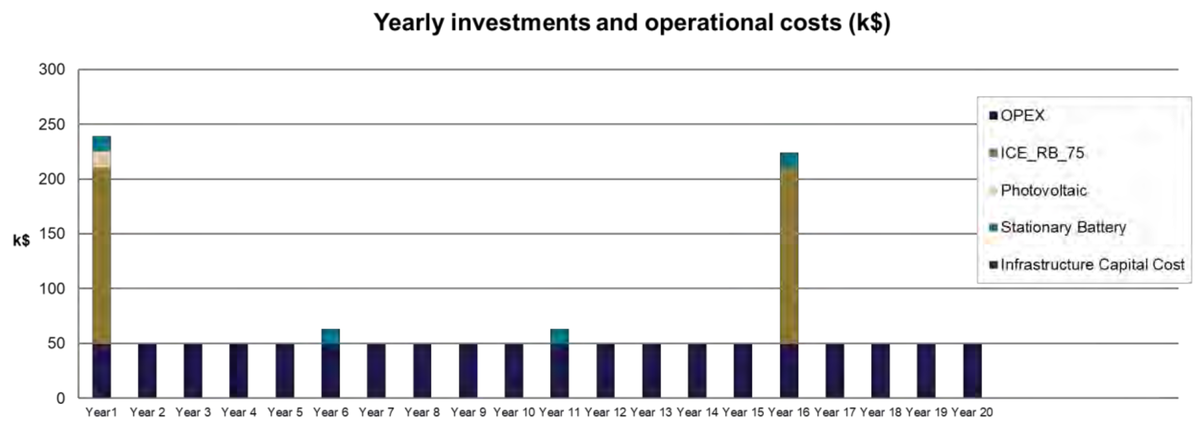


Figure 55. Bayview Elementary: Microgrid Life Cycle Annual Cost Summary

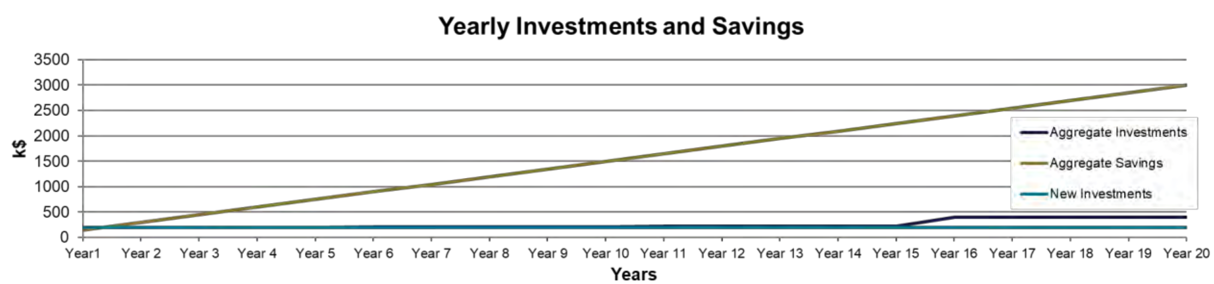


Figure 56. Bayview Elementary: Microgrid Life Cycle Cost Summary Curves

The preceding data demonstrates the feasibility of the Bayview Elementary School, and by extension, the entire site class pertaining to elementary schools.

Middletown Municipal Complex – Proxy Case for Class: Government Buildings + NY Waterways + NJNG CNG Station

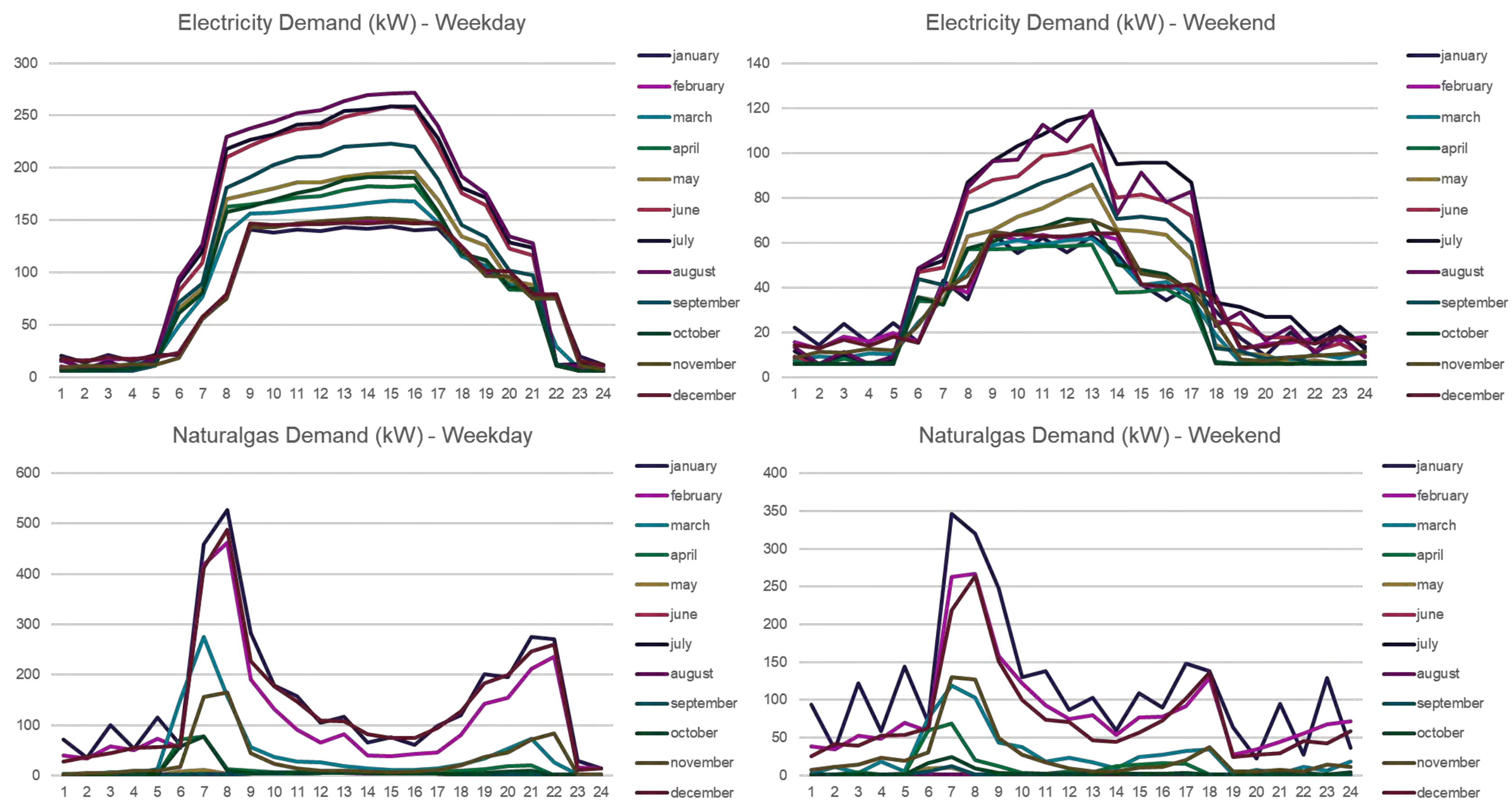


Figure 57. Middletown Municipal Complex Loads

Curtailment Parameters

	F1	VariableCost	MaxCurtailment	MaxHours
1	LowCR	1.92	0.6	8760
2	MidCR	1.92	0.1	8760
3	HighCR	36.73	0.3	8760

Figure 58. Middletown Municipal Complex Curtailment Parameters

The participant provided detailed electricity bills to model the electricity tariff in DER-CAM using the actual tariff schedule, General Service Secondary 3 Phase: JC_GS3_01D. Based on this tariff schedule the delivery charge per kWh is $0.021, the demand charge per kW is $6.62, and the monthly customer charge is $11.93.

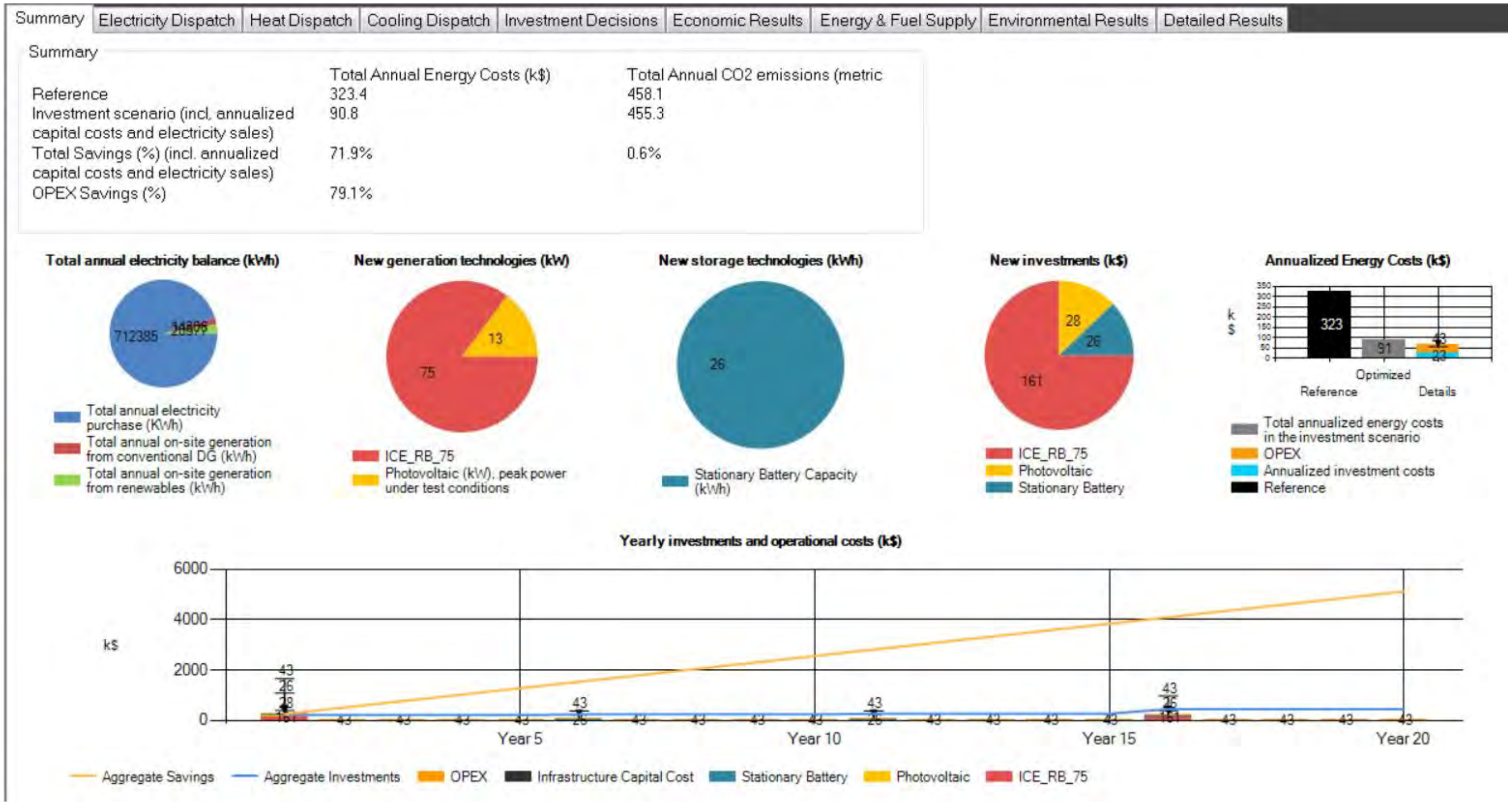


Figure 59. Middletown Municipal Complex: 3.C (PV 5%, ES 10%)

