# SARTA Microgrid Feasibility Study

September 2020


## Prepared by:

**Kristian Jokinen and Bryan Lee**

**CALSTART**


# Executive Summary

This study examines the techno-economic feasibility of constructing a microgrid that will serve the Stark Area Regional Transit Authority (SARTA). SARTA is a transit agency that serves Canton, Ohio and the surrounding region. SARTA currently has, either in operation or on order, a fleet of twelve fuel cell electric transit buses, five fuel cell paratransit buses, as well as multiple buses that are powered with compressed natural gas. Since SARTA deploys a low-emission fleet that requires compression, its ability to provide service is vulnerable to grid outages. If a prolonged outage were to occur, SARTA would not be able to dispense hydrogen or compressed natural gas to its vehicles, which would effectively disable its fleet. To protect against this possibility, SARTA aims to deploy a microgrid that will power hydrogen production equipment, hydrogen fueling equipment, bus depot ventilation and SARTA's information system. SARTA also seeks to explore expanding the microgrid to serve other local facilities that also value grid reliability, including a planned sanitation garage, a planned community center/health clinic, and a nearby elementary school. This study examined SARTA's energy needs, the Ohio regulatory framework surrounding microgrids, operational strategies and the techno-economic feasibility of implementing a microgrid.

There are multiple options for operating a microgrid. The microgrid can be built behind-the-meter, on the customer's side of the meter. Under this operating strategy, the microgrid is constructed on SARTA's property. SARTA can own the microgrid, in which case it would be responsible for capital expenditures, maintenance, and operation of the microgrid. Alternatively, SARTA can hire an energy services company to design, build, finance and own the microgrid. SARTA could then sign a power purchasing agreement to obtain power from the microgrid. In a third option, the microgrid can be built in front-of-the-meter by the distribution utility. Under this strategy, the microgrid can still be built on SARTA's property, but the generation would be owned by the utility's deregulated company, or a third party. This would be the strategy that would most likely enable expansion to include other customers. AEP Ohio, SARTA's utility company, has generally expressed interest in a front-of-the-meter microgrids, and has successfully sought Public Utility Commission of Ohio permission to build them in limited cases. However, the process of obtaining PUCO permission would be uncertain and time consuming. There is currently no mechanism in Ohio for distribution utilities to place microgrids into their tariffs, so the costs must be socialized among all ratepayers. As a result, a behind-the-meter is the most viable near-term operational strategy.

This study examined the feasibility of both a campus microgrid that only serves SARTA's facility and a district microgrid that provides power to both SARTA's facilities as well as a community center/health clinic that is owned by the City of Canton. Under the district microgrid model – which would require AEP Ohio's involvement as a distribution utility -- the microgrid components would serve both SARTA and the City of Canton's facilities in the event of an outage. However, CALSTART's analysis found that a district microgrid would not be economically viable. Currently, there is no electrical connection between the SARTA facility and the City of Canton's facility as they are not on the same feeder. As a result, there is no way to transport electricity between two facilities. The only way to establish a connection between the facilities would be to build power lines between the facilities. However, constructing power lines was deemed to be prohibitively expensive.

CALSTART explored microgrid components and the most feasible design for the microgrid. To conduct this analysis, CALSTART employed Sandia National Laboratory's Microgrid Design Toolkit (MDT). MDT was programmed to examine several technologies including trigeneration with a molten carbonate fuel cell, solid oxide fuel cells, solar panels, battery energy storage, and natural gas turbines. CALSTART was able to use the MDT software to weigh several factors including capital expenditures, the ability of the microgrid assets to provide sufficient energy, and the amount of renewable energy. Based on these criteria, CALSTART determined that trigeneration would not be feasible due to its high capital expenditures. Based upon the MDT model, CALSTART recommends a microgrid with 490 kW DC of solar panels, 1000 kW of natural gas turbines, while continuing the maintenance of two existing diesel generators (with a combined capacity of 575 kW) as back up. This design assumes that SARTA will be producing up to 500 kg/day of hydrogen on site via steam methane reformation, rather than receiving it as liquid hydrogen by truck, as it currently does. If SARTA opts to produce the same amount of hydrogen via onsite electrolysis, CALSTART's MDT analysis recommends a microgrid that includes 490 kW DC of solar panels, 4000 kW of natural gas turbines, and continued use of the existing 575 kW of diesel generators. Battery storage was not recommended because SARTA has a high load factor, meaning that the facility operates near peak power most of the time. As a result, SARTA would require a large battery storage system, which would be prohibitively expensive.

CALSTART held discussions with a microgrid developer who has expressed an interest in serving as an energy services company for a behind-the-meter microgrid. Based on the design for the microgrid with steam methane reformation, a microgrid developer estimated that this project's capital expenditures will be $1.75M - $2.25M with an estimated levelized cost of energy of $0.07-$0.09 per kWh. This price would be comparable to the cost of the utility power that SARTA currently buys from the grid (using a commercial retail electric service company provider).

Under the microgrid developer's model, SARTA would continue to be connected to the grid and take supplemental power therefrom. The developer did not estimate an uptime percentage but indicated it would be better than the grid. Further, additional considerations will need to be investigated, such as whether this arrangement would require SARTA to purchase power through a supplemental power tariff, or if standby charges may be applicable. It is believed that if SARTA uses microturbines for natural gas generation, net metering would be available for SARTA under Ohio law, and no standby charges would be incurred. In the end, the levelized cost of energy for SARTA's entire system will depend on these and other factors, including how the microgrid is used and whether it can be used to create additional value, such as managing peak load contribution to reduce capacity charges, or to participate in demand response programs.

Microgrids can greatly increase the attractiveness of hydrogen fuel and can play a major role in improving its economics and reliability. As a result, microgrids can be considered an enabling technology for the hydrogen economy. Since SARTA's microgrid will be the first transit-oriented microgrid in the Midwest, this microgrid will play an important role in facilitating further adoption of this technology in the future.

# Table of Contents

# List of Acronyms

| | |
|---|---|
| BTM | Behind the Meter |
| CHP | Combined Heat and Power |
| ESCO | Energy Services Company |
| FTM | In Front of the Meter |
| ITC | Investment Tax Credit |
| kW | kilowatt |
| kWh | kilowatt-hour |
| MW | megawatt |
| MWh | megawatt-hour |
| NMTC | New Market Tax Credit |
| PBR | Permit-by-rule |
| PPA | Power Purchase Agreement |
| PTIO | Permit-to-install and operate |
| PUCO | Public Utilities Commission of Ohio |
| REC | Renewable Energy Credit |
| SARTA | Stark Area Regional Transit Authority |
| SMR | Steam Methane Reformer |
| UPS | Uninterruptible Power Supply |

# Microgrid Evaluation and SARTA Campus Needs

## SARTA Microgrid Needs

The Stark Area Regional Transit Authority (SARTA) is a transit agency that serves Canton, Ohio and the surrounding area. SARTA has emerged as an early adopter of clean transportation technology. In 2012, SARTA installed a CNG station to fuel its CNG buses and allow the public to fuel private vehicles. SARTA was also an early adopter of zero emission buses and by 2021 will be operating twelve 40-foot hydrogen fuel cell buses and five hydrogen fuel cell paratransit buses, making SARTA the largest fuel cell bus operator in the United States, outside of California. SARTA expects to continue to expand its hydrogen fuel cell bus fleet in the future.

SARTA currently fuels its hydrogen fleet with liquid hydrogen that is delivered from a central production plant. However, SARTA aims to produce renewable on-site hydrogen through electrolysis, steam reformation, or trigeneration with a fuel cell. On-site production of hydrogen entails operational risks. Hydrogen production, storage, and dispensing requires large amounts of electricity. As a result, if there is an extended grid outage or electrical supplies are otherwise disrupted, SARTA would not be able to produce or dispense hydrogen. If the disruption lasts long enough, it would prevent refueling which would effectively disable its fleet. Furthermore, a power outage would disable its CNG station, which would disrupt the operations of the CNG buses.

These risks can be mitigated by deploying a microgrid(s). Microgrids[1] use distributed generation and energy storage assets to provide power in the event of an outage. During an outage, a microgrid can disconnect from the grid and use its own local distributed generation and energy storage systems to provide power. Microgrids also raise the possibility of deploying combined heat and power (CHP) where waste heat produced by distributed generation assets is captured and used to provide heating. This provides a more efficient solution than providing power and heat individually. Microgrids are also flexible because they can act either as a backup or as the primary source of power.

SARTA is exploring the possibility of deploying a microgrid to provide resiliency to its facilities. The proposed SARTA microgrid is intended to mitigate the risks of a grid outage or failure and its primary purpose is to provide power for the hydrogen generation and delivery equipment in the event of an outage, as well as for depot ventilation and for maintenance of SARTA’s computer and communication systems. In addition, SARTA is considering a district microgrid. SARTA envisions that a district microgrid could also potentially serve adjacent facilities, including Allen Elementary School and a community center owned by the City of Canton that will host a health clinic in the future. By including other facilities in the microgrid, SARTA aims to use the microgrid to serve the community by providing resiliency.

[1] The U.S. Department of Energy (DOE), describes a microgrid as: “a group of interconnected loads and distributed energy resources (DER) within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid, and that can connect and disconnect from the grid to enable it to operate in both grid-connected and ‘island’ mode.” [https://www.energy.gov]

## Microgrid Design Parameters

An important consideration in the microgrid is the type of generation and energy storage assets that will be included in the microgrid. The type of assets that can be incorporated into the microgrid is dependent on several factors and constraints. First, cost will act as a constraint on the microgrid. The microgrid needs to be cost effective. Space will also act as a constraint. SARTA's facilities have limited space and the microgrid assets will need to be able to fit on its property. Space could possibly be further constrained by standards and regulations that require microgrid assets to be located a certain distance away from buildings. The environmental impacts of the microgrid are also an important factor. Since SARTA is seeking to become net zero carbon, it would prefer to use renewable energy in its microgrid to maximize the environmental benefits of the bus.

The microgrid also needs to be able to power hydrogen generation and dispensing operations during an extended outage. Ohio has a relatively stable grid and the average outage duration for AEP customers is only 150 minutes,[2] making a 24 hour or longer outage a rare occurrence. However, a microgrid that can only power the facility for this short of a duration, while providing value for critical transit agency information technology system operations, would not keep the buses in operation. Hydrogen buses have a long range and only need to be fueled once per day. As a result, if a short duration grid outage occurred, a transit agency could respond by simply refueling after power is restored, without disrupting service. If the transit agency experiences a longer outage, then the transit agency cannot simply wait out the grid outage. In this case, the transit agency would need power to continue fueling its buses. Since SARTA is expected to have enough hydrogen storage for a full day of service, a microgrid that can power a transit agency for 24 hours or longer would ensure that all of the stored hydrogen could be dispensed.

SARTA is willing to use several types of assets to power the microgrid. SARTA's preferred option would be to use a trigeneration fuel cell. A trigeneration fuel cell is a molten carbonate or solid oxide fuel cell. These fuel cells use natural gas as an input and produce electricity, heat, and hydrogen. This is the preferred option because it produces hydrogen while also allowing for CHP functionality. SARTA would also prefer to include renewable energy generation assets to reduce emissions. Solar photovoltaics would be the preferred form of renewable energy generation. SARTA can also host natural gas turbines to produce power. Although these turbines use fossil fuels to produce power, they can be used for CHP. In addition, if gas turbines are powered with renewable natural gas, they can be run in an environmentally responsive manner. Lastly, SARTA can host batteries and uninterruptable power supply (UPS) systems as a form of energy storage. SARTA currently uses UPS systems to support its computer and communications systems.

## SARTA Campus Microgrid Needs

SARTA is in the process of expanding its depot facility to accommodate the co-location of a fleet of sanitation trucks. SARTA is currently expanding its garage to house vehicles that are owned by the sanitation department and constructing a training center that will host workforce development activities – an expansion that will likely double its current electricity load. SARTA anticipates it will also be installing hydrogen production facilities on its campus. SARTA will need to produce a significant amount of

[2] AEP Ohio. "Annual Performance Compared to Standard" Available at: https://www.puco.ohio.gov/puco/index.cfm/industry-information/statistical-reports/electric-reliability-performance-data/AEP-Ohio/

hydrogen on a daily basis. Each of the 40-foot fuel cell buses is fueled with approximately 30-35 kg of hydrogen per day. Each of the fuel cell paratransit vehicles is expected to be fueled with approximately 10-12 kg of hydrogen per day. As a result, SARTA will need up to 500 kg of hydrogen per day to fuel its fleet of hydrogen buses. However, SARTA plans to eventually host 1000 kg of hydrogen capacity to serve future fleet expansion, to have reserve hydrogen and to serve the public, as fuel cell vehicles become commercially available in Ohio.

## *SARTA Campus Electric and Gas Consumption*

The chart below outlines the monthly electricity consumption (in MWh) for SARTA's campus in 2018.

**Table 1: 2018 SARTA Campus Electricity Consumption**

| Month | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MWh | 218.8 | 196.8 | 192.8 | 239.6 | 201.6 | 192.8 | 217.2 | 192.8 | 200.8 | 210.4 | 203.2 | 227.2 |

In 2018, SARTA's campus consumed a total of 2,494 MWh. SARTA operates for 21.5 hours per day and has a relatively flat load profile, meaning that energy consumption is relatively constant throughout the day. There is a relatively small difference between times of high demand and low demand. After SARTA's facility expansion is complete, the campus is expected to consume twice as much power as current levels. As a result, the campus is expected to consume approximately 4,988 MWh per year.

**Table 2: Projected Electricity Consumption after SARTA Campus Expansion**

| Month | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MWh | 437.6 | 393.6 | 385.6 | 479.2 | 403.2 | 385.6 | 434.4 | 385.6 | 401.6 | 420.8 | 406.4 | 454.4 |

If hydrogen is produced on-site, this would increase expected electrical consumption. The increase in consumption would depend on the method of hydrogen production. However, hydrogen produced through either electrolysis or SMR would increase electricity demand.

Hydrogen produced through commercially available electrolysis systems consumes approximately 2.3 MW to produce hydrogen at a rate of 900 kg per day. This translates to 55.2 MWh of energy consumption per day. Hydrogen produced from SMR will introduce a less significant additional load, primarily from compression of natural gas into the SMR facility and of hydrogen into storage. The microgrid design analysis does not include the load from compressing natural gas into the SMR.

