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VILLAGE OF CROGHAN
LEWIS COUNTY, NEW YORK

CROGHAN MICROGRID STUDY
CROGHAN, NY

DEVELOPMENT AUTHORITY OF NORTH COUNTRY

SEPTEMBER, 2016

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I. EXECUTIVE SUMMARY

The Croghan Microgrid phase 1 feasibility assessment project was awarded by NYSERDA under the New York Prize Program to the Development Authority of the North Country (DANC). DANC is managing this project with subcontract services provided by a cross-functional team comprised of Larsen Engineers and Schneider Electric, and support from Lewis County Development Corporation (LCDC) and the Village of Croghan. The project is located in the Village of Croghan, Lewis County, New York and is innovative as well as socially, environmentally, and economically beneficial to the region.

The Village of Croghan, in association with DANC, has the unique opportunity to power a microgrid using renewable hydroelectric power generated by two turbines being proposed for Croghan Dam. This project will illustrate how microgrids can be successful to achieve resiliency in a critical part of the rural community as well as be replicable across the state at dams where renewable hydroelectric power may be developed.

Data collection has been finalized with cooperation from the Village to provide the input data on the NYSERDA standard forms for completing the cost benefit analysis by a third party. The documentation and findings of this analysis are enclosed as Appendix F. National Grid and the engineering team are working together to assess existing utility infrastructure and how it can serve the microgrid mainly powered by two 250KW hydropower units constructed as part of the Croghan Dam rehabilitation. The total consumption at the critical facilities is anticipated to be served by this continuous renewable power generation source. Determination of average and peak load curves for grid connected and island mode operating constraints is under way. Additional solar photovoltaic systems with and without a battery energy storage component were also considered to augment the resiliency of the network.

A Benefit-Cost Analysis (BCA) conducted by a third party has been performed as per NY Prize requirements. The Summary Report of this Analysis is included as Appendix F, and the complete set of associated files are included digitally in the primary submission of this document. The value of the Croghan microgrid to the regional economy during a long-term power outage is significant, avoiding approximately $270,000 of losses per day. Including all costs, including those not projected to be financed by NYSERDA grant monies upon potential reward, the overall cost-benefit ratio is 1.0 with modest assumptions about the prevalence of regional emergencies. In the event of a catastrophic, long-term power outage, the leveraging of sustainable, independent power to support critical facilities would be enormous. The actual capital costs associated with the Croghan microgrid are anticipated to be substantially lower than those used for the BCA report. As such, the microgrid project detailed here would present a much more favorable benefit-cost ratio.

II. PROJECT BACKGROUND

The Development Authority of the North Country (DANC) is a New York State public benefit corporation that builds and operates infrastructure projects in Jefferson, Lewis, and St. Lawrence Counties in the northern area of New York State. Realizing the potential benefit to the Croghan area, DANC opted to pursue the study of a local microgrid project. Several key organizational assets have aided DANC in facilitating this process, including local relationships and historical knowledge. The project also seeks to make the greatest use of a DANC responsibility, namely the rehabilitation of a dam facility on the Beaver River in the village of Croghan. While DANC has received some funding for implementing this dam rehabilitation, this study has identified a strategy toward not only further financing this project but leveraging this responsibility into a benefit to the economy, well-being, and resiliency of the area through recently-established state policies on renewable energy and microgrid technologies.

The following is a list of the project stakeholders that have been actively involved in the project during the proposal development stage and continue to guide the study with their input during data collection, progress meetings and telephone conversations.

- Lewis County Development Corporation (LCDC) – LCDC, with the input of Village of Croghan representative Glen Gagnier, has been involved in the redevelopment of the Croghan Dam for 13 years. Mr. Gagnier has institutional knowledge of the site and of its potential for the Village of Croghan and surrounding area. The LCDC supports DANC's application and will provide a substantial role to the entire project, from start to finish, including day to day inspections and consultations when necessary.
- Village of Croghan, NY – The Village supports the project recognizing the necessity of providing critical services to the Village and surrounding area. The Village will act as the co-municipal contact for the project, along with the Town of Croghan and the Lewis County Board of Legislature.
- National Grid – local electric supplier, providing transmission information and letter of support for project
- Enbridge St. Lawrence Gas – Local fuel (e.g. natural gas) distribution company, potential power source for microgrid, has confirmed that adequate natural gas distribution exists to provide fuel at each of the identified critical facilities.

- Gas station, convenience store, grocery store, ATM, fire department, library, retirement home, municipal building – sites of refuge within Village of Croghan, for community needs in emergency situations and a central school, health center, and additional places of refuge outside the village.

DANC has worked with consultants to study the cost, implications, and potential design considerations for rehabilitation of the dam and implementation of new hydroelectric assets. This effort has come in two parts, the first being a Hydropower Feasibility study developed by Larsen Engineers in July of 2015, which was followed up by a Peer Review report by Kleinschmidt in May of 2016. This second phase was intended to clarify issues identified in the initial report while further articulating costs in an effort to better understand the viability of the Croghan dam rehabilitation project as a self-sustaining revenue stream. These reports provide the costs and equipment specifications for dam rehab and hydroelectric power efforts discussed primarily in Task 3.5

III. TASK 1 –DEVELOPMENT OF MICROGRID CAPABILITIES

This section will identify the capabilities of the Croghan microgrid has developed by the project team. These include system capacities, facilities served, generation sources, communication considerations, and other technological aspects.

Task 1.1 Minimum Required Capabilities

Critical Facilities

The proposed microgrid is intended to serve numerous critical community facilities, itemized in Appendix A, including local non-government facilities, shelter facilities, critical infrastructure such as waste water treatment and sewerage lift pump stations, as well as commercial entities. These 14 facilities (plus nine sewerage lift pump stations) were finalized through a process which balanced infrastructure need, isolation challenges, electrical demand, and each facility's criticality to overall community function during a prolonged grid shutdown. By retaining power to these facilities during an emergency, residents of this area will be able to acquire basic necessities, find refuge, and/or rely on basic government services. Further, a number of businesses vital to the economic wellbeing of this community will be shielded from the financial burdens associated with prolonged power outage. Details of these economic impacts were carefully reviewed and presented for the third party reviewed included at the end of this document The spectrum of community functions represented include a small manufacturing facility, a museum, a fire hall, a small grocery store, a library, and an apartment building, representing a spectrum of community function.

Primary Generation Source(s)

The proposed microgrid avoids the integration of any new combustion-based power generation. While existing standby generation assets, currently being utilized by a number of the system's critical facilities, have been evaluated and identified as valuable tools for augmenting the system's ability to manage peak load, the Croghan microgrid project is intended to use continuous and variable renewable assets to meet its power demands. The primary generation source will be the rehabilitated hydro plant on the Beaver River, which consists of two turbine generators with a power generation capacity of 250kW each. In addition, the feasibility of up to 2MW of photo-voltaic (PV) generation in combination with battery energy storage was considered; however, it was determined that the needs of the microgrid's critical facilities could be comfortably met during an emergency grid shutdown with hydroelectric power generation and battery storage. The potential size of the battery energy storage system (BESS) will depend on the load profiles of the critical facilities, but preliminary estimates of need have been identified in Task 4 below. The BESS will allow for load management during islanding when peak load curves may exceed available Hydro generation for limited periods of time.

Grid-connected and Island mode operation

The Croghan microgrid has been conceived and, upon grant award, would be designed to generate power during everyday operations, with the hydroelectric component providing fixed-cost power to participating members through electricity credit distribution policies (Community Distributed Generation) established by the PSC in 2015. This arrangement is discussed in further detail in Task 4.

In island mode, i.e. during grid shutdown, the microgrid power generation sources (hydroelectric generation augmented to suit seasonal variability by the BESS) would be instantaneously leveraged to provide direct power to the incorporated critical facilities using both software and hardware controls. This switching and control system includes two key components: a PowerLogic Microgrid Controller (PMC) and Struxureware Demand Side Operation (SDSO) software, a combinatory system that can balance loads, optimize generation, control storage assets, and coordinate islanding and reconnection events at the millisecond and second timescale. A detailed sequence of operations that allows for safe, flexible islanding will be developed during the final design phase of this project, assuming grant award. High-level characterization of microgrid controls and proposed equipment are identified in Task 2.5. All design components will be considered for their capacity to follow system load and maintain system voltage when islanded within ANSI C84-1 standards, including all applicable interconnection and operation standards.