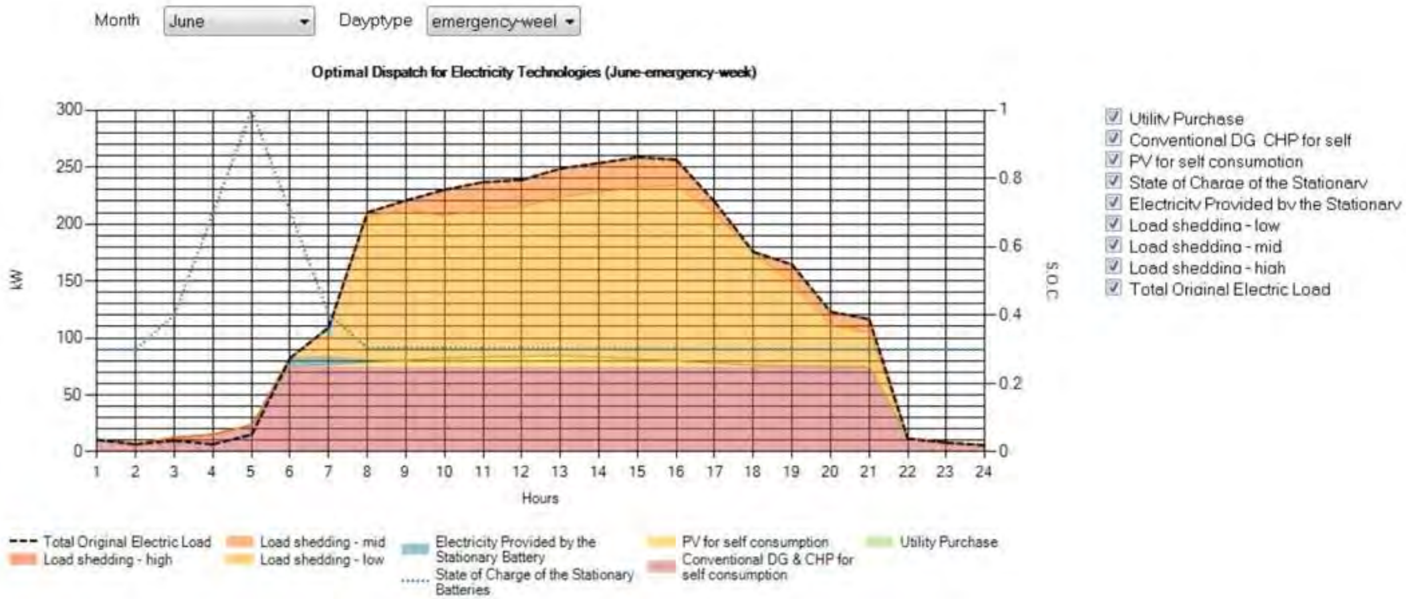


Figure 60. Middletown Municipal Complex: High Resiliency Case – Optimal DER Dispatch

Scenario #	Scenario Description	New DER Capacity (kW)	New DER Details (Type, #, kW)	Utility Purchase (MWh)	DER Generation (MWh)	Annualized Cost ($k)	Annualized Cost Savings ($k)	Annualized Cost Savings (%)	Annual CO2 emissions (metric tons)	Annual CO2 Emission Savings (metric tons)	Annual CO2 Emission Savings (%)
Normal Case											
1.A	Baseline: Normal Operation; No outages; Utility purchase only; No new and existing DER;	0	N/A	760	0	45.2	**0**	**0**	469	**0**	**0**
1.B	Cost optimization: No outages; New DER	0	N/A	760	0	45.2	**0**	**0.0%**	469	**0**	**0.0%**
1.C	Cost optimization with constraints: No outages; New DER (PV-5% & BESS-10%)	39	(PV,1,13); (BESS,1,26);	739	21	52.4	**-7.2**	**-15.9%**	459	**10**	**2.1%**
Low-Resiliency Case (12-Hour Outage)											
2.A	Low Resiliency Baseline: 12-Hour outages; Utility purchase only; No new and existing DER;	0	N/A	757	0	76.3	**0**	**0**	468	**0**	**0**
2.B	Cost optimization: 12-Hour outage; New DER	75	(ICE_75,1,75);	752	5	61.6	**14.7**	**19.3%**	470	**-2**	**-0.4%**
2.C	Cost optimization with constraints: 12-Hour outage; New DER (PV-5% & BESS-10%)	114	(ICE_75,1,75); (PV,1,13); (BESS,1,26);	732	25	68.6	**7.7**	**10.1%**	459	**9**	**1.9%**
High-Resiliency Case (7-Day Outage)											
3.A	High Resiliency Baseline: 7-Day outages; Utility purchase only; No new and existing DER;	0	N/A	737	0	323.4	**0**	**0**	458	**0**	**0**
3.B	Cost optimization: 7-Day outage; New DER	80	(ICE_75,1,75); (PV,1,5);	724	22	84.2	**239**	**74.0%**	461	**-3**	**-0.7%**
3.C	Cost optimization with constraints: 7-Day outage; New DER (PV-5% & BESS-10%)	114	(ICE_75,1,75); (PV,1,13); (BESS,1,26);	712	34	90.8	**233**	**71.9%**	455	**2.7**	**0.6%**

Figure 61. Middletown Municipal Complex: Microgrid Generation Life Cycle Cost Analysis Summary

						Investment Cost over 20 year project life cycle ($)	Annualized Investment Cost ($)
Capital Costs							
New DER							
Type	*#*	*kW*	*Life (years)*	*Size of PV (m^2)*	*Unit cost ($)*		
Solar PV	1	13	30	85	$27,690	$27,690	$1,801
ICE_75	1	75	15	N/A	$160,800	$321,600	$15,492
BESS	1	26	5	N/A	$26,000	$104,000	$6,005
		114				**$453,290**	**$23,298**
Operational Costs							
Electric costs						$611,900	$30,595
Natural-gas Costs						$216,400	$10,820
Fixed O&M Costs						$15,600	$780
Variable O&M Costs						$6,860	$343
						$850,760	**$42,538**
Load curtailment costs						**$499,900**	**$24,995**
					Total Costs	**$1,803,950**	**$90,831**

Note: Cost Summary reflects new generation resource sizing as per scenario 3.C

Note: The Operational costs include total electric costs, fuel costs, fixed and variable O&M costs

Note: The annualized capital costs are calculated using the life span of DER and the discount rate of 5%

Note: The O&M costs only include DER specific fixed and variable O&M costs, it does not include fuel costs.

Note: Annual O&M costs are assumed to be constant across all the 20 years of project life cycle.

Note: Natural gas costs include cost to serve existing thermal loads and new DG

Figure 62. Middletown Municipal Complex: Microgrid Life Cycle Cost Summary

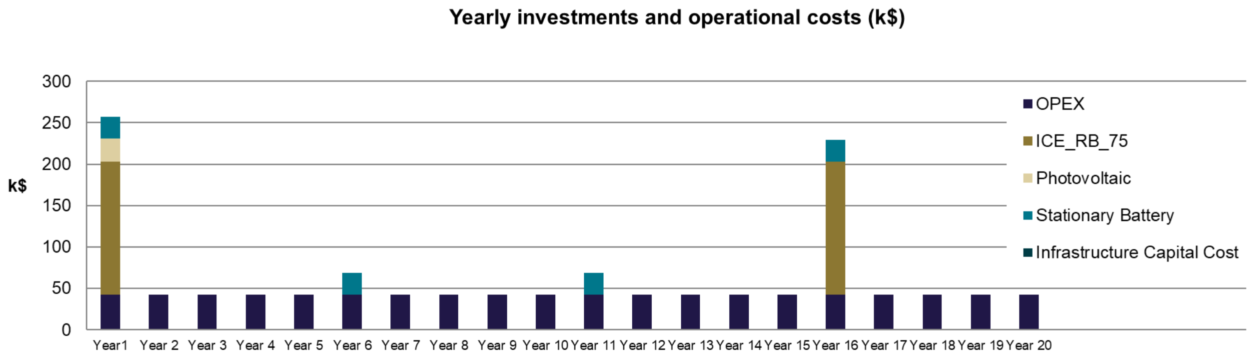


Figure 63. Middletown Municipal Complex: Microgrid Life Cycle Annual Cost Summary

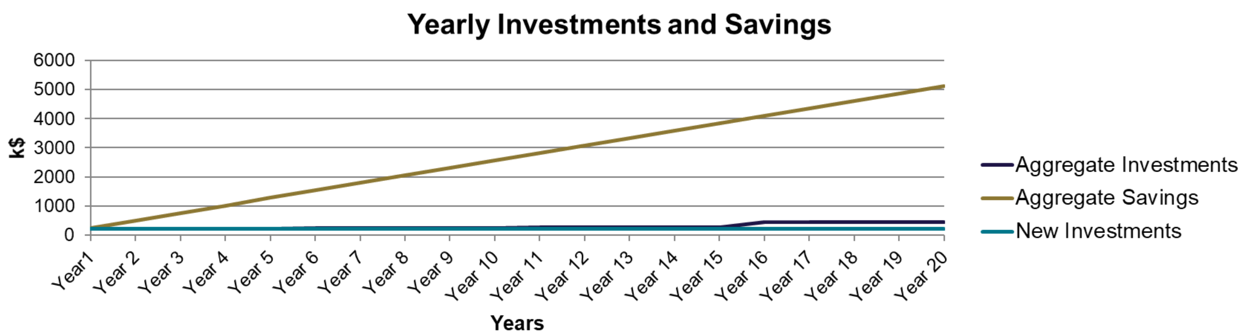


Figure 64. Middletown Municipal Complex: Microgrid Life Cycle Cost Summary Curves

The preceding data demonstrates the feasibility of the Middletown Municipal Complex, and by extension, the entire site class pertaining to government buildings, NY Waterways, and NJNG CNG Filling Station.

NWS Earle Administrative Facilities

NWS Earle, at the direction of its Public Works Officer, provided the aggregated data which is germane and necessary to meet the Study requirements. Data at the individual AMI meter level was neither provided, nor revealed.

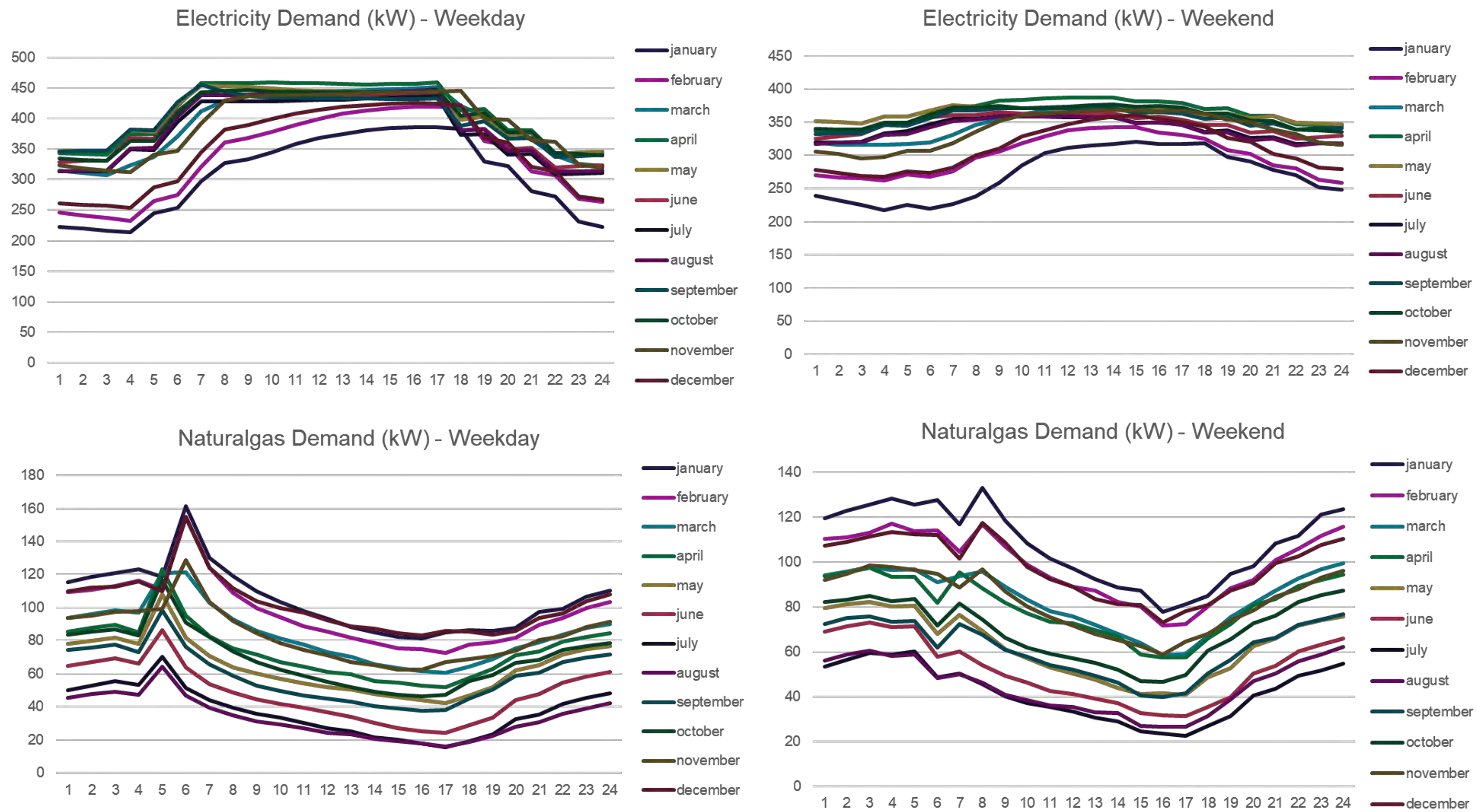


Figure 65. NWS Earle – Admin Building Loads

F1	Variable Cost ($/kWh)	Max Curtailment	Max Hours
LowCR	1.92	0.05	8760
MidCR	1.92	0.05	8760
HighCR	36.73	0.9	8760

Figure 66. NWS Earle – Admin Building Curtailment Parameters

The data provided by the participant only allowed modeling of the electricity tariff in DER-CAM as a blended rate of $0.09 per kWh that includes both energy and demand rates.