Regardless of the production method, energy is needed to compress, chill, and dispense hydrogen. For both electrolysis and SMR production, the peak load used for compression, chilling, and dispensing hydrogen will be between 225 and 360 kW.[3] Peak load times follow refueling patterns, which peak in late afternoon through the night.

### Table 3: Hourly Load Schedule for Hydrogen Compression, Chilling, and Dispensing

| Time | Power Demand (kW) |
|---:|---:|
| 0:00 | 300 |
| 1:00 | 225 |
| 2:00 | 225 |
| 3:00 | 225 |
| 4:00 | 225 |
| 5:00 | 225 |
| 6:00 | 225 |
| 7:00 | 225 |
| 8:00 | 225 |
| 9:00 | 225 |
| 10:00 | 225 |
| 11:00 | 225 |
| 12:00 | 225 |
| 13:00 | 225 |
| 14:00 | 225 |
| 15:00 | 225 |
| 16:00 | 225 |
| 17:00 | 225 |
| 18:00 | 360 |
| 19:00 | 300 |
| 20:00 | 300 |
| 21:00 | 300 |
| 22:00 | 300 |
| 23:00 | 300 |

SARTA also consumes large amounts of natural gas. The chart below outlines SARTA's monthly natural gas consumption during 2018.[4] Nearly all natural gas consumption is used for heating the facility and the garage. This does not include consumption for the CNG buses, which is metered separately.

[3] Personal correspondence with Jerry Cole, president of Hydrogen Ventures.
[4] The dates in Table 4 represents the month in which the gas bill was received. The gas that was billed was consumed in the previous month.

**Table 4: 2018 SARTA Campus Natural Gas Consumption**

| Month | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MCF | 2945 | 3098 | 2199 | 3056 | 1290 | 309 | 94 | 58 | 139 | 297 | 2014 | 3636 |

It is likely that SARTA's natural gas usage will double once the facility expansion is complete. Any further increase in natural gas consumption is dependent on the method of both hydrogen production and electrical generation. A trigeneration plant uses natural gas as an input and would substantially increase the natural gas consumption of the facility. As a reference, FuelCell Energy's SureSource 3000 consumes 362 scf[5] which translates to about 528.3 thousand cubic feet (MCF) per day.

If the facility produces hydrogen via steam reformation, the facility will need additional natural gas to produce the hydrogen. Each kg of hydrogen requires about 3.04 kg of natural gas.[6] This translates to approximately 1459.2 kg of natural gas per day or about 72 MCF of natural gas per day. Electrolysis does not require natural gas and would not increase natural gas consumption.

The method of electrical generation on the microgrid can also affect natural gas consumption. If natural gas turbines are used to produce power, it would substantially increase natural gas consumption.

## CNG Station

SARTA's CNG fueling station also consumes electricity and natural gas. The monthly amounts of electricity and CNG consumed in 2019 are outlined below:

**Table 5: 2019 SARTA CNG Station Electricity Consumption**

| Month | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MWh | 37.68 | 38.48 | 28.72 | 32.72 | 28.56 | 28.16 | 29.76 | 31.52 | 27.92 | 35.12 | 41.52 | 37.84 |

[5] FuelCell Energy, see: https://www.fuelcellenergy.com/wp-content/uploads/2017/02/Product-Spec-SureSource-3000.pdf

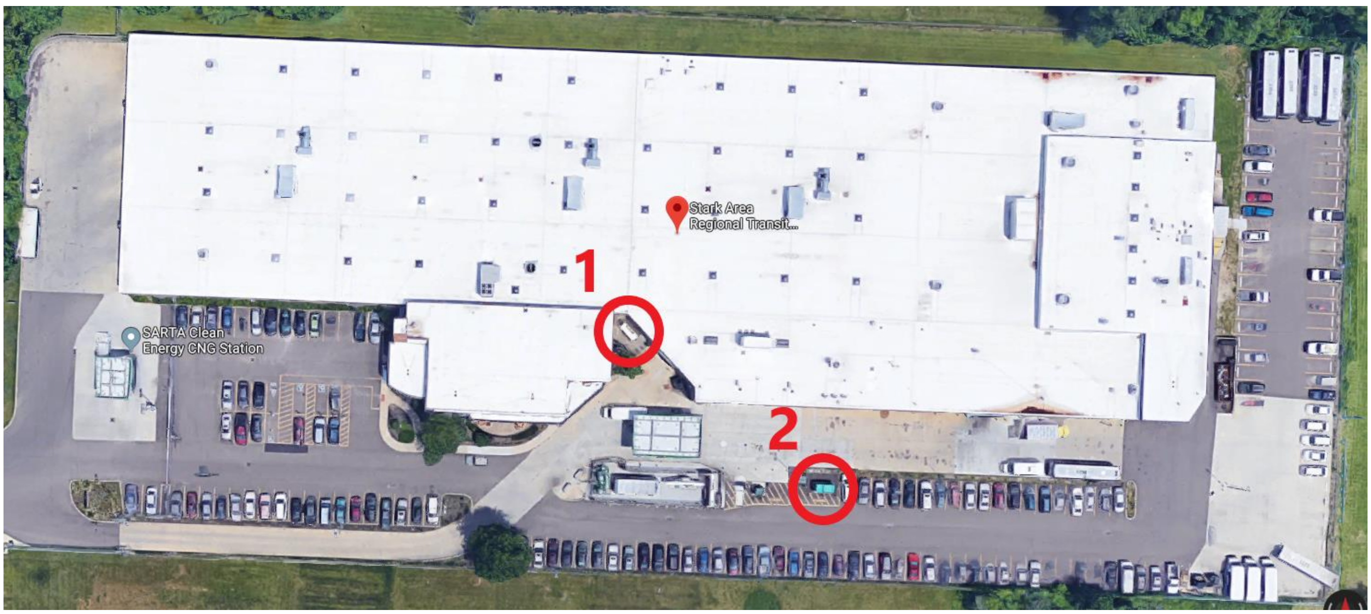
[6] A.M. Gandrik, R.A. Wood, M.W. Patterson, P.M. Mills, Htgr-integrated Hydrogen Production via Steam Methane Reforming Process Analysis, Idaho National Laboratory, Idaho Falls (ID), 2010 September, p. 49. Technical Evaluation Study TEV-954 Project No. 23843

**Table 6: 2019 SARTA CNG Station Natural Gas Consumption**

| Month | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MCF | 4120 | 3838 | 3869 | 3997 | 4101 | 3702 | 4009 | 4304 | 4379 | 4783 | 4316 | 4198 |

## *Critical Loads*

SARTA has two critical loads that must receive power in the event of a grid outage. These critical loads can currently receive emergency power from backup diesel generators.




1. Kohler 275REQZV Diesel Generator (275 kW): This generator supplies backup power to Dispatch, IT Server Room and Server Room HVAC, a few lights in the garage, and a few select wall outlets.
2. Cummins DQHAB Diesel Generator (300 kW): This generator supplies backup power to all roof top air handlers only to allow for bus storage to be inside in the event of a power failure.

SARTA has 500 gallons of diesel stored onsite to power these generators in the event of an outage. *Neither of these backup diesel generators provide support for refueling equipment*. Running at 100% power, the two generators combined consume 19.8 gallons per hour, which will provide 25 hours of resiliency capability. The two generators combined consume 10.9 gallons per hour when running at 50%, which will provide approximately 45 hours of resiliency capability.

# Regulatory Control

Microgrids are subject to regulations that can place restrictions on the microgrid. In the State of Ohio, the Public Utilities Commission of Ohio (PUCO) is the governmental body that regulates the distribution of electricity. Many of PUCO's regulations are codified in the Ohio Administrative Code. However, PUCO recognizes that there has been a rapid shift in electrical energy markets and is anticipating the adoption of new technologies, like distributed energy, onto the grid. As a result, PUCO aims to update regulatory structures to ensure that these technologies can reach their potential. In 2018, PUCO released *PowerForward: A Roadmap to Ohio's Electricity Future* to outline the actions and regulatory updates they will take to modernize Ohio's grid.

The shifting regulatory situation can make decisions about investing in microgrid technology more difficult. However, PUCO has expressed an interest in introducing more grid edge technologies, like distributed energy resources, microgrids, and energy storage to the general grid. PUCO regulates these assets based on where they are located on the grid: behind the meter or in front of the meter. While the regulatory structure is subject to change, *PowerForward* indicates that the regulatory distinction between behind the meter and in front of the meter is likely to be maintained. As a result, the regulations discussed in this section will probably remain relatively stable over the long-run.

## Behind the Meter

Ohio Administrative Code 4901:1-22 defines distributed generation as "all or part of a system of a distributed electrical generator or a static inverter either by itself or in the aggregate of twenty megawatts or less in size together with all protective, safety, and associated equipment installed at a point of common coupling" on an investor-owned utility's distribution system. According to PUCO, a behind-the-meter microgrid that is under twenty megawatts and connected to the utility's distribution system and operated in parallel with the utility's distribution system would fall under the definition of distributed generation.[7]

PUCO defines behind the meter as being in the customer's home or place of business. Currently, PUCO views behind the meter energy as separate from the utility. As a result, if distributed generation is installed behind the meter, an electric distribution utility cannot own it. However, an electric distribution utility sister company may own and operate the microgrid. *PowerForward* affirms this principle and states that PUCO intends to maintain this regulatory structure. This principle was reaffirmed at the May 1, 2019 meeting of the *PowerForward* Distribution System Planning Workgroup. At this meeting, the Workgroup proposed that behind the meter distributed generation and energy storage must be owned by a third party and will not be owned by the utility. The Workgroup also proposed that third parties will be able to own behind the meter microgrids, but did not specify under what circumstances utilities are able to own a microgrid behind the meter. Based on the current regulatory environment, it is probable that SARTA, a third party energy services company (ESCO), or a utility sister company would need to be the owner and operator of any microgrid that serves SARTA's facilities and could connect to the utility's distribution grid.

---

[7] PUCO, Distributed generation: generating your own electricity, https://puco.ohio.gov/wps/portal/gov/puco/utilities/electricity/resources/distributed-energy-generating-your-own-electricity

There is, however, additional legislation that has the potential to change this. The Ohio General Assembly introduced HB 247 in 2017. If HB 247 were to be enacted, it might allow regulated utilities to own Behind the Meter (BTM) microgrid components. This would allow AEP Ohio to own a BTM microgrid and sign a power purchasing agreement with SARTA. However, this legislation has not made it out of committee since 2017. As a result, there is no guarantee that this legislation will be enacted. However, if enacted, it might allow SARTA to work directly with AEP Ohio to build the microgrid.

Distributed generation is subject to regulation by PUCO under Ohio Administrative Code 4901:1-22. These regulations establish rules for interconnecting distributed energy resources to the grid via an investor-owned utility. To begin the interconnection process, the owner of the distributed generation system will need to initiate the pre-application process. In this process, the applicant will file an informal request for interconnection with the utility. The utility will begin discussions on connecting the microgrid to a specific location on the utility's distribution system and determining whether the microgrid will qualify for Level 1, Level 2, or Level 3 review procedures.[8] AEP will make this determination based on the location, type, size, and purpose of the microgrid.[9] Given the large generation requirements for the proposed microgrid system, it is extremely likely that it will need to be approved via Level 2 or Level 3 procedures.

After this, the applicant may file a formal application for interconnection. The applicant must provide information for its equipment package, which includes any interface components (like switchgears, inverters, etc.), an integrated electric source, access to the utility for equipment commissioning, and a schedule for periodic compliance testing. In addition, the equipment package must be certified meaning that it was submitted by a manufacturer to a nationally recognized lab testing or certification scheme, type-tested in a manner comparable to IEEE standard 1547, or listed by a nationally recognized testing and certification laboratory for continuous interactive operation with a utility grid. If solar equipment is included in the equipment package, the Operating current, Operating voltage, Maximum system voltage, and Short-circuit current must also be provided. After the application is complete, the applicant must pay a $300 fee for a preapplication report be conducted by the utility. In the preapplication report, AEP will provide specific information about the distribution system, that is required to make plans for interconnection. The report will include:

1. Total generation capacity of substation/area bus, bank or circuit based on normal or operating ratings likely to serve the proposed site.
2. Existing aggregate generation capacity interconnected to a substation/area bus, bank or circuit, which is the online amount of generation likely to serve the proposed site.
3. Aggregate queued generation capacity (in megawatts) for a substation/area bus, bank or circuit, which is the amount of generation in the queue likely to serve the proposed site.
4. Available generation capacity (in megawatts) of substation/area bus or bank and circuit most likely to serve the proposed site, which is the total capacity less the sum of existing aggregate generation capacity and aggregate queued generation capacity.
5. Substation nominal distribution voltage and/or transmission nominal voltage, if applicable.
6. Nominal distribution circuit voltage at the proposed site.
7. Approximate circuit distance between the proposed site and the substation.
8. Relevant line section(s) peak load estimate, and minimum load data, when available.

[8] Ohio Administrative Code 4901:1-22-04
[9] AEP, Interconnection Process, Available at: https://www.aepohio.com/global/utilities/lib/docs/builders/aepohio/Interconnection%20Process.pdf

9. Number and rating of protective devices and number and type (standard, bi-directional) of voltage regulating devices between the proposed site and the substation/area. Identify whether substation has a load tap changer.
10. Number of phases available at the site.
11. Limiting conductor ratings from the proposed point of interconnection to the distribution substation.
12. Based on the proposed point of interconnection, existing or known constraints such as, but not limited to, electrical dependencies at that location, short circuit interrupting capacity issues, power quality or stability issues on the circuit, capacity constraints, or secondary networks.[10]

After the preapplication report is delivered, AEP will conduct an engineering study to determine if the proposed distributed generation system complies with technical requirements and to evaluate how it will impact their distribution system. At a minimum, AEP is required to evaluate:

1. Institute of Electric and Electronics Engineers 1547 standard
2. Underwriters Laboratory 1741 standard for inverters, converters, and controllers for use in independent power systems
3. Additional appropriate criteria and interconnection parameters for the applicant's technology

After the engineering study is conducted, AEP will share the study's results. If the proposed system does not comply with the technical requirements, AEP will provide changes that are needed to meet the requirements. In addition, AEP may also determine that minor changes to their distribution system will need to be made to accommodate the distributed generation system. If the recommended changes are made and the applicant agrees to pay for the necessary modifications to the AEP distribution system, the study can be completed. At this point, AEP will provide the applicant with a proposed interconnection agreement and a construction agreement, if modifications to the AEP system are required.

