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City of Altoona Microgrid Feasibility Analysis: East Neighborhood Development Plan

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TABLE OF CONTENTS

GLOSSARY OF TERMS

AVERT (Avoided Emissions and Generation Tool): A tool developed by the U.S. Environmental Protection Agency (EPA) to estimate the emissions benefits of energy efficiency and renewable energy programs by analyzing how changes in energy generation affect emissions at the regional level.

BESS (Battery Energy Storage Systems): Systems that store energy in rechargeable batteries for later use. BESS can help balance electricity supply and demand, enhance grid stability, and provide backup power during outages.

CO_2 (Carbon Dioxide): A greenhouse gas that's a primary contributor to climate change. It's emitted from burning fossil fuels, deforestation, and other industrial processes.

DER (Distributed Energy Resource): Small-scale electricity generation or storage technologies, such as solar PV, wind, battery storage, and demand response, that are located close to end-users and can operate independently or in coordination with the grid.

HVAC (Heating, Ventilation, and Air Conditioning): A system that regulates indoor climate conditions, providing heating, cooling, and air circulation for buildings.

IECC (International Energy Conservation Code): A model energy code that establishes minimum efficiency standards for residential and commercial buildings to improve energy use and reduce environmental impact.

kBtu (Thousand British Thermal Units): A unit of measurement for energy, commonly used to quantify energy consumption in buildings and heating systems.

kW (Kilowatt): A unit of power equal to 1,000 watts, often used to measure the capacity of electrical appliances, solar PV systems, and generators.

kWh (Kilowatt-Hour): A unit of energy equivalent to using one kilowatt of power for one hour. It is commonly used in electricity billing to measure energy consumption.

MBtu (Million British Thermal Units): A unit of measurement for large-scale energy use, often used in industrial processes and heating system evaluations.

MWh (Megawatt-Hour): A unit of energy equal to 1,000 kilowatt-hours, commonly used to measure electricity generation and consumption on a larger scale.

NREL (National Renewable Energy Lab): A U.S. Department of Energy laboratory that conducts research and development on renewable energy, energy efficiency, and energy systems integration.

NPV (Net Present Value): A financial metric used to assess the profitability of an investment by calculating the present value of expected future cash flows, adjusted for time and risk.

PSC (Public Service Commission): A regulatory body that oversees utilities and ensures fair pricing, reliability, and compliance with energy policies in a given jurisdiction.

PV (Photovoltaics): A technology that converts sunlight directly into electricity using semiconductor materials, commonly used in solar panels for residential, commercial, and utility-scale applications.

SAG (Stakeholder Advisory Group): A group of representatives from various organizations, including local governments, utilities, and community members, who provide input and guidance on a project.

TEN (Thermal Energy Networks): A system that distributes heating and cooling energy through a network of pipes, utilizing sources such as geothermal, waste heat recovery, and heat pumps to improve energy efficiency and reduce emissions.

EXECUTIVE SUMMARY

This study details the work of Slipstream in partnership with the City of Altoona, Eau Claire Energy Cooperative (ECEC), and Dairyland Power Cooperative (DPC) to evaluate the potential for establishing a resilient, sustainable, and cost-effective microgrid for a planned mixed-use neighborhood in Altoona, Wisconsin, referred to as the East Neighborhood. This greenfield site presents a unique opportunity to plan for a microgrid from the ground up, integrating advanced energy technologies to meet the community's energy needs. The goals of the study were to assess energy efficiency measures, analyze distributed energy resource (DER) configurations, and evaluate the feasibility of various microgrid scenarios.

Two neighborhood development plans were considered. The Highly Residential development plan included a mix of single-family homes, multifamily dwellings, and seven commercial buildings, while the Sports Complex development plan reduced residential density and added a sports complex that could serve as a community resilience center. Six microgrid scenarios were developed to analyze various configurations of DERs, building energy efficiency measures, and HVAC configurations, including gas-fired heating with electric cooling, all-electric buildings with air-source heat pumps, and a thermal energy network (TEN) for shared heating and cooling. These scenarios explored individual building level assets like rooftop photovoltaics (PV) and individual battery energy storage systems (BESS), as well as community level assets such as a ground-mounted PV system, large-scale BESS, and a natural gas generator.

The study's results provide valuable insights into the financial and energy performance of the six microgrid scenarios. Table 1 summarizes the results for the six scenarios (A through F). The analysis revealed microgrid scenario D – All-Electric with Community Assets as the most cost-effective, without including factors such as health impacts, carbon emissions, avoided outage costs, or any amount of funding. These factors are not included in the assessment at stakeholder request to focus on specific economic impacts. Scenario specific savings refer to the difference in costs for how the neighborhood is composed, apart from the microgrid assets, including the different HVAC configurations, the natural gas infrastructure for mixed-energy scenarios, and load management options.

Table 1. Summary results.

Scenarios	A - Mixed energy with Individual Assets	B - Mixed energy with Community Assets	C - All-electric with Individual Assets	D - All-electric with Community Assets	E - TEN with Individual Assets	F - TEN with Community Assets
HVAC configuration	Gas-fired heating and electric cooling		Air-source heat pumps		Thermal energy network	
Development plan	Highly residential		Highly residential	Sports complex	Highly residential	Sports complex
Microgrid assets	Rooftop PV + Individual BESS	Ground PV + Large-scale BESS	Rooftop PV + Individual BESS	Ground PV + Large-scale BESS + Gas generator	Rooftop PV + Individual BESS	Ground PV + Large-scale BESS
Peak demand (kW)	1,424	1,424	8,133	6,069	3.383	2,385
Annual kWh consumption	7,461,491	7,461,491	25,576,608	21,473,261	17,166,218	14,108,122
Annual CO_2 emissions (tons)	4,972	4,957	4,356	3,475	2,088	2,077

PV size (kW)	2,690	2,500	3,307	2,500	2,563	2,500
BESS capacity (kW)	2,301	2,287	3,953	1,840	1,681	3,974
BESS energy (kWh)	6,361	6,649	20,060	10,927	8,777	9,849
Generator capacity (kW)	0	0	0	500	0	0
TEN size (# of boreholes)	0	0	0	0	1,200	953
Solar exported (kWh)	1,540,006	0	1,374,828	0	693,095	0
Total cost	$15,534,518	$13,427,687	$29,255,068	$16,706,395	$16,036,196	$18,074,399
Total energy benefits	$12,504,024	$12,205,621	$22,785,393	$16,664,116	$14,665,670	$15,547,823
Scenario specific savings	$19,014,685	$22,273,185	$23,430,951	$30,029,907	$0	$13,793,861
NPV	**$15,984,191**	**$21,051,118**	**$16,961,276**	**$29,987,629**	**-$1,370,526**	**$11,267,286**

Scenarios A and B explored a mixed-energy approach, where buildings relied on gas-fired heating and electric cooling. These configurations resulted in lower electrical demand but continued reliance on fossil fuels and therefore would produce the most emissions. Community-level assets in Scenario B reduced costs compared to Scenario A due to shared infrastructure benefits.

Scenarios C and D focused on all-electric buildings with air-source heat pumps, removing dependence on natural gas. While Scenario C relied on individual DER assets for each building, Scenario D leveraged shared community assets and included a natural gas generator, reducing BESS size and therefore overall costs.

Scenarios E and F incorporated a thermal energy network (district geothermal), an innovative district heating and cooling solution. While this approach offered significant reduction to electricity demand and emissions, it proved to be the least cost-effective option due to the high construction costs for implementing a TEN.

We acknowledge that with the current low utility rates and low frequency and duration of outages in the area, the economic feasibility of the microgrid based on current costs of electricity does not immediately pencil out without considering other scenario specific costs. This microgrid feasibility study represents a snapshot in time. Projections show that power and energy needs could double by 2035 or 2050, depending on the source. With these growing demands, utility prices are anticipated to increase, and outages may become more frequent and longer in duration due to the impacts of climate change. Consequently, the net present value (NPV), payback, and other financial metrics of the microgrid are expected to improve dynamically with the forecasting rise in electricity costs, both independently and relative to natural gas as an alternative heating and power source

To advance the microgrid project, the study recommends the following:

- **Neighborhood design and development.** Integrate considerations for neighborhood composition (Highly residential vs Sports complex), building construction design and materials, HVAC systems, and building load management options during the design and development process of the East Neighborhood. Load management technologies, such as smart panels or energy management information systems (EMIS), should be considered to enable flexible load control. These technologies can play a critical role in demand response programs and ensure efficient operation of the microgrid, particularly during peak demand or outage scenarios. Load management technologies would need to be integrated with Eau Claire Energy Cooperative's policy and programs.

- **Phased implementation approach to community-level assets.** Begin by establishing community-level assets through a phased approach, where components are installed progressively based on their individual value propositions, while ensuring they are microgrid ready, and available financing options. Implementing these assets through a third-party aggregator business model would ensures efficient utilization of investments while adapting to evolving neighborhood needs.
- **Develop a virtual power plant (VPP) and/or battery incentive program.** Future battery owners within the neighborhood could benefit from incentive programs such as demand-response payments or credits for participating in grid-balancing programs. These incentives would encourage battery owners to align their storage and discharge schedules with grid needs, further enhancing system reliability and cost efficiency. Furthermore, a VPP would aggregate all the neighborhoods DERs, balancing electrical loads and providing utility-scale and utility-grade grid services like a traditional power plant.
- **Define ownership and operations of the microgrid.** Establishing a clear ownership and operational structure is critical for long-term success. Stakeholders must determine how assets will be managed, whether through utility ownership, a third-party aggregator, or a hybrid model, to ensure reliability, regulatory compliance, and financial viability.
- **Leverage financing options.** Considering the high costs of implementing a microgrid to support a neighborhood of this size, leveraging financing options will be crucial to offset upfront costs and maximize the project's economic and environmental potential. Detailed design studies and interconnection agreements should be pursued to refine configurations and ensure compliance.

The Altoona East Neighborhood microgrid feasibility study demonstrates the transformative potential of microgrids in addressing climate change, energy resilience, and sustainable development. The innovative approach used in this study, including energy modeling for diverse building types, offers a replicable framework for similar projects. By addressing challenges early in the planning phase, this study highlights how tailored microgrid solutions can align with diverse community needs.

The findings emphasize the cost-effectiveness and resilience benefits of community-level assets, complemented by the phased implementation of individual-level solutions. By leveraging robust stakeholder collaboration, strategic planning, and available funding opportunities, the City of Altoona can position itself as a leader in energy innovation. The East Neighborhood microgrid has the potential to serve as a model for sustainable and resilient community development, providing long-term benefits for residents, the local grid, and the broader environment.

1 INTRODUCTION

As climate change normalizes extreme weather events, grid and community resiliency are put to the test. To respond to this growing need, the City of Altoona has been making concerted efforts to enhance its energy resilience and sustainability as part of its long-term development strategy. These efforts are grounded in the city's Energy Action Plan, developed collaboratively with Xcel Energy, which emphasizes energy efficiency, renewable energy adoption, and climate action[1]. Parallel to this, the 2022 Comprehensive Plan lays a strong foundation for integrating climate action, social equity, and economic vitality into municipal planning[2].

The planning for the East Neighborhood represents a pivotal step in achieving these goals. Guided by the East Neighborhood Residential Development Plan, this mixed-use development incorporates principles of sustainability, resilience, and traditional neighborhood design[3]. The site will host a combination of residential and commercial properties, designed to promote walkability, active transportation like cycling, and green infrastructure.

To support these ambitious goals, with funding from the Wisconsin Public Service Commission (PSC) and in partnership with Slipstream, Eau Claire Energy Cooperative (ECEC), and Dairyland Power Cooperative (DPC), the City of Altoona assessed the feasibility of establishing a microgrid for the East Neighborhood. The microgrid aims to ensure energy security, enable climate adaptation, and provide long-term economic benefits. Specifically, the study focuses on developing three cost-effective microgrid scenarios that align with the city's resilience goals while maintaining positive net present value (NPV). Initial conversations with the stakeholders shed light on a major hurdle for implementing a microgrid; ownership. To that end, a key part of this project was determining which elements of the planning belong to which parties involved, including the future residents and business owners of the East Neighborhood.

The microgrid feasibility study's goals include:

- **Evaluating the costs and benefits associated with implementing a microgrid:** Developing various microgrid scenarios to associate and compare costs and benefits with different designs.
- **Promoting resilience:** Planning a microgrid that can sustain critical operations during outages.
- **Supporting sustainability:** Incorporating renewable energy and energy efficiency technologies.
- **Fostering economic viability:** Identifying funding strategies and partnerships to provide positive net present value for microgrid feasibility.
- **Defining ownership structure and business model:** Establishing clear roles and responsibilities for stakeholders in owning, operating, and managing the microgrid, ensuring long-term financial and operational sustainability.

The report starts with providing project background and details on the City of Altoona and the East Neighborhood site. We then describe the methodology and results of the microgrid planning. The results highlight the tradeoffs between different system configurations to inform future microgrid planning, but a more in-depth design and analysis would be needed if the city decided to proceed with a microgrid installation. Finally, we provide a list of microgrid considerations for the site and its future development.

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[1] Xcel Energy, "Altoona Energy Action Plan," 2023.

[2] Vandewalle & Associates, "City of Altoona Comprehensive Plan," 2022.

[3] Vandewalle & Associates, "Altoona East Neighborhood Residential Development Plan," 2022.

1.1 BACKGROUND

Located in west-central Wisconsin, Altoona is a rapidly growing community with a population of over 8,000. The city is characterized by its commitment to sustainability and has integrated climate action into its planning processes. The 2022 Comprehensive Plan articulates a vision for a resilient, equitable, and economically vibrant community. It highlights opportunities for energy efficiency, renewable energy adoption, and sustainable infrastructure development[4].

The success of the East Neighborhood microgrid project is built on collaboration between the City of Altoona and its key utility partners. Eau Claire Energy Cooperative is the electric service provider for the East Neighborhood, and Dairyland Power Cooperative is the generation and transmission entity that supplies power to ECEC and its members. The area served by the cooperatives already benefits from highly reliable and relatively inexpensive energy compared to many climate-impacted regions.

The East Neighborhood is a planned mixed-use development designed to accommodate diverse housing options, vibrant open spaces, and neighborhood-scale commercial uses[5]. City of Altoona currently owns 80 acres of the total land considered for the development, but this study will focus on assessing the impact of a microgrid for the total 250-acre site. Two development plans are under consideration:

- **Highly residential development plan:** Primarily residential, featuring up to 642 single-family homes, 516 multifamily dwellings, and seven commercial buildings. Figure 1 shows a concept map of this development plan, created by Vandewalle & Associates Inc for the East Neighborhood Residential Development Plan.
- **Sports complex development plan:** A mixed-use configuration with reduced residential density and the addition of a sports complex (including a tri-use building, Olympic sized pool, and two ice rinks), that could serve as a community resilience hub or shelter.

[4] Vandewalle & Associates, “City of Altoona Comprehensive Plan.”