Operations and Maintenance

The primary power generation source for the Croghan microgrid, two microhydro turbines, will be operated during everyday conditions as a Community Distributed (CDG) asset, generating power and distributing the credits assigned for this power by the utility, to its subscribed membership. Under this arrangement, the developer, sponsor, or other entity earning revenue from power sales will be responsible for defining the operation and maintenance plan for the hydroelectric assets. It is presumed that this as-yet unidentified entity would follow all manufacturer's requirements. Long term maintenance of critical components such as inverters, primary battery storage media, switch gear, some control equipment, and the microgrid distribution network would be detailed in a comprehensive operations and maintenance plan, though the determination of responsibility for primary operation and maintenance of the microgrid assets is yet to be made.

Emergency Support, Resiliency, and Communication

The microgrid proposed in this study relies on a rehabilitated hydroelectric system to provide power to critical facilities in the case of grid-shutdown. As such, this system—designed to take full advantage of available resources and funded separately from the microgrid itself—is anticipated to generate more power than is required by the network of critical facilities even at peak demand. Despite seasonal variability—for which this study recommends the implementation of battery storage—hydroelectric power represents an uninterruptible power supply. As described above, any existing standby generation assets available will be incorporated for peak load management and will not be utilized for continuous or primary island mode support.

A primary cause of emergency outages in this part of the state is ice storms. These incidents can disrupt power distribution from the grid. The Village of Croghan is supplied by well-maintained network of National Grid transmission and distribution assets, but actual power generation occurs distant from the community. This leaves the Village somewhat vulnerable to major winter storms. By localizing the power generation and distribution network, the overall odds of an ice storm or other weather event disrupt power distribution are significantly reduced. To further this resiliency, an earlier phase of the study examined the implementation of a new, secondary underground network of power distribution between the hydroelectric asset and the critical facilities. The cost of running new, underground power lines proved exceedingly high. At this time, the project team has opted to reduce overall design costs by using overhead transmission.

With further data from the local utility, it is the intent of the team to determine the highest risk components of the system and mitigate them to the fullest extent feasible. The design phase of this project will undertake determination of risks and associated mitigation strategies. Black start functionality will be incorporated into the primary control and optimization scheme, though the final means and methodology for current and/or voltage sourced reference will be determined in the final design study phase of the project. The primary Hydro generation asset, as a continuous power source, will be the logical reference point.

As the Croghan microgrid relies on a hydroelectric power that will be provided power to the grid during normal operations, communication between microgrid operators and National Grid are critical to utility operations. Upon grant award, technical details regarding the specific two-way communication scheme including automation, seamless integration, security, and standardized protocols such as OpenADR will be finalized in cooperation with National Grid expectations and industry best practices. The project team brings recognized expertise in utility communication to bear on this project.

Task 1.2 Preferable Microgrid Capabilities

In addition to the minimum required capabilities identified under Task 1, the Croghan microgrid, as it has evolved through the course of this study, demonstrates other capacities, benefits, and innovations. The following sections will present further considerations and innovations for design, environmental impact, community benefit, private capital, and compliance to statewide initiatives.

Advanced monitoring, microgrid control, and communication operations

For optimal functionality, the Croghan microgrid will rely on advanced monitoring and control technologies to optimize, secure, and coordinate all system assets. Primary control will be through a master microgrid controller, as well as distributed control systems. Inter-operability with the continuous and variable renewable generation, as well as BESS and demand, will be optimized through cloud-based optimization algorithms. Predictive modeling and historical reference through the life of the system will enhance the optimization of the microgrid assets in both grid-connected as well as island modes. Input from the local utility with respect to substation automation and isolation functions will be required. Communication infrastructure will be required, and fully addressed during the design study phase of the project. Actual design constraints will be further addressed in the design study phase of this project, however fundamental constraints related to distances, site conditions, and existing infrastructure suitability will be addressed in the feasibility assessment.

Energy Conservation Measures, clean power sources, and community benefit

Given the mix and type of facilities that are intended to form the microgrid at Croghan, the anticipated reduction in generation requirements are expected to be limited. However, opportunities for reducing demand on the microgrid insofar as it provides greater flexibility to the system during emergency outages will be taken advantage of as they are identified should a grant for final design be awarded. ECM represent an alignment in incentives between microgrid operators, critical facilities, and all stakeholders involved in the project

As this microgrid relies on hydroelectric as its primary power source, the overall environmental impact is minimal. Diesel generators already owned and/or operated by critical facilities will be used to augment the system in extreme circumstances, but their overall employment is anticipated to be less than during outages preceding microgrid implementation, as generators once used for resiliency during grid shutdown will now be supplanted by direct hydroelectric power.

The Croghan microgrid project, as proposed, provides both benefits both directly to the community and to the economic wellbeing of the region. As designed, it will allow the community to maintain critical functions in the event of an emergency, including electrical outage. This includes but is not limited to the maintenance of electrical power for fire services, health services, water supply, shelter, and grocery services. By providing resiliency to these support services, residents of the Village of Croghan, and those living in outlying areas up to ten miles from the Village center (and in some cases, even further), the microgrid benefits the entire region. Additionally, the Croghan microgrid project will relieve the local grid transmission and distribution infrastructure, as well as remote generation infrastructure, of a continuous, significant load which is comprised of the primary critical and infrastructure facilities in the village. An average of 500kW, and up to 700kW, of local demand will be met by local, renewable generation resources.

Private Capital

While little private capital has yet to be sourced for the grant-eligible portions of the Croghan microgrid, the project team has articulated a unique opportunity for financing power generation (see further details under Task 3). This paradigm would take advantage of new Community Distributed Generation policies to finance the development of the system's primary power generation source through revenues from power sales. A private investor will be required to finance initial microhydro construction and costs will be recouped through a power purchase agreement. During everyday grid operation, the membership of this CDG will receive credits for renewable power generated in their name and pay the system owner at a rate at or below what they would have paid to the grid. Opportunities for other private capital to finance other microgrid assets will be identified as the project matures through grant award.

Reforming the Energy Vision

A microgrid which relies on the renewable, clean power generated by a rehabilitated hydroelectric asset falls in line with the intentions of New York State's Reforming the Energy Vision (REV) initiative. As the current owners of the dam are mandated to rehabilitate their facilities, this endeavor not only transforms this environmental responsibility into an asset, but provides the local community with resiliency and increased economic vitality through the use of renewable, locally-managed power.

IV. TASK 2 - PRELIMINARY TECHNICAL DESIGN

This section details the system's preliminary design; however, it should be noted that many final design decisions will be made in later phases of the project. The study team notes that NYSERDA requirements for this study have requested detailed conceptualization that can only be provided at a very high level prior to approval, commentary, and Cost-Benefit Analysis. Remaining details left unresolved in this phase of the study will be continually developed during ensuing project stages.

Tasks 2.1-2.4 Proposed Microgrid Infrastructure and Operations, Load Characterization, Distributed Energy Resources Characterization, Electrical and Thermal Infrastructure Characterization

The first four subtasks under this section are considered in one continuous narrative, as many of the issues can be addressed simultaneously. A basic one-line along with a plan of the site for the Village of Croghan Community Microgid project is included as a separate drawing in the submittal package. The anchor structure will be the Croghan Dam on the Beaver River. The dam is expected to be reconstructed with two new 250 kW hydro-electric generators added as a project separate from microgrid.Several scenarios were considered for distributing power to critical facilities during emergency operation. Each option is discussed in this study, but are summarized below:

1) Leveraging existing, utility-owned overhead powerlines. Under this scenario, switching equipment at power generation sites and each critical facility would allow the system to switch to microgrid operation during emergency operations. After analysis, this approach was discarded based on the cost, technical complexity, and implementation challenges presented by using assets owned by National Grid.
2) A separate, underground network of power distribution running between centrally located critical facilities, augmented by a controller-managed combination of solar and storage at

outlying pump stations. This option was also discarded due to assumed costs, as well as the technical and ownership complications associated with construction underground facilities across property lines and various right-of-ways.

3) A separate, overhead network of power distribution. As the lowest cost option which presents the least technical challenge, this approach was finally selected.

Each of the included facilities will be operate on a dual connection: their existing connection to National Grid's existing overhead distribution circuit and a new connection to the microgrid distribution. The microgrid circuit originates at the dam. Normally, the microgrid circuit and the dam hydro-power will be paralleled with the utility circuit. The system will use virtual net metering. In the event of loss of utility power, the utility connection will be opened and the hydro output will remain connected to the microgrid. The switching equipment and microgrid controls will be located in a prefabricated electrical house near the dam.

The building will contain the 13.2 kV and 480 V switchgear where the utility and microgrid circuits as well as the three sources can be added or removed. A G&W Viper recloser will be the interface to the utility circuit providing IEEE 1547 utility interface protective functions such as under/over frequency, under/over voltage, phase balance, through internal voltage and current sensing. When needed, the 480 V breakers will synchronize the DER's to the bus. The recloser will synchronize the microgrid to the utility when needed.