If the microgrid meets the technical requirements but AEP deems that it will affect the distribution system, the applicant will need to pay for an additional study to determine the impact it will have on AEP's systems. If the applicant agrees to pay for the study and to fund any necessary changes, system modifications, or system upgrades to AEP's distribution system, an interconnection agreement and a construction agreement will be provided.

Once the interconnection agreement is signed and payment is made for studies and/or construction costs, AEP will give approval to begin construction of the distributed generation system. AEP may request to observe the installation of the system and any commissioning tests. Once commissioning is complete, the applicant will provide AEP with a copy of the final inspection checkout, the results of the commissioning tests, and a proposed list of periodic interconnection test procedures. Once this material is reviewed and approved, AEP may grant written permission to begin the operation of the distributed generation system.

The proposed microgrid is likely to make SARTA a "self-generator." A self-generator is "an entity in this state [Ohio] that owns or hosts on its premises an electric generation facility that produces electricity primarily for the owner's consumption and that may provide any such excess electricity to another entity, whether the facility is installed or operated by the owner or by an agent under a contract." As a self-generator, Ohio Revised Code 4928.15 entitles SARTA to contract with its utility provider for backup electricity supply (also known as standby service).

[10] Ohio Administrative Code 4901:1-22-04

Standby service tariffs are established in PUCO No. 20, Revised Sheet No. 227.[11] There are three components of standby service. Supplemental Service is power that is intended to provide additional power to meet the facility's energy needs. Supplemental Services is power beyond what is provided by the facility's generation assets. Backup Service is power provided when a facility's generation assets are not operational due to unscheduled maintenance. Lastly, Maintenance Service is power provided when a facility's generation assets are not operational due to scheduled maintenance. Standby service includes one or more of these components. The facility may contract with their utility for standby service. Monthly charges for standby service is governed by the General Service Schedule. The SARTA Microgrid may qualify for two different schedules for standby power.

The microgrid will qualify for standby power under Schedule GS-3. Schedule GS-3 tariffs apply to facilities where the maximum demand exceeds 10 kW but is less than 8000 kW. The standby rates under GS-3 are as follows:

| Schedule Codes | | Distribution |
|---|---|---|
| 240, 242, | **Secondary Voltage:** | |
| 250 | Demand Charge ($ per KW) | 4.16 |
| | Excess KVA Demand Charge ($ per KVA) | 3.82 |
| | Off-Peak Excess Demand Charge ($ per KW) | 4.16 |
| | Customer Charge ($) | 22.79 |
| 244, 246, | **Primary Voltage:** | |
| 254 | Demand Charge ($ per KW) | 3.76 |
| | Excess KVA Demand Charge ($ per KVA) | 3.82 |
| | Off-Peak Excess Demand Charge ($ per KW) | 3.76 |
| | Customer Charge ($) | 95.47 |
| 248, 256 | **Subtransmission Voltage:** | |
| | Excess KVA Demand Charge ($ per KVA) | 3.82 |
| | Customer Charge ($) | 512.00 |
| 245, 257 | **Transmission Voltage:** | |
| | Excess KVA Demand Charge ($ per KVA) | 3.82 |
| | Customer Charge ($) | 512.00 |

A microgrid might also qualify for net metering, and thereby avoid having to purchase standby power. In the State of Ohio, net metering is governed by Ohio Administrative Code 4901:1-10-28. To qualify for net metering, the distributed generation system will need to comply with all of the following requirements:

1. Is fueled by solar, wind, biomass, landfill gas, or hydropower, or uses a microturbine or a fuel cell.
2. Is located on the customer-generator's premises.

[11] Ohio Power Company. "PUCO No. 20" Available at: https://www.puco.ohio.gov/emplibrary/files/docketing/tariffs/Electric/Ohio%20Power%20Company/PUCO%2020%20Standard%20Service.pdf.pdf

3. Is designed and installed to operate in parallel with AEP's system without adversely affecting the operation of equipment and service of AEP and its customers and without presenting safety hazards to AEP personnel or other customers.
4. Is intended primarily to offset part or all of the customer-generator's electricity needs.
5. The generating equipment is installed in accordance with the manufacturer's specifications and the National Electrical Code.
6. All equipment and installations comply with all applicable safety and performance standards established by the National Electrical Code, the Institute of Electrical and Electronic Engineers, Underwriters Laboratories, and any additional control and testing requirements adopted by PUCO.[12]

The electric utility's tariff for net metering must have the same rate structure, retail rate components, and monthly charges as the customer would have if they were not participating in net metering. The utility is responsible for calculating the net energy produced or consumed by the facility. If the customer is a net electricity consumer, it will be charged for its usage at normal rates. However, if a customer is a net electricity producer, the excess energy will be treated as a credit that will contribute to future billing cycles.

## In Front of the Meter

*PowerForward* defines in front of the meter as the part of the distribution system operated by utilities. However, the regulatory environment for in front of the meter microgrids remains unclear. In the past, PUCO has approved an in front of the meter microgrid. In 2017, PUCO allowed AEP Ohio to spend $10.5 million to develop utility microgrids for "public serving" facilities like fire & police stations, government buildings, hospitals, and water treatment plants. These costs were passed through to ratepayers within the AEP distribution utility system. The funds were intended to demonstrate microgrid projects. In addition, AEP Ohio was allowed to pursue a non-public serving microgrid. However, in both of these cases, AEP Ohio was not allowed to own behind-the-meter energy generation assets or energy storage resources.[13]

The AEP Ohio microgrids align with PUCO's objective of deploying non-wire alternatives to expand capacity and defer additional investments in distribution infrastructure. While PUCO allowed AEP Ohio to proceed with this project, it appears that regulations for deploying in front of the meter microgrids are still in their infancy. *PowerForward* states that the utility will continue to maintain its role as the owner and caretaker of the distribution system. It also leaves open the possibility that a "customer-specific application" could be installed in front of the meter. In such a case, the application would need to meet the utility's system requirements since the utility is ultimately responsible for guaranteeing the distribution system's stability and reliability.

Recent developments indicate that PUCO will ultimately support the implementation of customer-specific microgrid applications. At the May 1, 2019 meeting of the *PowerForward* Distribution System Planning Workgroup, the Workgroup proposed that third parties will be able to own front of meter distributed generation and energy storage assets. While this proposed has not been finalized, it appears that PUCO may ultimately allow third parties to own front of meter assets. However, it is important to remember that

[12] AEP. Net Energy Metering Service, https://www.aepohio.com/global/utilities/lib/docs/builders/aepohio/NetEnergyMeteringServicev1.pdf
[13] Elisa Wood. "Utility Microgrids Make Progress in Arizona and Ohio." Microgrid Knowledge. 1 September 2017. Accessed 8 July 8, 2019. Available: https://microgridknowledge.com/utility-microgrids-arizona-ohio/

these developments only represent a policy framework and that the regulations governing ownership of in front of meter assets still need to be fully developed.

## Regulations on Microgrid Components

The Ohio EPA and the Federal government have enacted regulations that will impact the operational abilities of microgrid components. These regulations will have a major impact on the deployment of diesel generators and natural gas turbines. Any generator or turbine that produces criteria emissions must obtain a permit-to-install and operate (PTIO) before it is installed and operated. A PTIO will establish emissions limits for the generator and operational restrictions that will ensure compliance with the emission limits. The operator is also required to monitor and maintain records about emissions from the generator. The PTIO must be renewed on a 5-year or 10-year cycle.[14]

The PTIO process can be avoided by obtaining a permit-by-rule (PBR). A PBR allows the operator of a low-emitting air pollution source to bypass the PTIO process. Generators that burn natural gas, propane or liquified petroleum gas, gasoline, or distillate oil are eligible for a PBR. An emergency electrical generator, which is defined as "a stationary reciprocating engine or stationary turbine engine, whose operation is limited to emergency situations and readiness testing and maintenance," is eligible to receive a PBR.[15] However, the PBR does place restrictions on the operation of an emergency generator. An emergency generator that is powered by an internal combustion engine and has an output of greater than 37.3 kW cannot operate for more than 500 hours in a rolling 12-month period. The generator also cannot be used for non-emergency purposes.[16] A PBR does not expire but must continue to meet all of the required criteria to remain valid.[17]

[14] Ohio Administrative Code Chapter 3745-77

[15] Ohio EPA. "Permit-by-rule Notification Form – Emergency Generator/Pump/Compressor." Available at: https://epa.ohio.gov/portals/27/pbr/PBRGENERATOR.pdf

[16] *Ibid.*

[17] Ohio EPA. (2018). "Permit-by-rule for Air Pollution Sources." Available at: https://www.epa.ohio.gov/portals/41/sb/PBRfactsheet.pdf

# Microgrid Operational Strategies

The microgrid will need to be operated within Ohio's regulatory framework. SARTA will also need to work with its utility company to operate the microgrid. The best strategy for operating the microgrid depends on whether the microgrid will be Behind the Meter (BTM) or Front of the Meter (FTM). BTM and FTM also influences which entity is best suited to partner with. A BTM microgrid would likely require SARTA to partner with an ESCO. If SARTA were to pursue a FTM microgrid, AEP Ohio would be the entity that SARTA partners with.

This section outlines the operational strategies that are best suited for BTM and FTM microgrids. This information was gathered through interviews with AEP Ohio and a microgrid developer.

## Behind the Meter

The SARTA microgrid can be built and operated BTM. This operational model provides a lot of flexibility. Typically, an ESCO will invest in generation projects and become the owner-operator of the microgrid. Under this operational model, there would be no upfront capital expenditures for SARTA because the ESCO would be constructing, operating, and maintaining the microgrid. Alternatively, it would be possible for SARTA to construct and own the microgrid and lease it out to an ESCO. In both situations, the microgrid can be constructed on SARTA's property but the ESCO would need access to it. The ESCO would then operate the microgrid and sign a Power Purchase Agreement (PPA) with SARTA and any other entity to provide power.

The microgrid has the ability to serve SARTA's campus only (including the proposed expansion to house the sanitation department's vehicles) or can be constructed as a district microgrid. If the microgrid is intended to serve other facilities besides SARTA, dedicated lines and communications equipment would need to be run to those facilities and a submeter would need to be installed. While this is technically possible, it is likely that installing the dedicated power lines would be prohibitively expensive. In addition, parts of a BTM microgrid might be subject to standby charges or may require a supplemental contract tariff. While assets like solar production or microturbines would be subject to a net metering agreement, it is likely that any natural gas fueled CHP plant or reciprocating engine would require standby charges.

## In Front of the Meter

The SARTA microgrid can also be designed as a FTM microgrid. If the microgrid is designed as a FTM microgrid, AEP Ohio, the utility serving SARTA, would own and operate the microgrid and its components. AEP Ohio would be responsible for designing and constructing the microgrid. Under this arrangement, AEP Ohio would own and operate the microgrid and SARTA would sign a bilateral agreement to purchase the power produced by the microgrid.

This operational strategy provides some advantages. It is possible that SARTA could socialize the cost of portions of the microgrid throughout AEP's distribution utility territory, as has been done for AEP's prior microgrid investments. However, there are some risks to this strategy. First, it is unclear that the PUCO would approve the microgrid project, since under its current recovery mechanism, it would have to socialize the cost among AEP's ratepayers. And second, the microgrid would thereafter be regulated by PUCO, which can introduce regulatory costs and delays to the project. A FTM microgrid may have to serve purposes other than powering SARTA's facility. This is especially true for the energy storage components of the microgrid. PUCO will only approve AEP Ohio ownership of energy storage assets if it can be demonstrated that it benefits the grid as a whole. As a result, key components of the microgrid will have to serve both the grid's needs as well as SARTA's needs. Lastly, AEP Ohio is not interested in owning or operating any hydrogen or trigeneration assets. AEP Ohio is only interested in managing electricity assets and is not interested in managing the hydrogen or trigeneration assets.

### *AEP Ohio Microgrid Pilot Program*

During this project, CALSTART explored the option of building a FTM microgrid through AEP Ohio's Microgrid Pilot Program. This program was funded by AEP's Electric Security Plan and the Smart Cities Rider. The pilot program provided funding for the majority of the capital expenditures of a microgrid as well as operations and maintenance costs (until 2024) in the form of a rebate. The pilot program would have funded the majority of the microgrid (up to 90-95%) but SARTA would have needed to share some of the costs. To qualify for the pilot program, the microgrid equipment must be owned by a nonprofit. This would require that SARTA own the microgrid. AEP Ohio could operate the equipment, own the microgrid controller, and fund maintenance until the end of the pilot period, at which point the responsibility for maintenance would transfer to SARTA. The project must provide some sort of "social good" benefit that helps both the utility and the host of the microgrid. Things that would be considered social good benefits would include, but are not limited to, increased reliability, carbon emission reductions, technology demonstrations, and projects that benefit low income residents. To meet the social good criteria, it is possible that the entire microgrid would need to be powered with renewables and energy storage. Lastly, there is a data collection requirement, meaning that AEP Ohio would have needed to collect data from the equipment until the pilot period ends.

A microgrid constructed under this program would require a unique operational strategy, involving two agreements. The first agreement would be between SARTA and AEP Ohio. This agreement would allow AEP Ohio to operate the microgrid, which would be owned by SARTA. The second agreement would be between SARTA and anyone else connected to the microgrid.

SARTA was initially interested in building the microgrid via the pilot program. However, there were some time constraints. First, to qualify for funding through the pilot program, the microgrid would need to be in service by the end of 2020.

Furthermore, there was only $10.2 million in funding remaining in the pilot program. AEP Ohio wants to fund multiple projects meaning that it could not devote all the funding to an individual project. As a result, it was unlikely that the Microgrid Pilot Program would be able to fund the entire microgrid project. In addition, AEP Ohio was considering other microgrid projects meaning that there was competition for the available funds. As of January 2020, AEP Ohio determined to not accept any more proposals. As a result, absent a new electric security plan, the only remaining avenue for working with AEP Ohio on this microgrid would be if HB 247 passes, which would allow it to be built BTM. However, since HB 247 was introduced in May 2017, it has not advanced out of committee. As a result, it is unlikely that HB 247 will be enacted in the near future.

# Microgrid Technical and Economic Assessment

This study examined three different microgrid scenarios

## 1 Trigeneration Microgrid

The first scenario we explored was using a trigeneration microgrid to provide power for the SARTA facility. Under this scenario a FuelCell Energy SureSource 3000 fuel cell would be used to produce electricity and heat for the facility, and hydrogen for the buses. The turnkey capital expenditures associated with building and installing the SureSource 3000 would be $25 million to $30 million[18]. In addition, since the SureSource 3000 consumes approximately 521.3 MCF of natural gas per day, SARTA would likely experience an increase in its natural gas utility bills. Based on current utility rates, this increase in natural gas consumption is projected to be at least $12,514.06 - $12,979.76 per month. Due to the high capital expenditures, this option was deemed to be infeasible.