[5] Vandewalle & Associates, “Altoona East Neighborhood Residential Development Plan.”

Figure 1. Site layout from East Neighborhood Residential Development Plan. [6]

The East Neighborhood will emphasize sustainability through measures such as energy-efficient building materials, renewable energy systems, and integrated green spaces. The proposed microgrid will complement these efforts by enhancing energy reliability and efficiency. It will integrate distributed energy resources (DERs) such as rooftop solar PV, community-scale solar farms, battery energy storage systems, or district geothermal heating and cooling.

[6] Vandewalle & Associates, "Altoona East Neighborhood Residential Development Plan."

2 METHODOLOGY

We conducted the feasibility study through a structured and iterative process, combining a four-stage methodology (Figure 2) with ongoing stakeholder engagement. These processes were supported by carefully selected tools designed to assess building energy demands, evaluate distributed energy resources (DERs), and optimize microgrid configurations, costs, and benefits. We collected energy, cost, technology, and site data to use as inputs in the analysis. The methodology ensured a robust understanding of the technical, economic, and environmental aspects of potential microgrid scenarios, alongside continuous engagement with stakeholders to refine assumptions and align outcomes with community goals. The four stages of the methodology are described below:

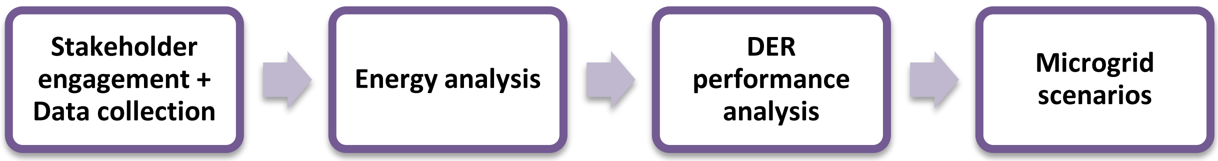

Figure 2. Feasibility study methodology stages.

Stakeholder engagement and data collection. A stakeholder advisory group was former, with ongoing meetings set-up throughout the project duration. With the support of the stakeholders, essential data on the neighborhoods composition, outage history of the area, and utility rates was collected. Stakeholder engagement also played a critical role in refining microgrid scenarios and identifying resilience priorities, ensuring that the solutions considered in the study aligned with the needs of local government and utilities, and the future residents of the neighborhood.

Energy analysis. The energy analysis process was carried out to develop accurate load profiles for the neighborhood. From the energy models that were built, hourly load profiles were generated to capture energy use throughout the day for different building types. These hourly results for individual buildings were scaled according to their size and quantity in the development. The scaled results were then aggregated to form a comprehensive load profile for the entire neighborhood, providing a holistic view of the community's energy demands.

DER performance analysis. Utilizing the load profiles created in the previous stage as the primary input, varying DER configurations were analyzed for each building type and at the community level. We utilized an optimization tool to quantify the energy performance, associated costs, and emissions produced over time for each configuration. This was an iterative process to identify configurations that could balance energy savings, costs, and emissions reductions.

Microgrid scenarios. The results from the DER performance analysis were evaluated, and microgrid scenarios were selected based on their technical and economic feasibility. In this final stage, the project team refined assumptions and adjusted configurations to synthesize the costs, benefits, and environmental impacts of the each microgrid scenario and ensure that at least one scenario met the resilience objectives without relying on societal benefit metrics. Detailed outputs were summarized to provide actionable recommendations for the project.

2.1 STAKEHOLDER ENGAGEMENT

Stakeholder engagement was a critical, ongoing task throughout the study. A Stakeholder Advisory Group (SAG) was created, which consisted of representatives from key organizations integral to the project:

- **City of Altoona**: City officials provided critical data on the proposed neighborhood's infrastructure, building types, and resiliency needs. Their input ensured the project aligned with the city's broader sustainability goals and development plans.
- **Eau Claire Energy Cooperative**: As the electric service provider for the East Neighborhood, ECEC contributed essential technical data, including the electric feeder schedule, outage history, and grid vulnerabilities. They also provided rate information, which was vital for the economic modeling of the microgrid.
- **Dairyland Power Cooperative**: As the generation and transmission cooperative supporting ECEC, they provided emissions data to ensure the microgrid's environmental impact could be accurately assessed. Their insights into power generation and delivery enhanced the technical feasibility of proposed DER configurations.

Having continuous engagement with these stakeholders facilitated the collection of high-quality data, guided the alignment of microgrid scenarios with the neighborhood's specific needs, and ensured that the proposed solutions were both technically feasible and economically viable. Regular meetings and collaborative discussions with SAG members helped refine the assumptions and parameters used in the analysis, ensuring that the project addressed resiliency goals, sustainability targets, and stakeholder priorities.

2.2 ENERGY ANALYSIS

The following sections describe the data and methodology used throughout the energy analysis steps.

2.2.1 Optimize Energy Efficiency Through Building Energy Modeling

To assess the potential for energy efficiency within the East Neighborhood, a series of energy models were developed for all ten building types present in the two proposed development plans. These models included single-family homes, multifamily residences, and seven different commercial building types (convenience store, family dining, dining lounge, retail store, healthcare clinic, medium office, and a small hotel). For the Sports Complex, the tri-use building was also modeled, while the energy consumption of the Olympic size pool and two ice rinks was estimated using the national median for these property types[7]. Two tools were used to develop the energy models:

- **BEopt (Building Energy Optimization Tool)**[8]: This tool developed by NREL was employed for residential energy modeling, specifically for single-family homes. BEopt enabled the team to simulate energy consumption under various efficiency measures, including building envelope materials and beneficial electrification. Its ability to model a wide range of efficiency improvements was crucial for understanding how design choices impact energy demand and costs.
- **Sketchbox**[9]: Slipstream's simplified building energy modeling tool, provided detailed energy simulations for multifamily and commercial buildings. The tool captured the diversity of building types and their associated load profiles, generating accurate hourly energy consumption data. This information was essential for understanding the energy demand patterns of the entire neighborhood.

[7] "US Energy Use Intensity by Property Type."
[8] "BEopt: Building Energy Optimization Tool," https://www.nrel.gov/buildings/beopt.html.
[9] "Sketchbox," 2024, http://www.youtube.com/playlist?list=PL-mtgGdh8bvh3GsfC1Fpe8bJSO2uDRFo5.

The modeling inputs were comprehensive, encompassing building size, occupancy levels, envelope insulation, glazing properties, HVAC systems and their efficiencies, and lighting power densities. Specifically, the sizes used in the models were:

- **Single-family homes**: Each dwelling was modeled at 1,200 ft^2.
- **Multifamily dwellings**: Each unit was modeled at 1,150 ft^2.
- **Commercial buildings**: The seven commercial buildings modeled made up a combined area of 146,400 ft^2.
- **Sports Complex**: Modeled tri-use building at 110,000 ft^2, the Olympic size pool at 24,000 ft^2, and the two ice rinks at 41,600 ft^2 each. For a total of 217,200 ft^2.

Inputs related to envelope characteristics were specified to meet the requirements of minimum International Energy Conservation Code (IECC) standards in Wisconsin (2009 for residential buildings and 2015 for commercial buildings)[10]. For advanced energy efficiency scenarios, the IECC 2021 code standards were used. Inputs not related to these IECC standards, such as HVAC systems and specifications, occupancy levels, and appliance configurations, were derived from the Pacific Northwest National Laboratory's (PNNL) Prototype Building Models[11]. The envelope characteristics considered are the following:

- **Window Type**: Windows are a major source of heat loss and gain in buildings. Energy-efficient windows incorporate double or triple glazing with low-emissivity (low-E) coatings that reduce heat transfer while allowing natural light to enter. Properly selected and installed windows help minimize heating and cooling loads, enhancing overall efficiency.
- **Wall Sheathing**: The type of sheathing used in a building's exterior walls impacts its insulation properties. High-performance materials, such as extruded polystyrene (XPS) which is a type of foam insulation known for its high R-value and moisture resistance, reduce thermal bridging and improve heat retention, reducing heating and cooling energy demands.
- **Roof Insulation**: Roof insulation plays a crucial role in preventing heat loss in winter and heat gain in summer. Higher R-value insulation materials, such as spray foam or rigid foam boards, create a thermal barrier that enhances energy efficiency and reduces HVAC loads.
- **Floor Slab**: Insulating the floor slab, particularly in colder climates, prevents heat loss to the ground and helps maintain stable indoor temperatures. Slab insulation is particularly important for radiant floor heating systems, improving heat retention and reducing energy consumption.
- **Air Leakage**: Air infiltration through gaps and cracks in the building envelope increases energy waste by allowing conditioned air to escape. Sealing leaks with weatherstripping, caulking, and high-performance air barriers reduces energy loss, improves comfort, and enhances HVAC system efficiency.
- **Space Conditioning Ducts**: Duct systems distribute heated and cooled air throughout a building. Poorly insulated or leaky ducts lead to significant energy losses. Proper duct sealing, insulation, and optimized design improve energy efficiency by ensuring conditioned air reaches its intended destination without unnecessary waste.

10 "Wisconsin | Building Energy Codes Program."
11 "Prototype Building Models | Building Energy Codes Program."

For comparison, energy models for single-family homes were created for six configurations, representing two building envelope standards (minimum code requirements and IECC 2021) and three HVAC and water heater configurations:

1. **Gas furnace, gas water heater, and central air conditioner**: Representing a standard mixed-energy household**.**
2. **All-electric home with an electric water heater and air source heat pump (ASHP)**: Designed to explore a transition to electric heating and cooling
3. **All-electric home with an electric water heater and ground source heat pump (GSHP)**: Representing a high-efficiency all-electric configuration.

In total, six energy models were created for each building type: two versions of each HVAC configuration (one built to IECC 2009/2015 standards, and one built to IECC 2021 standards). With ten building types modeled, this resulted in a comprehensive set of 60 energy models used to explore the efficiency potential of different configurations. Figure 3 below provides a visual comparison of the energy usage intensity (EUI; measured in kBtu/ft^2) across the six different configurations for single-family homes.

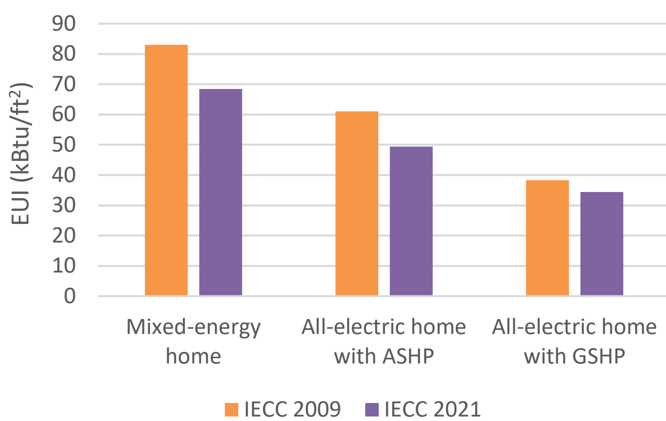

Figure 3. Single-family homes EUI comparison

The results highlighted several key observations:

- For a mixed-energy single-family home, building to IECC 2021 standards reduced EUI by approximately 18% compared to the IECC 2009 standard. This reduction was mainly due to improved thermal characteristics, which lowered heating requirements and thus reduced natural gas consumption.
- Among the building envelope elements, the biggest contributors to reducing energy consumption were:
    1. Air leakage: Improving air tightness significantly reduced heat loss and resulted in noticeable energy savings.
    2. Wall sheathing: Enhanced insulation in wall sheathing contributed to overall efficiency, especially during winter months.
- The comparison of different HVAC and water heating configurations also yielded notable results. Transitioning from a gas furnace, gas water heater, and central A/C to an all-electric home with an

air source heat pump and electric resistance water heater reduced energy consumption by approximately 27%. The use of an air source heat pump accounted for a 22% reduction, while the electric resistance water heater contributed an additional 5% reduction. Upgrading further to a heat pump water heater (HPWH) could add a 4% reduction in energy use. A ground source heat pump proved the most efficient, leading to a total energy consumption reduction of 54% compared to the baseline mixed-energy configuration.

The costs associated with upgrading building envelope materials and HVAC systems were also analyzed. When looking at building envelope upgrades, the highest cost investments were associated with higher efficiency window types and better roof insulation**.** Conversely, reducing air leakage was the most cost-effective strategy, given the relatively low cost of sealing measures compared to the energy savings achieved. Upgrading space heating ducts also showed good cost-effectiveness, though not as impactful in energy reduction. The scatter plot below (Figure 4) shows the relationship between energy savings (in MBtu/year) and the increase in building materials costs for various building envelope elements.

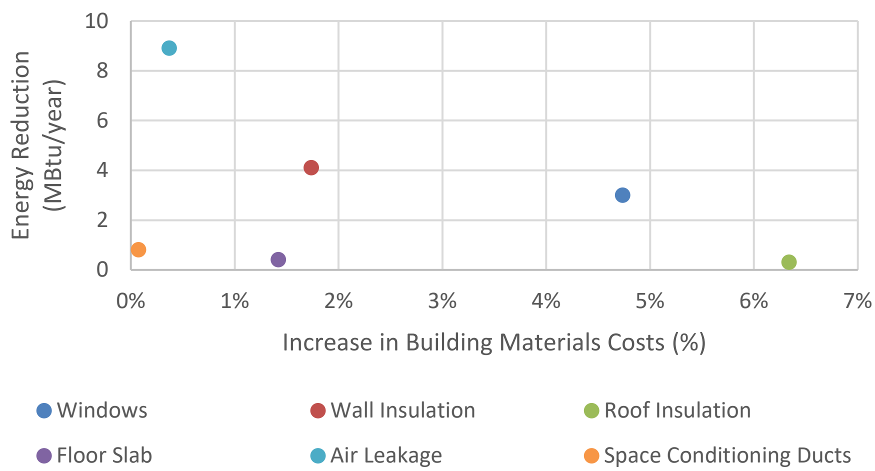

Figure 4. Building envelope upgrades from IECC 2009 to 2021 – energy and cost comparison

Regarding water heater options, the electric resistance water heater was identified as the least costly in terms of equipment costs compared to gas-fired or HPWHs. However, due to the higher cost of electricity versus natural gas in the area, this option resulted in higher utility bill costs (10% increase) for residents.

For HVAC configurations, the air source heat pump presented the lowest equipment costs compared to both the gas furnace plus central air conditioner combination and the ground source heat pump. However, as with the electric resistance water heater, air source heat pumps led to higher utility bills for residents (22% increase) due to the increased reliance on electricity. Importantly, these higher electricity costs would be partially offset with the implementation of solar PV systems, which would reduce reliance on grid electricity and contribute to overall cost savings for residents. Figure 5 provides a visual representation of the energy savings versus equipment cost for the different HVAC and water heater options. The energy savings are compared to the base case of gas-fired equipment, which is why the gas water heater and gas boiler with central AC show no savings in the graph.