Also proposed is a 1 MWhr battery storage unit in the vicinity of the dam. The batteries are modular in self standing shipping container sized structures. These devices will feed into the dam electrical room.

DER	Type	Rating	Fuel
Croghan Dam	Hydro	500 kW	None
Microgrid Batteries	Storage	500 kW	None

Table of DER characteristics

Upon loss of utility power, the recloser will isolate the utility circuit, and the DER output would be adjusted as necessary to accommodate the load. The hydro output should be able to handle the load swings and not need to be tripped. The microgrid loads will experience a voltage sag but probably not an interruption (zero voltage). This needs further investigation.

If the controller determines the pre-islanding load exceeds DER capability, the DER's will be shut down and the facility standby generators will pick up the facilities so equipped. The microgrid controller will lock out sufficient facility standby generation (Prevent the facility from switching off the standby generation) so that the DER's can support the load. The DER generation will then be added to the microgrid. The controller will manage DER generation and load thereafter.

When utility power is restored and after a delay to demonstrate stability, the microgrid sources would be synchronized to the utility across the recloser. The DER's will be returned to parallel mode operation. This transient would probably be bumpless to the microgrid facilities.

Mode	Annual Energy	Demand	Average
Paralleled	-	-	-
Islanded	650 MWh	300 kW	-

Estimated electrical consumption

The electrical consumption data for the microgrid are shown in Appendix C. The available electrical load data was very limited. Where available, peak monthly loads are presented in Appendix E. Estimates of peak monthly load are derived using known electrical consumption with conservative load factors and operating times to arrive at a peak demand maximum of 320kW Temporary monitoring will be required to collect further data to adjust the load estimates. However, the demand is expected to be less than 500 kW. The DER sizing could be adjusted if the actual load data warrants.

The hydro-generator is the main source of power in island mode. While in microgrid mode, the microgrid controller will aid the optimization between the hydro and output from diesel generators, while battery storage will provide power to outlying facilities (shown in Appendix B) that are not directly connected to the microgrid's overhead distribution, and an approximate 1MWhr battery near the dam facilities would provide back-up power if and when winter weather reduces river flow or temporarily incapacitates hydroelectric generation.

If generation is short for whatever reason, there is approximately 200 kW of standby generation spread over several facilities. Some of these could be set up as load shed where the microgrid controller forces the facility load to disconnect from the microgrid and switch to the standby generator. If the hydro-generator is out of service, the standby generator load shed and would be the means to manage the load. Scheduled maintenance would be planned for late summer with typically the lowest river flow and good probability of sun shine.

Historically, the major threat to the utility electrical system is a winter ice storm that has left the town without power for extended periods. This is the design basis for the microgrid. The microgrid distribution would utilize new conductors on existing utility poles fed by the Beaver River dam hydro-generator and battery storage as shown in the single line diagram in the appendix. Fortunately, winter river flow is only exceeded by the spring thaw. If hydrogeneration and battery could not support load, the standby generator load shed could be implemented.

Another potential problem would be ice dams on the river. The proposed BESS at the dam facility would mitigate power loss to the microgrid during the event of an ice dam, but for optimal operation, any ice dams would need to be cleared quickly to minimize flood damage. This study recommends the development of an ice management protocol as part of the dam rehabilitation and hydroelectric implementation project, including review of prior best practices and the frequency of ice events.

The hydro-turbine and generator are an extremely reliable system. The weak point for electromechanical generators is the prime mover. The hydro-turbine is extremely simple and has been in use for over one hundred years.

Since the DERs do not use any fuels, production can be considered indefinite as long as the natural resources are available.

The NYSERDA questions do not define "black start capability." For a black start connected to the utility, the hydro-generator would be closed into the utility system (assuming the system is deenergized and load is within the hydro-generator capability). If it is intended that the DER helps provide utility black start, it is possible but the utility would need to accommodate the capability.

While grid connected, the 500 kW hydro-generator could help with voltage control and reactive power support. Frequency control would not be as practical since utility frequency variations are so small. They would indirectly contribute to frequency control by real power supply. The hydro-generator provides very good load following. These capabilities would need to be contracted through one of the available demand response programs.

While in grid-connected mode, the utility system dominates electrical performance. However, the local paralleled sources would help maintain voltage and power quality in the immediate area. With the hydro sources operating, there will be appreciable improvement of voltage sag ride through capability. Since some sensitive equipment can be disrupted by voltage suddenly dropping to less than 80% to 85% and most voltage sags are above 60%, these sources could eliminate most disruptive voltage sags locally. While voltage sags have not been recently identified as a recurrent issue in the Croghan area, the existence of a local distributed generation asset will certainly provide National Grid a resource with which to ease potential sags due to weak feeds, high impedance, or other utility faults in the region.

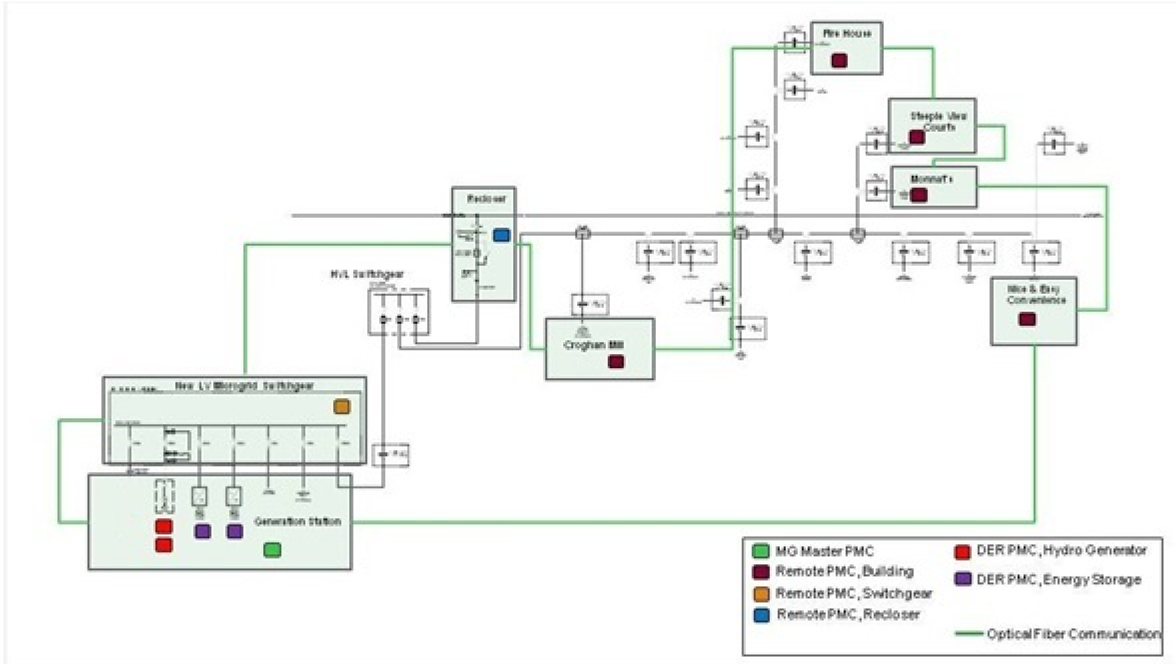
Task 2.5 Microgrid and Building Controls Characterization

A distributed microgrid controller system will be provided to govern the operation of the microgrid. This controller consists of two components: the PowerLogic Microgrid Controller (PMC), a reactive real-time controller that is operating on the millisecond and second time scale and Struxureware Demand Side Operation (SDSO) software, a predictive controller that provides optimized DER schedules in 15-minute windows for the day ahead. The PMC maintains responsibility for balancing of generation with loads, the optimization of all generation components and the coordination of islanding/reconnection events. During grid-tied and Islanded operation the microgrid controller manages the optimization of the energy storage component of the microgrid. This optimization will take into account the energy availability from the DER's, and the anticipated energy consumption within the microgrid. Storage optimization may also take into account external factors determined by Utility requirements and other forecasting inputs. SDSO utilizes outside information in the form of weather and load forecasts, energy tariff data such as Time-of-Use rates and user-imposed system constraints to further optimize the microgrid. The microgrid controller will process Demand Response requests via the utility interface. The PMC will in turn evaluate system capability and issue Demand Response commands to the generation, energy storage and load components within the Microgrid.