## 2 District Microgrid

The second scenario we explored was a microgrid that serves SARTA's campus and the City of Canton community center/health clinic (see Appendix A). Under this scenario, the hydrogen would be produced via SMR or electrolysis. This microgrid assumes that the dispensing equipment loads, the servers, and the garage maintenance/air handlers are critical, uninterruptible loads. The rest of the facility, as well as the City of Canton's facilities, are considered to be a critical, interruptible load. This microgrid has a bidirectional connection to the utility grid. In the event of a grid outage or failure, the microgrid will island and will continue to serve the facilities. The microgrid is designed to operate in islanded mode for up to 24 hours. A district microgrid can be constructed either BTM or FTM. In a BTM microgrid, the microgrid components would be located on SARTA's site and power lines would need to be constructed so the microgrid can provide power to the City of Canton's facilities. In a FTM microgrid, the components would also be located on SARTA's site. Since the microgrid would be FTM, there was the possibility that AEP's equipment could be used to transport the power from SARTA's facilities to the City of Canton's site. However, since the SARTA site and the City of Canton's facilities are not on the same feeder, it is not possible to do this. As a result, a FTM microgrid would also need to include power lines so the electricity can be transported to the City of Canton. Constructing power lines was deemed to be prohibitively expensive and as a result, both a FTM and BTM district microgrid has been deemed infeasible.

## 3 Campus Microgrid

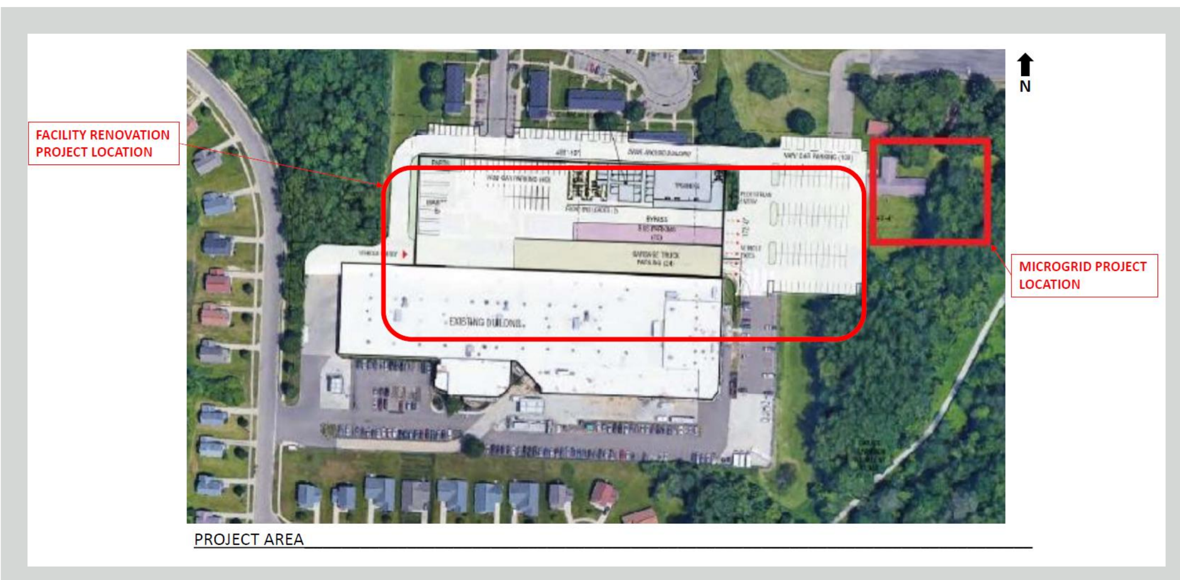
The final scenario we explored was a microgrid that would exclusively serve SARTA's facility. This design would need to serve SARTA's garage, the CNG fueling station, the hydrogen production equipment, and the hydrogen chilling, compression, and dispensing equipment for a minimum of 24 hours. At the time of writing, AEP Ohio was unable to be a partner to build a FTM microgrid. As a result, we explored prospects for designing a BTM campus microgrid.

---

[18] Jerald A. Cole and Maureen Marshall. (2020). "Expansion of Stark Area Regional Transportation Authority Hydrogen Refueling Capabilities: A Feasibility Study." *See*: http://www.midwesthydrogen.org/site/assets/files/1413/sarta_expansion_hydrogen_refueling_capabilities_final.pdf

CALSTART explored designing a BTM microgrid with either an electrolyzer or a steam methane reformer. CALSTART's analysis indicated that the electrolyzer would need approximately 2.3 MW of power at all times and would consume approximately 55.2 MWh of energy per day, in addition to the energy that the facility will consume. Providing this much energy without grid power would be a major challenge. SARTA is also limited in its ability to generate this much onsite energy. Previous analysis indicates that SARTA would need 13.9 MW DC of solar panels just to power the electrolyzer. Since SARTA has limited space, providing this much power via solar would not be feasible and SARTA would need to primarily produce this energy with natural gas generators or get it from the grid.

CALSTART also examined using a steam methane reformer to produce SARTA's hydrogen. A steam methane reformer consumes much lower amounts of power, meaning that it would be easier to power SARTA's facility and the hydrogen production without grid power. Furthermore, CALSTART deemed that using a steam methane reformer would be more energy efficient than the electrolyzer at the size SARTA would require. Since the reformer directly converts natural gas to hydrogen, there would be fewer energy conversion losses as compared to a scenario where natural gas is run through a generator to produce electricity that is used to power electrolysis. Due to these factors, the steam methane reformer was determined to be a better fit for SARTA's needs. However, design analysis for a microgrid that can serve a steam methane reformer and an electrolyzer is included in this report.




## Steam Methane Reformer Microgrid Design

A microgrid developer provided analysis for the design of the microgrid. Based on the provided parameters, the microgrid developer proposed that the microgrid consist of solar, diesel generators, natural gas generators, and a microgrid controller, together with a grid connection. The developer decided that this would be the best distributed generation portfolio due to the site's high load factor. SARTA's facilities have a load factor of 80% meaning that the average load is 80% of the maximum load. This implies that the facility runs near peak load for most of the day. Due to the high load factor, battery storage would not be an appropriate solution. The high load factor means that SARTA would need a very large battery system to provide the required energy storage, which would be economically infeasible. Instead, the developer's microgrid design calls for 490 kW of rooftop solar located on the roof of SARTA's garage, the preexisting diesel generators, and 750 kW of natural gas generators.

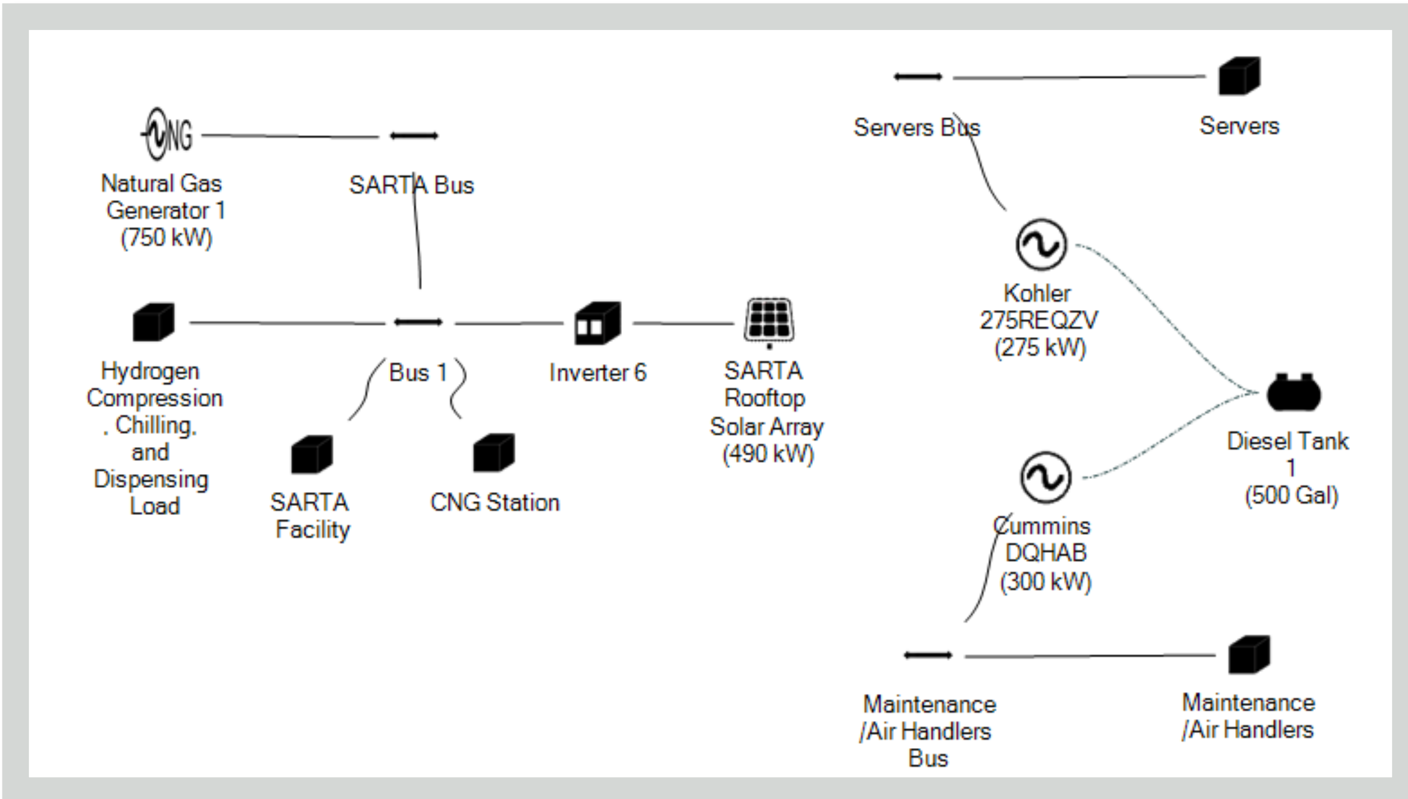
This design provided by the developer was modeled in the Microgrid Design Toolkit (MDT), a software program developed by Sandia National Laboratories. MDT allows users to input relevant site-specific characteristics like utility electricity rates, natural gas charges, energy consumption (including time of use), frequency of outages and grid failures, and solar energy production potential. MDT is designed to allow users to select what types of components and equipment they are willing to use in the microgrid and input equipment characteristics like estimated capital expenditures and fuel utilization rates. Once this data is input into the model, the user can specify custom design parameters. MDT then provides quantitative analysis to determine feasible designs that can meet all of the criteria. MDT assumes that there are tradeoffs between the different design parameters. For example, increasing the reliability and time that the microgrid can operate involves installing additional generation and storage assets, which increases the cost. To balance these tradeoffs, MDT's algorithms create a Pareto frontier to optimize performance of the design parameters. It then recommends designs on the Pareto frontier that are able to meet all of the design parameters.

Our MDT model optimized for several criteria. SARTA has three principal criteria: cost, energy availability (percent of load served by the microgrid), and low emissions. For the first criteria, SARTA seeks a microgrid design that provides resiliency at the lowest cost possible. For the second criteria, SARTA wants proven technology that provides maximum reliance. For this reason, SARTA seeks sufficient local generation to support its critical loads during an outage. This includes the proposed hydrogen production facility, hydrogen and CNG compressors and dispensing equipment. SARTA also has vital IT server and air handling equipment (to ensure hydrogen does not accumulate in the bus garage) that must continue to be powered in the event of an outage. As a result, the CNG fueling station, the hydrogen production and dispensing equipment, the server equipment, and the air handling equipment were considered to be critical uninterruptible loads, meaning that in the event of islanding, these loads would not be shed. The load from compressing natural gas into the SMR was not included in this analysis.

The rest of the SARTA depot was considered to be a secondary interruptible load that can be shed in the event of an outage, and insufficient local generation to support all demand. The microgrid was designed to guarantee that critical, uninterruptible loads would attain a minimum energy availability of 99% and secondary, interruptible loads would maintain an energy availability of at least 94%.[19] MDT was also programmed to maximize the use of solar energy. Lastly, MDT was programmed to achieve a 20% spinning reserve, which is additional power capacity above the load requirements, to be able to respond to voltage spikes.

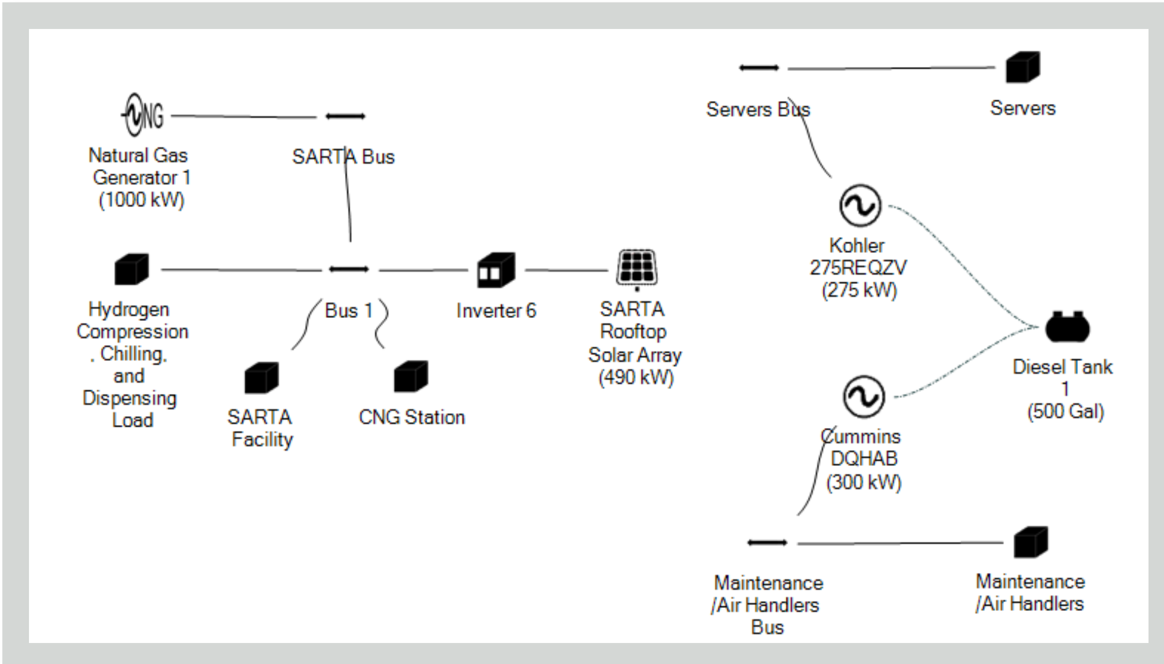
The developer's proposed design was modelled in MDT to determine if it could meet the design parameters. MDT was programmed to simulated one 24-hour outage, one 48-hour outage, and a week-long outage each year. The MDT model indicated that the design would only meet 91% of the energy needs for the critical, uninterruptible loads, meaning that this load could only be met if the load from the bus garage (except for the air handlers and servers) is shed in the event of an outage.