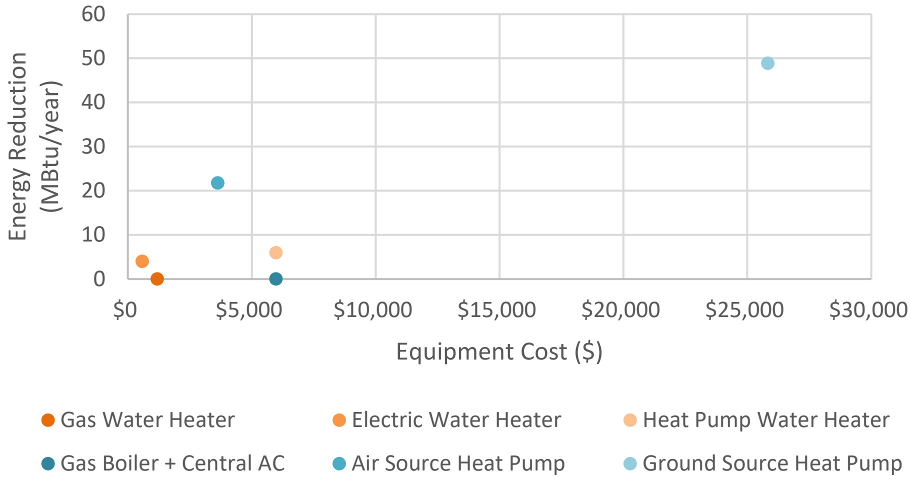

Figure 5. Building HVAC and water heater upgrades – energy and cost comparison

The costs for equipment and building materials were sourced from the National Renewable Energy Laboratory (NREL) database[12], which supports the BEopt tool. This database includes costs for building envelope materials (walls, roofs, floors, thermal mass, windows and doors), air flow (air leakage and mechanical ventilation), space conditioning equipment (HVAC), lighting, and home appliances (water heater, refrigerator, oven, washer, and dryer). Therefore, overall costs for each single-family home configuration were estimated through the energy models. Figure 6 presents a cost comparison for the six configurations. Results show that the cheapest configuration is to build all-electric homes with an ASHP that meets the minimum code requirements (IECC 2009). Considering the maximum number of single-family homes for the site (642), building them as all-electric homes with an ASHP instead of a mixed-energy home could produce up to $2.5M in savings for the developer. Figure 6 further supports this assessment by comparing building cost with energy usage intensity.

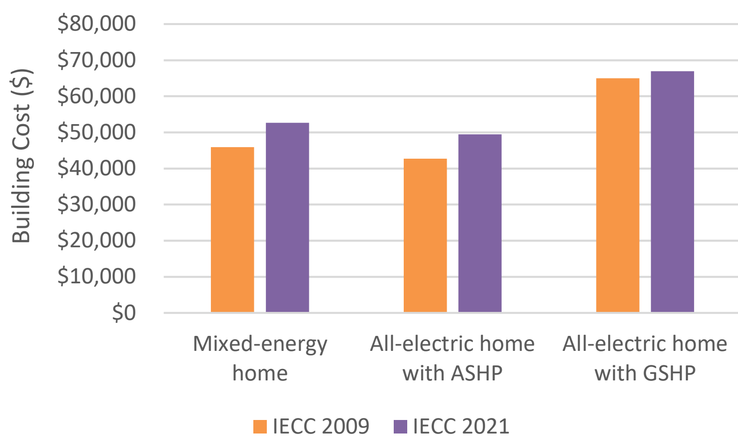

Figure 6. Single-family homes cost comparison

When selecting home appliances for the initial development of the neighborhood, or for future home modifications, consideration should be given to incentive programs offered by ECEC and DPC. Both cooperatives offer a variety of incentive programs to promote energy-efficient appliances and practices

12 "National Residential Efficiency Measures Database | NREL."

among their members. Incorporating these incentive programs into the development of the Altoona East Neighborhood can yield significant benefits. The future residents of the neighborhood can reduce upfront costs and enjoy long-term energy savings by utilizing available rebates for energy-efficient appliances and systems. Educating future residents about these programs fosters a culture of energy consciousness and community-wide participation in sustainability initiatives.

2.2.2 Projected Building Load Profiles

The projected building heating, cooling, and electric load profiles for the East Neighborhood were created using a combination of BEopt and Sketchbox to model the energy use of individual buildings. Each of the ten building types was simulated to generate hourly energy consumption data, which then served as the basis for aggregating the entire neighborhood's energy profile. This process provided insights into the electricity, heating and cooling demands of the mixed-use community throughout different times of the year.

To align with a cost-conscious development approach, the building electric load profiles selected for the rest of the study were the ones resulting from the energy models developed based on minimum code requirements (IECC 2009 for residential buildings and IECC 2015 for commercial buildings). This ensures that overall expenses associated with building construction materials are kept to a minimum. In terms of HVAC and water heater configurations, all three configurations presented in the previous section will be analyzed throughout the study. These different configurations provide flexibility for evaluating the impact of each approach on the neighborhood's energy consumption, overall demand, and suitability for DERs. By considering all three configurations throughout the study, it was possible to develop a comprehensive comparison of the advantages and challenges associated with each option as they relate to different microgrid scenarios.

To develop a comprehensive load profile for the entire neighborhood, the load profiles for individual buildings were scaled and aggregated based on the projected number of residential units and commercial buildings in the two proposed development plans. This approach allowed for a realistic estimation of total neighborhood energy demand under a variety of development and equipment configurations. Residential buildings were scaled based on the number of single-family homes or multifamily units projected for each development plan considered.

- **Highly residential**: Includes between 505 to 642 single-family homes and 412 to 516 multifamily units.
- **Sports complex**: Includes between 422 to 548 single-family homes and 372 to 466 multifamily units, along with the addition of a Sports Complex.

To provide a complete analysis, full neighborhood building load profiles were created for both the minimum and maximum number of residential buildings in each development plan and for each HVAC configuration. This resulted in a detailed dataset that captures potential variations in energy consumption based on the neighborhood's composition and the chosen energy technologies. Comparing the neighborhood's load for each development plan, Table 2 shows the annual electricity consumption and peak demand for each neighborhood composition scenario. Individual buildings, even of the same type, rarely hit their individual peak demands at the exact same time. Residential homes, which when aggregated are the largest consumers of the proposed neighborhood, experience their peak demand between 4 to 10 PM[13]. Therefore, to account

[13] Johnson, "Stochastic Behavior-Based Load Simulator (LoadSim): Documentation."

for this diversity a coincidence factor of 0.6 was used, which recognizes that only a fraction of all buildings (which are mostly homes) are likely to be at or near their respective peaks simultaneously. This value is considered conservative as it's relatively high compared to what might be used for a smaller, more heterogeneous, collection of loads[14]. This approach avoids underestimating demand by assuming overly dispersed peaks, while also preventing overestimation that would occur if every building's peak was assumed to coincide perfectly.

Table 2. Neighborhood electricity consumption for both development plans.

HVAC configuration	Neighborhood development plan	Residential density	Electricity consumption (kWh/year)	Peak demand (kW)
Gas-fired heating and electric cooling	Highly residential	Minimum	7,461,491	1,424
		Maximum	8,937,420	1,744
	Sports complex	Minimum	7,615,288	1,295
		Maximum	8,355,250	1,534
Air-source heat pumps	Highly residential	Minimum	20,771,028	6,478
		Maximum	25,576,608	8,133
	Sports complex	Minimum	21,473,261	6,069
		Maximum	22,499,240	7,088
Thermal Energy Network	Highly residential	Minimum	14,004,269	2,705
		Maximum	17,166,218	3,383
	Sports complex	Minimum	14,108,122	2,385
		Maximum	16,995,288	3,004

To illustrate the differences in energy consumption associated with different HVAC configurations, Figures 7 and 8 compare aggregated neighborhood electricity demand load profiles (in kW) across typical winter and summer days respectively. The winter day load profile shows how heating demand varies among the three HVAC configurations, especially during the night where the temperatures are lower. As shown, the all-electric configuration with ASHP exhibits a much higher energy demand during the morning and evening heating peaks compared to the mixed-energy configuration, whose heating demand is covered by gas fire HVAC equipment. The GSHP configuration demonstrates the lowest overall demand due to its superior heating efficiency.

[14] Blake, "Coincidence Factor Study."

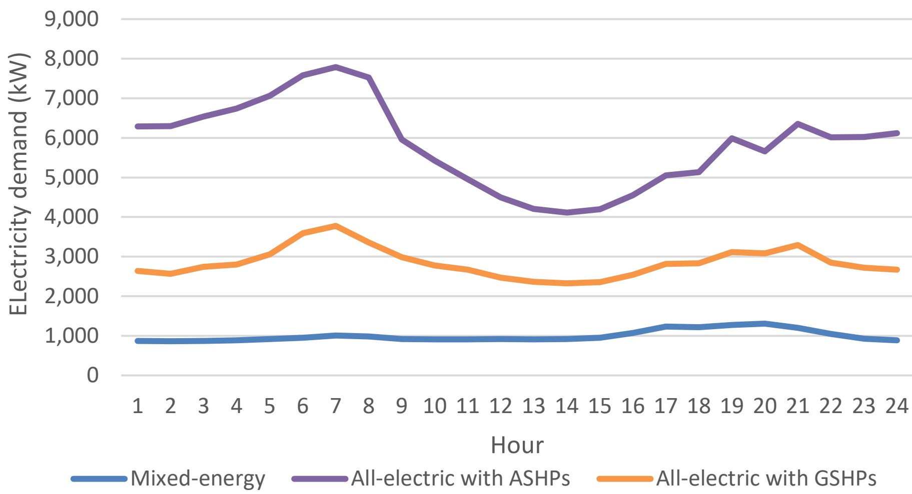

Figure 7. Winter day neighborhood aggregated building load profile

The summer day electricity loads are generally lower than winter day electricity loads when using all electric HVAC systems in this climate. The graph shows how all three neighborhood load profiles follow a similar load curve, since cooling in all three is covered by electricity consuming HVAC equipment. The GSHP configuration again shows reduced demand compared to other configurations, reflecting its efficient cooling capabilities.

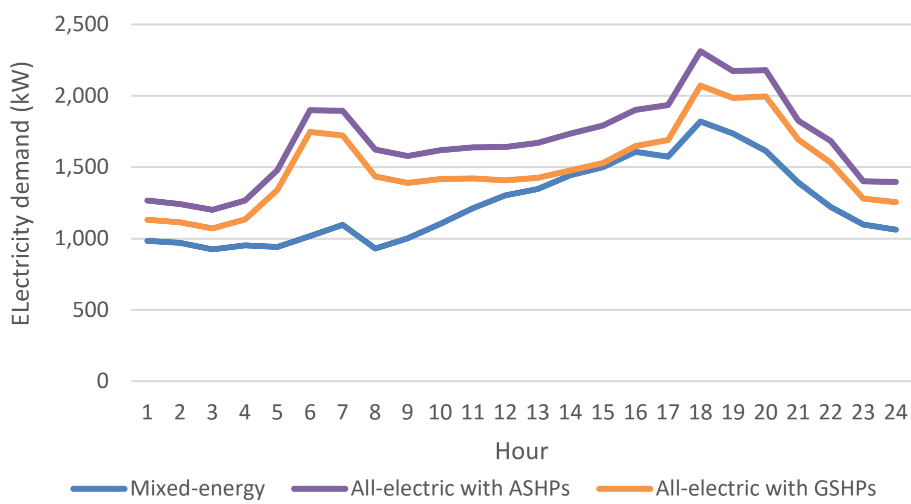

Figure 8. Summer day neighborhood aggregated building load profile

2.2.3 Heat Pumps and Thermal Energy Network

Heat pump technologies, specifically air-source heat pumps (ASHP) and ground-source heat pumps (GSHP), were analyzed across all building types to evaluate their performance and feasibility as alternatives to conventional gas-fired systems. To model the thermal energy network (TEN), or district geothermal system, TRNSYS (Transient System Integration Tool)[15] was used for its robust simulation capabilities in thermal energy systems. This tool enabled the team to evaluate the scalability and performance of geothermal heating and cooling, ensuring that the system could meet the neighborhood's aggregated heating and cooling loads and evaluate its benefits and constraints.

[15] "TRNSYS: Transient System Simulation Tool," https://www.trnsys.com/.

Using BEopt for single-family homes and Sketchbox for multifamily and commercial buildings, we modeled all building types with both ASHPs and GSHPs. This allowed us to compare the energy consumption and associated costs of these systems to the base case, which used gas-fired equipment for space heating, gas water heaters, and central air conditioning. The analysis showed clear differences in performance as shown and explained in the Projected Building Load Profiles section.

- **Air Source Heat Pumps (ASHPs)**: These systems were modeled to reflect typical outdoor temperature performance. ASHPs are generally more affordable to install than GSHPs but exhibit lower efficiency during extreme cold weather, leading to higher energy demand during peak heating periods.
- **Ground Source Heat Pumps (GSHPs)**: GSHP systems, utilizing ground loops for thermal exchange, achieved higher efficiency by leveraging the stable subsurface temperature. Although installation costs for GSHPs are significantly higher, their operational energy demand is substantially reduced, especially for heating.

In addition to individual heat pump systems, the feasibility of implementing a TEN was explored using TRNSYS. For this analysis, heating and cooling loads of the neighborhood, extracted from the previously created energy models, were aggregated to determine the size and performance requirements for a shared geothermal loop system.

As shown in Figure 9, the neighborhood's load profile is biased toward heating demand, a common characteristic in Wisconsin's cold climate. This imbalance between heating and cooling loads poses challenges for district geothermal system design, particularly in meeting peak winter heating demands without oversizing the system. This imbalance could be mitigated by implementing heat-load reduction measures such as insulation or energy recovery ventilation, or with supplemental heating systems like gas or electric boilers as backup systems for peak heating periods. Climate change is another consideration, with equivalent full load heating hours tending to reduce in future climate scenarios, which may help improve the balance between heating and cooling demands over time.