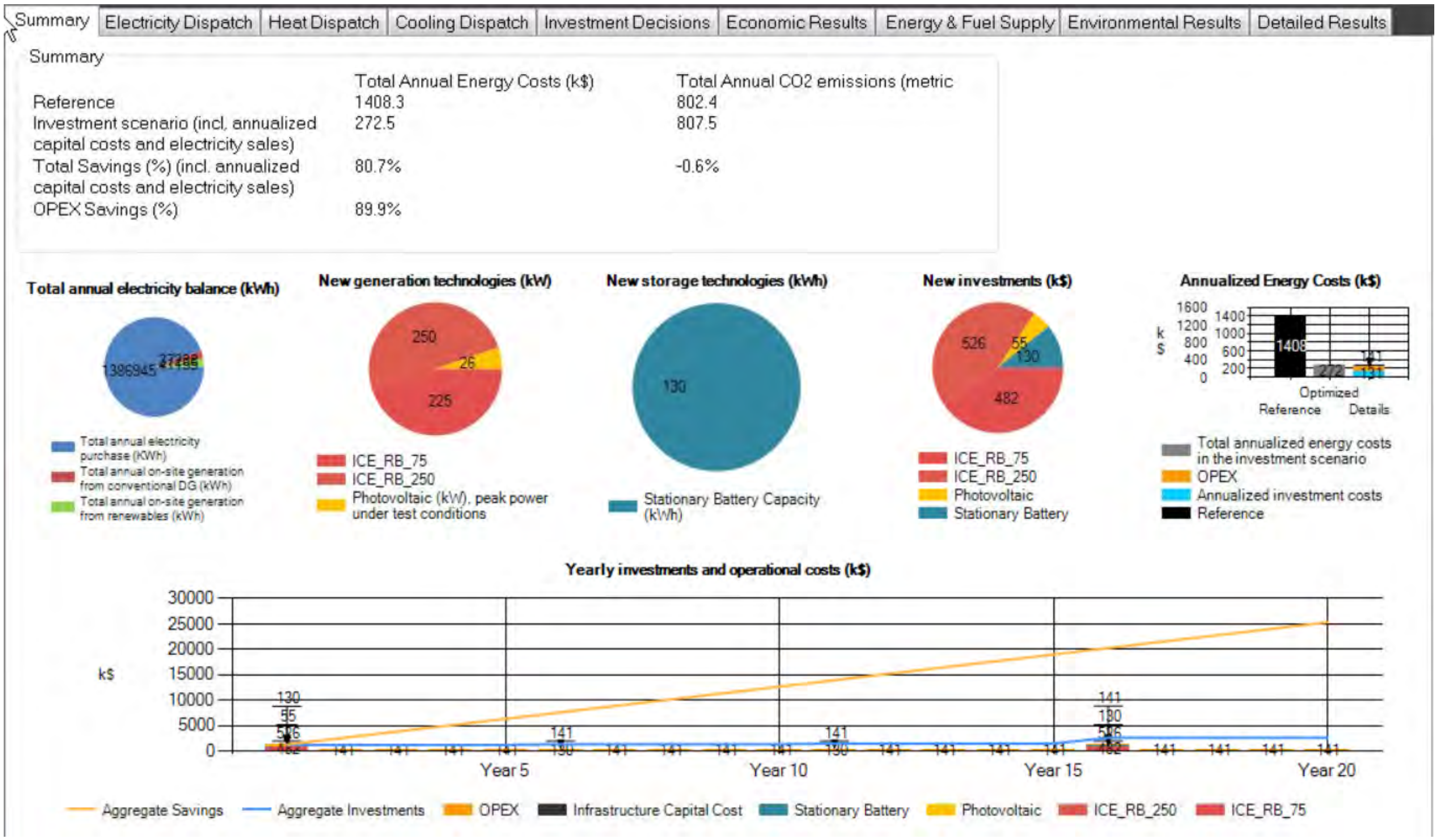


Figure 67. NWS Earle – Admin Building: Resiliency Cost Optimization Forced 3.C

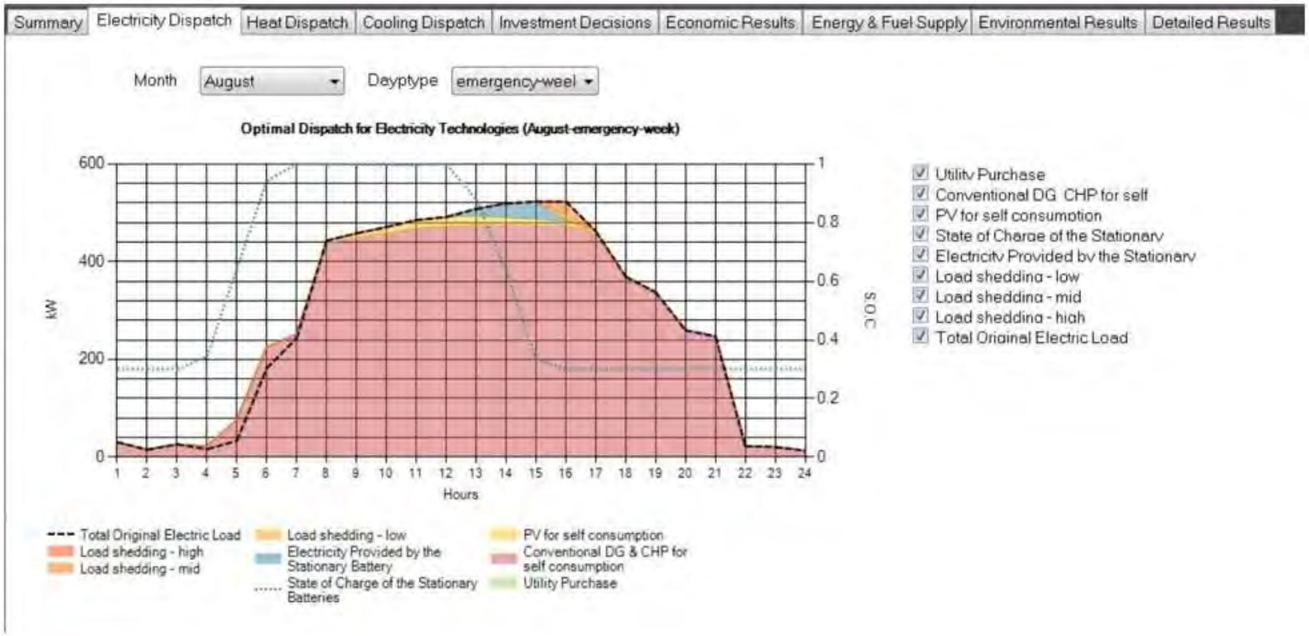


Figure 68. NWS Earle – Admin Building: High Resiliency Case – Optimal DER Dispatch

Scenario #	Scenario Description	New DER Capacity (kW)	New DER Details (Type, #, kW)	Utility Purchase (MWh)	DER Generation (MWh)	Annualized Cost ($k)	Annualized Cost Savings ($k)	Annualized Cost Savings (%)	Annual CO2 emissions (metric tons)	Annual CO2 Emission Savings (metric tons)	Annual CO2 Emission Savings (%)
Normal Case											
1.A	Baseline: Normal Operation; No outages; Utility purchase only; No new and existing DER;	0	N/A	1,465	0	141.0	**0**	**0**	823	**0**	**0**
1.B	Cost optimization: No outages; New DER	158	(PV,1,158);	1,215	249	140.9	**0.1**	**0.1%**	696	**127**	**15.4%**
1.C	Cost optimization with constraints: No outages; New DER (PV-5%)	26	(PV,1,26);	1,423	41	141.0	**0**	**0.0%**	802	**21**	**2.6%**
Low-Resiliency Case (12-Hour Outage)											
2.A	Low Resiliency Baseline: 12-Hour outages; Utility purchase only; No new and existing DER;	0	N/A	1,459	0	313.4	**0**	**0**	820	**0**	**0**
2.B	Cost optimization: 12-Hour outage; New DER	708	(PV,1,458); (ICE_250,1,250);	813	651	207.3	**106.1**	**33.9%**	493	**326.8**	**39.9%**
2.C	Cost optimization with constraints: 12-Hour outage; New DER (PV-5% & BESS-25%)	556	(ICE_75,2,150); (ICE_250,1,250); (PV,1,26); (BESS,1,130);	1,419	45	264.3	**49.1**	**15.7%**	802	**18**	**2.2%**
High-Resiliency Case (7-Day Outage)											
3.A	High Resiliency Baseline: 7-Day outages; Utility purchase only; No new and existing DER;	0	N/A	1,426	0	1,408.3	**0**	**0**	802	**0**	**0**
3.B	Cost optimization: 7-Day outage; New DER	796	(ICE_75,1,75); (ICE_250,1,250); (PV,1,471);	777	686	215.6	**1,193**	**84.7%**	488	**314.5**	**39.2%**
3.C	Cost optimization with constraints: 7-Day outage; New DER (PV-5% & BESS-25%)	631	(ICE_75,3,225); (ICE_250,1,250); (PV,1,26); (BESS,1,130);	1,386	77	272.5	**1,136**	**80.7%**	807	**-4.6**	**-0.6%**

Figure 69. NWS Earle – Admin Building: Microgrid Generation Life Cycle Cost Analysis Summary

						Investment Cost over 20 year project life cycle ($)	Annualized Investment Cost ($)
Capital Costs							
New DER							
Type	*#*	*kW*	*Life (years)*	*Size of PV (m^2)*	*Unit cost ($)*		
Solar PV	1	26	30	170	$55,380	$55,380	$3,603
ICE_75	3	75	15	N/A	$160,800	$964,800	$46,476
ICE_250	1	250	15	N/A	$526,000	$1,052,000	$50,676
BESS	1	130	5	N/A	$130,000	$520,000	$30,027
		631				**$2,592,180**	**$130,781**
Operational Costs							
Electric costs						$2,499,260	$124,963
Natural-gas Costs						$233,890	$11,695
Fixed O&M Costs						$75,660	$3,783
Variable O&M Costs						$17,874	$894
						$2,826,684	**$141,334**
Load curtailment costs						**$6,979**	**$349**
					Total Costs	**$5,425,844**	**$272,464**

Note: Cost Summary reflects new generation resource sizing as per scenario 3.C

Note: The Operational costs include total electric costs, fuel costs, fixed and variable O&M costs

Note: The annualized capital costs are calculated using the life span of DER and the discount rate of 5%

Note: The O&M costs only include DER specific fixed and variable O&M costs, it does not include fuel costs.

Note: Annual O&M costs are assumed to be constant across all the 20 years of project life cycle.

Note: Natural gas costs include cost to serve existing thermal loads and new DG

Figure 70. NWS Earle – Admin Building: Microgrid Life Cycle Cost Summary

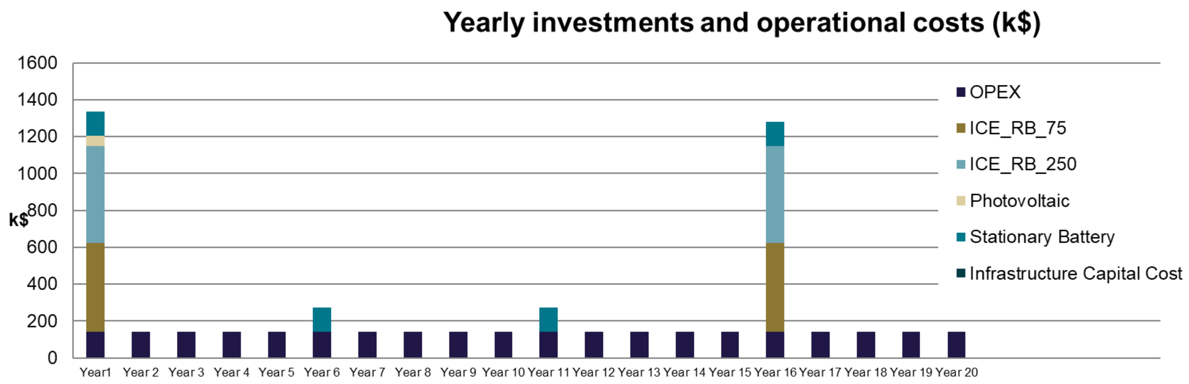


Figure 71. NWS Earle – Admin Building: Microgrid Life Cycle Annual Cost Summary

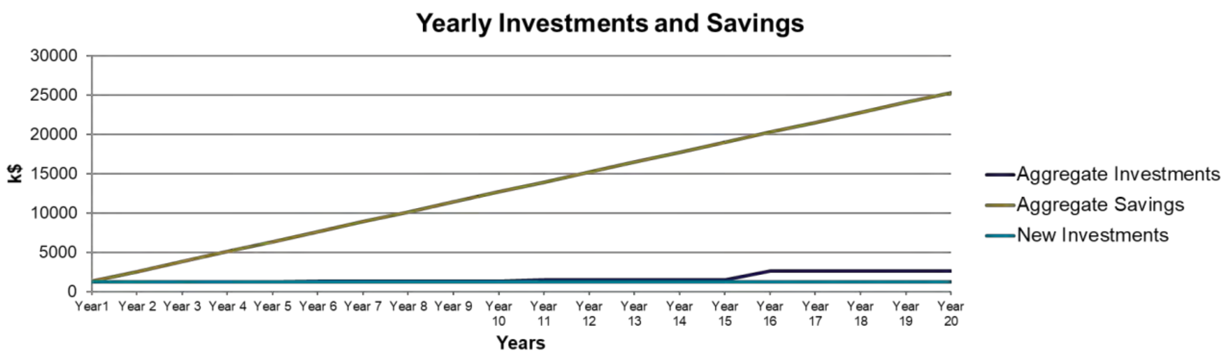


Figure 72. NWS Earle – Admin Building: Microgrid Life Cycle Cost Summary Curves

The preceding data demonstrates the feasibility of the NWS Earle Administrative Facility.