[19] Based on discussion with Sandia National Labs.

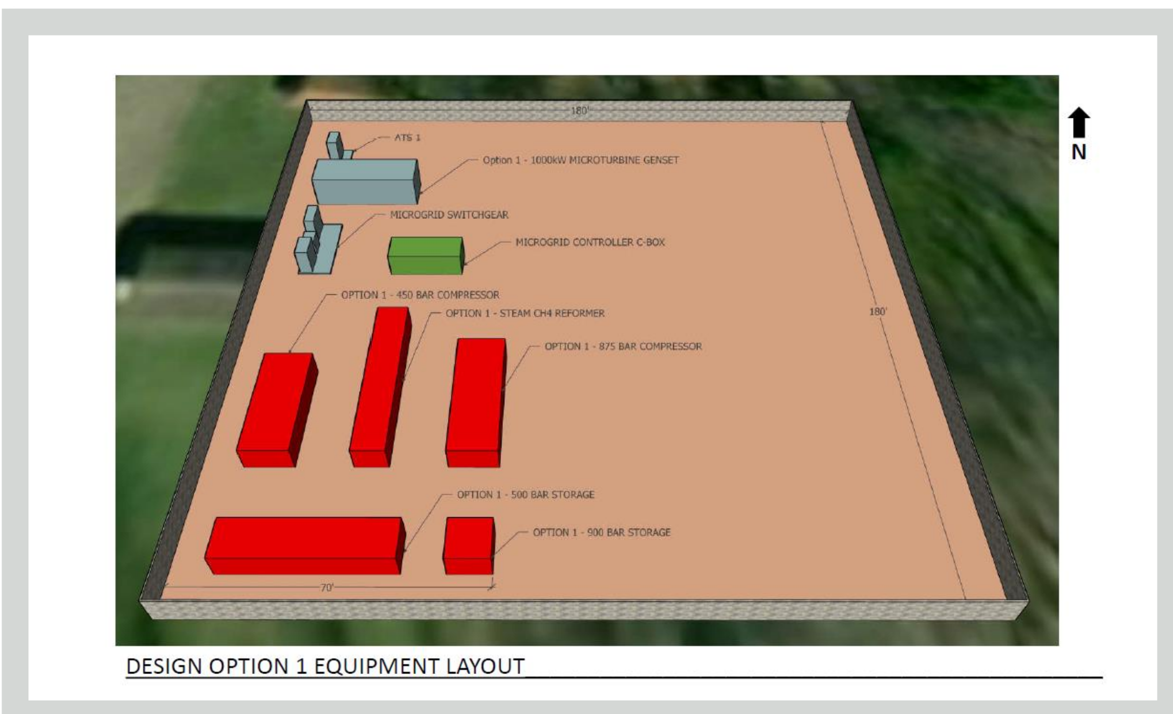



**Design as proposed by the microgrid developer**

The results from the MDT model indicated that the 750 kW natural gas generator might be too small for this system. As a result, a second MDT model was run that replaced the 750 kW natural gas generator with a 1000 kW natural gas generator. The results indicated that this design would provide 99.9% energy availability for the critical, uninterruptible loads without having to shed any loads in the event of an outage. As a result, it would appear that that 1000 kW natural gas generator is a more appropriate size for this microgrid (see Appendix B).




**MDT Design with Hydrogen Production via SMR**




**Steam Methane Reformer Microgrid Conceptual Design**

The main constraint on this microgrid design is the availability of fuel. It is important to note that these results assume that fuel for the natural gas and diesel generators should be available during a grid outage. Since natural gas is delivered via pipeline to SARTA, the only circumstances under which natural gas would not be available would be if the pipeline network were to be disrupted. Since Ohio has few natural disasters that are likely to disrupt the natural gas pipeline network (i.e. earthquakes), it is safe to assume that natural gas will be available. A bigger concern is access to diesel. SARTA currently has 500 gallons of diesel in on-site storage, which is enough to power the diesel generators for approximately 24 hours at full power or for approximately 48 hours at half power. If an outage were to extend beyond this, SARTA would need to procure additional diesel to continue operating the diesel generators. During an emergency, however, it can be difficult to obtain diesel if roads are disabled or if fuel is diverted to emergency responders and crisis management teams.[20]

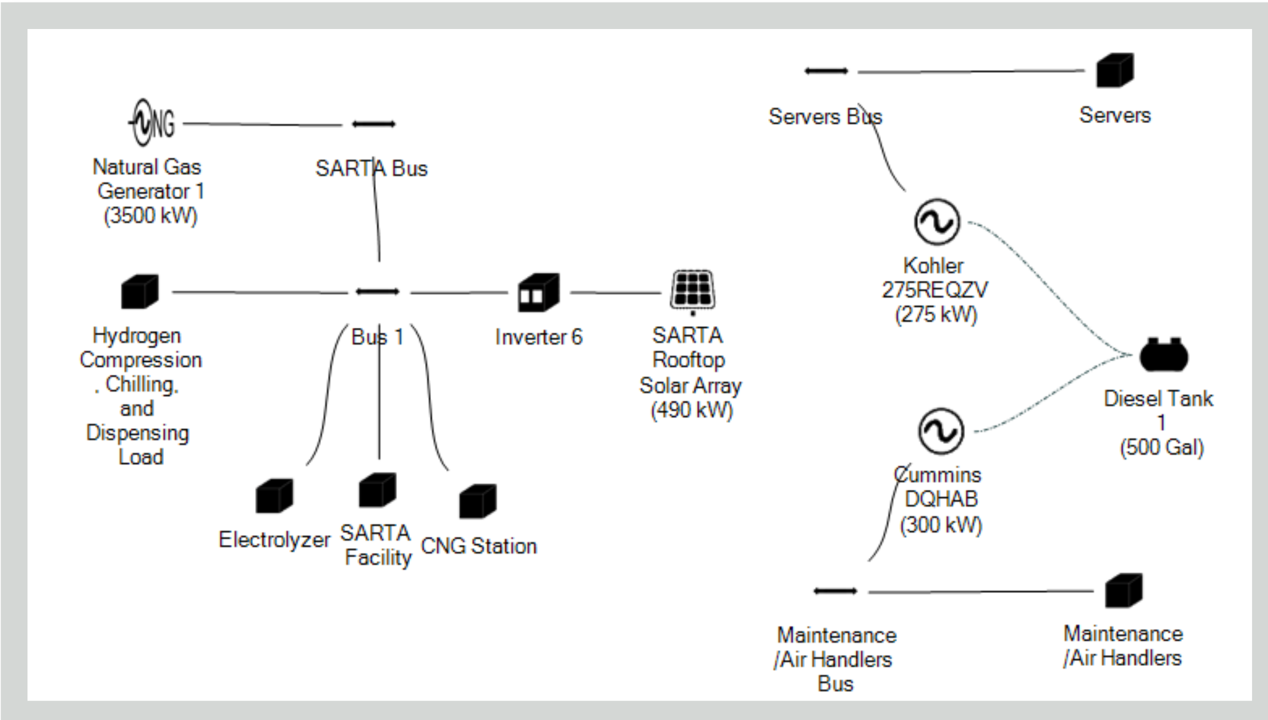
Despite confirmation of the validity of this design, a decision will need to be made about the type of natural gas generator that will be used in the microgrid. The microgrid can use either reciprocating engines or a microturbine. Reciprocating engines are cheaper to install but require more maintenance. Microturbines are slightly more expensive but do not require as much maintenance. However, the ability to net meter microturbines could be critical to avoiding standby charges or special supplemental contract tariffs.

In addition to providing resiliency for the bus depot, the microgrid can also be used to generate revenue through demand response programs, net metering, or selling excess electricity on PJM energy markets. Reciprocating engines cannot be net metered in the State of Ohio and as a result would not be able to receive market value for excess energy. However, microturbines can be net metered and can offset the entire cost of the delivered electricity (minus demand charges).[21] As a result, this decision is important because it will influence the types of activities the microgrid can engage in. To maximize the value and capabilities of the microgrid, it is highly recommended that SARTA uses microturbines.

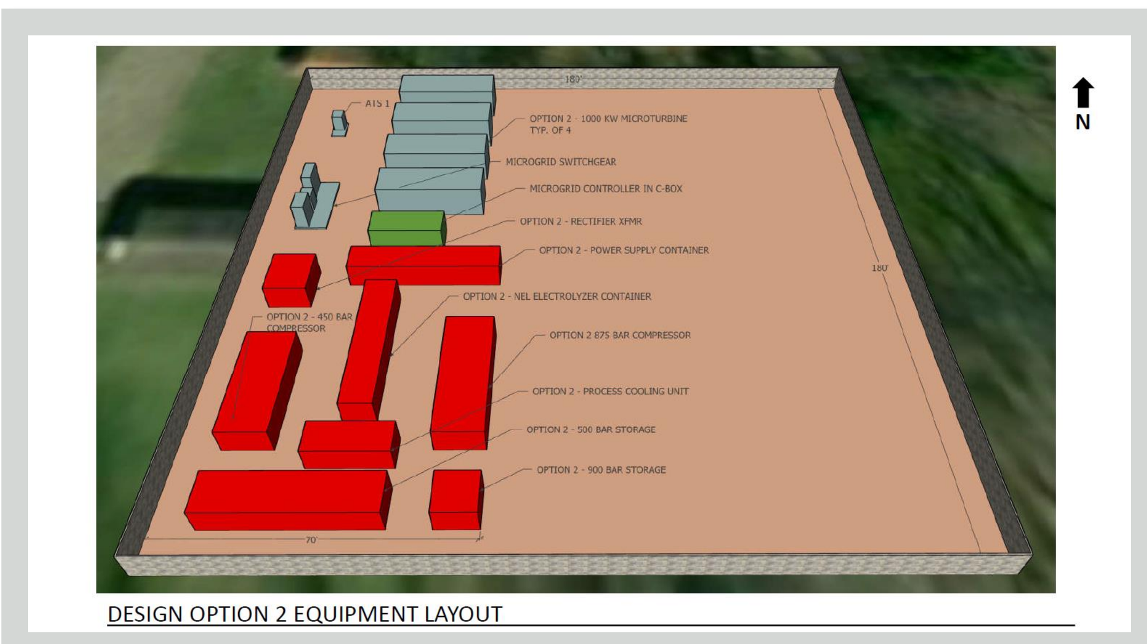
### *Electrolyzer Microgrid Design*

If SARTA opted to produce its hydrogen with an electrolyzer, the power demands of the microgrid would increase. The electrolyzer and its balance-of-plant components consume approximately 2.3 MW of power. A microgrid that supports hydrogen production via electrolysis could continue to use a similar design as a microgrid that serves hydrogen production via steam methane reforming. However, it would need a larger natural gas generator. Modelling with the MDT toolkit indicates that a microgrid that contains 490 kW of rooftop solar, incorporates the existing diesel generators, and includes a 3500 kW natural gas turbine would be able to power this facility. However, since microturbines are generally built in 1000 kW increments, this design will require a 4000 kW generator (see Appendix B).

[20] Ericson, Sean and Dan Olis. (2019). A Comparison of Fuel Choice for Backup Generators. Golden, CO: National Renewable Energy Laboratory. NREL/ TP-6A50-72509. https://www.nrel.gov/docs/fy19osti/72509.pdf.
[21] Ohio Administrative Code 4901:1-10-28.




**MDT Design with Hydrogen Production via Electrolysis**




**Electrolyzer Microgrid Conceptual Design**

## Other Design Considerations

It is important to note that the above designs are conceptual, and not intended to be the only microgrid solution, nor the final designs. Final designs will need to be prepared by the developer and will depend on several factors that are currently unknown. Some of these factors include the actual costs for the procurement and installation of microgrid equipment and whether the new buildings being constructed as part of SARTA's facility expansion can host solar panels, which would allow for additional solar. Before the microgrid is built, additional analysis will need to be conducted to further refine the design so that it best meets SARTA's needs.

There are also variations of these designs that can be included, depending on SARTA's needs. The above designs did not include a battery because SARTA's facility has a high load factor and batteries would add substantially to the capital expenditures. However, batteries can provide value to a microgrid as they can be deployed to power the microgrid during shorter outages. The use of the battery would eliminate the need to start up the generators during shorter outages, which would save fuel. A battery that is sized to power SARTA's facility for about 2-3 hours, which is long enough to serve the facility for the average grid outage event, would allow SARTA to avoid fuel costs during shorter outages. Furthermore, the addition of a battery may allow SARTA to use the microgrid to manage peak load contribution and to provide revenue-generating ancillary services (see Analysis of Other Revenue and Savings Section).

## Projected Energy Costs

The cost to purchase and install the microgrid as designed by the microgrid developer (with a 750 kW natural gas generator) would be approximately $2 million and would likely fall within a range of $1.75 to $2.25 million. This estimate assumes that the cost to build the solar panel system would cost $700,000 and the cost installed for the natural gas generator would be approximately $1,5000 per kW. This also assumes that the microgrid controller is approximately 15% of the microgrid cost. If the microgrid instead used a 1000 kW natural gas generator, the estimated cost would rise to approximately $2.5 million. These figures do not include any upgrades to transformers or switchgear. The capital expenditures of the microgrid design with the electrolyzer would rise to approximately $6.8 million. Grants from the Department of Energy or other governmental agencies could possibly be leveraged to fund this project.