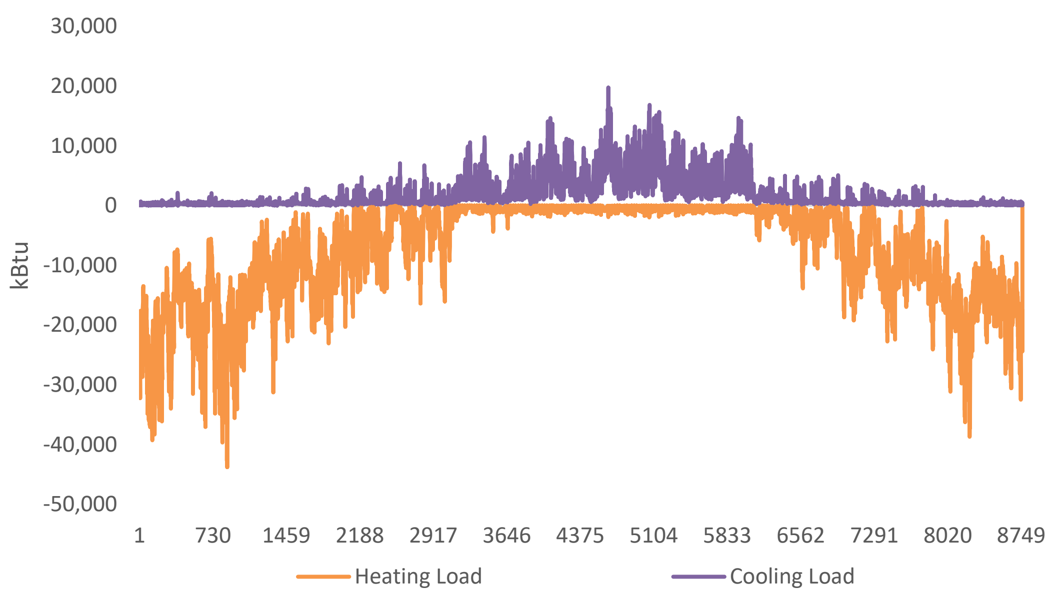

Figure 9. Total neighborhood HVAC loads over an entire 365-day year (8760 hours).

Implementing a thermal energy network presents substantial opportunities, especially for a greenfield development like the East Neighborhood. One of the primary barriers to widespread adoption of thermal energy networks in Wisconsin has been the high upfront costs of installation and the regulatory uncertainty surrounding ownership and operations[16]. However, greenfield projects like the East Neighborhood can overcome the cost barrier by capitalizing on the opportunity to "dig once" during construction, significantly reducing installation expenses. Also, these networks can leverage diverse thermal loads, such as those from the planned sports complex ice rinks and swimming pool, retail spaces, and residential units, to optimize system efficiency and reduce peak load.

2.3 DER PERFORMANCE ANALYSIS

There are three types of distributed energy resources (DERs) considered in this study: solar PV, BESS, and natural gas generators, all of which will be subject to ECEC's interconnection application and interconnection process. REopt (Renewable Energy Integration & Optimization),[17] a techno-economic optimization platform developed by NREL, was used to evaluate the performance and economic feasibility of these three DERs. REopt helped determine the optimal sizing of these DERs, balancing energy generation, storage, and cost-effectiveness to meet neighborhood energy needs. In this section we will describe each of the DERs considered, the process of applying them to the proposed neighborhood, and their respective considerations and inputs for the tool used.

2.3.1 Solar Photovoltaics (PV)

The solar PV analysis was conducted using REopt to evaluate the potential for integrating solar generation at both the individual building level and as a community-scale system. We considered the installation of both behind-the-meter rooftop PV systems on residential and commercial buildings, as well as a front-of-the-meter ground-mounted PV system at a designated landfill site.

We began by estimating the available area for solar panel installation. For the rooftop PV systems, we estimated the available installation area based on the building type, size, and roof configuration. Single-family homes, modeled at 1,200 ft^2 each, were assumed to have gable roofs with approximately 50% of the total roof area suitable for PV panels. This translates to roughly 300 ft^2 of usable space per home for solar installations. Multifamily buildings were modeled similarly, but we assumed a three-story configuration where the rooftop area of a single unit serves three stacked dwelling units. With each multifamily unit sized at 1,150 ft^2, this translates to roughly 575 ft^2 of usable space for solar installations. Meanwhile, commercial buildings were assumed to have flat roofs, with 70% of the total area available for PV installations after accounting for space constraints like rooftop equipment and maintenance pathways. This resulted in 56,233 ft^2 of available area for solar installations across the 7 commercial building types. The sports complex development plan adds a sports complex with a rooftop area available for PV installation of 152,040 ft^2. Table 3 shows the total available rooftop area for the neighborhood in both development scenarios.

[16] The AnnDyl Policy Group, "Accelerating Thermal Energy Network Deployment in Wisconsin - Policy Barriers and Opportunities."
[17] "REopt: Renewable Energy Integration and Optimization," https://www.nrel.gov/reopt/index.html.

Table 3. Neighborhood electricity consumption for both development scenarios.

Neighborhood development scenario	Residential density	Rooftop area available for PV (ft^2)
Highly residential	Minimum	444,633
	Maximum	545,533
Sports complex	Minimum	548,773
	Maximum	640,623

For the community-scale ground-mounted PV system, a designated landfill site was evaluated. The site was identified as a prime location for a community-scale solar PV system due to its expansive open space (approx. 15 acres), minimal shading, and limited competing land use. Measurements of the site area were used to estimate the capacity for large-scale solar panel deployment, as shown in Figure 10. Based on an analysis of the design and layout of the landfill site, a ground- mounted system consisting of tilted PV panels and ballasted mounting systems (or non-ground penetrating racking) is recommended as penetrations through the landfill cap would be subject to local regulatory approval.

Figure 10. Landfill area determined for community-scale ground-mounted PV system.

To optimize solar generation, the tilt and orientation of the panels were specified based on building type and system location. For residential buildings with gable roofs, including single-family and multifamily homes, the panels were assumed to have a tilt angle of 25°, reflecting the typical roof slope for these structures. In contrast, the commercial buildings' flat roofs were modeled with a tilt angle of 10°, a common configuration for cost-effective rooftop racking systems. The ground-mounted PV panels at the landfill site were assumed to be installed at a 15° tilt angle, balancing solar exposure and installation costs.

Integrating PV systems into a microgrid requires careful consideration of inverter compatibility, as inverters play a crucial role in converting and managing solar energy output. To ensure seamless integration with future microgrid operations, all inverters specified for the project must be compatible with SunSpec Modbus communication standards. This compatibility may be achieved natively, through a firmware upgrade, or with the addition of external hardware. SunSpec Modbus compatibility enables advanced inverter functionalities that are essential for microgrid operation, including voltage regulation, power factor management, and export limiting[18].

[18] "SunSpec Modbus Specifications - SunSpec Alliance."

2.3.2 Battery Energy Storage System (BESS)

The sizing and optimization of Battery Energy Storage Systems (BESS) for the East Neighborhood were performed using REopt. This tool determines the optimal size of BESS based on a combination of inputs, including load profiles, electricity tariffs, and system performance constraints. The tool uses a mixed-integer linear programming approach to optimize the balance between system costs (capital, operations, and maintenance) and resilience benefits. For the analysis we allowed the BESS to be charged from the grid as needed, to ensure sufficient energy availability for covering outages. REopt constrains the BESS to a minimum state of charge of 20%, as discharging the battery below 20% on a regular basis would reduce the lifespan[19].

For the East Neighborhood, BESS was modeled at both the individual building scale and the community scale to evaluate the trade-offs between localized energy storage and centralized system. At the individual building scale, we considered rooftop PV systems coupled with appropriately sized battery storage to evaluate self-sufficiency for each building type. The REopt tool accounted for the energy demand of each building type, PV generation profiles, and the ability of BESS to support the building load during the designated outage scenarios. At the community scale, we sized a centralized BESS to operate in conjunction with the ground-mounted PV system at the landfill site. The analysis incorporated assumptions regarding outage durations and critical load priorities, ensuring that battery storage could meet resiliency targets while maintaining economic feasibility.

2.3.3 Natural Gas Generator

The analysis of the Natural Gas Generator for the East Neighborhood was conducted using the REopt tool to evaluate its role as a community-scale asset within the microgrid. REopt optimized the size and operation of the generator to reduce peak demands, improve resilience, and complement other DERs, including the ground-mounted PV system and large-scale BESS. By serving as a dispatchable resource, the generator could play a crucial role in reducing peak demands for the entire neighborhood, minimizing grid dependency and associated demand charges, supporting resilience goals by providing reliable backup power for critical facilities during grid outages, and complementing solar PV and BESS to ensure continuous energy supply, particularly during periods of high demand or low renewable generation.

The generator was modeled as a prime generator, meaning it was assumed to operate continuously during periods of high energy demand to support the grid. Another critical parameter for generator modeling is the minimum load. The generator was constrained to run with a minimum load of 50%, as extended operation at lower loads can decrease the life of the generator and cause maintenance issues, unplanned shutdowns, and increased emissions[20].

From an economic standpoint, the inclusion of a natural gas generator poses a limitation on the funding opportunities available for the project. As the generator is not considered a renewable energy source, it is ineligible for tax credits under the Inflation Reduction Act (IRA) and other incentive programs aimed at renewable technologies. This financial consideration highlights the need to weigh the generator's resilience benefits against its impact on project economics and funding eligibility.

[19] Anderson et al., "The REopt Web Tool User Manual."
[20] Jabeck, "The Impact of Generator Set Underloading."

2.3.4 Cost Variables

Upfront and ongoing costs of the microgrid and battery technology, as well as the energy, wholesale and demand charge rates are a significant influence on the identification of a least- cost solution. Table 4 details the upfront costs for the PV and BESS, including PV operations and maintenance cost (O&M)[21], both the storage capacity cost and power capacity cost, and the 10-year replacement cost.[22]

Table 4. PV and BESS system costs – upfront, operations and maintenance, and replacement.

Variable	Input Cost
PV system capital cost ($/kW)	$2,600 for Residential $1,790 for Commercial
PV O&M cost ($/kW per year)	$18
BESS storage capacity cost ($/kWh)	$455
BESS power capacity cost ($/kW)	$910
BESS storage capacity replacement cost ($/kWh)	$318
BESS power capacity replacement cost ($/kW)	$715

Table 5 lists the utility and wholesale rates utilized in the analysis. Under ECEC's rate structure we considered their single-phase and small commercial time-of-use rate (Rate AT) for residential buildings, their three-phase general rate (Rate R) for small commercial buildings, and their annual average demand rate (Rate CA) for larger commercial buildings[23]. In the timing column, Summer refers to the months of June to September, while Winter refers to all other months (October to May). On-Peak times are from 4 PM to 8 PM, while overnight times are from 9 PM to 5 AM. As the limit for net metering is 20 kW for systems under 20 kW capacity, and 40 kW for systems with a capacity between 20 kW and 40 kW, we utilized ECEC's avoided cost rate (wholesale rate) for sale of excess solar. For net present value (NPV) calculations, we assume a 2.5 percent escalation rate for operations and maintenance costs, a 1.7 percent increase in electricity rates, and a 6.38 percent discount rate.[24]

Table 5. Current utility and wholesale energy rates.

Variable	Timing	Rate AT (Time-Of-Use)	Rate R	Rate CA
Demand limit (kW)	Annual	0 to 50	0 to 50	Over 50
Service charge	Monthly	$37.00	$54.00	$54.00
Energy rate ($/kWh)	Summer	On-Peak $0.3655	$0.129	$0.067
	Winter	On-Peak $0.2455	$0.113	$0.060
	Off-Peak	$0.0925	-	-
	Overnight	$0.0595	-	-
Demand charge ($/kW per month)	Summer	-	-	$14.00
	Winter	-	-	$10.50
Wholesale rate ($/kWh)	Annual	$0.035		

There are other significant costs specific to each neighborhood and microgrid scenario that will be considered when comparing each scenario to develop a holistic financial comparison, considering microgrid assets and neighborhood composition since they are dependent of each other. Beginning with the difference

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[21] NREL, "2024 Electricity ATB Technologies and Data Overview."
[22] "Home - National Residential Efficiency Measures Database | NREL."
[23] Eau Claire Energy Cooperative, "Rates."
[24] Anderson et al., "The REopt Web Tool User Manual."

in equipment cost for the three HVAC configurations (mixed-energy, air-source heat pumps, or a thermal energy network), described in the section 2.2.1. For neighborhood scenarios with mixed-energy consuming buildings (electricity and natural gas), the cost of the natural gas infrastructure should also be considered since it could be avoided in scenarios where the neighborhood only consumes electricity. Finally, in scenarios where the microgrid storage assets are meant to only support the mission-critical 25% load, building load management systems capable of controlling the neighborhoods loads need to be considered. To estimate this load management cost, we considered technologies like smart panels for all buildings. This type of technology would allow the eventual microgrid controller to reduce loads across the neighborhood in the event of an outage to allow the microgrid energy storage assets to support these loads for the intended period. All these costs are summarized in Table 6 below.

Table 6. Scenario specific costs.

Variable	Related Costs
Mixed-energy scenario equipment[25]	$5,980 per home
Air-source heat pumps[26]	$3,630 per home
Thermal energy network infrastructure[27]	$23,028 per borehole
Natural gas infrastructure[28]	$405,231 per mile
Building load management control equipment[29]	$3,500 per smart panel

2.3.5 Resiliency Inputs

There are two resiliency inputs of interest for this analysis: (1) length of outage for the system to withstand and (2) monetary value to assign to increased resiliency.

Length of outage

To identify outage lengths of interest, we used detailed data provided by Eau Claire Energy Cooperative, the electric provider in this area. This included data on the electric feeders responsible for distributing power to the neighborhood, as well as historical outage records. Elco Feeder 4 serves as the main feed for this location. In the event of a contingency where Elco Feeder 4 is unavailable, the neighborhood would be supplied by Equity Feeder 4, acting as the contingency feeder.

To understand the reliability of the distribution system, the following metrics are commonly used[30]:

- **SAIDI (System Average Interruption Duration Index)** – total minutes of interruption the average customer experiences.
- **SAIFI (System Average Interruption Frequency Index)** – average number of times a customer experiences and outage during the year.
- **SAIDI (Customer Average Interruption Duration Index)** – average time required to restore service.

[25] "Home - National Residential Efficiency Measures Database | NREL."
[26] "Home - National Residential Efficiency Measures Database | NREL."
[27] Oh and Beckers, "Cost and Performance Analysis for Five Existing Geothermal Heat Pump-Based District Energy Systems in the United States."
[28] "Natural Gas Feasibility Report Cities of San Louis AZ and San Luis Rio Colorado Sonora."
[29] "SPAN® Panel | Lower Your Energy Bill."
[30] "Distribution System Reliability Metrics."

Outage data for both feeders, shown in Table 7, indicated relatively strong performance, with average interruptions being slightly under one outage per year for each feed. This suggests that outages in the area are generally infrequent and short in duration. However, given the increasing frequency and intensity of extreme weather events caused by climate change, there is a higher vulnerability to natural disasters that could result in longer and more frequent outages. While historical data indicates that most outages last less than an hour, we decided to model two outage durations: 1-hour and 4-hour outages. This decision reflects the need to plan for both short-term and moderate-duration outages, particularly under future climate conditions.

Table 7. Outage metrics by feeder.

Feeder	SAIDI (minutes per year)	SAIFI (interruptions per year)	CAIDI (minutes per interruption)
Elco Feeder 4 (Main Feed)	32.77	0.90	36.41
Equity Feeder 4 (Contingency Feed)	108.21	0.89	121.03

To ensure the analysis accounts for critical seasonal variations in energy demand, we simulated outages during peak winter days and peak summer days. While the data shows that outages have historically occurred more frequently in summer months, modeling outages during peak demand seasons provides a conservative approach to evaluating the resiliency needs of the neighborhood.