A distributed microgrid controller system will be provided to govern the operation of the microgrid. This controller consists of two components: the PowerLogic Microgrid Controller (PMC), a reactive real-time controller that is operating on the millisecond and second time scale and Struxureware Demand Side Operation (SDSO) software, a predictive controller that provides optimized DER schedules in 15-minute windows for the day ahead. The PMC maintains responsibility for balancing of generation with loads, optimization of generation and storage components and the coordination of islanding/reconnection events. SDSO utilizes outside information in the form of weather and load forecasts, energy tariff data such as Time-of-Use rates, Demand Response commands, and user-imposed system constraints to further optimize the microgrid.

The PMC will be capable of interfacing with the local controllers provided by the DER vendors. These local DER controllers will be responsible for the most basic level operation of the DER, i.e. maintaining the required voltage and frequency output for system stability. The PMC will provide a level of coordination above these local controllers such that the site load is shared between DER and the utility grid (when connected) at an optimal level.

A free standing master PMC enclosure will be provided at the microgrid distribution switchboard. Wall-mounted distributed remote PMC enclosures will be located at each DER to enable secure and dedicated control of each resource. Remote PMC enclosures will also be located at each microgrid participant building, and at the recloser interface with the utility. The majority of the participant buildings do not currently have a building management controller.



Proposed Control System Layout

A modular architecture provides an optimized solution today and can be easily expanded to control additional equipment in the future. The flexibility of the I/O and communications architecture allows it to be easily adapted to a wide range of distributed energy resources and microgrid equipment.

The Microgrid will incorporate two hydro-electric generators totaling 500 kW. Additional DER's will include 500 kW, 1MWhr of energy storage system. The two hydro-electric generators located at the Croghan Dam will serve as the anchor resources during islanded operation.

When operating in normal grid connected (parallel mode) the G&W pole top recloser will provide utility voltage and load current through internal sensors. The information will be communicated to the PMC by fiber link. If any parameters exceed the IEEE 1547 limits, the recloser will be opened and the utility will be isolated from the microgrid. The PMC will commence the sequence for Islanded operation by assessing the load level and generating capability. If loading exceeds capability, the DER sources will be shut down and the facility standby generators will pick at the facilities so equipped. The PMC will lock out sufficient facility standby generation (Prevent the facility from switching off the standby generation) so that the DER's can support the load. The DER generation will then be added to the microgrid. The PMC will manage DER generation and load thereafter. If the loading is within the DER capability when the microgrid is disconnected from the utility, the DER generation will remain operating through the transition to islanded operation. Should any DER source drop off line the PMC will work via the remote PMC controllers located at particular facilities to perform load shedding in order to maintain a stable microgrid. The PMC will constantly monitor for utility availability. Once the utility service is restored, it will synchronize the DER's to the utility across the recloser and perform a near bumpless reconnection of the utility.

The PowerLogic Microgrid Control System is built from the same standard, rugged, and reliable hardware platform used in thousands of critical applications in the industrial automation and process industries. To ensure resilience against severe weather conditions, Control system components will be housed in protective indoor, or outdoor rated enclosures, and control points will be linked via a buried self healing optical fiber ring. All control panels will be equipped with a battery-based uninterruptible power supply.

Task 2.6 IT/Telecommunications Infrastructure Characterization

A newly-installed, closed self-healing underground optical fiber ring will form the physical communication medium between control components within the microgrid. The master PMC will communicate with local controllers and utility interfaces using Modbus TCP, DNP3, and proprietary remote I/O protocols. The PMC will interface with the DSO hardware via Modbus TCP. External communications between the microgrid and the utility will be in accordance to the specifications of the utility to be further determined. The PMC may be interconnected with other external interfaces to facilitate the provision of ancillary grid support services such as frequency regulation.

If communications with the utility is lost during normal grid tied operation, the PMC will be able to access whether there is also a loss of the utility voltage and frequency reference. If the determination is that the utility EPS is electrically present, but communication to the utility has been lost the microgrid will continue to operate and be seen as a load center on the utility EPS. If the utility stipulates that a loss of communication under any circumstance should direct islanded operation of the microgrid then the PMC will act accordingly. If the loss of communications with the utility can also be associated with a loss of utility voltage and frequency reference the microgrid will disconnect from the utility and commence the Islanded operation sequence. Once the microgrid is islanded from the utility it can operate in the absence of communications with the utility.

V. TASK 3 - COMMERCIAL AND FINANCIAL FEASIBILITY

Task 3.1 Commercial Viability - Customers

The Croghan microgrid will serve 24 facilities including fifteen businesses, municipal sewer system, religious institutions, senior housing within, or very near, the Village of Croghan. Loss of these facilities during an emergency could impact up to 7,500 people in the region These entities are to be served in the case of power outage, to increase the community’s overall economic resiliency and emergency preparedness. These critical facilities will not be served under grid failure event in the absence of microgrid.

The Croghan microgrid project is an extension of the current Dam rehab and micro-hydro project which is independently progressing with State and local funding. Power produced from this facility with a total 500KW capacity is planned to be net-metered as a Community Distributed Generation (CDG) facility with multiple members using the power. This group includes multiple DANC facilities in the National Grid service area, and will potentially include Village of Croghan facilities, and other critical facilities, within the microgrid.

The facilities included in the microgrid will be connected to Grid power during normal operation and switch to hydro-power only augmented with existing standby generators during islanded operation. Additional revenue opportunities for DANC are possible through the use of Community Distributed Generation and remote net metering a community group through established policies. Contractual agreements stipulating critical facility requirements and expectations during islanded operation (i.e. extended grid power failure) will be arranged prior to system implementation.

The microgrid system includes battery storage for load management and enables the micro-hydro to become the local source of power when the grid power is down. This design concept will improve the operation and make the power available under emergency conditions, serve the adjacent industrial area, and preserve established jobs.

Building space and land area could be developed with low cost power while bringing new customers into the grid service area. Power generation in this distribution area will help the Utility in providing better service to the Village.

The critical facility list includes customers that are expected to be the member of the Community Distributed Generation system and purchase power generated by the hydro-power system at Croghan dam. The Village and community facilities retaining power during an emergency will also indirectly help other residents and businesses near the grid area with access to the basic needs of food and fuel, etc.

The Development Authority of North Country (DANC) will be the owner of the microgrid along with the Dam and hydro-power generation system to establish a remote net-metered - Community Distributed Generation (CDG) facility. This CDG facility will serve the local power needs of specified metered accounts as members of the CDG system for year-round service. The members of CDG located outside the microgrid area will not receive power during island mode, in order to assure safe power distribution within the microgrid area. This short term and infrequent disruption of power is unpredictable and unavoidable.

The Village stakeholders, DANC, and Consultants selected the critical facilities within the microgrid that will be served by the hydro-power under normal and grid shut down conditions. The facilities outside the microgrid will have power under normal conditions and access to Village facilities under power failure conditions.

As a part of CDG project development, a power purchase agreement will be executed by the critical and non-critical members of the CDG. Specific energy consumption allocation will be made for each of the members based on their previous year energy use data. The critical members within the microgrid will be a part of the total group that represents DANC facilities outside the microgrid, but within the County, and designed to purchase power produced by the hydro-power plant.

DANC has already identified a group of facilities using their power consumption characteristics to comprise a major part of the total power produced at the CDG facility at Croghan Dam. Remaining power will be allocated to manufacturing plants, commercial establishments, and critical facilities located in the Village and microgrid service area. Presentations to local businesses and other institutions will be made to offer membership and buy power at reduced costs.

The hydro-power system does not make it possible to serve any other energy commodity such as steam, hot water, or chilled water.

Task 3.2 Commercial Viability – Value Proposition

The microgrid project in combination with the hydro-power facility will make Croghan a unique small community demonstrating energy resilience and energy independence. Using 100% renewable energy generated within the microgrid and assuring power during Grid failure makes the community an attractive place to locate and grow. Keeping established jobs and creating new jobs will be possible with this project acting as a catalyst for economic development. DANC will realize their mission by helping the Village gain this benefit. Tourism to see such a system in place will also help the community and County, transforming Lewis County into a destination see many examples of Green Energy from Wind, Hydro and Biogas-fueled power generation in North Country.

National Grid will benefit by having renewable energy generation connected to the grid in their distribution system and serve the area with up to 500 kW of power after hydropower installation. This power need not be carried from remote generation points and will serve well as part of the solutions envisioned in the New York REV initiative.

Strengths of the Project:

1. The existing Dam that has been required by the New York State Department of Environmental Conservation to be rehabilitated and DANC's desire to install a 500KW hydro-power system as part of the Project.
2. Under the current NYERDA program, a Community Distributed Generation(CDG) system can be remotely installed to supply power to the members
3. DANC and Village of Croghan already have the consumption to utilize the power production at the Site
4. Croghan is a small Village with a history of old lumber mills and businesses that operated near the Dam using the hydro-power(mechanical energy)
5. The Village has multiple small businesses which have emergency generators and a natural gas system to provide backup power.
6. DANC and Village of Croghan have a close working relationship to support the project that can help create an energy resilient community and set an example for other communities in New York of local economic development
7. The revenues generated from the sale of hydro-power by a system owned by DANC at a slightly lower rate than that offered by the grid will provide the funds to cover the local cost (25% share) of the microgrid capital costs when financed with low interest municipal bonds over 20 years.