The microgrid developer estimates that power from their design can be provided at a base rate of $0.07 - $0.09 per kWh. The levelized cost of energy for the electrolyzer design would likely be substantially higher due to the high capital expenditure costs associated with that design. There are, however, a few factors that can influence this estimated levelized cost of energy. The type of natural gas generator will have a major impact. If a reciprocating engine is used, the energy produced by the generator could not be net metered. This means that the microgrid would then be subject to standby charges, which can add substantially to the levelized cost of energy. If a microturbine is used, the energy produced by the microgrid could then be net metered. However, more clarification is need about the impacts this will have for energy costs. While energy costs would be net metered, it is unclear how much demand charges and transmission charges can be reduced. Another key question is obtaining power to fill the gap between the amount of energy that is produced by the microgrid and the energy requirements of the facility. Although the microgrid components will be sized to provide resiliency for the facility under most circumstances, there are still instances where the instantaneous energy demand exceeds the generation capacity of the microgrid. In such a case, SARTA would need to use grid power to make up for this shortfall. This would likely add to energy costs. Further investigation will be needed to optimize the microgrid system to minimize the size of this shortfall and to understand how this will affect energy costs.

## *Sustainability*

One of SARTA's objectives for transitioning to a zero-emission fleet is to reduce the environmental impact of their transit operations. As a result, in addition to adopting zero emission buses, SARTA aims to fuel its buses with zero- or low-emission fuel sources. SARTA has already explored options for using landfill gas in a SMR to provide renewable hydrogen for its buses.[22] However, SARTA also has an interest in operating its facilities in an environmentally responsible manner, and where possible, that these facilities are powered with renewable energy.

It is important to note that transitioning to onsite hydrogen production would reduce SARTA's carbon footprint, especially if carbon dioxide can be captured and used from steam reformation. Currently, SARTA uses liquid hydrogen that is delivered via truck. This hydrogen is produced via steam methane reforming and is trucked from Ontario, Canada, which is approximately 280 miles away. According to Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, the delivered hydrogen has a wells-to-pump carbon intensity of 14.9 kg of carbon dioxide for each kg of hydrogen produced. However, the well-to-pump carbon intensity of hydrogen produced via onsite SMR would be 11.95 kg of carbon dioxide per kg of hydrogen. This represents an approximately 20% decrease in carbon intensity, even without capturing the carbon dioxide.

The SARTA microgrid also offers potential sustainability improvements to business as usual. The proposed design includes an energy portfolio of solar panels, natural gas generators, and diesel generators. As a result, while solar energy is in the energy portfolio, the proposed use of generators commits SARTA to using fossil fuels to power the microgrid. To operate the microgrid, SARTA would be heavily reliant on natural gas to produce power, which will produce greenhouse gas emissions. However according the GREET Model, the electricity produced by the microgrid will be less carbon intensive than grid power. According to AEP Ohio's sustainability reports, its energy portfolio is 29% coal, 31% natural gas, 34.5% nuclear, 2.5% wind, 1.5% hydroelectric, 0.5% solar, 0.5% biomass, and 0.5% from other sources.[23] Assuming that this energy portfolio is representative of Ohio's grid power, the GREET Model estimates that standard grid power electricity emits 0.42 kg of carbon dioxide per kWh of electricity. The GREET Model estimates that a natural gas simple cycle generator, will produce 0.35 kg of carbon dioxide per kWh. As a result, the microgrid is expected to produce 17% fewer carbon dioxide emissions than typical grid power.

If SARTA wanted to become carbon neutral, they could use renewable natural gas to produce hydrogen and to power the natural gas turbine. This option would entail purchasing landfill gas (or another source of renewable natural gas) to run through the SMR and/or to power the natural gas turbines. If SARTA uses a SMR to produce their hydrogen, they could purchase renewable natural gas for use in both systems. Alternatively, in the event of an outage, the SMR could theoretically be turned off and the renewable natural gas that it uses be diverted for use in the natural gas turbine. This would allow the hydrogen production equipment and turbines to operate with a carbon neutral fuel. It is important to note

[22] Jerald A. Cole and Maureen Marshall. (2020). "Expansion of Stark Area Regional Transportation Authority Hydrogen Refueling Capabilities: A Feasibility Study"
[23] AEP Ohio. "Environmental Disclosure Information – Quarterly Comparisons" Available at: https://aepohio.com/global/utilities/lib/docs/environment/2019MarchQuarterlyComparison.pdf

that the current market price for landfill gas is approximately $15 per dekatherm.  This is significantly higher than the regular natural gas that SARTA purchases.

# Analysis of Other Revenue and Savings

## Projected Value of Savings

### *Resiliency*

One of the main benefits of a microgrid is that it can provide resiliency to the grid. Resiliency is defined as "Robustness and recovery characteristics of utility infrastructure and operations, which avoid or minimize interruptions of service during an extraordinary and hazardous event."[24] The ability to maintain operations and mitigate damages in the event of a power outage is extremely important. Outages can occur for a variety of reasons including conducting maintenance or making upgrades to the system. However, oftentimes outages are unplanned. Unplanned outages can occur because of natural disasters, extreme weather events, cyber attacks, storms, failures in the distribution or transmission systems, or mismanagement of the grid.[25] Unfortunately, outages are inconvenient for customers and can inflict large financial losses if the outage lasts for an extended period of time. Severe power outages, like the one that occurred in the American Northeast in 2003, can even disrupt normal business operations for several days. As a result, a microgrid's ability to promote resiliency is valuable. This is especially true in Stark County, Ohio where there is a relatively high risk of events, like extreme weather and flooding, that have the potential to disrupt the grid.[26]

It is important to distinguish between reliability and resiliency. Reliability is a measure of the grid's ability to avoid local and small-scale disruptions to the grid whereas resiliency is the ability to respond to systemic large-scale and long duration outages. SAIFI, SAIDI, and CAIDI are well established reliability metrics. It is important to note that these metrics only measure short-term outages and do not measure extreme outages that last several days. As a result, these are insufficient metrics for measuring resiliency. Many of the benefits of resiliency are qualitative in nature, making it difficult to establish metrics to measure it. Despite this, SAIFI, SAIDI, and CAIDI figures can be valuable for estimating the frequency at which disruptions to the grid occur. For example, based on these figures from AEP Ohio, a typical facility served by AEP Ohio can expect to experience 1.3 power outages a year that last for an average of 150 minutes.[27]

Microgrids are well equipped to promote reliability and resiliency because they offer distributed energy generation and energy storage. Many microgrids can provide the majority or all of its energy needs yet remain connected to the grid to draw backup power or to sell excess energy produced. However, they can also temporarily isolate from the grid by entering "island mode." If a planned or unplanned outage occurs on the grid, a microgrid can go into "island mode" and provide energy for itself from its distributed generation or energy storage assets. This feature of microgrids provides a certain level of self-sufficiency and the ability to avoid the damages caused by outages, which increases reliability. Since the

[24] Keogh, M., & Cody, C. (2013). Resilience in Regulated Utilities. Washington, DC: National Association of Regulatory Utility Commissioners.
[25] Mike O'Boyle "What 'Resilience' Means in a Clean Energy Future." *GreenTech Media*. 29 November 2017. Accessed 12 July 2019. Available at: https://www.greentechmedia.com/articles/read/resilience-in-a-clean-energy-future#gs.p9ameu
[26] Stark County (2017). "Stark County 2017 Multi-Jurisdictional Hazard Mitigation Plan." Available at: https://www.starkcountyohio.gov/StarkCounty/media/EMA/Stark-2017_Hazard_Mitigation_Plan-08142017.pdf
[27] AEP Ohio. "Annual performance compared to standard." Available at: https://www.puco.ohio.gov/industry-information/statistical-reports/electric-reliability-performance-data/aep-ohio/

microgrid is self-sufficient, it can play a role in demand response management and can even provide additional power to the grid when needed.  As a result, it also plays a major role in resiliency.

Putting a financial valuation on resiliency is difficult because power outages occur infrequently, and it is difficult to predict the damages that will occur in the event of an outage.  In addition, it is difficult to value the grid management services that microgrids can provide.  One way to value resiliency is to use revealed preference methods.  These methods involve observing behaviors that defend against the damages that would be caused by an outage.  In this context, this entails observing how much entities spend on resiliency improvements.[28]  There have been some observed defensive behaviors.  For example, in 2009, the City of Henderson, Kentucky, invested $330,000 in a diesel generator to protect Henderson Area Rapid Transit facilities against power outages.[29]  A study conducted by Cleveland State University in 2017 showed that the cost for data centers to go from 99.93% (SAIDI, SAIFI grid uptime) to 99.999% uptime is between 5-20 cents per kWh.[30]

Other transit agencies have considered installing microgrids and have explored the costs associated with implementing this resiliency measure.  The amount that these transit agencies are willing to pay for a microgrid constitutes a revealed preference method.  Many of the agencies considering installing a microgrid are larger transit agencies who will need to electrify hundreds of buses.  However, the revealed preference valuation for these transit agencies can be adjusted proportionally to calculate the value of resiliency for a smaller fleet.  Using this methodology, the net present value of resiliency for a fleet with 17 buses is $2,614,766.95.[31]  This figure is consistent with the projected capital costs of SARTA's microgrid, based on the steam methane reformer design.

The microgrid is also likely to have positive externalities for the surrounding community.  These positive externalities should also be accounted for in resiliency figures.  If there is a grid outage that disrupts transit service, it will affect entities other than SARTA.  If transit service stops, many riders would struggle to find alternative methods of transportation.  Since many riders rely on SARTA for transportation to work and school, disruptions to transit service would almost certainly have a negative economic impact on Canton and surrounding communities.  As a result, the microgrid provides positive externalities for the local community.  These externalities, while difficult to quantify, are an additional resiliency benefit.

## Demand Response

Demand response programs allow electricity end-users to curtail the amount of energy it draws from the grid during times of high demand, high electricity prices, or when the grid is experiencing reliability problems in exchange for payments.  Typically, during a demand response event, a utility customer will decrease its grid energy consumption by reducing the amount of HVAC it uses or even by partially or fully curtailing activity at its site.  Some industrial sites will engage in demand response by using backup

---

[28] National Association of Regulatory Utility Commissioners. "The Value of Resilience for Distributed Energy Resources: An Overview of Current Analytical Practices." Available at: https://microgridknowledge.com/white-paper/value-resilience-distributed-energy-resources/

[29] FTA.  "Cumulative Table of ARRA Section 1512 Reports Submitted by FTA Grant Recipients." Available at: http://www.fta.dot.gov/about/12350_10542.html

[30] Thomas, Andrew R. and Henning, Mark, "Valuing Resiliency from Microgrids: How End Users Can Estimate the Marginal Value of Resilient Power" (2017). *Urban Publications*. 0 1 2 3 1516. https://engagedscholarship.csuohio.edu/urban_facpub/1516

[31] CALSTART internal reference calculations

power during peak hours.[32] The SARTA microgrid can potentially emulate this model of demand response and generate revenue by islanding during demand response events and producing its own power.

PJM offers two types of demand response programs that end-users may choose to participate in. Economic demand response is a voluntary program that allows end-users to reduce its load when the wholesale price of electricity is high. During an economic demand response event, the curtailed load is used to displace generation resources. The end-user will receive payments for reducing its load. PJM also offers an emergency demand response program where customers are offered financial incentives to reduce load during times when there is a power supply shortage on the grid.

PJM contracts with curtailment service providers to manage demand response. Curtailment service providers are entities that work with electricity end-users to aggregate demand response requests, submit the requests and verification to PJM, and disburse demand response payments. Typically, curtailment service providers are utilities or energy service companies. AEP Ohio currently does not offer any demand response programs to customers.[33] However, AEP Energy Partners is a registered curtailment service provider that can enroll companies in demand response programs.[34]

Measuring the financial value of demand response is an extremely complex process and requires detailed analysis of PJM energy markets. Much of the information needed to perform this analysis is either proprietary or not publicly available. As a result, SARTA will need to consult with a microgrid developer to determine how a microgrid will affect its ability to participate in demand response markets.

## Projected Value of Revenue Streams

### *Renewable Energy Credits (RECs)*

In 2008, Ohio elected S.B. 221, which mandated an Alternative Energy Portfolio Standard (AEPS). The AEPS stipulated that a certain percentage of energy produced by utilities had to come from alternative energy sources and that a certain portion of the alternative energy had to come from solar. In 2009, the AEPS stipulated that 0.25% of energy produced must come from alternative sources. Each year, the standard increases until 2024, when the standard is set at 12.5%. In addition, there is a “solar carve out,” which requires that a part of the alternative energy comes from solar. In 2009, 0.004% of all energy produced must come from solar and that standard would rise to 0.5% by 2024. In 2014, S.B. 310 froze the AEPS at 2014 levels for two years, after which the standards would resume. As a result, the 12.5% alternative energy standard was delayed until 2026.[35]

To comply with the AEPS, utility companies were required to redeem RECs (also known as green tags). A REC is awarded whenever a MWh is produced from an alternative source and fed into the utility transmission or distribution system. Generation equipment must be approved by PUCO in order to

[32] PJM. “Demand Response Factsheet”. Available at: https://learn.pjm.com/three-priorities/buying-and-selling-energy/markets-faqs/~/media/BD49AF2D60314BECA9FAAB4026E12B1A.ashx
[33] AEP National Accounts. “EE Programs Across AEP System.” Updated 23 July 2018.
[34] https://www.pjm.com/markets-and-operations/demand-response/csps.aspx
[35] DSIRE, “Alternative Energy Portfolio Standard.” NC Clean Energy Technology Center. Available at: https://programs.dsireusa.org/system/program/detail/2934

generate RECs.[36] Solar photovoltaics, wind, geothermal, biomass, biomethane, landfill gas, solid waste, fuel cells, cogeneration, and waste heat recovery are alternative energy sources that can be awarded RECs. RECs are tradeable assets and to comply with the AEPS, utilities may redeem RECs that they generated or purchased on the market. PJM set a price floor for RECs at $45/MWh. In addition, PJM set a price floor at $200/MWh (for 2019 and 2020) for complying with the solar carveout. This price floor will decrease by $50/MWh every two years until it falls to a price floor of $50/MWh.[37] This microgrid will be using generation equipment that can earn RECs. However, RECs can only be earned if the electricity is transferred to utility lines. As a result, the number of RECs generated by this microgrid is dependent on how much energy it produces and how much of this energy is transferred to the grid.

It is important to note that the regulatory framework surrounding RECs has changed. In the summer of 2019, the Ohio General Assembly passed and Governor DeWine signed into law HB 6, which permanently rolled back the renewable portfolio standards in Ohio. In the summer of 2020 two bills were introduced into the General Assembly to repeal HB 6 as a result of a public corruption scandal surrounding the passage of HB 6 that included the arrest by the FBI of the Speaker of the House and a FirstEnergy lobbyist. As of the time of this paper, it is uncertain whether HB 6 will be rescinded, and whether the portfolio standards in Ohio will be reinstated.