Critical load determination

To determine the critical loads that must be maintained during an outage, we applied the Clean Coalition's definition of tier 1, tier 2, and tier 3 loads.[31] Tier 1 loads include essential services required to sustain life and safety, such as healthcare facilities and emergency services, while tier 2 and tier 3 loads include increasingly non-essential systems. Using this framework, we determined that 25% of the neighborhood's total load represents critical loads that must remain powered during an outage. These include essential building systems in facilities such as the healthcare clinic and public safety facilities or facilities that could serve as a shelter (medium office building and small hotel), as well as critical residential needs like heating, refrigeration, and basic lighting. Table 8 outlines the prioritization of facilities in the neighborhood. Considering that during short duration outages residents tend to stay at home instead of going to a shelter, we prioritized essential residential needs over shelters.

Table 8. Critical load priorities.

Critical Load Tier	Neighborhood Facility
Tier 1: critical loads	• Healthcare clinic • Emergency systems • Required standby systems • Residential critical loads (HVAC, refrigeration & life safety loads)
Tier 2: priority loads (public safety / shelters)	• Medium office • Small hotel • Optional Standby
Tier 3: discretionary loads	• Dining establishments • Stores / retail

[31] Francescato, "How a Standardized Value of Resilience Will Proliferate Community Microgrids."

To evaluate system performance under outage conditions, we simulated two scenarios: 100% load which assumes that the microgrid must supply the neighborhood's entire energy demand during an outage, and 25% critical load which focuses only on the critical 25% load to determine the storage and generation capacity needed to sustain essential services.

This dual-scenario approach allowed for a comprehensive understanding of the resiliency needs for both full-load conditions and mission-critical operations. It also informed the sizing of backup systems, including BESS and natural gas generator, ensuring that the microgrid can provide reliable power during grid outages of varying durations and seasonal peak demands. By addressing both current outage vulnerabilities and future climate-related risks, this analysis provides a robust foundation for evaluating the resiliency benefits of the proposed microgrid solutions.

Resiliency monetary value

Installation of microgrids has resiliency benefits, which often make the difference between the system being cost-effective or not.[32] Although these benefits are widely acknowledged, there is not a standardized way to monetize the benefits.[33] Previous methods to quantify the value include willingness-to-pay surveys and tools to help facilities develop bottom-up monetary estimates for lost time spent on critical functions. In this study, the monetary value of resilience is determined for all microgrid scenarios, but it's not a part of our financial analysis.

There are limited studies that quantify the more human benefits from microgrids. The best reference for these values is a study from Lawrence Berkeley National Lab that includes estimates from willingness-to-pay studies for the residential and commercial sector.[34] Table 9 illustrates the study's findings on the value of resiliency across outage lengths and sectors.

Table 9. Value of resiliency across outage lengths.

Cost per kW	Momentary	1 hour	4 hours	8 hours	16 hours
Large Commercial	$15.9	$21.8	$48.4	$103.2	$203.0
Small Commercial	$187.9	$295.0	$857.1	$2,138.1	$4,128.3
Residential	$2.6	$3.3	$6.2	$11.3	$21.2

2.3.6 Emissions Data and Costs

We utilized hourly emissions data to estimate the impact of each system on the environment. The emissions data include carbon dioxide emissions and criteria pollutants, including nitrogen oxides, sulfur dioxide, and particulate matter. The hourly emissions data for each comes from EPA's Avoided Emissions and Generation Tool (AVERT), which models marginal emissions rates for the region based on historical dispatch data.[35] The data assumes a gradual greening of the grid and reduces emissions factors by 2.1 percent annually.[36]

To estimate the monetary impact of the emissions savings, we apply cost per ton estimates to each. Table 10 lists the cost per ton for each of the major pollutants.[37] The air quality pollutants have significant costs

32 Anderson, Hotchkiss, and Murphy, "Valuing Resilience in Electricity Systems."
33 Rickerson, Zitelman, and Jones, "Valuing Resilience for Microgrids: Challenges, Innovative Approaches, and State Needs."
34 Sullivan, Schellenberg, and Blundell, "Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States."
35 US EPA, "AVoided Emissions and geneRation Tool (AVERT)."
36 Anderson et al., "The REopt Web Tool User Manual."
37 Interagency Working Group on Social Cost of Greenhouse Gases, "Technical Support Document: Social Cost of Carbon, Methane."

per ton as the reduction in emissions has the potential to prevent premature death, which is valued at roughly $9 million. The cost for each is assumed to increased gradually over the analysis lifetime.

Table 10. Pollutant costs per ton.

Pollutant	Cost per Ton	Source
Carbon dioxide	$51	Federal value
Nitrogen oxides	$19,542	CACES EASIUR model
Sulfur dioxide	$40,551	CACES EASIUR model
Particulate matter	$139,804	CACES EASIUR model

2.4 MICROGRID SCENARIOS

As a greenfield site with a concept neighborhood structure, this project presented a unique opportunity to analyze multiple microgrid scenarios tailored to different neighborhood compositions and energy system configurations. As described across the previous sections, the study explored how variations in infrastructure, building materials, energy-consuming equipment (particularly HVAC systems), and microgrid asset configurations could impact energy performance, resilience, and economic viability.

Taking these factors into account, we analyzed six distinct scenarios to evaluate the range of possibilities for the neighborhood. These scenarios encompassed different combinations of renewable energy systems, battery storage capacities, natural gas generators, and thermal energy networks. Table 11 summarizes the primary inputs that vary between the selected scenarios, providing a foundation for understanding their relative performance and trade-offs. The selected residential density parameters for each scenario provided the best economic results.

Table 11. Microgrid scenarios and key inputs.

<table>
<tr><th>Inputs</th><th>A - Mixed energy with Individual Assets</th><th>B - Mixed energy with Community Assets</th><th>C - All-electric with Individual Assets</th><th>D - All-electric with Community Assets</th><th>E - TEN with Individual Assets</th><th>F - TEN with Community Assets</th></tr>
<tr><td>HVAC configuration</td><td colspan="2">Gas-fired heating and electric cooling</td><td colspan="2">Air-source heat pumps</td><td colspan="2">Thermal energy network</td></tr>
<tr><td>Neighborhood development plan</td><td colspan="2">Highly residential</td><td>Highly residential</td><td>Sports complex</td><td>Highly residential</td><td>Sports complex</td></tr>
<tr><td>Residential density</td><td colspan="2">Minimum quantity</td><td>Maximum quantity</td><td>Minimum quantity</td><td>Maximum quantity</td><td>Minimum quantity</td></tr>
<tr><td>Load profile</td><td>Tier 1 at full load (100%). Tier 2 and 3 at critical load (25%)</td><td>Full load (100%)</td><td>Healthcare Clinic at full load (100%). Tier 2, 3 and residential at critical load (25%)</td><td>Critical Load (25%)</td><td>Healthcare Clinic at full load (100%). Tier 2, 3 and residential at critical load (25%)</td><td>Full load (100%)</td></tr>
<tr><td>Utility rates</td><td>Rate AT
Rate R
Rate CA
Wholesale rate</td><td>Wholesale rate</td><td>Rate AT
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Wholesale rate</td><td>Wholesale rate</td><td>Rate AT
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Wholesale rate</td><td>Wholesale rate</td></tr>
</table>

Microgrid assets	Rooftop PV + Individual BESS	Landfill PV + Large-scale BESS	Rooftop PV + Individual BESS	Landfill PV + Large-scale BESS + gas generator	Rooftop PV + Individual BESS	Landfill PV + Large-scale BESS
Outage coverage	1 hour for Tier 1 and 3 loads. 4 hours for Tier 2 loads.	1 hour	1 hour for healthcare clinic and Tier 3 loads. 4 hours for residential and Tier 2 loads.	1 hour	1 hour for healthcare clinic and Tier 3 loads. 4 hours for residential and Tier 2 loads.	1 hour
Load Management	Tier 2 and 3 loads	No	Tier 2, 3 and residential loads	All buildings	Tier 2, 3 and residential loads	No
Peak demand (kW)	1,424	1,424	8,133	6,069	3.383	2,385
Annual kWh	7,461,491	7,461,491	25,576,608	21,473,261	17,166,218	14,108,122
Annual CO_2 emissions (tons)	4,972	4,957	4,356	3,475	2,088	2,077

The six scenarios outlined above provide a comprehensive framework for understanding how various design choices influence the performance and viability of a microgrid for the East Neighborhood. By comparing these scenarios, the study aims to inform stakeholders about the trade-offs and opportunities associated with each configuration, paving the way for informed decision-making and sustainable community development.

3 RESULTS

Table 12 illustrates the performance outputs for the six alternative scenarios. In general, considering the size of these systems and the costs of producing electricity in the area, the scenarios don't produce a positive net present value. By accounting for other scenario specific costs to determine scenario specific savings, we developed a holistic approach to determine the financial impact of the microgrid under different neighborhood composition scenarios. Therefore, the NPV calculations presented in the following Financial Impact section account for all microgrid assets costs (PV, BESS, and generator), lifecycle benefits of energy savings and export benefits, and comparative capital cost savings from scenario specific costs (individual building HVAC equipment or TEN infrastructure, natural gas infrastructure, and load management equipment). Factors such as health impacts, carbon emissions, and avoided outage costs are not included in these values. No amount of funding is considered in these values either, but initial results show that some of these scenarios could produce a positive NPV without other financial considerations.

As the City of Altoona reviews these results and plans for the future of the neighborhood microgrid, these factors should be considered.

Table 12. Results summary.

Scenarios	A	B	C	D	E	F
PV size (kW)	2,690	2,500	3,307	2,500	2,563	2,500
BESS capacity (kW)	2,301	2,287	3,953	1,840	1,681	3,974
BESS energy (kWh)	6,361	6,649	20,060	10,927	8,777	9,849
Generator capacity (kW)	0	0	0	500	0	0
TEN size (number of boreholes)	0	0	0	0	1,200	953
Upfront cost	$11,668,906	$9,581,148	$21,006,861	$11,785,760	$11,980,418	$12,572,828
Scenario specific added costs	Natural gas infrastructure + Load management controls	Natural gas infrastructure	Load management controls	Load management controls	TEN + Load management controls	TEN
Net present value	-$3,030,494	-$1,222,066	-$6,469,675	-$42,279	-$1,370,526	-$2,526,576
Simple payback	>25	>25	>25	23.7	>25	>25
Solar energy exported (kWh)	1,540,006	0	1,374,828	0	693,095	0
Total renewable	45%	39%	16%	14%	23%	21%
Lifecycle CO_2 emissions (tons)	27,494	23,064	108,901	86,866	52,202	51,913

3.1 FINANCIAL IMPACT

The financial impact of each scenario is provided in Table 10. As mentioned, the upfront cost considers PV, BESS, and natural gas generator costs. REopt assumes a full battery replacement at 10 years, as the functional capacity of the battery would degrade over this time. While 10-year replacement is the simplest BESS management strategy, other strategies such as augmentation, oversizing, or modular implementation are also possible and may result in reduced total costs.[38] The analysis period considered is 25 years, which is related to the expected lifespan of PV panels.

All energy and demand savings are provided by the optimized dispatch of the BESS. Scenario specific costs considered as savings, as explain in the Cost Variables section. Export credits are a function of how much excess solar generation is sold back to the grid. For current distributed generation (DG) system owners, ECEC's service policy is that they net meter up to a certain cap and then pay out at avoided cost. This proved to be a limiting factor in making sure these microgrid scenarios reached a positive NPV. Therefore, considering the possible number of new electricity consumers and DG owners in the cooperatives distribution system, a change in rate structure could be considered and could benefit the implementation of a microgrid at the site. Any proposed new rate structure should primarily maintain fairness across all electric cooperative members. It is also important to note that any changes made by ECEC shall not violate the terms of their wholesale power contract with Dairyland Power Cooperative.

Table 13. Financial impacts of each scenario: costs and benefits.

	A	B	C	D	E	F
PV + BESS cost	$11,668,906	$9,581,148	$21,006,861	$11,121,260	$11,980,418	$12,572,828
Generator cost	$0	$0	$0	$664,500	$0	$0
PV O&M + BESS replacement	$3,865,612	$3,846,539	$8,248,207	$4,920,635	$4,055,778	$5,501,571
Total Cost	**$15,534,518**	**$13,427,687**	**$29,255,068**	**$16,706,395**	**$16,036,196**	**$18,074,399**
Energy Savings	$8,876,411	$12,205,621	$18,626,013	$16,664,116	$12,377,718	$15,547,823
Demand Savings	$251,788	$0	$764,310	$0	$496,581	$0
Export Credits	$3,375,825	$0	$3,395,070	$0	$1,791,371	$0
Total Energy Benefits	**$12,504,024**	**$12,205,621**	**$22,785,393**	**$16,664,116**	**$14,665,670**	**$15,547,823**
Scenario Specific Savings	$19,014,685	$22,273,185	$23,430,951	$30,029,907	$0	$13,793,861
NPV	**$15,984,191**	**$21,051,118**	**$16,961,276**	**$29,987,629**	**-$1,370,526**	**$11,267,286**

[38] Shin and Hur, "Optimal Energy Storage Sizing with Battery Augmentation for Renewable-Plus-Storage Power Plants."

3.2 RESILIENCY IMPACT

Battery energy storage systems play a pivotal role in ensuring the resilience of the East Neighborhood microgrid. Sizing these systems involves a careful balance between technical and economic considerations, accounting for the neighborhood's energy demands, outage scenarios, and the duration of support required during grid interruptions. The systems were sized based on the peak demand to cover either 100% of the neighborhood's load or 25% of the critical load, prioritizing life-sustaining and safety-critical operations.

The process begins by analyzing the neighborhood's peak energy demand, as derived from the detailed load profiles created during the energy modeling phase. For instance, in the all-electric scenarios, where heating loads are electrified, BESS must be sized to accommodate higher peak demands during winter. This ensures that even during an extended outage, critical operations such as heating, refrigeration, and emergency systems remain functional. By contrast, mixed-energy scenarios, with gas-fired systems handling some thermal loads, require less capacity for resilience during outages but still necessitate robust storage to support critical electric systems. The all-electric scenarios have a higher guarantee of covering all resiliency needs, including heating, in the event of an emergency. Research shows that natural gas infrastructure is often impacted by emergency events and can take longer than electrical systems to restore.[39]

The resilience benefits of BESS extend beyond individual buildings to the community level. By maintaining power during outages, the microgrid ensures that critical facilities such as healthcare clinics and public safety buildings can continue operations, minimizing disruptions and safeguarding public health and safety. This reliability also supports economic stability, preventing revenue loss for businesses and ensuring continuity of essential services. By integrating seamlessly with other DERs and leveraging advanced optimization tools, the microgrid not only enhances community resilience but also delivers significant economic and environmental benefits.

3.3 ADDITIONAL BENEFITS

A microgrid at the proposed site would provide significant monetary benefits beyond the energy, demand, and export savings. The benefits include the monetary value of resiliency and the societal benefits of reduced carbon and criteria pollutant emissions. This section will highlight those benefits and show how the inclusion of the benefits impact NPV. Additionally, the third sub-section will explain the different ways that a microgrid could provide support to the local grid.