NWS Earle Waterfront Facilities

NWS Earle, at the direction of its Public Works Officer, provided the aggregated data which is germane and necessary to meet the Study requirements. Data at the individual AMI meter level was neither provided, nor revealed.

- Assumed Ship(s)-In Months: **Jan, Mar, Apr, Jul, Aug, Sep, and Oct**
- Assumed number of Ship(s)-In days per month: **Seven (7)**
- The load profile for a typical ship-in day is shown below.

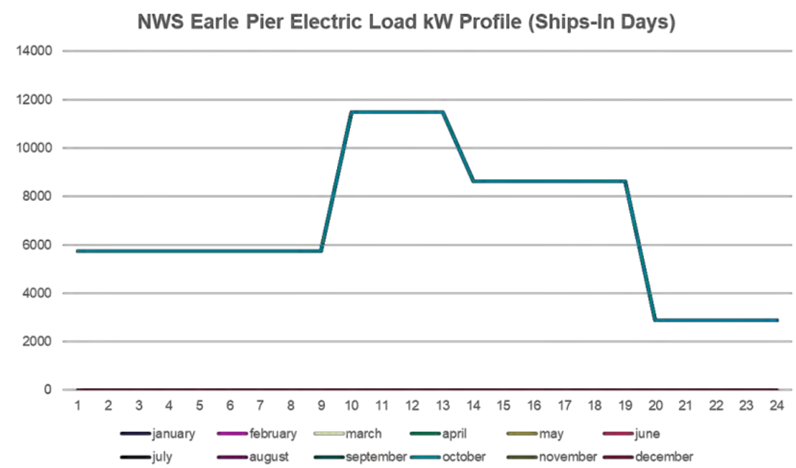


Figure 73. NWS Earle – Pier Loads Profile

Demand Response Parameters

	F1	VariableCost	MaxContribution	MaxHours
1	LowDR	0.25	0.9	8760
2	MidDR	0.09	0	0
3	HighDR	0.09	0	0

Figure 74. NWS Earle – Pier Curtailment Parameters

Note: The 5% PV capacity and 10% ES capacity were calculated based on 10% of total peak load (11.5 MW)). The assumption is that only 10% of the waterfront load is critical.

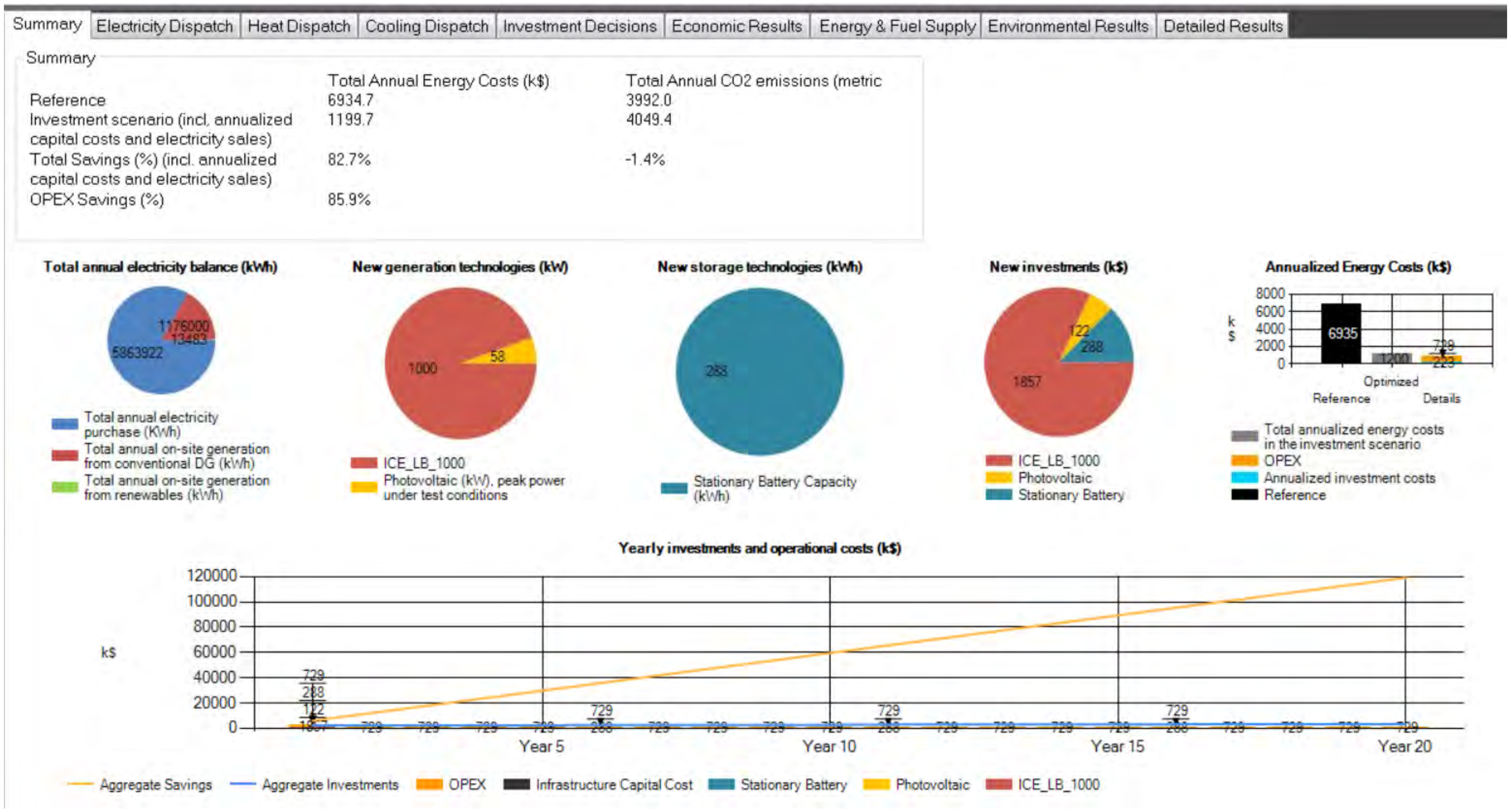


Figure 75. NWS Earle – Pier: 3.C (90% of peak load is considered non-critical and assumed curtailable at 25 cents per kWh, this assumption is aligned with the input received from NWS that ships can power themselves) (5% PV (57.5 kW) and 25% ES (287.5 kW))

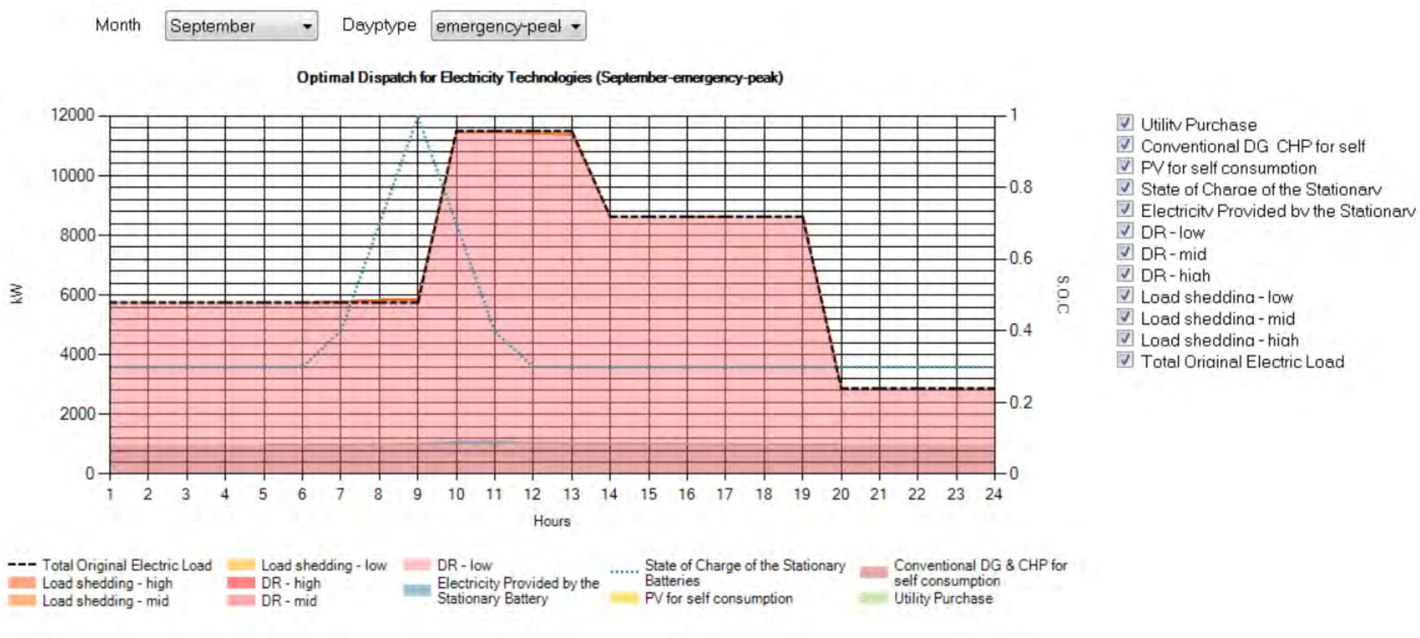


Figure 76. NWS Earle – Pier: DER Dispatch Curve 3.C

Scenario #	Scenario Description	New DER Capacity (kW)	New DER Details (Type, #, kW)	Utility Purchase (MWh)	DER Generation (MWh)	Annualized Cost ($k)	Annualized Cost Savings ($k)	Annualized Cost Savings (%)	Annual CO2 emissions (metric tons)	Annual CO2 Emission Savings (metric tons)	Annual CO2 Emission Savings (%)
Normal Case											
1.A	Baseline: Normal Operation; No outages; Utility purchase only; No new and existing DER;	0	N/A	8,029	0	853.8	**0**	**0**	4,591	**0**	**0**
1.B	Cost optimization: No outages; New DER	0	N/A	8,029	0	853.8	**0**	**0.0%**	4,591	**0**	**0.0%**
1.C	Cost optimization with constraints: No outages; New DER (PV-5% & BESS 25%)	345	(PV,1,57.5); (BESS,1,287.5);	8,017	13	935.3	**-81.5**	**-9.5%**	4,584	**7**	**0.2%**
Low-Resiliency Case (12-Hour Outage)											
2.A	Low Resiliency Baseline: 12-Hour outages; Utility purchase only; No new and existing DER;	0	N/A	7,926	0	1402.4	**0**	**0**	4,536	**0**	**0**
2.B	Cost optimization: 12-Hour outage; New DER	1,000	(ICE_1000,1,1000)	6,762	1,176	1155.7	**246.7**	**17.6%**	4,518	**18.1**	**0.4%**
2.C	Cost optimization with constraints: 12-Hour outage; New DER (PV-5% & BESS 25%)	1,345	(PV,1,57.5); (ICE_1000,1,1000); (BESS,1,287.5);	6,750	1,189	1225.3	**177.1**	**12.6%**	4,511	**24.3**	**0.5%**
High-Resiliency Case (7-Day Outage)											
3.A	High Resiliency Baseline: 7-Day outages; Utility purchase only; No new and existing DER;	0	N/A	6,882	0	6,934.7	**0**	**0**	3,992	**0**	**0**
3.B	Cost optimization: 7-Day outage; New DER	10,000	(ICE_5000,2,10000);	1,139	6,848	1,592.1	**5,343**	**77.0%**	4,034	**-42**	**-1.1%**
3.C	Cost optimization with constraints: 7-Day outage; New DER (PV-5% & BESS 25%); 90% Demand Response;	1,345	(PV,1,57.5); (ICE_1000,1,1000); (BESS,1,287.5);	5,863	1,189	1,199.7	**5,735**	**82.7%**	4,049	**-57.4**	**-1.4%**

Figure 77. NWS Earle – Waterfront: Microgrid Generation Life Cycle Cost Analysis Summary

						Investment Cost over 20 year project life cycle ($)	Annualized Investment Cost ($)
Capital Costs							
New DER							
Type	*#*	*kW*	*Life (years)*	*Size of PV (m^2)*	*Unit cost ($)*		
Solar PV	1	57.5	30	376	$122,475	$122,475	$7,967
ICE_500	1	1000	20	N/A	$1,857,000	$1,857,000	$149,010
BESS	1	288	5	N/A	$287,500	$1,150,000	$66,405
		1345				**$3,129,475**	**$223,383**
Operational Costs							
Electric costs						$11,730,603	$586,530
Natural-gas Costs						$2,227,700	$111,385
Fixed O&M Costs						$167,325	$8,366
Variable O&M Costs						$446,880	$22,344
						$14,572,508	**$728,625**
Load curtailment costs						**$4,953,691**	**$247,685**
					Total Costs	**$22,655,674**	**$1,199,693**

Note: Cost Summary reflects new generation resource sizing as per scenario 3.C

Note: The Operational costs include total electric costs, fuel costs, fixed and variable O&M costs

Note: The annualized capital costs are calculated using the life span of DER and the discount rate of 5%

Note: The O&M costs only include DER specific fixed and variable O&M costs, it does not include fuel costs.