### *Frequency Regulation Markets*

Grid managers are constantly aiming to balance energy production and consumption to maintain power frequency and the stability of the grid. If more energy is produced than is being consumed, power frequency will increase and if energy consumption exceeds production, frequency will decrease. Grid operators aim to maintain a frequency of 60 Hz. Grid operators can achieve this by encouraging energy producers to adjust their behavior. PJM manages grid frequency by allowing customers to participate in frequency regulation markets. Under this scheme, customers can generate revenue by helping to manage the grid's frequency. For example, a customer can use a battery to temporarily store energy from the grid when frequency rises. Alternatively, a customer can release energy from their battery to the grid when frequency falls. Demand response can also be used as a method of frequency regulation.

PJM offers two frequency regulation markets. Participation in these markets is triggered automatically by a market signal. Regulation D markets are for frequency regulation services that are needed instantaneously. Since Regulation D markets require the instantaneous delivery of frequency regulation services, customers need to have assets that can provide instantaneous power. Regulation A markets are for frequency regulation services that address longer-term changes in frequency. As a result, Regulation A markets do not require instantaneous power.

Based on the proposed design, SARTA's microgrid would not be able to participate in Regulation D markets. The primary generation asset in SARTA's microgrid design is a natural gas turbine, which is not able to instantaneously start up to produce power. To participate in Regulation D markets, SARTA would likely need to use a microgrid design variant that includes battery storage. However, SARTA's microgrid might be able to participate in Regulation A markets, depending on how the microgrid is used. If the microgrid is used primarily as a resiliency measure, then the generation assets and especially the natural gas generator will be idle for significant portions of the day. As a result, it would be available for

[36] PUCO, "Alternative Energy Portfolio Standard Report by the Public Utilities Commission to the General Assembly of the State of Ohio for Compliance Years 2009 to 2010." (2012). Available at: http://dis.puc.state.oh.us/TiffToPDf/A1001001A12H15B51144H86168.pdf

[37] PJM. "Program Information - Ohio" Available at: https://www.pjm-eis.com/program-information/ohio.aspx

use in frequency regulation markets and could potentially be used to generate energy for the grid when frequency drops. However, if the microgrid is used as the primary source of power for SARTA's facility, then the energy it generates will be consumed by the facility and will not be available for use in frequency regulation markets.

Measuring the financial value of frequency regulation is an extremely complex process and requires detailed analysis of PJM energy markets. Much of the information needed to perform this analysis is either proprietary or not publicly available. As a result, SARTA should consult with the microgrid developer to obtain an analysis of demand response markets.

## *Investment Tax Credits (ITC)*

Internal Revenue Code Section 48 provides a tax credit for investments in certain types of energy projects. Section 48 provides tax credits for a wide range of renewable energy investments. Renewable energy technologies like solar photovoltaic, fuel cells, small wind microturbines, and CHP are eligible for tax credits. Solar photovoltaic projects are eligible for a tax credit equal to 30% of the cost of system if construction begins in 2019. The tax credit decreases to 26% if construction begins in 2020, 22% if construction begins in 2021, and from 2022 onwards the tax credit will be 10%. It is important to note that these deadlines are for the beginning of construction. However, if a project receives an ITC that is greater than 10%, the system must be online by December 31, 2023. In addition, only the owner of the system can claim the ITC. Small wind power (100 kW of capacity or less) is eligible for the same tax credits as solar. Fuel cells are eligible for the ITC and are limited to $1500 per 0.5 kW in capacity. Lastly, CHP equipment qualifies for an ITC of 10%.[38]

It is important to note that the ITC for some technologies will phase out over time. The solar ITC is permanent and will remain at 10% beyond 2022. However, the ITC for wind, fuel cells, and CHP has been approved until 2024. It is unclear whether the ITC will be enacted beyond this date. Due to SARTA's status as a tax-exempt entity, they would not be able to directly take advantage of these tax credits. However, if a separate entity, like an ESCO, owned and operated the microgrid, they would be able to benefit from these tax credits and pass these benefits on to SARTA.

## *Energy Efficiency Credits*

Federal tax deductions for energy efficiency upgrades to non-residential buildings expired at the end of 2017.[39] However, Ohio offers the Qualified Energy Project Tax Exemption, which is an Ohio tax exemption program for renewable energy generation. Under this program, "Qualified Energy Projects" remain exempt from taxation if the project is completed within the deadlines and it meets the Ohio Jobs Requirement. The Ohio Director of Development Services approves a project's status as a Qualified Energy Project. If the project uses renewable energy, the project must have a minimum nameplate capacity of 250 kW, the application for Qualified Energy Projects status must be submitted by December 31, 2020, and construction on the facility must begin before January 1, 2021 to qualify for the exemption. To meet the Ohio Jobs Requirement, 80% of the full-time equivalent employees involved in the construction of the project must be Ohio-domiciled for solar projects and 50% for all other types of

[38] Congressional Research Service. "The Energy Credit: An Investment Tax Credit for Renewable Energy." (2018). Available at: https://fas.org/sgp/crs/misc/IF10479.pdf
[39] Energy Star. "Federal Income Tax Credits and Other Incentives for Energy Efficiency." Available at: https://www.energystar.gov/about/federal_tax_credits

projects. If the nameplate capacity of the project is 5 MW or greater, the project must receive approval from the local Board of County Commissioners and provide emergency response training to emergency services.[40]

## New Market Tax Credits (NMTC)

The New Market Tax Credit program is a tax credit program that is designed to incentivize private investment in low income communities and promote community development. In the NMTC program, investors provide funding to a community development entity (CDE) in exchange for tax credits and equity in the CDE. The CDE then makes loans or investments to “qualified businesses” in low-income communities at favorable interest rates. To qualify for investments from the CDE, the qualified business must be located in a severely distressed census tract.[41] The City of Canton is located in a severely distressed census tract and thus CDE-mediated investments in Canton are eligible to earn NMTCs.[42]

The New Market Tax Credits are awarded against Federal tax obligations. The total tax credit is equal to 39% of the investment made in the CDE. The NMTC can be realized over a period of seven years. During the first four years, the credit is 5% of the investment. In the final three years, the credit is 6% of the investment.[43] The NMTC expires in 2019. However, there is legislation called the New Markets Tax Credit Extension Act of 2019 that is currently being debated in the US Senate. If passed, this bill would indefinitely extend the NMTC.[44]

As it currently stands, SARTA could not directly benefit from the NMTC program. Since SARTA is a public transit agency that has tax-exempt status, the NMTC would not be useful. In addition, since SARTA is a public agency, it is unlikely to be considered a qualified business. As a result, SARTA could not directly receive an investment from a CDE. However, the microgrid could potentially benefit from the NMTC program. If SARTA were to contract with an ESCO to operate the microgrid, that company could potentially become a qualified business. In order to become a qualified business, the company would need to demonstrate that:

1. At least 50% of the total gross income is from the active conduct of a qualified business in a low-income community
2. At least 40% of the use of tangible property of the business is within a low-income community
3. At least 40% of the services performed by the business’ employees are performed in a low-income community
4. Less than 5% of the average of the aggregate unadjusted basis of the property is attributable to collectibles (e.g. art and antiques), other than those held for sale in the ordinary course of business; and

---

[40] Ohio Development Services Agency. “Qualified Energy Project Tax Exemption.” Available at: https://development.ohio.gov/bs/bs_qepte.htm

[41] US Department of Treasury. “New Markets Tax Credit Program Factsheet” CDFI Fund. Available at: https://www.cdfifund.gov/Documents/NMTC%20Fact%20Sheet_Jan2018.pdf

[42] Novogradac. “NMTC Mapping Tool.” Available at: https://www.novoco.com/resource-centers/new-markets-tax-credits/data-tools/nmtc-mapping-tool

[43] Urban Institute. “Tax Policy Center’s Briefing Book: What is the new markets tax credit, and how does it work?” Tax Policy Center. Available at: https://www.taxpolicycenter.org/briefing-book/what-new-markets-tax-credit-and-how-does-it-work

[44] New Markets Tax Credit Coalition. “Factsheet: The New Markets Tax Credit Extension Act” Available at: https://nmtccoalition.org/wp-content/uploads/2018/10/NMTC-Extension-Act-2017-Fact-Sheet-October-31.pdf

5. Less than 5% of the average of the aggregate unadjusted basis of the property is attributable to non-qualified financial property (e.g. debt instruments with a term in excess of 18 months)[45].
6. If the energy services company could meet these requirements, then it would be eligible to receive loans or an investment from a CDE.

[45] Community Development Financial Institutions Fund. “Introduction to the New Markets Tax Credit Program.” (2017). Available at: https://www.cdfifund.gov/Documents/2017%20Introduction%20to%20NMTC%20Program%20Presentation%20For%20Release.pdf

# Role of the Microgrid

This microgrid is unique because it aims to serve as a resiliency measure for a transit bus fleet. This is a novel application of microgrid technology. This is especially true as the microgrid will be serving hydrogen production and dispensing equipment. As a result, SARTA's microgrid can serve as a first-mover demonstration in this space. Due to the innovative and novel nature of this project, it will have an impact on the hydrogen and the microgrid industry.

## Hydrogen Economy

Ohio is an established leader in the hydrogen economy. Since 2002, Ohio has invested nearly $100 million in fuel cell research and development and market readiness activities and the Ohio State University has emerged as a major player in fuel cell research. This investment has facilitated the hydrogen economy. Ohio has the largest fuel cell bus fleet outside of California. In addition, numerous fuel cell companies operate in the state, making Ohio a vital part of the fuel cell supply chain. In 2017, Ohio companies realized $100 million in revenue from fuel cell component sales[46] and is positioned as the third largest producer of hydrogen fuel cell components. This activity supports thousands of jobs and economists expect that Ohio and the Midwest region will benefit as this emerging industry continues to develop.

To continue developing the hydrogen transportation sector, infrastructure and fueling stations will need to be built to facilitate the deployment of additional vehicles. To plan infrastructure, the Hydrogen Roadmap has identified several high-priority, heavily trafficked corridors to focus efforts on. The Cleveland-Akron-Canton has been identified as one of these regions. SARTA is planning on constructing a hydrogen fueling station at its facilities in Canton to fuel their transit bus fleet and offer fueling services to the public. This continues the trend of transit bus agencies serving as an early adopter in this sector.

The proposed microgrid can play a role in further developing the hydrogen economy and the zero emission bus industry in Ohio. The main risk of adopting hydrogen as a fuel is that currently the utility grid must be operational to produce hydrogen or fuel a vehicle. If the grid were to experience an outage, the fueling station would lose the ability to refuel vehicles. The main value proposition that a microgrid can offer is resiliency. If there is a grid failure, the microgrid can provide temporary power to the hydrogen equipment, allowing operations to continue. The deployment of microgrids can help to mitigate a major risk that is associated with deploying hydrogen. This makes hydrogen and fuel cell vehicles more attractive.

The microgrid can also encourage a shift towards more cost-effective methods of hydrogen production. Currently SARTA and other transit agencies using hydrogen, rely on delivered hydrogen to power their fleets. The delivery of hydrogen adds significantly to the cost of hydrogen per kilogram, increasing operational costs. In 2018, SARTA paid an average of $5.88 per kg of hydrogen (generation and delivery cost)[47] and incurred additional expenses to gasify, store, and dispense the hydrogen. The Department of Energy estimated that hydrogen costs would need to fall to $4 per kg at the pump (including production, delivery, and storage costs) to reach parity with fossil fuels on a cost per mile

[46] Kristian Jokinen (2017) "Hydrogen Roadmap for the US Midwest Region," Stark Area Regional Transit Authority.
[47] Leslie Eudy. (2019) "Fuel Cell Electric Bus Evaluation Results." NREL. Presented at the "Fuel Cell Electric Bus Technology: Technical Capabilities & Experience" webinar by the California Transit Association (June 13, 2019).

basis.[48] As a result, reducing fueling costs will be extremely important for expanding the hydrogen economy and making the economic case for hydrogen.

A potential avenue for increasing the economic competitiveness of hydrogen is to shift to a distributed production model. Under this model, transit agencies would host hydrogen production infrastructure at their depots and produce hydrogen on-site. This can potentially lower the price of hydrogen by eliminating hydrogen transportation costs. The microgrid can play a role in encouraging distributed production as it can provide a source of clean energy to power the production process and it provides resiliency to the production equipment. With resiliency, a facility using SMR can continue to produce hydrogen as long as it maintained access to natural gas. A facility using electrolysis can continue to produce hydrogen as long as it has access to water and electricity.

Microgrids can greatly increase the attractiveness of hydrogen fuel and can play a major role in improving its economics and reliability. As a result, microgrids can be considered an enabling technology for the hydrogen economy. Since SARTA's microgrid will be the first transit-oriented microgrid in the Midwest, this microgrid will play an important role in facilitating further adoption of this technology in the future.

## Smart Grids and Microgrids

The SARTA microgrid also plays a major role in advancing the smart grid. The State of Ohio has demonstrated an interest in modernizing the grid and to eventually create a smart grid. In *PowerForward*, PUCO states that it aims to upgrade distribution infrastructure and incorporate new technologies like distributed energy resources into the distribution system. The main objective of this is to strengthen the grid so Ohio can eventually transition to a smart grid. The deployment of microgrids is a component of *PowerForward's* smart grid strategy as microgrids can be used to provide demand response and other ancillary power services that can be used to better manage the grid.

Amid this regulatory backdrop, there have been several proposals for microgrids within Ohio. Many of these microgrid proposals have dealt with traditional microgrid applications that are focused on powering critical loads in buildings. For example, in 2016, AEP Ohio requested funding to build multiple microgrids in Columbus, Ohio that would serve vital facilities like hospitals and water plants.[49] In 2018, researchers from Cleveland State University and Case Western Reserve University released a feasibility study for a proposed microgrid that would serve Cleveland, Ohio.[50] Lastly, Pitt Ohio will deploy a microgrid at its trucking facility in Parma, Ohio to power truck terminals, fuel pumps, HVAC systems, and lights.[51]

Thus far, most of the microgrids in Ohio will power buildings or other stationary assets. However, SARTA's microgrid would be the first microgrid that powers vehicles and transportation in the Midwest.