3.3.1 Resiliency monetary value

The monetary value of resiliency is calculated by taking the average hourly critical load for each building in the neighborhood, multiplied by the average outage length (CAIDI) and the deemed value of resiliency for an outage of that length for each building type (Table 9). The value is then applied to frequency of outages throughout the project's lifetime. For scenarios with gas-fired heating equipment, since the microgrid can't provide resilience this critical load, the monetary value of resilience will be much less.

The lifetime savings for resiliency depend directly on the frequency of emergency events and outages. As these outages are irregular in nature, there is no way to know how often the outages will occur during the lifetime of the system. However, research does show that outages are expected to increase in frequency as extreme weather events increase and as the grid faces generation shortages.[40]

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[39] Lewis and Mullendore, "Valuing Resilience in Solar+Storage Microgrids: A New Critical Load Tiering Approach."

[40] Robert Walton, "MISO Prepares for 'worst-Case Scenarios,' Heads into Summer with Insufficient Firm Generation."

Table 14 lists the resiliency monetary value for different outage frequencies across the system lifetime.

Table 14. Monetary value of resiliency: comparisons depending on outage frequency.

Scenarios	A	B	C	D	E	F
Avg. critical load for entire neighborhood (kW)	1532	1629	1318	898	671	2663
Outage frequency	Value of resiliency					
One year	$3,310,352	$8,049,392	$12,014,137	$11,569,435	$9,564,246	$34,941,289
Two years	$1,655,176	$4,024,696	$6,007,068	$5,784,717	$4,782,123	$17,470,645
Five years	$662,070	$1,609,878	$2,402,827	$2,313,887	$1,912,849	$6,988,258
Ten years	$331,035	$804,939	$1,201,414	$1,156,943	$956,425	$3,494,129
Once ever	$132,414	$321,976	$480,565	$462,777	$382,570	$1,397,652

Utilizing the monetary values for an outage occurring every year, Table 15 shows the NPV for each system when the value of resiliency is included. Valuing resiliency causes an increase in the NPV across scenarios, with the most significant increase seen in the TEN with Community Assets scenario, where the combination of the 9.8 MWh battery and the higher critical load provides the greatest resiliency value.

Table 15. Resiliency monetary value impact on net present value.

	A	B	C	D	E	F
Total cost	$15,534,518	$13,427,687	$29,255,068	$16,706,395	$16,036,196	$18,074,399
Energy benefits	$12,504,024	$12,205,621	$22,785,393	$16,664,116	$14,665,670	$15,547,823
NPV without resiliency	**$15,984,191**	**$21,051,118**	**$16,961,276**	**$29,987,629**	**-$1,370,526**	**$11,267,286**
Resiliency benefit	$3,310,352	$8,049,392	$12,014,137	$11,569,435	$9,564,246	$34,941,289
NPV with resiliency	**$19,294,543**	**$29,100,511**	**$28,975,413**	**$41,557,063**	**$8,193,720**	**$46,208,575**

3.3.2 Emissions benefits

The emissions benefits from adding PV and BESS are significant. The systems would greatly reduce both criteria pollutants and carbon dioxide emissions. Criteria pollutants are directly linked to reduced health issues and generate significant monetary value as a result. Similarly, the monetary value from pricing the adverse environmental impacts of carbon dioxide emissions led to significant benefits. Table 16 illustrates the emissions reductions in tons and the resulting monetary benefits. It's important to note that although it may seem like the mixed-energy scenarios provide better emissions benefits than other scenarios, the reality is that these scenarios produce higher amounts of emissions because of the high amounts of natural gas consumption, as shown in section 2.4.

Table 16. Emissions reductions and monetary values.

	A	B	C	D	E	F
NO_X savings (tons)	27.26	24.59	31.79	24.15	31.01	24.59
SO_2 savings (tons)	34.29	26.76	24.26	21.09	24.97	25.57
$PM_{2.5}$ savings (tons)	0.39	2.6	8.55	2.68	0.26	2.62

Health benefit	**$1,977,867**	**$1,929,173**	**$2,800,332**	**$1,701,835**	**$1,654,770**	**$1,883,713**
CO_2 emission savings (tons)	1,533	6,398	403	3,247	4,332	4,214
Carbon reduction benefit	**$78,198**	**$326,287**	**$20,549**	**$165,609**	**$220,936**	**$214,940**

Table 17 illustrates how adding the monetary value of the reduced air quality health impacts and reduced carbon emissions impacts NPV. By including the value of emissions savings, the scenario achieves a positive NPV.

Table 17. Carbon and criteria pollutant monetary value impact on net present value.

	A	B	C	D	E	F
Total cost	$15,534,518	$13,427,687	$29,255,068	$16,706,395	$16,036,196	$18,074,399
Energy benefit	$12,504,024	$12,205,621	$22,785,393	$16,664,116	$14,665,670	$15,547,823
Resiliency benefit	$3,310,352	$8,049,392	$12,014,137	$11,569,435	$9,564,246	$34,941,289
NPV with resiliency	**$19,294,543**	**$29,100,511**	**$28,975,413**	**$41,557,063**	**$8,193,720**	**$46,208,575**
Emissions benefit	$2,056,065	$2,255,460	$2,820,880	$1,867,443	$1,875,706	$2,098,653
NPV with emissions + resiliency	**$21,350,608**	**$31,355,971**	**$31,796,294**	**$43,424,507**	**$10,069,426**	**$48,307,228**

3.3.3 Grid Support

Beyond the direct financial, resiliency, and emissions benefits described in the previous sections, the implementation of a neighborhood microgrid in the East Neighborhood offers substantial opportunities to support the local grid and provide value to the electric cooperatives serving the area. These benefits extend to grid stability, cost management, and operational flexibility. This section explores these additional benefits in detail.

Battery Support of the Grid, Incentives for Battery Owners, and Virtual Power Plants (VPP). The large-scale Battery Energy Storage Systems (BESS) included in three of the microgrid scenarios could provide critical support to the grid by balancing supply and demand in real-time. During periods of excess generation from solar PV systems, the batteries can absorb surplus energy that would be lost in curtailment or fed back into the grid at the low avoided cost rate. This energy would assist in preventing grid overloads during peak demand periods by dispatching the stored energy to reduce strain on the grid.

Battery owners within the neighborhood, as in individual building microgrid asset scenarios, could also benefit from incentives provided by the distribution electric cooperative (ECEC), such as demand-response payments or credits for participating in grid-balancing programs. These incentives encourage battery owners to align their storage and discharge schedules with grid needs, further enhancing system reliability and cost efficiency. ECEC should consider implementing battery incentive programs to capitalize on the potential high integration of individual BESS systems within the neighborhood or a virtual power plant (VPP) that aggregates all the neighborhoods DERs and can balance electrical loads and provide utility-scale and utility-grade grid services like a traditional power plant[41]. Such programs would allow the cooperative to aggregate

[41] Downing, "Pathways to Commercial Liftoff: Virtual Power Plants."

and coordinate these systems to provide grid services efficiently and offer financial rewards to participants. A contracted external aggregator could also be considered to support the cooperative with the operation and maintenance of the VPP and its assets; however, consideration would need to be given to ECEC's wholesale power purchase requirements with Dairyland Power Cooperative.

Time-of-Use (TOU) Optimization. The integration of a microgrid enables the neighborhood to respond effectively to time-of-use (TOU) pricing structures, like ECEC's single-phase and small commercial time-of-use rate. By leveraging BESS and demand management strategies, the microgrid can shift energy consumption from high-cost periods to times when electricity prices are lower. This capability benefits both residents, who experience reduced utility bills, and the cooperatives, which face lower peak demand charges from their wholesale power suppliers. For instance, the microgrid can prioritize charging BESS during off-peak hours, when electricity is cheapest, and then discharge during peak hours to supply local loads. This not only reduces energy costs but also enhances the overall economic value of the microgrid by maximizing the utilization of distributed energy resources (DERs).

Ancillary Services (Voltage and Frequency Support). By coordinating the operation of BESS, natural gas generators, and solar PV systems, the microgrid can regulate voltage levels and maintain frequency stability, particularly during periods of grid disturbances. The ability to provide such services reduces the burden on the cooperatives to invest in additional grid infrastructure or procure ancillary services from external sources. Additionally, the microgrid's advanced controls and SunSpec Modbus-compatible inverters (as detailed in the Solar Photovoltaics (PV) and Battery Energy Storage System (BESS) sections) enable precise voltage regulation, reactive power management, and frequency response, helping to facilitate a stable and resilient grid.

Peak Plant Replacement. By reducing peak energy demand through load management, BESS, and DERs, the neighborhood microgrid can help defer or eliminate the need for new peaking power plants. The microgrid's ability to replace peak plant capacity also creates a more accurate avoided-cost incentive for the cooperatives. Instead of basing incentives solely on wholesale energy prices, the cooperatives can incorporate the long-term cost savings associated with reduced reliance on peaking plants into their incentive structures. This approach not only rewards the microgrid for its contributions but also aligns incentives with broader grid benefits.

Additionally, by having a truer avoided-cost incentive, the return on investment (ROI) for the cooperatives on the microgrid assets they own would also improve, making these investments more financially viable. This avoided cost represents a significant benefit for the cooperatives, as peaking plants are among the most expensive and least efficient generation assets to operate.

Load Flexibility (Shifting and Shedding). Load shifting and shedding capabilities within the microgrid provide additional flexibility to manage demand during critical periods. The microgrid could prioritize essential loads while shedding non-essential loads during grid emergencies or extreme peak demand events. For example, during a cold winter day with high heating loads (considering that these loads are covered by electricity consuming equipment), the microgrid could shift non-essential energy consumption (e.g., EV charging or water heating) to off-peak hours. In more extreme scenarios, it could shed these non-essential loads entirely to ensure sufficient capacity for critical services, such as healthcare facilities or emergency response centers. This proactive demand management enhances grid reliability and minimizes the risk of outages.

The East Neighborhood microgrid offers transformative potential not only for the community it serves but also for the local grid and the electric cooperatives supporting it. By enabling battery support, TOU optimization, ancillary services, peak plant replacement, and load management, the microgrid provides a robust set of tools to enhance grid stability, reduce costs, and improve resilience. These additional benefits further underscore the value of investing in microgrid solutions as part of a comprehensive strategy for sustainable and reliable energy systems.

4 MICROGRID DESIGN CHECKLIST AND RECOMMENDATIONS

Through this feasibility study, we identified best practices for evaluating and designing microgrids for the East Neighborhood. The following section summarizes these considerations, starting with specific design next steps to transition from feasibility analysis to the design and interconnection of the East Neighborhood microgrid, followed by more general recommendations.

4.1 NEXT STEPS: DESIGN AND INTERCONNECTION

These steps aim to ensure that the microgrid is not only technically feasible but also economically viable and prepared for future energy demands and innovations.

Neighborhood design and development. Integrate considerations for neighborhood composition (Highly residential vs Sports complex), building construction design and materials, HVAC systems, and building load management options during the design and development process of the East Neighborhood. Specific attention should be given to the construction design considerations outlined in section 2.2.1, including key measures such as ensuring low levels of air leakage and incorporating high-performing wall insulation materials.

Building energy codes, such as IECC or ASHRAE 90.1, should serve as references to ensure that construction meets or exceeds modern efficiency standards. These codes provide guidance on envelope insulation, air leakage control, and other energy-efficient practices, enabling the neighborhood to achieve reduced energy consumption and lower operational costs. Load management technologies, such as smart panels or energy management information systems (EMIS), should be considered to enable flexible load control. For sites intended to provide resiliency benefits, it will be important to consider what measures can be installed that can shed or shift load to reduce the amount of energy needed during an outage. These technologies can play a critical role in demand response programs and ensure efficient operation of the microgrid, particularly during peak demand or outage scenarios.

Utilize microgrid ready design and a phased approach during construction. The upfront capital costs associated with establishing a microgrid are often a deterrent. A phased approach, where components are installed progressively based on their individual value propositions while ensuring they are microgrid ready, could reduce initial financial burdens while ensuring future compatibility. For example, solar PV arrays can be installed first, with inverters confirmed to be microgrid compatible. NREL provides suggestions on RFP language to include, to ensure solar panels and inverters are microgrid-ready.[42] Language should include that inverters should comply with applicable provisions in the IEEE Series of Interconnection Standards (specifically IEEE 1547-2018) and that the inverters should be multi-mode DC to AC inverters with islanding functionality. During planning and construction, consideration should be given as to how to create or save enough space for the future battery installation.

Another solution could be to adopt a strategy like the small block microgrids implemented in Prince George's County, Maryland[43], where the community demonstrated how small-scale modular microgrids built block by block, including rooftop PV and BESS, can serve as zero-energy communities with shared infrastructure. This phased approach allows for incremental expansion of the microgrid, starting with individual blocks or groups of buildings, and scaling up over time as more resources and funding become available.

[42] Booth, "Microgrid-Ready Solar PV - Planning for Resiliency."

[43] Stanley, "BlockEnergy Breaks Ground on First-of-Its-Kind Zero Energy Community in Prince George's County, Maryland."

Specify microgrid-ready inverters for all PV arrays. Components that are SunSpec Modbus compliant enable microgrid readiness by facilitating interoperability and standardization. By having a common communication protocol, it allows different devices from different manufacturers to communicate and interact. For example, a hybrid inverter with PV can share data with a BESS, forwarding a charge and discharge plan to align with the customer's loads needs. All inverters considered for the neighborhood microgrid should be SunSpec Modbus compliant, enabling them to interface with a microgrid controller.

Specifying multi-mode inverters (which can operate in grid-tied or grid-forming modes) will ensure that there is sufficient power available to establish a stable signal during islanded operation to support the balance of the inverters. While the BESS inverter will by default be multi-mode and provide grid-forming capabilities, specifying additional PV inverters as multi-mode in addition can help support the BESS inverter and may lower the total costs.

Perform a site survey to confirm acceptable BESS installation location. The National Fire Protection agency (NFPA) provides installation guidelines within NFPA 855 for allowable locations of a BESS, along with required enclosures and fire suppression systems.[44] For Li-ion battery systems, general installations require 10 feet setbacks, or 3 feet if the system is UL 9540 and UL 9540A-listed and includes advanced fire safety measures. The survey should evaluate individual building installations for smaller BESS and centralized locations for a large-scale system. Confirming allowable capacities, enclosures, and fire suppression requirements at this stage will help streamline the subsequent design and permitting processes.

Consider BESS replacement strategy in the bidding process. The battery cells used in a BESS today naturally degrade over time, a fact which must be accounted for in the design of the system. To ensure that the BESS provides all the expected benefits for the site, there are three typical strategies which the city could consider at installation; replacement, augmentation, and oversizing.[45] The first option is a full replacement roughly 10 years into the project lifetime. With an augmentation strategy, new cells would be added periodically to offset the degradation of older cells, and older cells would be removed as their capacity degrades below acceptable limits. The last option is to oversize the system at the onset, so that as the system degrades, it still hits the minimum usable capacity needs.