Note: Annual O&M costs are assumed to be constant across all the 20 years of project life cycle.

Note: Natural gas costs include cost to serve existing thermal loads and new DG

Figure 78. NWS Earle – Waterfront: Microgrid Life Cycle Cost Summary

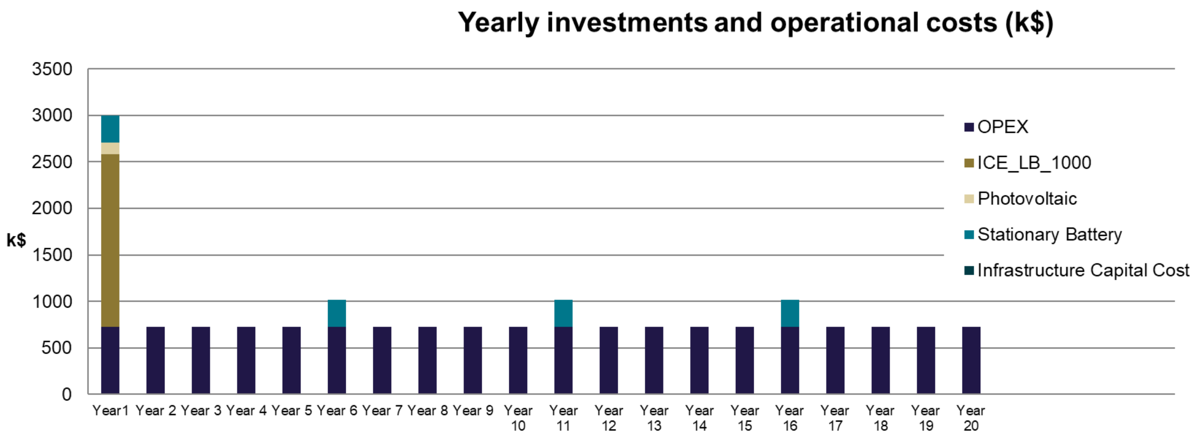


Figure 79. NWS Earle – Waterfront: Microgrid Life Cycle Annual Cost Summary

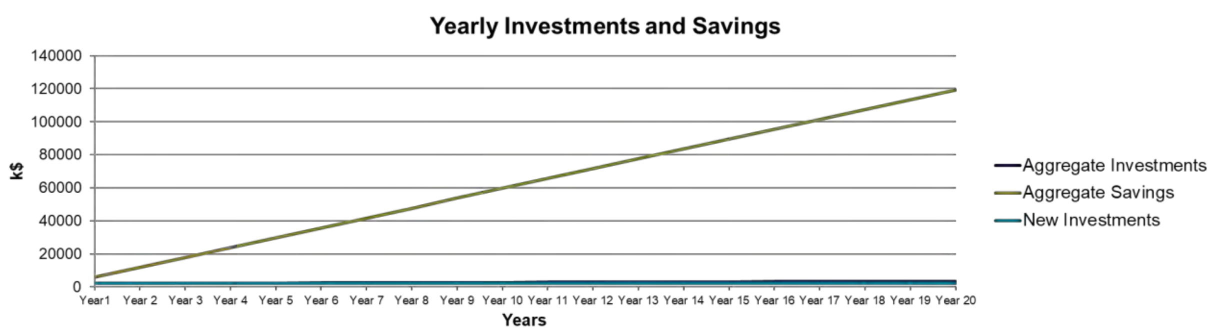


Figure 80. NWS Earle – Waterfront: Microgrid Life Cycle Cost Summary Curves

The preceding data demonstrates the feasibility of the NWS Earle Waterfront Facility.

TOMSA – Proxy Case for Class: Fire Stations

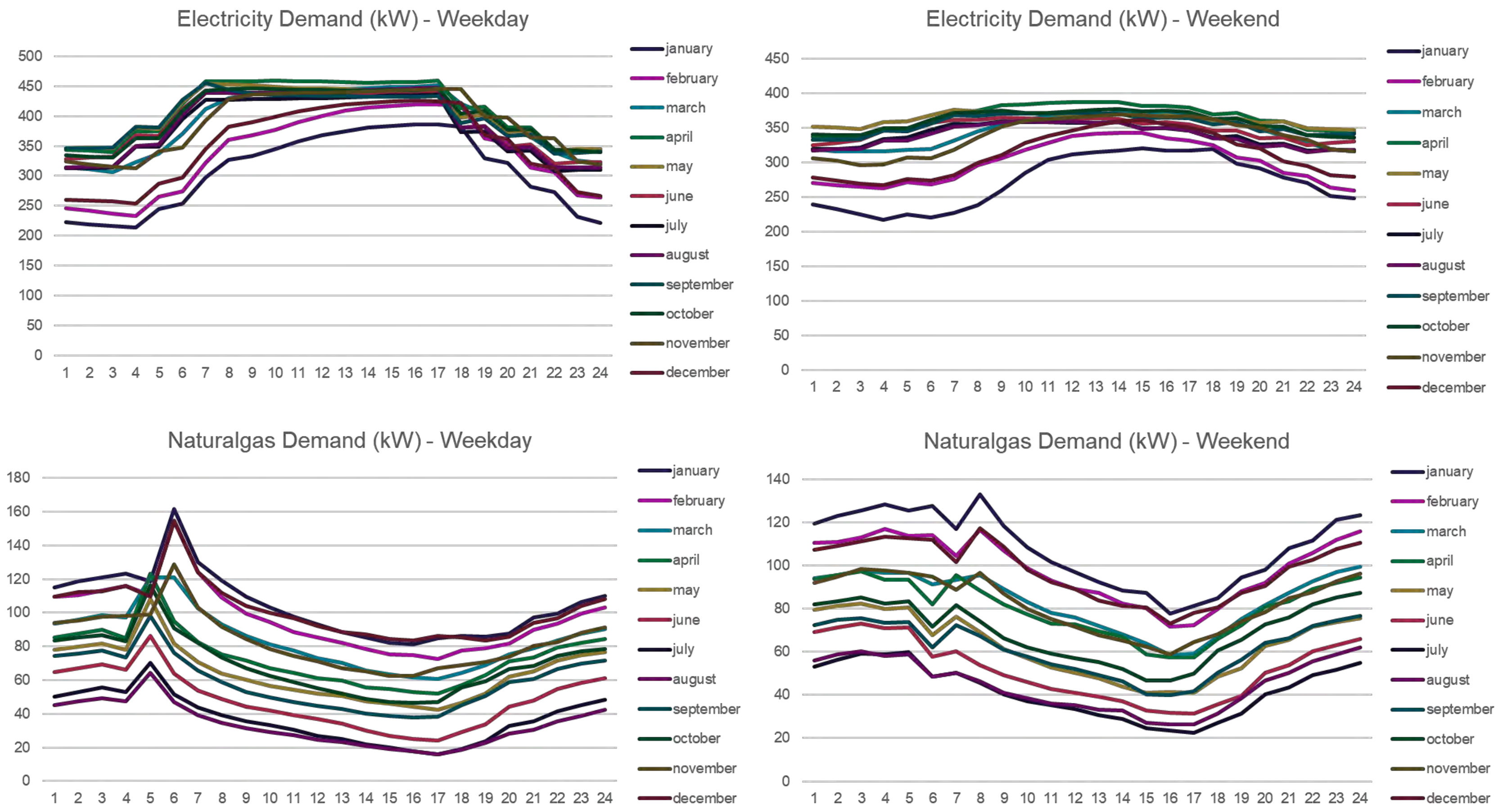


Figure 81. TOMSA Loads

Curtailment Parameters

	F1	VariableCost	MaxCurtailment	MaxHours
1	LowCR	1.92	0.05	8760
2	MidCR	1.92	0.05	8760
3	HighCR	36.73	0.9	8760

Figure 82. TOMSA Curtailment Parameters

The data provided by the participant only allowed modeling of the electricity tariff in DER-CAM as a blended rate of $0.12 per kWh that includes both energy and demand rates.

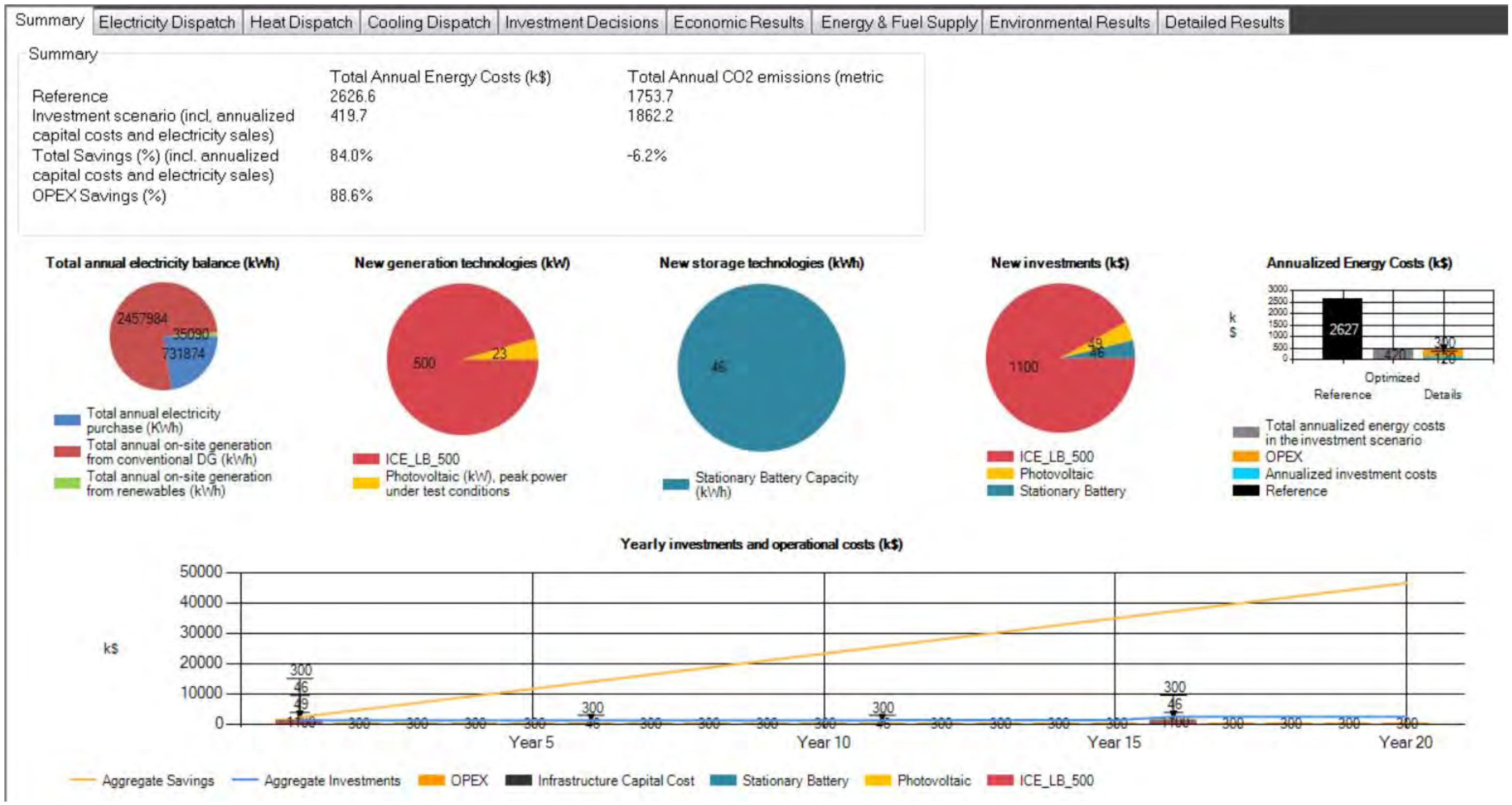


Figure 83. TOMSA: 3.C (PV 5% & BESS 10%)