The threats in development of this project are:

1. Dam Rehab with micro-hydro-power project is not undertaken if there are no funding or long term loans available to fund the design and construction.
2. Microgrid design and installation depends on the selection of this project by NYSERDA. Many detailed design decisions left partially unresolved in this phase of the study will be further developed following this selection. In case the project is not selected for future funding, then the project viability will depend on any future funding in support of green renewable power based microgrid implementation.

This project is unique with the presence of Croghan Dam on Beaver River where a planned rehab project can provide around-the-clock power generation from hydro-power to serve remote as well as local manufacturing plants adjacent to the Dam. Building space for energy storage in existing facility offers lower cost for implementation. This power would also be available during the shutdown to serve the microgrid. This system will be 100% powered with renewable energy and serve a small community within a mile radius.

There are many small dams in the State which are now looking for rehabilitation opportunities to serve their communities. This project sets an example of how renewable energy sources can become the economic engine to help the communities not only in North Country but the rest of the State. This project leverages the benefit of having a hydro-power system to revive a historic community and make it a destination for seeing renewable energy applications that serve municipalities and local critical facilities. Croghan is historically known to be the place to help the surrounding area with food, shelter, and fueling resources. Enhancing this community with a power system for long term service during power failure would make it an asset to the whole area. With availability of hydro-power combined with battery storage and existing emergency generators the area can provide resilience for a much longer duration than 5 to 10 days. The area could be augmented in the future with the installation of solar PV as costs continue to drop.

The Value proposition to the community is that the total project provides Energy Independence, lower energy costs, resilient power source to deal with Climate related failures. Economic development is expected to occur by attracting businesses that want to be 100% powered by renewable energy. Tourism will bring new people to North Country, transforming the area into a destination for others to visit and learn about new technology. This will expand on the current cultural attractions, such as the Maple Museum and Railroad Museum, which currently bring visitors to town. Added revenue to local food merchants, as well as the hospitality industry, will also result from this project.

Controlling the cost of power for 20 years is a great advantage since Utility costs are expected to go up 2 to 3% per year. This project thus offers greater savings to all microgrid and CDG members under public ownership. It should be noted that people generally expect to pay a premium for renewable energy, but in this case the members of hydro-power CDG will be paying less than the current price of energy paid to National Grid and pass along electricity charges to DANC and Croghan users at the cost of generation. Controlling future increases in energy cost is not possible with grid power as the investments in Transmission and Distribution system are bound to increase future power rates.

This project complies with the future goals of distributed generation, benefitting the utility by reducing the need for future investment in grid improvements. While National Grid has not identified direct benefits to infrastructure or congestion relief, it is anticipated that improvements in resiliency and available power will positively contribute to local distribution. Preliminary information about local distribution provided by National Grid indicates that the infrastructure currently in place can support some level of added Distributed Generation, but further information about interconnection and interconnect costs will emerge as the project track further through design. This project will utilize new technology for power generation with hydro-power and wireless controls to monitor and operate the assets which are part of the microgrid project.

Task 3.3 Commercial Viability – Project Team

The project owner is the Development Authority of the North Country, a public authority that serves the common interests of Jefferson, Lewis, and St. Lawrence counties by providing technical services and infrastructure. This organization leads a team comprised of Larsen Engineers, a Civil and Environmental, and Renewable Engineering consulting firm with sixty years of experience in sustainable energy and project development, and Schneider Electric, global specialists in energy management, design, and implementation and industry leaders in electrical infrastructure. Details regarding responsibilities of system construction and operation will be developed as part of the design process. This group works closely with the former mayor of the Village of Croghan and board champion, receiving information about this project will fit into the local economic context. This relationship has provided a direct connection between the development team and the local community, securing support and enthusiasm from business owners and municipal government.

The Development Authority of the North Country (DANC), the project owner, provides services to bolster the economic development of the region. As such, it leverages tens of millions of dollars in assets to serve its community. It is anticipated that DANC will provide approximately 25% of the funding necessary for the development and implementation of the microgrid, financing most of this over the long-term through energy credit savings and sales via the dam rehabilitation project.

As the project proceeds, additional strengths, skills, and relationships will need to be developed. A letter of commitment from the utility will be required as will the inclusion of suppliers and additional contractors through competitive processes and established relationships. Further investment will be necessary to supply between 25 and 50% of funding. These sources are anticipated to be drawn from local development authorities and other parties interested in supporting the economic development and emergency resiliency of the region. Finally, legal and regulatory advisers will need to be included to streamline the permitting process and implementation phases of the project. These knowledge bases, when not included among existing team members, will be incorporated through existing business networks and relationships.

Task 3.4 Commercial Viability – Creating and Delivering Value

Microgrid Technologies

The primary source of energy for the proposed Croghan micro-grid will be a set of hydro-turbines located at the Croghan dam. The rehabilitation project for this site is in the process of being developed and implemented separate from the micro-grid effort, with the intention of providing 500kW of electrical demand during peak system performance. This energy strategy will be augmented through the use of existing generation equipment at several of the critical facility locations (both diesel and natural gas) as well as battery storage for improving the functionality of the system in island mode and providing electricity to critical facilities too distant from the proposed micro-grid infrastructure to be economically served. The benefits of these technologies are reliability and access, while design challenges include designing control systems and providing load balancing. The PowerLogic Microgrid Control System, described in detail in Task 2.5, is built from the same standard, rugged, and reliable hardware platform used in thousands of critical applications in the industrial automation and process industries. It is the controller for dozens of operating microgrids.

Construction, Operation, and Benefits

The preliminary design established within this document will be advanced toward final design by Schneider Electric, following all necessary equipment specifications and utility requirements. A permitting phase will be required, though no special permissions are anticipated. Construction of the grid will be executed by qualified contractors and subcontractors following final design approval while details of ongoing system operation remain to be understood as the project approaches final design. It is anticipated that a contract will be issued for ongoing operations and maintenance costs under the supervision of DANC, including any repairs and equipment replacements as well as ongoing operational supervision. The proposed technologies powering and operating the micro-grid are all established products for power management that will be customized for the project, including controllers, cabling, switchgear, and battery storage. Task 1 identifies some of these materials. The project will require collaboration with the utility during the interconnection phase, the costs and limitations of which will be identified during the design phase. During normal operation, coordination with the utility will be necessary to distribute Community Distributed Generation credits to purchasers on a monthly basis.

Project benefits are distributed to the community through several channels. Purchasers of power from the primary power source will benefit from cost savings and increased stability during normal operations. Critical facilities will see resiliency during emergency situations, benefiting the economic interests of the local community while also providing resources to community members not directly associated with the micro-grid. This enhanced local resiliency will provide a net benefit to the community by increasing emergency preparedness and providing a more stable environment for the attraction of new business through the use of local resources. As a primarily rural community in a region of the state that has suffered long-term power outages due to weather in the past (perhaps most notably a 1998 ice storm that left over 100,000 people without power for up to three weeks), a reliable microgrid in the Croghan area would provide a critical buffer against the effects of severe weather on the economy of the community as well as the wellbeing of its citizens.

Business, Commercialization, and Energy Market

The project owner, DANC, will charge energy purchasers through a Community Distributed Generation model as a host/sponsor. Members of this Community Distributed Generation group will be assigned credits based on historical energy usage as a percentage of system output. These credits will be administered through the utility during normal system operations based on reporting from the host/sponsor. This plan could be replicated in other areas where scaled power generation used to power a micro-grid to marry emergency resiliency with the benefits of renewable and sustainable energy technologies in localized deployments. Community Distributed Generation is relatively new in New York state, but regulations and policies are beginning to streamline the process of including purchasers/members, and it is anticipated that a preliminary billing analysis for potential members, along with contractual agreements between sponsor/host and members, will be the primary barrier to the inclusion of power purchasers. The Village of Croghan and the surrounding area is comprised of a variety of businesses, agricultural interests, cultural institutions, and residences. Many of these entities serve as perfect candidates for CDG membership and could realize significant savings by purchasing energy credits through the micro-grid's main power source. As this project is further developed through the design phase, legal counsel will be incorporated to provide guidance on the individual relationships, agreements, and utility or PSC negotiations needed to bring this project to full commercialization.