Note that the 10-year life expectancy is not a set requirement. Each battery manufacturer and its cell/module have an expected number of cycles (full charge to full discharge). For Li-ion batteries with lithium iron phosphate (LFP) chemistry, the number of cycles can range from 2,000 to 8,000. The 10-year expectancy forecasts a full cycle each day, which results in 3,650 cycles. Battery degradation also entails reduction in available capacity. As a battery ages and/or is cycled, it loses its kWh capacity non-linearly. A battery is deemed end of life when it reaches 80%, or in some manufacturer's specification sheets at 70%, available capacity. These lower available capacity batteries are the modules that cause the above three strategies: replacement, augmentation, or oversizing. If utilized elsewhere, they are termed second life batteries. Second life batteries are not in scope of this feasibility study's evaluation due to the unproven nature and current high-cost relative to new Li-ion batteries.

Specify microgrid controller requirements. The microgrid controller is the central system responsible for coordinating and optimizing the operation of all DERs, such as PV, BESS, or generators, ensuring seamless transitions between grid-tied and islanded operation modes while maintaining system stability and meeting

[44] National Fire Protection Association, "NFPA 855: Standard for the Installation of Stationary Energy Storage Systems."
[45] Shin and Hur, "Optimal Energy Storage Sizing with Battery Augmentation for Renewable-Plus-Storage Power Plants."

performance objectives. Consideration should be given to the systems that the cooperatives are currently utilizing to maximize integration. The IEEE 2030.7 standard provides technical specifications and requirements for microgrid controllers to ensure that components are interoperable and have interfaces that comply with functional standards[46].

4.2 GENERAL RECOMMENDATIONS

Microgrid installation. Size the microgrid for forecasted power and energy needs, while reserving adequate space for future expansion. This recommendation is particularly important for BESS and solar PV arrays, as these components often have strict clearance and land usage requirements. During neighborhood planning, designating physical areas for potential expansion can prevent costly retrofits or logistical challenges later, ensuring that the microgrid remains adaptable to evolving energy needs.

After installation, for O&M and future planning, prioritize data collection and start early. The quality and quantity of primary data collected directly impacts the relevance and robustness of the results for the proposed microgrid. Key data to collect should cover each buildings energy loads (both electric and natural gas). Electric interval data should be collected where available or a robust plan for estimating an hourly load profile and calibrating this to actual usage should be developed. To meet the objectives of resilience and financial performance, a microgrid needs to carefully balance loads, sources, and storage elements, all of which fluctuate in real-time. Having robust interval data is vital for determining technology sizes when backup power is a requirement of the microgrid.

Consider alternatives for natural gas-burning end uses including generators, space heating, and water heating. In the mixed-energy scenarios, natural gas usage represents about 82% of the total energy usage of the East Neighborhood. The majority of this was used for space heating, with some additional use for water heating. To achieve the city's emissions reduction goals, implementing electricity consuming end uses instead of natural gas fired ones should be considered. This will add significant electric load, requiring larger batteries and PV arrays to meet critical demand at each site connected to the microgrid. However, additional electric uses, especially when implemented through a load control system, can also enhance the ability of a microgrid to reduce emissions and increase energy benefits.

When sizing DER components, determine the critical loads at each site. The amount of load that must be sustained during an outage is a critical factor in the size of storage required for a microgrid. Accurate determination of critical loads at each site is crucial for sizing distributed energy resources. Once the neighborhood development plan is finalized, including building infrastructure and main energy consuming equipment, it's important to identify the energy requirements of critical loads.

It may prove useful to utilize the Clean Coalition's VOR123 methodology[47]. The methodology suggests that most buildings can split their load into three tiers. Tier 1 represents roughly 10 percent of load and are critical items that require power always. Tier 2 represents roughly 15 percent of total load and are all other priority loads, and Tier 3 represents the last 75 percent and all discretionary loads. To utilize this methodology, split all the major spaces in the building into Tier 1, Tier 2 and Tier 3. From there, data such as square footage, occupancy, or submetering can be used to estimate energy needs for each tier.

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46 "2030.7-2017 - IEEE Standard for the Specification of Microgrid Controllers | IEEE Standard | IEEE Xplore."

47 Lewis and Mullendore, "Valuing Resilience in Solar+Storage Microgrids: A New Critical Load Tiering Approach."

Develop a battery incentive program and/or a virtual power plan (VPP). For individual battery energy storage systems (BESS), it is recommended that Eau Claire Energy Cooperative develop a battery incentive program and/or virtual power plant initiative. By offering financial incentives or rate structures that allow ECEC to control battery discharges, community members would be encouraged to invest in home or business BESS systems. This strategy would provide additional grid support while increasing local energy resilience and reducing peak demand. A VPP would ensure efficient operations and control of the microgrid and its energy assets. Compliance with technical standards such as IEEE 1547-2018 and UL 9540A should also be specified to guarantee system safety and performance.

Include resiliency benefits in calculations of cost-effectiveness. Resiliency benefits are one of the primary reasons to install a microgrid system and are often significant. It is important to consider the monetary value of these benefits when making decisions about investment. There are several methods a site could use to value resiliency:

- Utilize national estimates from LBNL. This is one of the most cited values of resiliency but is limited as it only includes values for outage durations up to 16 hours[48].
- Estimate the value using NREL's Customer Damage Function Calculator. This tool allows the user to input any damaged equipment costs, lost data costs, food or product spoilage costs, or any other interruption costs[49].
- Estimate human health benefits for a community resiliency center. Other studies have considered their population and estimated how many people would need electricity dependent medical care or heating and cooling centers to estimate health impacts and associated avoided costs[50].

[48] Sullivan, Schellenberg, and Blundell, "Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States."
[49] "Customer Damage Function Calculator."
[50] Rolon et al., "Solar and Energy Storage for Resiliency."

5 MICROGRID OWNERSHIP STRUCTURE AND OPERATING AGREEMENT

Defining the ownership structure for the East Neighborhood community microgrid poses challenges for all project stakeholders. Microgrid ownership and operation is not a typical responsibility for any stakeholder and requires additional support beyond each of their current day-to-day responsibilities and duties. As a public entity, the City of Altoona was not established to serve as an energy provider, making operation and ownership a novel and challenging endeavor. Further staffing, subject matter experts, and operation/maintenance would be critical for microgrid functionality. As a distribution utility operating under a wholesale power contract with Dairyland Power, ECEC's capacity to own generation assets is limited by contract terms, despite their role in distributing power to the community. This restricts their ability to take full ownership of microgrid assets, especially of the size of the community level assets. While Dairyland supports the region's energy needs, it must look at what is best for its customers and scale new generation and control based upon that economic impact and feasibility. These constraints create a need for an alternative ownership and operational model that allows the microgrid to function effectively while aligning with the interests and capabilities of all stakeholders. To address this, the project stakeholders must consider third-party models that separate ownership from operation while ensuring that the microgrid remains financially and technically viable.

The challenges faced in defining ownership for the East Neighborhood microgrid are not unique, as similar issues have been addressed in other community microgrid projects. One approach that has been successfully implemented is the privately-owned or Microgrid-as-a-Service (MaaS) model, where a third-party entity designs, finances, owns, and operates the microgrid while providing energy services to the community. This business model allows customers to stabilize long-term energy costs and ensure resiliency without a major capital outlay[51]. For this project, this model would provide professional management and technical expertise while alleviating financial and operational burdens from the municipality and electric cooperatives.

Another approach is the Public-Private Partnership model, which enables a municipal or cooperative entity to partner with a private developer that assumes responsibility for designing, financing, and maintaining the microgrid. In the context of this project, the City of Altoona or ECEC could enter into an agreement with a private microgrid developer to construct and operate the microgrid systems, and they would benefit from the resiliency and cost savings of the microgrid without needing to take on full ownership or operational duties.

Given the constraints faced by the City of Altoona, ECEC, and Dairyland Power, the most feasible ownership model for the East Neighborhood microgrid involves contracting a third-party aggregator to take on the role of owner and operator. By structuring the project in this way, the stakeholders can benefit from professional expertise in microgrid operation while avoiding regulatory limitations and financial risks. A third-party aggregator would be responsible for system management, maintenance, and coordination with the utility, ensuring that the microgrid functions effectively in both grid-connected and islanded modes. Additionally, the Federal Energy Regulatory Commission (FERC) Order 2222[52] provides a significant opportunity for DER aggregators to participate in regional electricity markets. This order enables DERs, including those managed within microgrids, to aggregate and provide energy, capacity, and ancillary services to the grid.

[51] Zinaman et al., "White Paper: Enabling Regulatory and Business Models for Broad Microgrid Deployment."
[52] Zhou, Hurlbut, and Xu, "A Primer on FERC Order No. 2222."

5.1 MICROGRID OPERATIONS

The successful operation of the East Neighborhood microgrid will require clear roles and responsibilities among all participating entities to ensure grid stability, regulatory compliance, and the efficient management of distributed energy resources (DERs). Eau Claire Energy Cooperative (ECEC) will serve as the Distribution Provider, responsible for overseeing the microgrid's integration with the broader electricity network, while a third-party aggregator will act as the Community Microgrid Aggregator (CMG Aggregator) to coordinate and optimize the performance of microgrid assets. This operational framework will ensure that the microgrid functions reliably in both Blue Sky Mode (connected to the grid) and Island Mode (disconnected from the grid during outages or emergencies).

As the Distribution Provider, ECEC will maintain overall control of the distribution system, ensuring compliance with grid regulations and operational safety. ECEC will provide distribution services to all participating customers, manage the transition between interconnected and islanded operation, and monitor interconnection requirements to ensure that the microgrid complies with all regulatory and technical standards. Additionally, ECEC will coordinate with the CMG Aggregator to support voltage and frequency stability, ensuring DER assets, including PV, BESS, and generators, operate within specified parameters. In the event of planned or unplanned outages, ECEC will oversee the transition from grid-connected to islanded mode to minimize service disruptions.

The CMG Aggregator will be a third-party entity contracted to manage and optimize DER operations within the microgrid. Their role will include real-time dispatch of energy resources based on grid conditions, energy pricing, and demand forecasts. The aggregator will coordinate transitions between islanded and grid-connected operation, ensuring stability while optimizing energy flows. To maximize economic benefits, the CMG Aggregator will implement load management strategies such as demand response programs, energy arbitrage, and peak shaving. Additionally, they will provide ancillary services, including voltage regulation and frequency support, while ensuring the cybersecurity and data security of microgrid assets.

Blue Sky Mode Operations

During normal operation, the microgrid will function as an integrated part of the broader utility grid. The CMG Aggregator will monitor energy generation and storage to optimize energy consumption, reduce peak demand, and participate in demand response programs. Solar PV and BESS assets will primarily serve on-site consumption, exporting excess energy to the grid when financially beneficial. The microgrid will implement load shifting and peak shaving strategies to reduce demand charges and overall electricity costs. It will also provide grid services, such as frequency regulation and voltage support, to benefit both ECEC and Dairyland Power Cooperative (DPC). Additionally, time-of-use (TOU) optimization will be used to strategically discharge stored energy during peak pricing periods, further improving economic performance.

Island Mode Operations

In the event of a grid outage, the microgrid will transition to Island Mode, operating independently from the utility. The transition will be automatically managed by the CMG Aggregator in coordination with ECEC. Critical loads will be prioritized to maintain essential services such as emergency lighting, refrigeration, heating, and medical equipment. Deploying BESS will provide immediate power stability to facilitate a seamless transition, while local generation will be balanced against demand to maintain reliable service. If necessary, backup generation assets may be deployed to supplement power supply during extended outages when renewable generation is insufficient.

Grid Reconnection and Resynchronization

When the external grid is restored, the microgrid must safely reconnect to ECEC's distribution network. The reconnection process will involve synchronizing voltage and frequency between the microgrid and the utility grid, gradually restoring loads and distributed resources to prevent instability, and resuming participation in energy markets and demand response programs. Properly managing this transition is essential to ensuring seamless reintegration with the broader electricity system.

Long-Term Operational Considerations

To ensure long-term operational success, the microgrid will require ongoing system monitoring and performance evaluation. Smart metering and real-time data analytics should be used be used to track energy flows, detect anomalies, and optimize system efficiency. Automated microgrid controls will enable real-time decision-making, ensuring continuous optimization of energy distribution. Predictive maintenance strategies will be implemented to reduce unexpected equipment failures and extend the lifespan of DER assets. Finally, cybersecurity protocols should be established to protect against threats that could impact either grid-connected or islanded operations.

5.2 OPERATING AGREEMENT

The proposed Microgrid Operating Agreement (MOA) for the East Neighborhood microgrid should outline clear responsibilities, performance requirements, and financial arrangements to ensure long-term operational success[53]. The agreement should define the roles of the third-party aggregator, ECEC, and the City of Altoona, ensuring that all parties have clear expectations and accountability mechanisms. The agreement should establish an operational framework for the microgrid, including requirements for maintaining service during grid outages.

Financial arrangements must be structured to facilitate cost-sharing among stakeholders. Revenue-sharing mechanisms should be established to allocate earnings from ancillary services, such as demand response participation and energy arbitrage. The MOA should also include a well-defined regulatory compliance plan, ensuring that all interconnection agreements, permitting processes, and reporting requirements are met. It should outline responsibilities for ongoing performance monitoring and reporting. Finally, the agreement should include provisions for dispute resolution, mediation procedures, and mechanisms for expanding the microgrid over time. As the neighborhood grows, additional distributed energy resources (DERs), such as rooftop solar, EV charging stations, and expanded BESS capacity, should be seamlessly integrated into the microgrid framework.

To further support the project stakeholders in their development of the MOA, the following is an outline of the sections that are normally included in an MOA[54] describing what each of them entails as it pertains to this project:

1. Recitals & Agreement

The introductory section lays the groundwork for the agreement, clearly defining the stakeholders and their roles, including the City of Altoona, Eau Claire Energy Cooperative (ECEC), Dairyland Power Cooperative (DPC), and the third-party aggregator. It outlines the overarching goals of the project, such as enhancing energy resilience, integrating distributed energy resources (DERs), and ensuring compliance with regulatory

[53] PG&E, "Community Microgrid Technical Best Practices Guide."
[54] PG&E, "Microgrid Incentive Program (MIP) Handbook."

standards, and defines governance of the project (microgrid), its energy resources, and its operation.

2. Term & Termination

This section specifies the duration of the agreement and details the conditions for its extension, modification, or termination. It includes timelines for key project milestones, such as commissioning and operational start dates, ensuring that all parties have a shared understanding of critical deadlines. It also outlines termination clauses to address breaches of contract, regulatory changes, or unforeseen circumstances, providing a structured approach to managing contract closure.

3. Project Development

Responsibilities during the planning, design, and construction phases are laid out here, clarifying each party's role in ensuring the microgrid's successful implementation. The third-party aggregator’s tasks include designing and procuring microgrid components, while other stakeholders focus on securing permits, finalizing interconnection agreements, and meeting industry technical standards. This section ensures accountability and coordination across all phases of project development.