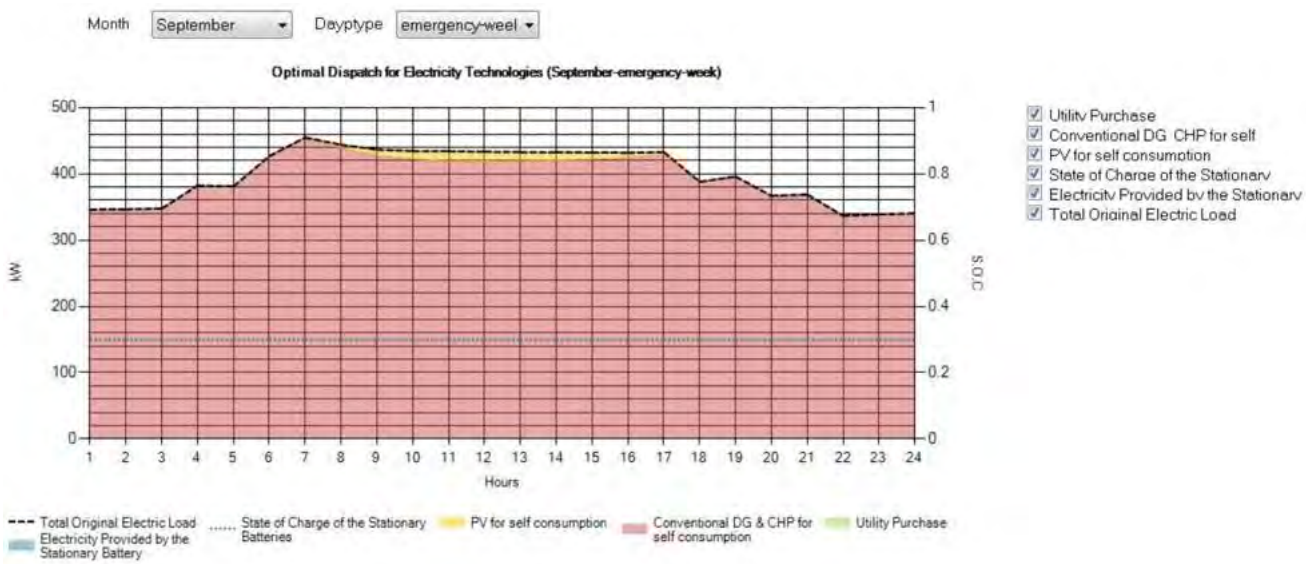


Figure 84. TOMSA: High Resiliency Case – Optimal DER Dispatch

Scenario #	Scenario Description	New DER Capacity (kW)	New DER Details (Type, #, kW)	Utility Purchase (MWh)	DER Generation (MWh)	Annualized Cost ($k)	Annualized Cost Savings ($k)	Annualized Cost Savings (%)	Annual CO2 emissions (metric tons)	Annual CO2 Emission Savings (metric tons)	Annual CO2 Emission Savings (%)
Normal Case											
1.A	Baseline: Normal Operation; No outages; Utility purchase only; No new and existing DER;	0	N/A	3,222	0	408.3	**0**	**0**	1,789	**0**	**0**
1.B	Cost optimization: No outages; New DER	308	(PV,1,308);	2,735	487	392.6	**15.7**	**3.8%**	1,541	**248**	**13.9%**
1.C	Cost optimization with constraints: No outages; New DER (PV-5% & BESS-10%)	319	(ICE_250,1,250); (PV,1,23); (BESS,1,46);	1,156	2,065	414.5	**-6.2**	**-1.5%**	2,096	**-307**	**-17.2%**
Low-Resiliency Case (12-Hour Outage)											
2.A	Low Resiliency Baseline: 12-Hour outages; Utility purchase only; No new and existing DER;	0	N/A	3,217	0	573.4	**0**	**0**	1,786	**0**	**0**
2.B	Cost optimization: 12-Hour outage; New DER	633	(PV,1,308); (ICE_250,1,250);(ICE_75,1,75);	267	2,954	396	**177.4**	**30.9%**	1,948	**-161.8**	**-9.1%**
2.C	Cost optimization with constraints: 12-Hour outage; New DER (PV-5% & BESS-10%)	569	(PV,1,23); (ICE_500,1,500); (BESS,1,46);	734	2,490	419.9	**153.5**	**26.8%**	1,862	**-76.1**	**-4.3%**
High-Resiliency Case (7-Day Outage)											
3.A	High Resiliency Baseline: 7-Day outages; Utility purchase only; No new and existing DER;	0	N/A	3,155	0	2,626.6	**0**	**0**	1,754	**0**	**0**
3.B	Cost optimization: 7-Day outage; New DER	708	(PV,1,308); (ICE_250,1,250);(ICE_75,2,75);	112	3,109	406.4	**2,220**	**84.5%**	1,976	**-222.1**	**-12.7%**
3.C	Cost optimization with constraints: 7-Day outage; New DER (PV-5% & BESS-10%)	569	(PV,1,23); (ICE_500,1,500); (BESS,1,46);	731	2,492	419.7	**2,207**	**84.0%**	1,862	**-108.5**	**-6.2%**

Figure 85. TOMSA: Microgrid Generation Life Cycle Cost Analysis Summary

						Investment Cost over 20 year project life cycle ($)	Annualized Investment Cost ($)
Capital Costs							
New DER							
Type	*#*	*kW*	*Life (years)*	*Size of PV (m^2)*	*Unit cost ($)*		
Solar PV	1	23	30	150	$48,990	$48,990	$3,187
ICE_500	1	500	15	N/A	$1,100,000	$2,200,000	$105,977
BESS	1	46	5	N/A	$46,000	$184,000	$10,625
		569				**$2,432,990**	**$119,788**
Operational Costs							
Electric costs						$1,782,677	$89,134
Natural-gas Costs						$3,156,258	$157,813
Fixed O&M Costs						$27,600	$1,380
Variable O&M Costs						$1,032,353	$51,618
						$5,998,889	**$299,944**
Load curtailment costs						**$0**	**$0**
					Total Costs	**$8,431,879**	**$419,733**

Note: Cost Summary reflects new generation resource sizing as per scenario 3.C

Note: The Operational costs include total electric costs, fuel costs, fixed and variable O&M costs

Note: The annualized capital costs are calculated using the life span of DER and the discount rate of 5%

Note: The O&M costs only include DER specific fixed and variable O&M costs, it does not include fuel costs.

Note: Annual O&M costs are assumed to be constant across all the 20 years of project life cycle.

Note: Natural gas costs include cost to serve existing thermal loads and new DG

Figure 86. TOMSA: Microgrid Life Cycle Cost Summary

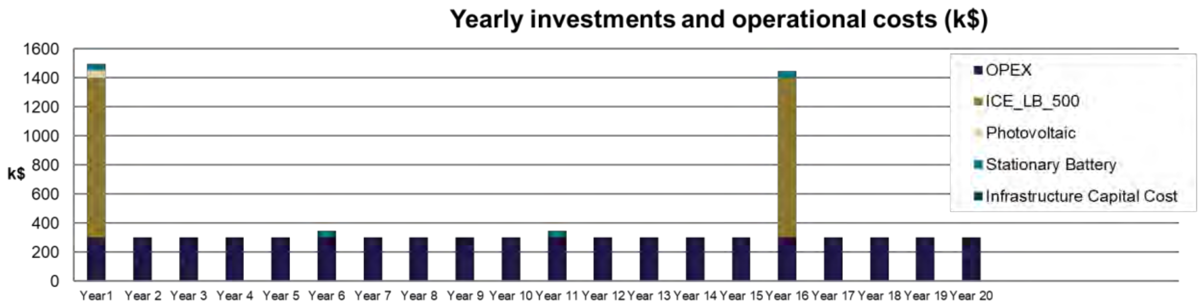


Figure 87. TOMSA: Microgrid Life Cycle Annual Cost Summary

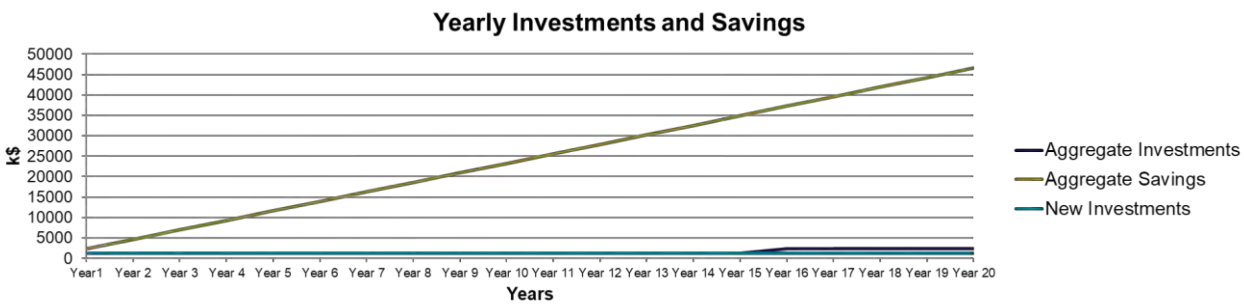


Figure 88. TOMSA: Microgrid Life Cycle Cost Summary Curves

The preceding data demonstrates the feasibility of the TOMSA facility, and by extension, the entire site class TOMSA and Fire Stations.

Summarized Generation, Storage and Investment Requirements by Site

The following table summarizes all participating sites in the proposed microgrid for Middletown. Using the proxy cases and electric usage scaling factors, full cost and benefit estimates have been developed to support a favorable feasibility assessment based upon the 7-day outage scenario 3.C, in all instances. A benefit/cost ratio (BCR) is provided for each site where a value >1.0 indicates favorable feasibility.

Table 5.
Generation, Storage, and Investment Requirements by Site

					Annualized				20-year Project Life Cycle				
Participant	New DER Capacity (kW)	PV (kW)	NG Fired DG (kW)	BESS (kW)	Capital Costs	O&M Costs	Total Costs	Total Cost Savings	Capital Costs	O&M Costs	Total Costs	Total Cost Savings	BCR
Middletown North High School	1338	88	1075	175	$217,047	$453,378	$670,425	$1,964,047	$3,064,975	$9,067,562	$12,132,537	$39,280,938	3.24
Thorne Middle	511	34	411	67	$82,896	$173,158	$256,054	$750,125	$1,170,601	$3,463,158	$4,633,759	$15,002,501	3.24
Middletown South High School	1072	70	861	140	$173,830	$363,104	$536,933	$1,572,976	$2,454,692	$7,262,074	$9,716,766	$31,459,512	3.24
Thompson Middle School	456	30	366	60	$73,899	$154,364	$228,263	$668,709	$1,043,548	$3,087,279	$4,130,827	$13,374,180	3.24
Bayshore Middle	571	38	458	75	$92,551	$193,324	$285,875	$837,487	$1,306,933	$3,866,490	$5,173,422	$16,749,743	3.24
Bayview Elementary	96	7	75	14	$19,695	$56,193	$75,888	$149,695	$392,510	$1,123,860	$1,516,370	$2,993,908	1.97
Ocean Ave Elementary	60	4	47	9	$12,386	$35,340	$47,726	$94,143	$246,848	$706,790	$953,638	$1,882,854	1.97
Port Monmouth Elementary	47	3	37	7	$9,652	$27,539	$37,192	$73,363	$192,363	$550,787	$743,150	$1,467,269	1.97
Harmony Elementary	90	7	71	13	$18,524	$52,850	$71,374	$140,790	$369,160	$1,057,001	$1,426,161	$2,815,800	1.97
River Plaza Elementary	47	3	37	7	$9,652	$27,539	$37,192	$73,363	$192,363	$550,787	$743,150	$1,467,269	1.97

Participant	New DER Capacity (kW)	PV (kW)	NG Fired DG (kW)	BESS (kW)	Annualized Capital Costs	Annualized O&M Costs	Annualized Total Costs	Annualized Total Cost Savings	20-year Project Life Cycle Capital Costs	20-year Project Life Cycle O&M Costs	20-year Project Life Cycle Total Costs	20-year Project Life Cycle Total Cost Savings	BCR
Nut Swamp Elementary	80	6	62	12	$16,348	$46,642	$62,990	$124,251	$325,794	$932,836	$1,258,630	$2,485,029	1.97
Lincroft Elementary	62	5	48	9	$12,721	$36,295	$49,016	$96,687	$253,519	$725,893	$979,412	$1,933,742	1.97
Navesink Elementary	80	6	62	12	$16,404	$46,801	$63,205	$124,675	$326,906	$936,019	$1,262,926	$2,493,510	1.97
Fairview Elementary	58	4	45	8	$11,884	$33,907	$45,791	$90,326	$236,840	$678,136	$914,977	$1,806,522	1.97
New Monmouth Elementary	106	8	82	15	$21,648	$61,765	$83,413	$164,538	$431,427	$1,235,291	$1,666,718	$3,290,754	1.97
Leonardo Elementary	50	4	39	7	$10,322	$29,450	$39,772	$78,452	$205,706	$588,992	$794,698	$1,569,045	1.97
Middletown Village Elementary	72	5	56	10	$14,674	$41,866	$56,540	$111,529	$292,437	$837,323	$1,129,760	$2,230,589	1.97
Middletown Municipal Complex	114	13	75	26	$23,298	$67,533	$90,831	$255,898	$453,290	$1,350,660	$1,803,950	$5,117,969	2.84
Monmouth County Highway Dept. Building &	6	1	4	1	$1,148	$3,328	$4,477	$12,612	$22,341	$66,569	$88,911	$252,248	2.84
Middletown DPW	41	5	27	9	$8,401	$24,350	$32,751	$92,269	$163,443	$487,008	$650,451	$1,845,390	2.84
NY Waterways	67	8	44	15	$13,659	$39,591	$53,250	$150,021	$265,742	$791,827	$1,057,569	$3,000,418	2.84
NJNG CNG Station	6	1	4	1	$1,148	$3,328	$4,477	$12,612	$22,341	$66,569	$88,911	$252,248	2.84
TOMSA	569	23	500	46	$119,788	$299,944	$419,733	$2,326,688	$2,432,990	$5,998,889	$8,431,879	$46,533,765	5.52
Middletown Fire Station 4	5.3	0.2	4.6	0.4	$1,109	$2,776	$3,885	$21,537	$22,521	$55,528	$78,049	$430,735	5.52
Middletown Fire Station 3	2.6	0.1	2.3	0.2	$554	$1,388	$1,943	$10,768	$11,260	$27,764	$39,024	$215,368	5.52