The CDG component of this project will be discussed further in section 3.5, but analysis of current energy market trends indicate that utility rates are set to increase as much as 3% in coming years. This forecast encourages the development of independent energy generation that provides many users value in both cost and, in the case of critical facilities in a local microgrid, reliability.

Task 3.5 – Financial Viability

The Village of Croghan and DANC will benefit from Governor Cuomo's game-changing plan released in July of 2015 promoting community distributed generation (CDG). The stakeholders will benefit from energy generated from a renewable resource while realizing the added bonus of remote net metering to both (a) allow non-microgrid entities to partake in clean energy and (b) expanding the potential customer base. Accordingly, DANC is currently reviewing, among other alternatives, a plan to distribute power at reduced prices to Croghan businesses, municipality entities, religious institutions, senior housing, and remote benefactors that would include other citizens and businesses of the Village of Croghan. Current utility prices hover around \$0.075-\$0.09 per kWh for large users, and \$0.013-\$0.015 per kWh for small users. The 500 kW hydro facility is expected to deliver power to large users for \$0.08 per kWh or less, and to small customers for \$.10 per kWh or less. These cost savings are an added bonus for customers that are also realizing the benefits of renewable resilient energy. Under this model, the revenue streams from customers could be secured under a power purchase agreement (PPA) at established rates, although the revenue stream will vary seasonally depending on water flow. It is anticipated that this model could provide customers with power at an initial rate less than their existing utility rate, adding the value of resiliency, with long-term savings continuing to accumulate as grid costs increase. Larsen Engineers has constructed a sophisticated financial model to evaluate, and conduct sensitivity analysis on, 41 separate variables including known factors including proposed equipment costs, kWh grid rates, inflation rates, cost of capital, loan interest rates, marketable power rates, and other factors. This modeling evaluates and analyzes the system based only on costs relative to the development of a system that will operate as a Community Distributed Generation asset, leaving out microgrid components such as controllers and distribution as a separate project. As a result of this analysis, Larsen Engineers concludes that such a project is financially lucrative with the sale of power through Community Distributed Generation (CDG). If additional sources of funding can be obtained, for example from a USDA REAP-like grant or a grant from the NY Prize program, the project is even more economically attractive. As detailed throughout this document, the CDG program reduces the risk of the proven PPA business model.

In a previous version of this study, two models were evaluated – private ownership and public ownership. However, because the benefits that will accrue to DANC are much higher under public ownership, that model is evaluated in greater detail in this study, and the option of private ownership will not be considered. There is a very simple reason that public ownership provides greater benefits than private ownership, and it is because the former option eliminates the middle man. Under private ownership, the developer must be compensated for project risk, and this reduces the amount of savings that purchasers of power can receive. Under public ownership, DANC can pass along generated power at cost to customers, which results in more savings than those realized under private ownership, even with the advantage of accelerated depreciation and tax credits.

Under the public ownership scenario described in this study, DANC will own and operate the hydropower system, assume all project risk, and arrange for project financing. Because DANC is a public (not-for-profit) entity, it cannot make a profit on the sale of power nor take advantage of investment tax credits and accelerated depreciation. DANC will therefore pass along power at cost to large and small users, after paying for debt service, operating and maintenance costs, and Community Distributed Generation (CDG) administrative costs.

Two turbines were evaluated in this analysis – the most expensive Mavel turbine, which generates 2,829,000 kWh per year, and the least expensive MJ2 VLH turbine, which generates 2,849,000 kWh per year. These values were determined by a report on the dam rehabilitation effort developed by Kleinschmidt entitled the Croghan Dam Peer Review Report in May of 2016. Their calculation used a lower head elevation than identified in earlier Dam studies at 818’. Please note that although significantly more power can be generated at the higher elevation of 819' (the original head elevation identified), the lower elevation was used as a conservative measure. More information about the DANC reports developed to study dam rehabilitation and hydroelectric power in Croghan can be found under II. Project Background above.

It should also be noted that the cost to repair the dam has NOT been subtracted from total construction cost in the values used for BCA or the overall financial viability discussed here In early versions of this feasibility study, dam remediation costs were subtracted from total construction cost because the dam will need to be repaired whether or not hydropower is installed. Therefore, the cost to repair the dam is not relevant. However, it is also true that DANC will need to raise funds to repair the dam in either case, and if hydropower is installed, it should generate enough savings to not only pay for the hydropower facility, but the dam repair costs as well. This can be accomplished if the cash flow from the project is positive when total construction costs are incorporated in the analysis, including dam remediation costs.

Under the public ownership scenario, it is also likely that DANC could receive considerable financial assistance in the form of grants from state and federal agencies. DANC has already received $375,000 from ESD to repair the dam. In order to evaluate the impact of financial assistance, three grant options were evaluated for each of the two turbines; 0%, 25%, and 50%, where the percentage indicates the grant amount received as a fraction of total construction cost less $375,000. For example, suppose, as in Option #2 below, total construction cost for one option is equal to $4,192,000. $375,000 is subtracted from this amount immediately, as DANC has already received these funds from ESD. The total amount of funds to be borrowed for the 0% case is thus $3,817,000; for the 25% case, $2,862,750; and for the 50% case, $1,908,500.

Assumptions used in this analysis of the public ownership option are listed below:

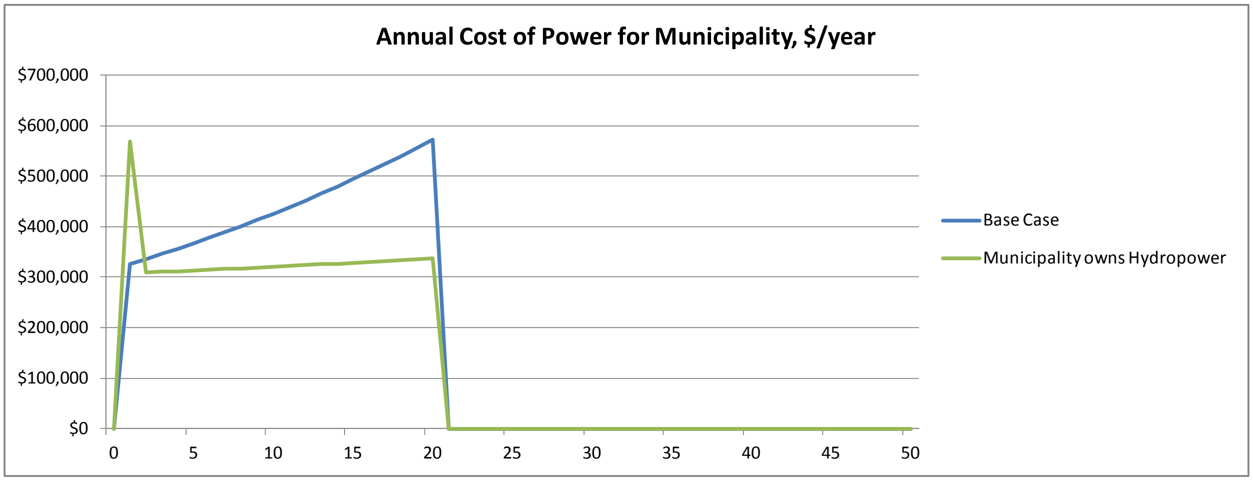
- Time horizon for the project is 20 years.
- Inflation rate of grid power is 3% per year.
- Annual operating and maintenance costs are $36,383 per year and grow at 2% per year.
- Administrative expenses for CDG management are $0.01/kWh/year and grow at 1% per year.
- Current grid rates for power paid to the utility are $0.08/kWh for large users and $0.14/kWh for small users.
- 1,298,412 kWh/year of power generated by the turbine will go to large (critical) users, with the remainder going to small users.
- The total construction cost used for each turbine configuration in this analysis is the larger amount calculated by Kleinschmidt in their report of May 2016. The cost to repair the dam has NOT been subtracted from total construction cost.
- The project is assumed to start at year 0 (today). The hydropower system will become fully operational one year from today.