4. Project Operation

The operational framework for the microgrid is detailed, covering its two primary modes: Blue Sky Mode (grid-connected) and Island Mode (grid-disconnected). It emphasizes the importance of maintaining performance metrics and reporting requirements while defining the responsibilities for day-to-day operations, maintenance, and system monitoring. Transition protocols between operating modes are also established to ensure smooth and reliable functionality under varying conditions.

5. System Change

This section addresses the procedures for modifying the microgrid, whether through upgrades, expansions, or repairs. It establishes a clear process for proposing and approving changes, ensuring that all modifications maintain the system's integrity and align with regulatory requirements. Cost-sharing mechanisms for enhancements are also outlined, promoting financial transparency and collaboration among stakeholders.

6. Events of Default, Remedies, and Default

Clear definitions of what constitutes a default by any party are provided, along with remedies for resolving such issues. The section specifies steps for addressing non-compliance or underperformance, outlines penalties for failing to meet contractual obligations, and details processes for restoring compliance. This ensures that all parties have a framework for addressing disputes effectively and minimizing disruptions.

7. Governmental Charges

This part clarifies the responsibilities of each party regarding taxes, fees, and other governmental charges associated with the microgrid’s development and operation. It defines how these costs will be managed to ensure compliance with local and state regulations, providing financial clarity and reducing the risk of legal complications.

8. Covenants

Commitments made by each party to support the microgrid’s success are detailed here. These include ensuring access to DERs for maintenance, adhering to environmental and safety standards, and participating in regular stakeholder meetings to review performance. This section fosters ongoing collaboration and accountability among the involved entities.

9. Liability, Indemnity, Consequential Damages, and Insurance

Liability and indemnification responsibilities are defined to protect the parties involved. The section includes limitations on liability for indirect or consequential damages, specifies insurance requirements for property and operational risks, and includes indemnity clauses to safeguard stakeholders from legal claims related to the microgrid's operation.

10. Assignment

Conditions for transferring rights and obligations under the agreement are specified here. The section includes approval processes for assigning responsibilities to new entities and ensures protections are in place to maintain continuity of service and compliance during transitions. This ensures the microgrid remains operational and effective regardless of ownership changes.

11. Dispute Resolution

Mechanisms for resolving disputes are outlined to ensure conflicts are addressed efficiently and fairly. This section includes procedures for mediation and arbitration, jurisdiction and governing law for legal proceedings, and timelines for resolving disputes to minimize operational disruptions and maintain trust among stakeholders.

12. Intellectual Property, Agreement Deliverables, and Use Rights

Ownership and use of intellectual property developed during the project are addressed here. The section defines rights to software, data, and operational methodologies, establishes provisions for sharing deliverables among stakeholders, and includes protections for proprietary information to ensure equitable and secure use of project assets.

13. Confidentiality and Data Security

This part ensures that sensitive information remains protected and that data security measures comply with industry standards. It includes confidentiality obligations for all parties, requirements for data encryption and access controls, and procedures for breach notifications, safeguarding the integrity of project data.

14. General Provisions

General clauses ensure the agreement's enforceability and clarity. These include governing law and jurisdiction, severability clauses to address invalid provisions, and processes for amendments and waivers. This section ensures the agreement remains adaptable and enforceable under changing conditions.

15. Notices

Formal communication methods between parties are detailed, specifying designated points of contact, accepted methods of communication such as email or certified mail, and timelines for responding to notices. This ensures clear and reliable communication throughout the agreement's term.

By structuring the Microgrid Operating Agreement with these detailed sections, the East Neighborhood microgrid project can establish a robust framework that supports its development, operation, and ongoing collaboration among stakeholders. To move forward, project stakeholders should convene for a series of consultations to finalize the ownership structure and refine the MOA framework.

6 FINANCING OPTIONS

The upfront cost for a microgrid of the scale that's being proposed can be a deterrent to installation. In addition to the piecemeal installation discussed in section 4.1 above, there are several financing options that the stakeholders can consider.

We recognize that national and federal initiatives and funding programs are subject to change, creating uncertainty in future funding availability. This uncertainty reinforces our recommendation that project partners explore additional private and state funding opportunities to ensure the successful implementation of a microgrid for the East Neighborhood.

6.1 FUNDING SOURCES

Inflation Reduction Act (IRA) Tax Credits[55]

The Investment Tax Credit (ITC) and the Production Tax Credit (PTC) are two key incentives under the Inflation Reduction Act (IRA) that can support the financial viability of the East Neighborhood microgrid. These tax credits provide significant cost reductions for renewable energy projects, including solar PV, battery energy storage systems (BESS), and microgrid controllers.

The ITC provides a one-time tax credit of 30% of eligible project costs for qualifying energy projects. This credit applies to projects such as rooftop and ground-mounted solar PV, BESS installations, and microgrid controllers of 20 MW or less. Additional bonus incentives can further increase the ITC amount:

- 10% bonus if the project meets domestic content requirements for steel, iron, and manufactured products.
- 10-20% bonus for projects that provide benefits to low-income communities.

The PTC, in contrast, provides a per-kilowatt-hour (kWh) credit for electricity generated from renewable sources over a ten-year period. This could apply to solar PV production at both the individual building level and the landfill-based community solar system.

Since the City of Altoona, Eau Claire Energy Cooperative, and Dairyland Power are non-taxable entities, they may elect to receive direct pay under the IRA's Elective Pay provision, which allows them to obtain a cash refund in place of the tax credit. However, to receive this benefit, the project must be fully paid upfront, with the cash reimbursement processed after tax filings. This means that securing interim financing or grants to cover initial costs would be necessary.

These tax credits provide a substantial funding source for microgrid development, especially if stacked with additional state or federal grants.

Wisconsin Public Service Commission (PSC) Energy Innovation Grant Program (EIGP)[56]

The Wisconsin PSC's Office of Energy Innovation (OEI) Energy Innovation Grant Program (EIGP) has historically funded energy projects that advance innovative and clean energy technologies. This feasibility study is one of those examples. Although this program is not currently open, the PSC has consistently offered it over the past five years. If funding is reinstated in future rounds, it should be considered as a critical funding source.

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55 "IRS Clean Energy Tax Incentives Elective Pay Eligible Tax Credits."
56 "PSC Energy Innovation Grant Program."

The EIGP has previously awarded up to $750,000 for Level 3 microgrid implementation projects. These grants target community resilience centers, municipal microgrid initiatives, and other energy projects that provide enhanced grid reliability and emergency preparedness.

To maximize the likelihood of funding, the microgrid proposal should emphasize its potential to enhance resilience, integrate renewable energy, and provide valuable data for future grid modernization efforts in Wisconsin.

Wisconsin Solar for All Program[57]

The Solar for All program is an upcoming state initiative designed to expand solar access for low- and moderate-income (LMI) households across Wisconsin. This program, administered by the Wisconsin Economic Development Corporation (WEDC), is anticipated to launch in summer 2025 and is particularly well suited to support rooftop solar for residential buildings (single-family and multifamily), and community solar initiatives. Since the East Neighborhood microgrid includes multifamily housing and community-scale solar on a landfill site, and at least a portion of the neighborhood is considered for affordable housing, then it is well-positioned to qualify for this funding. Once funding becomes available, the project stakeholders should prioritize applying for community solar and multifamily solar incentives to enhance project feasibility and affordability for residents.

Energy Efficiency Programs from Eau Claire Energy Cooperative[58]

Eau Claire Energy Cooperative (ECEC) offers incentive programs to promote energy-efficient appliances and systems. These programs are designed to encourage homeowners and businesses to invest in energy-saving technologies, reducing overall energy consumption while enhancing sustainability. Integrating these incentives into the development of the Altoona East Neighborhood can provide financial benefits for future residents and align with broader energy efficiency goals.

ECEC provides rebates for ENERGY STAR-certified appliances, allowing homeowners to reduce the upfront cost of energy-efficient refrigerators, clothes washer and dryers, and other household devices. Additionally, members who purchase qualifying energy-efficient water heaters, particularly those integrated with ECEC's load management programs, are eligible for financial incentives. Participation in these programs ensures optimized energy use and lower electricity costs. ECEC also offers incentives for home energy audits and improvements identified through evaluations, helping homeowners implement measures such as insulation upgrades and HVAC system efficiency enhancements. Furthermore, through Wisconsin's Focus on Energy program, ECEC members can access additional incentives for various energy-saving upgrades, including high-efficiency heating and cooling systems.

By incorporating these incentives into neighborhood planning, future residents and businesses can take advantage of cost savings while improving energy efficiency, making the microgrid-supported community more economically and environmentally sustainable.

Focus on Energy Rebates and Incentives[59]

Wisconsin's Focus on Energy program provides a range of financial incentives to promote energy efficiency and renewable energy adoption for residential, commercial, and industrial projects. As a statewide initiative,

[57] Barthel, "Solar for All."
[58] Eau Claire Energy Cooperative, "Save Energy And Money."
[59] Focus on Energy, "Rebates & Incentives."

Focus on Energy partners with utilities, including ECEC, to support energy-saving technologies that reduce emissions and improve overall energy performance.

- **New Home Construction Incentives:** Builders and developers can qualify for incentives when constructing energy-efficient homes that meet Focus on Energy's high-performance standards. These include incentives for proper insulation, high-performance HVAC systems, and efficient building envelopes.
- **Renewable Energy Rebates:** Incentives are available for solar PV installations, helping offset the costs of implementing rooftop or ground-mounted solar systems in the community.
- **Energy-Efficient Equipment Rebates:** Homeowners and businesses within the East Neighborhood can receive rebates for high-efficiency HVAC systems, water heaters, smart thermostats, and other energy-saving technologies.
- **Multifamily Building Efficiency Incentives:** Developers of multifamily residences can access specific rebates for whole-building energy upgrades, including enhanced insulation, lighting improvements, and optimized heating and cooling systems.

Leveraging Focus on Energy's rebate programs can significantly reduce initial investment costs for homeowners and developers within the East Neighborhood. By aligning the microgrid project with these funding opportunities, stakeholders can maximize financial savings while advancing the project's sustainability and resilience goals.

7 CONCLUSION

The Altoona East Neighborhood Microgrid Feasibility Study represents a comprehensive effort to explore the viability of establishing a microgrid that aligns with the City of Altoona's sustainability and resilience objectives. This study has highlighted the potential of integrating distributed energy resources (DERs) such as solar PV systems, battery energy storage systems (BESS), natural gas generators, and thermal energy networks (TEN) to achieve energy security, environmental sustainability, and economic feasibility. The results provide a roadmap for informed decision-making as the City of Altoona, along with its partners, consider advancing to the next stages of project development.

Key findings from the study emphasize the trade-offs between different microgrid configurations. The analysis revealed that a microgrid scenario with community level assets (ground-mounted solar PV, large-scale BESS, and a natural gas generator) for an all-electric neighborhood supported by air-source heat pumps as the most cost-effective, without including factors such as health impacts, carbon emissions, and avoided outage costs. No amount of funding is considered either, but initial results show that some of these scenarios could produce a positive NPV without other financial considerations. While the six selected scenarios provide varying degrees of cost savings and emissions reductions, the inclusion of resilience and emissions benefits significantly improves the net present value (NPV) of the systems. The analysis demonstrates that a well-designed microgrid can meet critical load requirements during outages while contributing to the City's climate action goals through reduced greenhouse gas emissions.

We acknowledge that with the current low utility rates and low frequency and duration of outages in the area, the economic feasibility of the microgrid based on current costs of electricity does not immediately pencil out. This microgrid feasibility study represents a snapshot in time. Projections show that power and energy needs could double by 2035 or 2050, depending on the source. With these growing demands, utility prices are anticipated to increase, and outages may become more frequent and longer in duration due to the impacts of climate change. Consequently, the net present value (NPV), return on investment (ROI), and other financial metrics of the microgrid are expected to improve dynamically with the forecasting rise in electricity costs, both independently and relative to natural gas as an alternative heating and power source.

The study also underscores the importance of strategic planning and stakeholder collaboration. The involvement of the City of Altoona, Eau Claire Energy Cooperative, and Dairyland Power Cooperative has been instrumental in defining project goals, assessing technical feasibility, and aligning with regulatory and financial frameworks. This collaborative approach ensures that the proposed microgrid is not only technically sound but also aligns with the broader community's needs and priorities.

The implementation of the microgrid should follow a phased approach, as outlined in the Next Steps section. Results from this study show that, in general, scenarios with community-level assets are more cost-effective due to economies of scale. Once the neighborhood design and composition have been finalized, including the number of buildings and their energy consumption patterns, we recommend implementing community-level assets (ground-mounted PV in the landfill, large scale BESS, etc.) through a third-party aggregator business model. This phased approach allows the project to adapt to evolving needs and resources while ensuring efficient utilization of investments.

A virtual power plant initiative or battery incentive program should be developed to take advantage of any future battery systems implemented in the community and to encourage the future East Neighborhood residents and business owners to invest in individual BESS. These storage systems paired with a well-developed program and energy management system would enhance the overall resilience of the neighborhood, allowing for greater energy independence during outages, while also providing valuable grid support benefits to the electric cooperatives, such as peak shaving and voltage stabilization.

Leveraging funding opportunities will be critical for reducing upfront costs and enhancing the economic viability of the microgrid. Programs such as the IRA Tax Credits, Wisconsin’s Solar for All initiative, the OEI Energy Innovation Grant Program, and the range of incentive offerings from Focus on Energy provide substantial financial support. By utilizing these programs, the project partners can reduce capital costs while maximizing the environmental and resilience benefits of the microgrid.

By emphasizing the monetary value of resilience and grid services, the microgrid can deliver significant benefits to the local grid and community. These include peak demand reduction, voltage stabilization, and ancillary services. Value stacking these benefits strengthens the case for investment in the microgrid and ensures alignment with broader energy and resilience goals.

This study also offers valuable lessons for the replicability of microgrid projects in other greenfield developments. The innovative process of performing a microgrid feasibility study from the ground up, including modeling energy impacts for different building types, demonstrates a practical framework for developing an energy efficient neighborhood and designing energy systems that align with modern sustainability and resilience goals. By addressing challenges early in the planning phase, this study highlights how tailored microgrid solutions can be developed for diverse community needs.

Given the limitations of public entities and cooperatives in owning generation assets, contracting a third-party aggregator to own and operate the microgrid represents the most feasible path forward. A detailed Microgrid Operating Agreement (MOA) should be developed to formalize roles and responsibilities. This agreement will ensure that all stakeholders are aligned and that the microgrid operates efficiently and effectively over its lifecycle.

The Altoona East Neighborhood microgrid represents a transformative opportunity for the City of Altoona to lead in energy innovation, demonstrating how local communities can address the challenges of climate change and energy reliability through advanced microgrid solutions. With continued stakeholder collaboration and strategic planning, this project has the potential to become a model for sustainable and resilient community development.

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