---

48 Colin Cunliff & Batt Odgerel. (2020). *Federal Energy R&D: Hydrogen & Fuel Cells*. Information Technology & Innovation Foundation. Available at: http://www2.itif.org/2020-budget-fuel-cells.pdf

49 Julia Pyper. "AEP Seeks $52 Million to Build up to 10 Ohio Microgrids" *GreenTech Media*. 30 November 2016. Accessed 8 July 2019. Available at: https://www.greentechmedia.com/articles/read/aep-seeks-52-million-to-build-up-to-10-ohio-microgrids#gs.no22n9

50 Ahmed, Ali H.; Thomas, Andrew R.; and Henning, Mark, "Techno-Economic Feasibility Analysis of a Microgrid in Downtown Cleveland, Ohio" (2018). Urban Publications. 0 1 2 3 1559. https://engagedscholarship.csuohio.edu/urban_facpub/1559

51 Andrew Burger. "Ohio Trucking Terminal Installs Renewable Energy Microgrid." *Microgrid Knowledge*. 10 December 2018. Accessed 8 July 2019. Available at: https://microgridknowledge.com/renewable-energy-microgrid-trucking/

This marks a major advancement as it will effectively incorporate zero emission transportation into the smart grid. This will provide many opportunities and challenges. Zero emission vehicles consume large amounts of power and the rapid deployment of zero emission bus fleets will greatly increase the amount of electricity that utilities will need to provide to customers. This increase in electricity demand will stress the grid and pose challenges to utilities, who will likely have to invest significant capital to upgrade their transmission and distribution systems. Microgrids provide an avenue for utilities to manage this demand. Transit agencies can use microgrids to produce all or some of their own power, which will reduce the burden on the grid. The SARTA microgrid would be an early demonstration of microgrid technology in Ohio and can serve as proof of concept for integrating zero emission transportation into the grid. As a result, it provides an opportunity to demonstrate the applicability of this technology to the zero emission transportation sector and could potentially pave the way for similar deployments in the future.

# Conclusion and Lessons Learned

This report provided a techno-economic feasibility assessment of a microgrid at SARTA. This report outlined the energy and natural gas needs of the SARTA microgrid, the regulatory framework that governs microgrids in Ohio, possible operational strategies for the microgrid, a techno-economic analysis of the microgrid, and an assessment of ancillary services the microgrid can provide. This report ultimately concludes that a campus microgrid, that powers all loads at SARTA's bus depot, is feasible. A microgrid developer has expressed interest in partnering with SARTA and serving as an owner-operator of the microgrid. Under this operational strategy, the developer would own the microgrid and would sign a PPA with SARTA. The developer's analysis concludes that a microgrid with 490 kW DC of solar panels, 1000 kW of natural gas turbines, and 575 kW of diesel generators will serve SARTA's needs. The validity of this design has been independently confirmed by CALSTART with modelling conducted with the Microgrid Design Toolkit, which was developed by Sandia National Laboratories. The capital expenditures associated with this project are expected to be $1.75M - $2.25M with a levelized cost of energy of $0.07-$0.09 per kWh. This price is comparable to the cost of the utility power that SARTA currently buys.

Engaging with a microgrid developer/ESCO eliminates much of the risk associated with this project as SARTA would not be responsible for the construction, operation, or maintenance of the microgrid. The developer would accept these risks and would sign a PPA with SARTA to provide power. At this point in time, a key unknown is the cost per kWh that SARTA would pay as part of a PPA. While the projected levelized cost of energy favorable, there are other factors that can increase that cost. If the local utility requires SARTA to obtain standby power, that will increase the levelized cost of energy. The levelized cost of energy will also depend on how the microgrid is used and whether it can be used for ancillary services, like demand response. As a result, more analysis will need to be conducted to better understand the financial implications this microgrid will have for SARTA.

This project has also uncovered wider lessons for the microgrid industry as a whole. One key lesson is that the regulatory environment will have a big impact on the microgrid. Regulations will have an influence on and possibly constrain which components can be used in the microgrid, financing strategies, operational strategies, and whether the microgrid should be built FTM or BTM. Each state has unique energy and utility regulations. Those who are considering building a microgrid should become familiar with relevant regulations and consult with their utility company early in the process.

When planning for resiliency, transit agencies should note that fuel cell buses are also more resilient than battery electric buses, especially for large fleets. One of the main challenges of battery electric buses is that charging requires large amounts of power and it is difficult for a microgrid to provide enough power to charge multiple buses. Hydrogen production via electrolysis is also energy intensive but SMR can greatly reduce the amount of power that is required. Excess hydrogen can theoretically be produced when the grid is functioning and placed in long-term storage. When there is a grid outage, this stored hydrogen can be deployed to fuel the buses. While the storage and dispensing equipment requires power, it is a much smaller load than a battery electric bus. A microgrid using this operational strategy can fuel more buses than it would be able to charge. As a result, microgrids are better able to meet the needs of a fuel cell bus fleet than a battery electric bus fleet.

Another major challenge for microgrids is financing. Microgrids are expensive to deploy and require large amounts of upfront capital expenditures. For example, a small 190 kW microgrid that powers car chargers at the San Diego Zoo cost about $1 million. Microgrids that serve transit agencies would be much larger than this and cost significantly more. Although Ohio's regulatory environment provides options for avoiding large upfront capital expenditures, there might be other jurisdictions where the regulatory environment does not allow for this. If a transit agency needed to fund the construction costs of a microgrid, it could pose serious financial burdens. Since transit operators are almost entirely dependent on grants and funding allocations from state governments, many transit agencies would struggle to raise the required capital to build a microgrid. This is especially true for small transit agencies.

The SARTA microgrid also highlighted the challenges associated with deploying a microgrid in a space-constrained facility. Microgrid components can occupy large amounts of physical space which made it difficult to design a microgrid that can fit on SARTA's property. SARTA was able to mitigate this problem because it was already in the process of expanding its facility and was able to obtain additional land. However, other transit properties will struggle to replicate this. While SARTA was somewhat space constrained, many transit agencies, especially those in densely populated urban areas, have even less space available. Furthermore, purchasing additional land is expensive and will likely not be financially feasible without support from the state or local governments. This increases the difficulty for these agencies to construct a microgrid. It also limits the number of solar panels that can be deployed, forcing transit agencies to rely more heavily on other generation assets like natural gas turbines or stationary fuel cells. This problem is especially pronounced for space-constrained large fleets which will have to provide greater amounts of energy on a relatively small area. To deploy microgrids, space-constrained transit properties will need to develop innovative agreements for locating some of the microgrid components on nearby properties.

Lastly, the SARTA microgrid has demonstrated the challenges of deploying sufficient generation assets to power a transit-oriented microgrid. Although microgrids can be built to supply only critical load during islanding, transit-based microgrids still require large amounts of energy, oftentimes at the megawatt scale, especially if electrolysis is used to make hydrogen (or if the buses are battery electric). Due to their low power density, it is difficult to fit enough solar panels on a transit property to produce this much power. This problem is compounded in regions of the country that receive low amounts of solar insolation. Deploying internal combustion generators to make up for this shortfall is also problematic due to the emissions they produce, especially in ozone nonattainment regions. As a result, some jurisdictions have restrictive regulatory and permitting requirements for internal combustion generators. One alternative to internal combustion generators would be to deploy stationary fuel cells. Hydrogen fuel cells can make use of stored hydrogen to produce power in the event of an outage. Alternatively, solid oxide, molten carbonate and phosphoric acid fuel cells use natural gas to produce electricity, and produce a fraction of the emissions. Since fuel cells produce power through an electro-chemical reaction, rather than combustion, they produce far fewer criteria emissions and face lower regulatory and permitting requirements. In fact, some stationary fuel cells are completely exempt from air district permitting requirements in some jurisdictions. Despite their benefits, few stationary fuel cells have been deployed in microgrids. This has occurred because there are only a few stationary fuel cell manufacturers and fuel cells are expensive. Further efforts need to be taken to increase commercial offerings for stationary fuel cells and to reduce their price.

Zero emission buses have experienced rapid technological development and are rapidly being deployed across the United States and the world. In addition, many industry experts project that other types of vehicles will rapidly electrify. Bloomberg New Energy Finance predicts that by 2050, about 10% of the global heavy-duty commercial fleet and about 20% of the global medium-duty commercial fleet will be electrified. Demand for microgrids will increase as transit agencies recognize that vehicle electrification introduces resiliency risks. However, the electrification of other classes of vehicles will likely drive further demand for microgrids as utilities and private fleets seek ways to better manage the grid and provide resiliency. Our work with the SARTA microgrid has revealed several unique challenges that fleet operators face when deploying microgrids and these limitations also apply to microgrids that serve other types of medium- and heavy-duty vehicles. Efforts will need to be undertaken to address these challenges to enable deployments of transportation-oriented microgrid deployments in the future.

# Appendix A: Maps

## District Map


1. SARTA’s Campus
2. Allen Elementary School
3. City of Canton/Health Clinic

## SARTA Expansion

# Appendix B: Microgrid Components

## List of Steam Methane Reformer Microgrid Components

| System | Equipment Name | Type/Capacity | Qty. | Dimension (L' x W' x H') | Min. Clearance | Equipment ROM ($) | Comments |
|---|---|---|---|---|---|---|---|
| Hydrogen Generation | Hydrogen Compressor | 450 bar | 1 | 30' x 12' | | | |
| Hydrogen Generation | Hydrogen Compressor | 875 bar | 1 | 35' x 12' | | | |
| Hydrogen Generation | Hydrogen Fueling Dispenser | 700 bar | 1 | 10' x 4' | | | Location undetermined, not in scope |
| Hydrogen Generation | Hydrogen Fueling Dispensers | 350 bar | 2 | 10' x 4' | | | Location undetermined, not in scope |
| Hydrogen Generation | Hydrogen Storage Tank | 500 bar | 1 | 40' x 10' | | | |
| Hydrogen Generation | Hydrogen Storage Tank | 900 bar | 1 | 10' x 10' | | | |
| Hydrogen Generation | Steam Methane Reformer | 900 kg/day | 1 | 46' x 8' | | | |
| Microgrid | Automatic Transfer Switch 1 | 480V Pad Mount | 1 | 3.3' x 3.6' x 7.5' | 3' Front | $9,321 | |
| Microgrid | Distribution Panel | 120/208V Pad Mount | 1 | 4.75' x 3.8' x 7.5' | 3' Front | $8,414 | |
| Microgrid | Microgrid Controller | Rack-Mounted in C-Box | 1 | 20' x 8' (container) | N/A | $200,000 | Conditioned, dry location |
| Microgrid | Microgrid Switchgear | 277/480V Pad mount | 1 | 6.5' x 3.5' x 7.5' on 20' x 8' pad | 3' Front | $13,128 | Equipment pad includes space for step down xfmr and distribution panels |
| Microgrid | Natural Gas Generator | 1000 kW Microturbine | 1 | 29.9' x 9.8' x 9.5' | Left (5'), Right (0'), Front (5.6'), Rear (6.6') | $1,000,000 | Locate min 20' from H2 equipment |
| Microgrid | Natural Gas Generator | 1000 kW Reciprocating | 1 | 53' x 9.8' x 9.8' | Front (23') | $1,075,000 | Alternate to microturbine. Locate min 20' from H2 equipment |
| Microgrid | Rooftop Solar | 490 kW-DC | 1 | N/A | | | Modules and inverters located on rooftop |
| Microgrid | Step Down Transformer | 277/480V Primary – 120/208V Secondary. Pad mount | 1 | 3.8' x 3.3' | 3' Front | $5,630 | Assumed loads under 277/480V are limited to Microgrid controller, lighting, HVAC for C-Box and convenience receptacles |

## List of Electrolyzer Microgrid Components

| System | Equipment Name | Qty. | Type/Capacity | Dimension (L' x W' x H') | Min. Clearance | Equipment ROM ($) | Comments |
|---|---|---|---|---|---|---|---|
| Hydrogen Generation | Hydrogen Compressor | 1 | 450 bar | 30' x 12' | | | |
| Hydrogen Generation | Hydrogen Compressor | 1 | 875 bar | 35' x 12' | | | |
| Hydrogen Generation | Hydrogen Fueling Dispenser | 1 | 700 bar | 10' x 4' | | | Location undetermined, not in scope |
| Hydrogen Generation | Hydrogen Fueling Dispensers | 2 | 350 bar | 10' x4' | | | Location undetermined, not in scope |
| Hydrogen Generation | Hydrogen Storage Tank | 1 | 500 bar | 40' x 10' | | | |
| Hydrogen Generation | Hydrogen Storage Tank | 1 | 900 bar | 10' x 10' | | | |
| Hydrogen Generation | NEL Electrolyzer Container | 1 | 900 kg/day | 40' x 8' | | | |
| Hydrogen Generation | Power Supply Container | 1 | | 40' x 8' | | | |
| Hydrogen Generation | Process Cooling Unit | 1 | | 20' x 8' | | | |
| Hydrogen Generation | Rectifier / Transformer | 1 | | 11' x 13' | | | |
| Microgrid | Automatic Transfer Switch 1 | 1 | 480V Pad Mount | 3.3' x 3.6' x 7.5' | 3' Front | $9,321 | |
| Microgrid | Distribution Panel | 1 | 120/208V Pad Mount | 4.75' x 3.8' x 7.5' | 3' Front | $8,414 | |
| Microgrid | Microgrid Controller | 1 | Rack-Mounted in C-Box | 20' x 8' (container) | N/A | $200,000 | Conditioned dry location |
| Microgrid | Microgrid Switchgear | 1 | Pad mount | 6.5' x 3.5' x 7.5' on 20' x 8' pad | 3' Front | $15,753 | Equipment pad includes space for step down xfmr and distribution panels |
| Microgrid | Natural Gas Generator | 4 | 4000 kW Microturbine | 29.9' x 9.8' x 9.5' (ea) | Left (5'), Right (0'), Front (5.6'), Rear (6.6') | $3,600,000 | Locate min 20' from H2 equipment |
| Microgrid | Natural Gas Generator | 2 | 1500 kW + 2000 kW Reciprocating | 53' x 9.8' x 9.8' | Front (23') | $3,150,000 | Alternate to microturbine. Locate min 20' from H2 equipment |
| Microgrid | Rooftop Solar | 1 | 490 kW-DC | N/A | | | Modules and inverters located on rooftop |
| Microgrid | Step Down Transformer | 1 | 277/480V Primary - 120/208V Secondary. Pad mount | 3.8' x 3.3' | 3' Front | $5,630 | Assumed loads under 277/480V are limited to Microgrid controller, lighting, HVAC for C-Box and convenience receptacles |

* Please note that the provided cost estimates only include equipment costs and do not include installation costs.