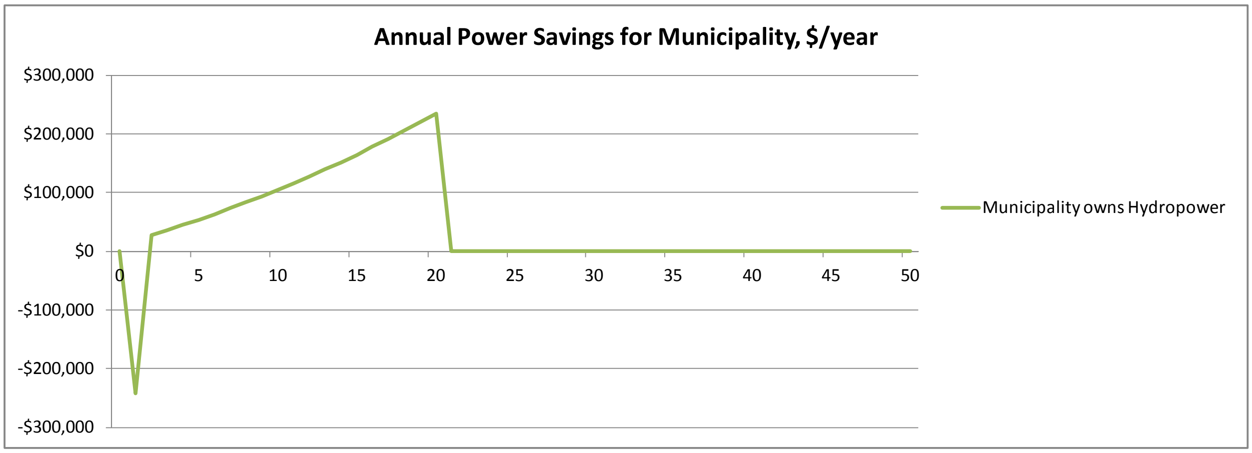
- DANC can obtain a low-interest loan at 2.5% per year with repayment terms of 20 years for the full amount of total construction cost, less the grant of $375,000 already received from ESD, less additional grants received. DANC will begin repaying the loan each month as an ordinary annuity, with the first payment on the loan (principal and interest) due one month from today.
- As a simplifying assumption, proceeds from the loans and grants are assumed to be received today, and all uses of these proceeds are assumed to be disbursed today.
- Until the hydroturbine becomes operational, DANC and other power purchasers will continue to buy power at regular rates from the grid, and no operating expenses from the hydropower system are incurred, except for repayment of principal and interest on the loan, which can be paid from the ESD grant of $375,000 during the first year.
- For the discounted cash flow analysis, a discount rate of 3% per year was used.
- This analysis includes estimated production cost of power in $/kWh. Please note that this amount will change each year due to inflation. Therefore, this cost is estimated using non-inflated (year 0) costs, even though the turbine does not become operational until year 1.

For each of the six options evaluated in this study, the costs associated with the base case and the hydropower option are calculated. The base case is simply the "do nothing" scenario – DANC and its residents continue to purchase power from the utility, and the dam is not repaired. Costs for each option for each of the twenty years are shown graphically on the following pages, for all six options (MJ2 VLH turbine at 0%, 25% and 50% grant funding levels, and Mavel turbine at 0%, 25% and 50% grant funding levels). Savings (base case costs minus hydropower costs) are also shown graphically for each year for each of the six options. Finally, the total cost of power for the base case and the hydropower system, and the expected savings, are reported for the total 20-year period, in both cumulative value and present worth for each option. Cumulative value is simply the total value of energy savings over the 20-year period. The present worth metric discounts annual savings for each year back to today, and sums the discounted values into one number, similar to net present value.

Option #1
MJ2 VLH is used at lower elevation (818')
2,849 MWh generated per year (Kleinschmidt)
Total construction cost is $4,192,000 less $375K grant from ESD, or $3,817,000
No other grants obtained
Construction cost includes remediation of dam
20 year time horizon

Current average weighted cost of purchased power - $0.1127/kWh (today's cost)
Estimated production cost - $0.1075/kWh (today's cost)



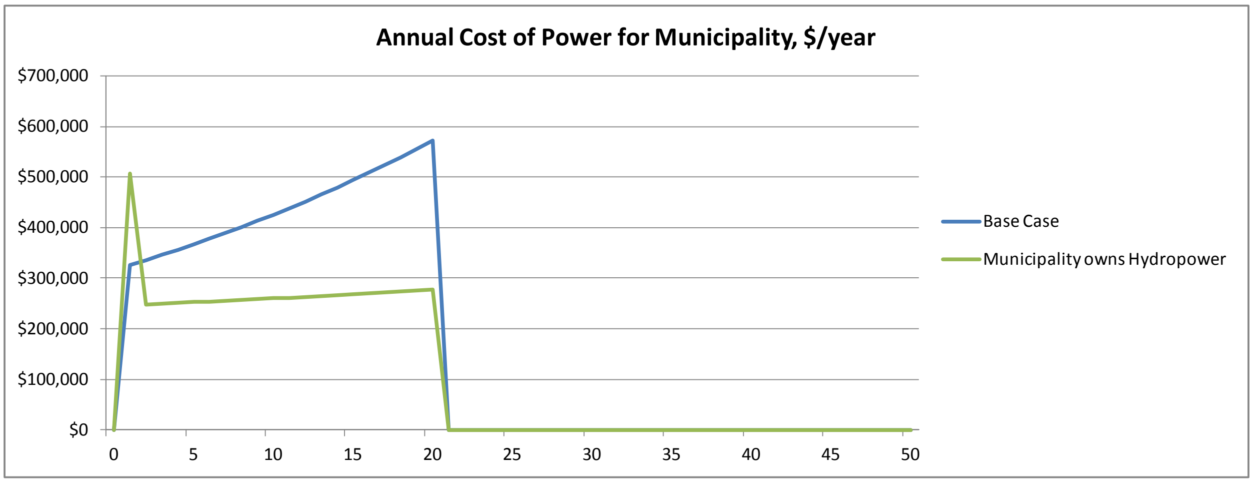


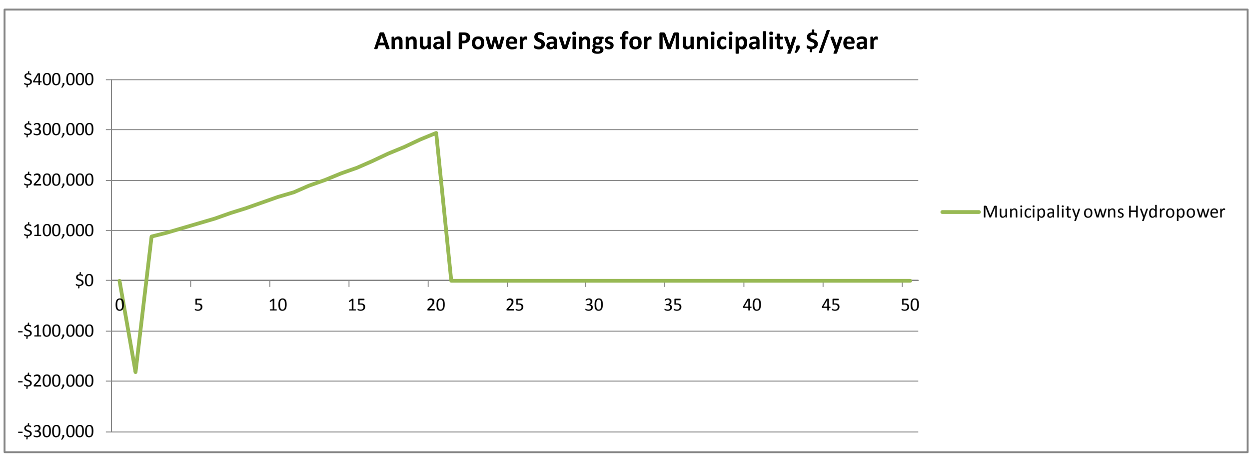
FINANCIAL METRICS FOR MUNICIPALITY - MUNICIPALITY OWNS HYDRO

COST OF POWER OVER PROJECT LIFE			
Metric	**Base Case**	**Hydropower**	**Savings**
Cumulative	**$8,763,699**	**$6,695,602**	**$2,068,097**
Present Worth	**$6,419,106**	**$5,085,586**	**$1,333,519**

Option #2
MJ2 VLH is used at lower elevation (818')
2,849 MWh generated per year (Kleinschmidt)
Total construction cost is $4,192,000 less $375K grant from ESD, or $3,817,000
25% grant obtained, reducing total construction cost to $2,862,750
Construction cost includes remediation of dam
20 year time horizon

Current average weighted cost of purchased power - $0.1127/kWh (today's cost)
Current production cost - $0.0865/kWh (today's cost)