					Annualized				20-year Project Life Cycle				
Participant	New DER Capacity (kW)	PV (kW)	NG Fired DG (kW)	BESS (kW)	Capital Costs	O&M Costs	Total Costs	Total Cost Savings	Capital Costs	O&M Costs	Total Costs	Total Cost Savings	BCR
Middletown Fire Station 7	2.6	0.1	2.3	0.2	$550	$1,377	$1,927	$10,682	$11,170	$27,542	$38,712	$213,645	5.52
EARLE NWS (Admin)	631	26	475	130	$130,781	$141,683	$272,464	$1,266,581	$2,592,180	$2,833,664	$5,425,844	$25,331,617	4.67
EARLE NWS (Water Front)	1345	58	1000	288	$223,383	$976,310	$1,199,693	$5,958,383	$3,129,475	$19,526,199	$22,655,674	$119,167,658	5.26
Grand Total	**7583**	**455**	**5971**	**1157**	**$1,337,953**	**$3,395,125**	**$4,733,078**	**$17,233,211**	**$21,633,377**	**$67,902,498**	**$89,535,875**	**$344,664,225**	**3.85**

All participating sites show a positive BCR and a positive financial return under the requirements of case 3.C which is a 7-day outage. The overall project BCR is also positive.

Note that totals costs are exclusive of communications, control systems, and soft costs. For the purpose of this Study, real estate related costs are assumed to be addressed by the allocation of required space at each proposed participating site.

Microgrid Alternatives and Recommendation

Microgrid Alternatives

In consideration of the foregoing research and analysis, and prior to providing a recommendation, it is necessary to qualitatively explain the microgrid design/formation alternatives available for consideration. As a well-aligned starting point, we refer back to the BPU Microgrid Report dated November 30, 2016. As noted earlier, this report provides a sound foundation of understanding to the BPU pertaining to microgrid definitions and configuration. In order to maintain consistency these definitions are restated from the 2016 report, in paraphrased form, as follows:

Microgrid Definition and Classification

The U.S. Department of Energy (USDOE) Microgrid Exchange Group in 2012 developed a generally accepted definition of a microgrid as

> *A microgrid is a group of interconnected loads and distributed energy resources (DER) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.*

The above definition for microgrids covers a broad array of systems, technologies, customer types and interconnection types. Below is one classification of microgrids based on interconnection to the grid.

1. *Level 1 or single customer microgrid.* This is a single DER system such as a photovoltaic solar (PV) system, combined heat and power (CHP) or fuel cell (FC) system that is serving one customer through a single meter. This microgrid class is connected to and can island from the distribution grid.

2. *Level 2 or single customer/campus setting; also referred to as the partial feeder microgrid.* This classification includes either a single or multiple DER system connecting multiple buildings, but controlled by one meter at the point of common coupling. This microgrid class is connected to and can island from the distribution grid.

3. *Level 3 or multiple customers/advanced microgrid; also referred to as the full feeder microgrid.* This is a single or multiple DER system that serves several different buildings/customers that are not on the same meter or on the same site as the DER. An advanced microgrid has one point of common coupling (PCC). The individual buildings/customers may be independently connected to the larger distribution grid and through the microgrid PCC.

Below is a schematic that documents the three levels of microgrids including their PCC.

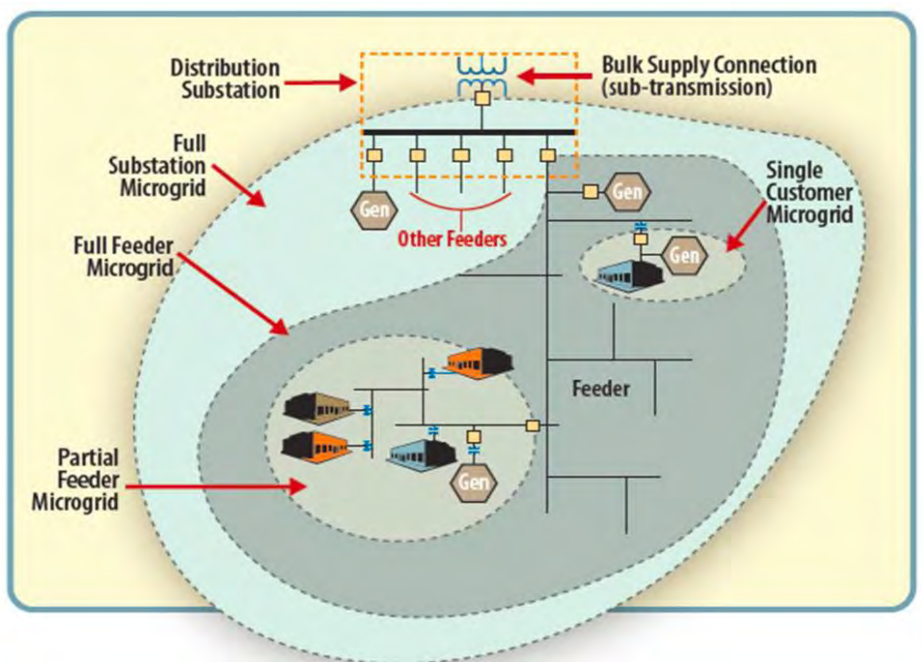


Figure 89. Three Levels of Microgrids

The aligning concept when considering Level 3 microgrids is affinity within the context of the distribution system. This requires shared infrastructure whether that might be a feeder, a substation bus, or a whole substation. This shared affinity allows for consolidation of load and generation. Unfortunately, this would require the crossing of rights of way or the ownership of generation by the utility, both of which are prohibited.

With these definitions in mind, the next step is to summarize the comparative decision dimensions discussed in this Study, and to frame them in the context of these microgrid alternatives based on a suitability matrix in the following table where a green checkmark highlights an open pathway for the pursuit of implementation, and a red X indicates a systemic block.

Table 6.
Suitability Matrix for Microgrid Levels

					Financing Options			Balancing Scenario			
Microgrid Alternative	Local DER	Statutory/Code Compliance	Regulatory Compliance	Financial Feasibility	1	2	3	1	2	3	4
1	✓	✓	✓	✓	✗	✓	✓	✗	✗	✓	✓
2	✓	✗	✗	✓	✗	✓	✓	✗	✗	✓	✓
3	✓	✗	✗	✓	✗	✓	✓	✗	✗	✓	✓

This table illustrates where impediments exist beyond simple financial feasibility. In essence, the statutory limits on crossing rights of way, combined with the inability to own or rate-base generation on the part of the utility, severely constrain the viability of microgrid options in New Jersey.

Effectively, the alternatives that are truly feasible are those that that call for decentralization of generation and the avoidance of electric utility ownership (Balancing Scenarios 3 and 4) for local DER. This means that a microgrid design that allows for independent ownership and alternative financing outside of traditional utility based bond or rate financing, is the most viable approach to be taken in order to move quickly to address reliability and resilience requirements. The value derived from the microgrid under blue sky or green sky scenarios (as defined in Appendix A) through bilateral power purchase agreements represent an attractive mechanism for generating returns in the eyes of providers of independent financing (Financing Options 2 and 3).

The control systems and communication infrastructure represent a cost to implement any of the microgrid alternatives. These systems, as described previously, will manage the energy system coupling, islanding and control, and potential for grid supply. Such control systems may be selected as best fits the requirements defined in final design.

Level 1 microgrids call for fully distributed generation and individual islanding by site. The cross-coordination of these sites can be accomplished in a variety of ways in order to achieve a higher level of performance. These methods might include utility control or transactive energy methodologies as described previously. These control systems can be adapted over time as ownership, operation, and technological capabilities evolve. Ultimately, the goal is to elevate reliability and resiliency while following the path of least resistance in terms of regulation and access to financing. The following map illustrates the location of the participating sites.

Figure 90. Middletown TC DER Microgrid Feasibility Study Participants

In the following two line diagrams, one can see a hypothetical illustration of how a coordinated set of Level 1 microgrids might operate in blue sky, or normal operating conditions, and then in grey sky, or islanded operation. These diagrams depict some level of storage based upon feeder affinity simply to illustrate the opportunity, or potential evolutionary path that might be followed.

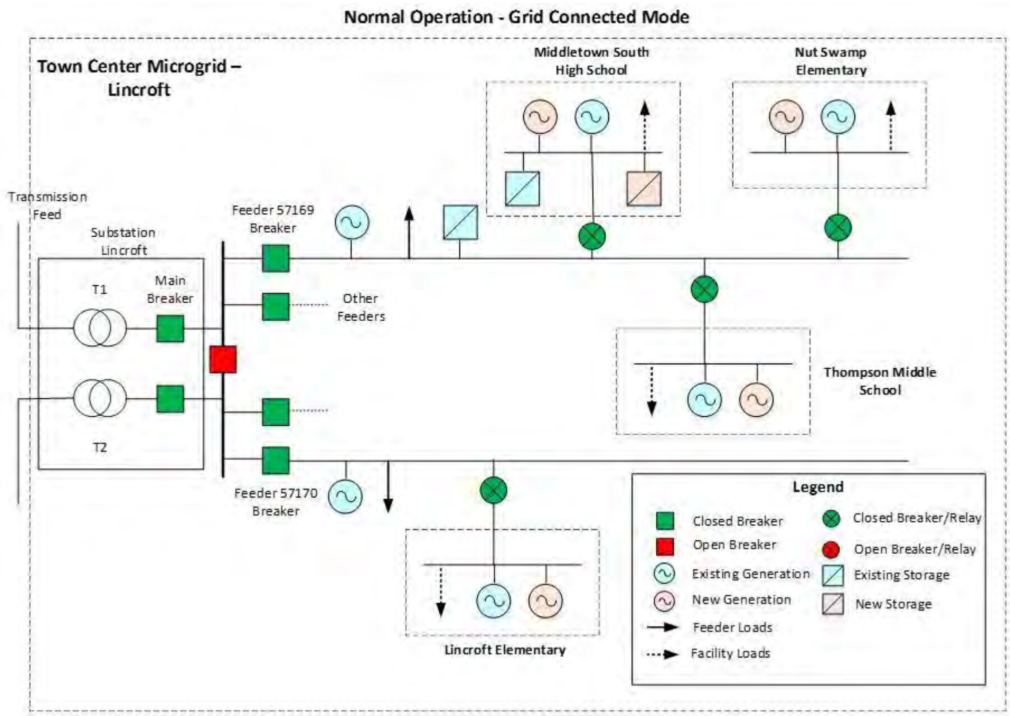


Figure 91. Blue Sky Line Diagram

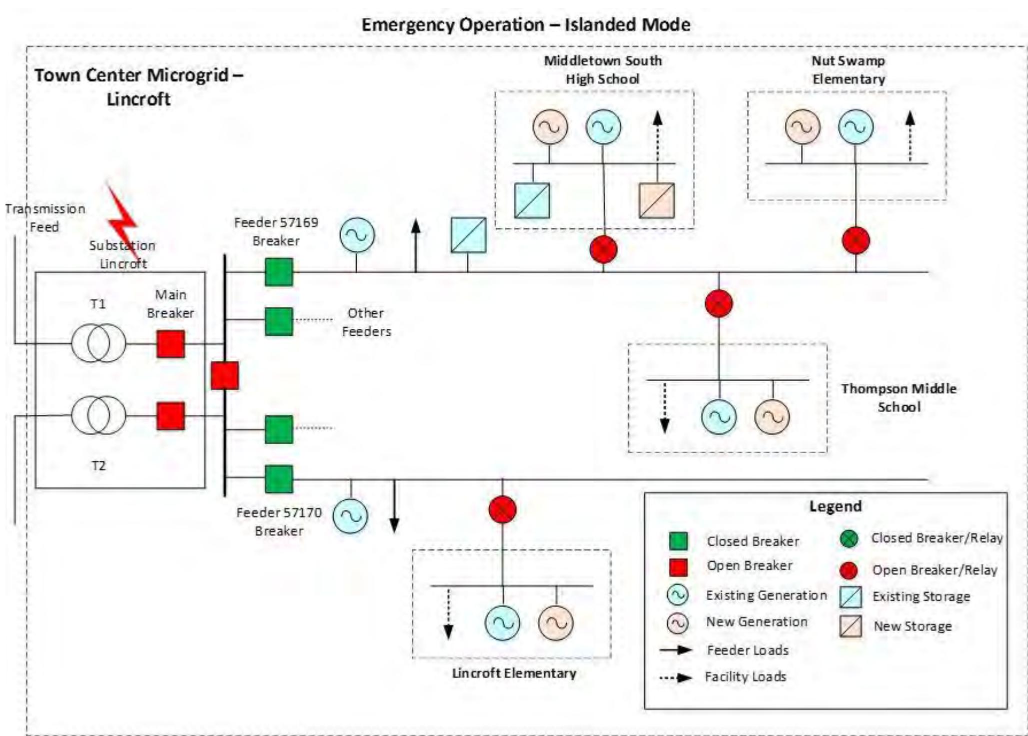


Figure 92. Grey Sky Line Diagram

Level 3 microgrids, as described above, are moderately centralized, and can be called "copper bound" based upon the need to rely upon existing utility infrastructure in the distribution system feeders and substations. Despite the regulatory and statutory impediments, the challenge with the use of the existing system is rooted in the inherent reliability issues that drove the microgrid interest in the first place, coupled with minimal utility investment. It would appear to be a self-defeating proposition to call for distributed generation and a microgrid, then turn around and support the recommendation by relying on the same system that is already in question.

Investments in reconductoring or undergrounding of the system are certainly possible, but would be expensive, and necessarily rate-based by the utility, which calls into question the matter of cross-subsidizing by the ratepayers. The following map illustrates one potential view of a Level 3 microgrid based upon substation affinity.

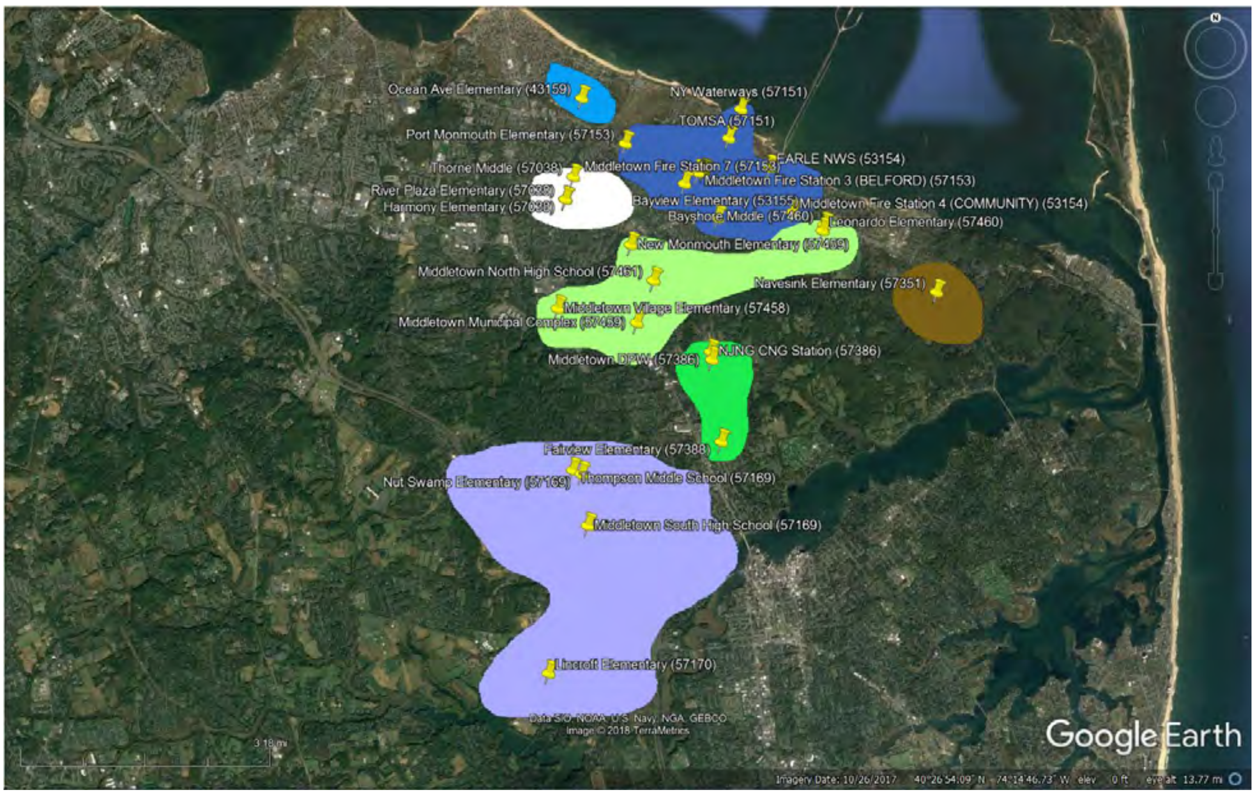


Figure 93. Level 3 Microgrid Example (Substation Affinity)

Finally, in the interest of modulating investment, and allowing for the development of a copper bound, advanced microgrid, placing local generation and storage at each site provides for immediate benefit, but not all sites necessarily demand action. A prioritized approach to deploying only those sites that are most critical, or perhaps those with the highest benefit-cost ratio, but allow for significant immediate benefit under the Level 1 distributed model. Should regulatory relief be offered in the form of a regulatory sandbox as described above, or other statutory or policy change, then the remaining sites on the participant list might be addressed as a Level 3 microgrid. The control overlay could be adapted or replaced as necessary to coordinate accordingly.

Recommendations

Therefore, the recommendation for the proposed Middletown TC DER microgrid can be summarized as follows:

Primary Actions – Consider commencing in second half of 2019:

- Prioritize a subset of the participating sites based on critical services and BCR
  - Must include: NWS Earle, TOMSA, NY Waterways, Middletown North High School, Middletown Municipal Complex, and one fire station, at a minimum
- Select a P3 financing partner with a best-in-class design, build, and operations team
  - In the case of NWS Earle, any proposed opportunity for DoD participation in financing and operation of the Level 1 microgrid will be subject to approval by the Navy, and availability of funds
- Develop a distributed set of Level 1 microgrids with locally sited generation and storage
- Implement a single control system that coordinates load serving and grid support services under grey, blue, and green sky conditions
- Determine appropriate operating entity – agency, peer utility, or P3 team
- Implement a bilateral power purchase agreement between the financier and the utility
- Begin to address data bound concerns with advanced metering project approval and data management policy action

Secondary Actions – Consider addressing in second half of 2020:

- Prioritize a second subset of the participating sites based upon critical services and BCR
  - Must include: A fire station, a selection of other schools, and NJNG CNG filling station
- Implement a regulatory sandbox as described previously in order to address rights of way and generation ownership concerns
- Determine if utility or P3 financing is desirable
- Determine appropriate operating entity – agency, peer utility, or P3 team
- Develop one or more Level 3 microgrids with moderately centralized generation and storage according to substation and feeder affinity
- Determine and carry out necessary distribution system hardening actions to address copper bound concerns

Conclusions

A number of key experiences and conclusions were noted during the course of the Feasibility Study for the proposed TC DER microgrid for Middletown, New Jersey:

To begin with, the Middletown case is unique in terms of the other opportunities identified around the State. The nature of the selected Middletown participant sites, including NWS Earle, a sewer plant, a transportation hub, fire stations, a municipal complex, and numerous schools, provides a mix of critical infrastructure that must be addressed for improved reliability in light of their location in proximity to the shore and the risk of catastrophic interruption.

Also, the local distribution system exhibits highly variable reliability metrics, which increase operation risk and raise costs for each of the participating sites.

The local government, citizenry, and stakeholder groups are highly supportive of moving forward with a microgrid implementation based upon current understanding of costs and benefits.

The economic feasibility and benefit/cost ratio for each of the participating sites is compelling. The investments necessary to provide local generation and storage for each site are outweighed by the reliability and efficiency improvements for each location.

The regulatory and statutory constraints are significant headwinds that hamper the opportunity to develop advanced microgrids in New Jersey. The ability to mitigate these constraints through regulatory relief would open up a range of ownership and implementation options that currently make a true, Level 3 microgrid illegal.

The challenge with securing the data necessary to perform this Study, and to complete a detailed design, are significant. The lack of AMI data is a statewide issue, and the inherent issues with data access under the current system pose delays in work and a persistent lack of transparency.

The opportunity to influence future state energy policy and to advance the cause and benefits of microgrids in the State of New Jersey is imminent with the advent of work on the 2019 EMP.

The technologies to enable a Level 1 or Level 3 microgrid are available right now and are evolving quickly with cutting efforts from firms interested in enabling blue, grey, and green sky environments (Appendix A).

There is a strong appetite and a compelling environment for the leverage of public-private partnerships to accelerate the financing, implementation, and operation of microgrids, thereby accelerating adoption of these systems statewide, in spite of structural regulatory constraints.

There is an opportunity to explore immediate next steps in implementing the Middletown TC DER microgrid, even in lieu of regulatory action. The business case is compelling and worthy of detailed validation, prioritization, and development.

Appendix A: Environments

A1 Catastrophic Storm (Grey Sky)

The impact of a second Superstorm/Hurricane with a direct hit on the Middletown Shore community is likely to be equally devastating (or perhaps more so) as the first one, as there has been little storm hardening done to the electric grid beyond just the basic service restoration. A similar impact scenario is therefore envisioned as follows.

Time Period (days)	Phase	Situation / Activity
T-2	Orderly Evacuation	Evacuation warnings are issued. Population of 20,000 is dislocated from the impacted area.
T-1	Panic Evacuation / Bracing	
T=0	Storm Breaks	Sustained winds 140+ mph. Storm Surge 12+ ft. Coastal areas submerged, roadways destroyed.
T+1	Storm Stalls	Rainfall exceeds 2 in. per hour for 10+ hours. Flooding extends inland. Large trees fall on roadways and power lines.
T+2	Rescue	Major roads cleared – passable with emergency vehicles. General population fuel supply disrupted.
T+5	Cleanup Begins	
T+10	Power Restore 1 50%	
T+20	Power Restore 2 90%	
T+30	Long Term Rebuild Commence	

A2 Normal Grid Operations (Blue Sky)

The normal operation of the grid system as it currently functions during a hot summer day is described in terms of a typically time-varying temperature profile. A representative 24-hour impact would therefore likely resemble the following building load response.

Time of Day (hour)	Phase	Situation / Activity
12:00 AM	Minimum Premise Load	Ambient temperatures minimized. Commercial or municipal buildings are lightly occupied, HVAC in setback mode, lighting minimal.
6:00 AM	Wake Up	Building and HVAC load starts up as lighting and cooling are activated for the day.
9:00 AM	Load Climbing	Ambient temperature climbs and begin calling for increased compressor and fan load.
3:00 PM	Maximum Building Load	Peak power draw required to maintain thermal SETPOINT of building envelope.
7:00 PM	Ambient Reducing	
10:00 PM	Setback	Building systems / thermostat drops HVAC and lighting load.

HVAC = heating, ventilation, and air conditioning

A3 High Penetration DER Scenario with EV (Green Sky)

The continuing drop in cost for DER leads to an oversaturation of solar PV within the Middletown region within the next 10-year period. Additionally, the scenario envisions much higher adoption of both stationary and mobile energy storage. This is entirely consistent with the revised accelerated goals of the New Jersey 2019 Energy Master Plan revisions. The extreme variability of this generation and new load profiles causes wide swings in voltage on the utility distribution system, as there has been little investment in balancing infrastructure. A typical daily time variant impact sequence is therefore envisioned as follows bringing grid conditions that the microgrid could help manage.

Time of Day (hour)	Phase	Situation / Activity
12:00 AM	Maximum EV Load	Most vehicles would be set to activate charging upon general TOU rate decrease.
4:00 AM	Lowest Load	Most 85 mi. range EVs recharged at Level 2, building lighting and cooling loads at a relative minimum.
6:00 AM	Increased Load, EVs Unplug	Building and HVAC load rises as lighting and cooling are activated for the day.
9:00 AM	PV Output Rising, High Workplace EV Load	Local DER generation begins and supplements grid power serving building load, which may include workplace charging of EV at Level 2.
12:00 PM	Maximum PV Output	Closest to maximum rated PV power achieved, reducing grid power draw to a daily minimum.
4:00 PM	Maximum Commercial Building Load Reached	
6:00 PM	System Peak Load	Reduced PV direct output.

DER = distributed energy resources
EV = electric vehicle
HVAC = heating, ventilation, and air conditioning
PV = photovoltaic
TOU = time-of-use

Appendix B: Candidate Technology Examples

The following technologies are shown as a reference to the description of operational parameters in the Microgrid Technology section of this Study. This is intended to provide a more intuitive understanding of the particular DER type.

Saft - Small Scale Energy Storage Solution

Groundmount Solar

Rooftop Solar

Small Natural Gas Generation