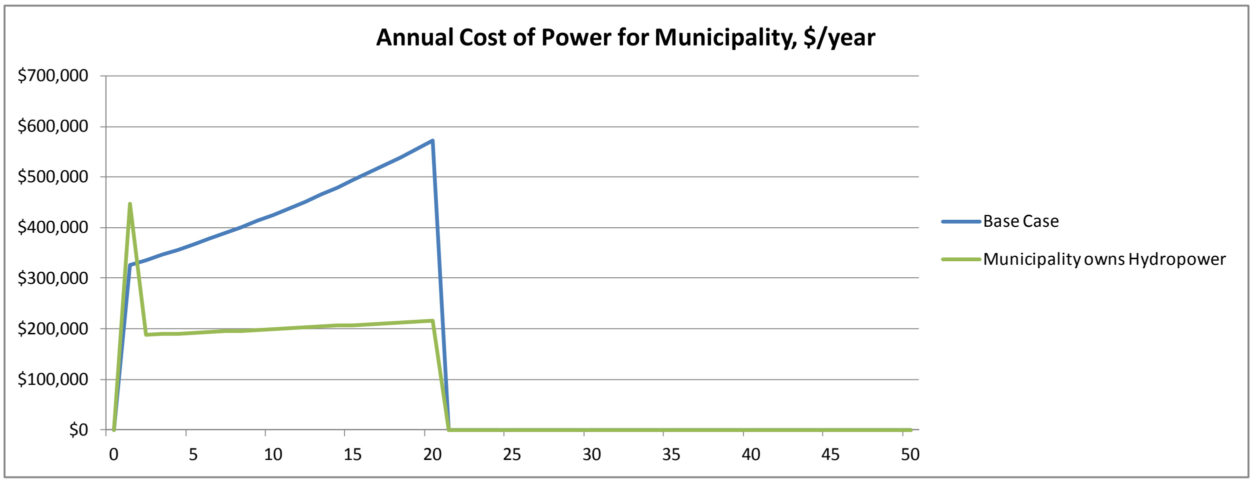


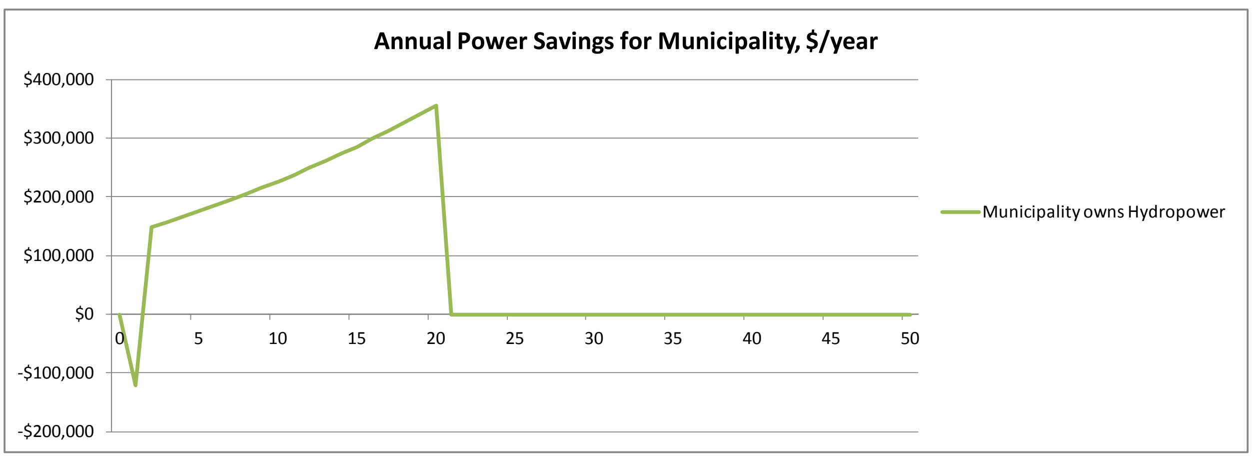
FINANCIAL METRICS FOR MUNICIPALITY - MUNICIPALITY OWNS HYDRO

COST OF POWER OVER PROJECT LIFE			
Metric	**Base Case**	**Hydropower**	**Savings**
Cumulative	**$8,763,699**	**$5,485,162**	**$3,278,537**
Present Worth	**$6,419,106**	**$4,172,857**	**$2,246,249**

Option #3
MJ2 VLH is used at lower elevation (818')
2,849 MWh generated per year (Kleinschmidt)
Total construction cost is $4,192,000 less $375K grant from ESD, or $3,817,000
50% grant obtained, reducing total construction cost to $1,908,500
Construction cost includes remediation of dam
20 year time horizon

Current average weighted cost of purchased power - $0.1127/kWh (today's cost)
Current production cost - $0.0653/kWh (today's cost)



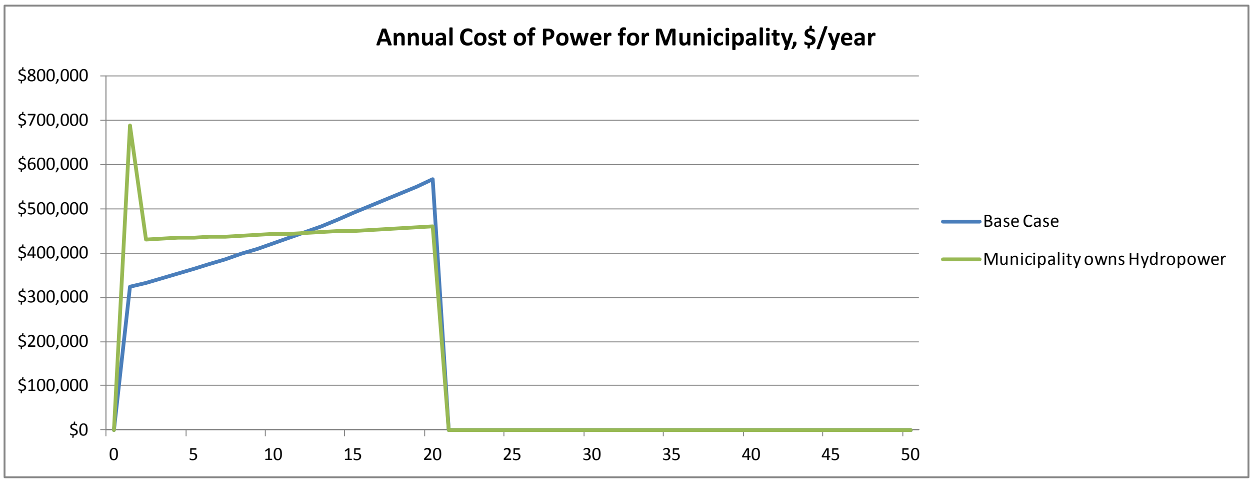


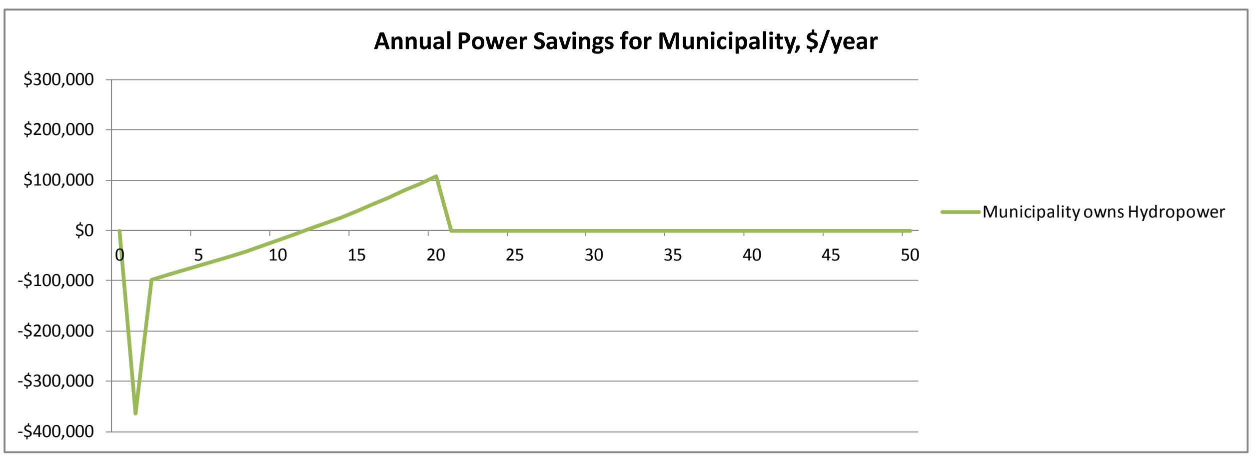
FINANCIAL METRICS FOR MUNICIPALITY - MUNICIPALITY OWNS HYDRO

COST OF POWER OVER PROJECT LIFE			
Metric	**Base Case**	**Hydropower**	**Savings**
Cumulative	**$8,763,699**	**$4,274,721**	**$4,488,977**
Present Worth	**$6,419,106**	**$3,260,128**	**$3,158,978**

Option #4
Mavel turbine is used at lower elevation (818')
2,829 MWh generated per year (Kleinschmidt)
Total construction cost is $6,114,000 less $375K grant from ESD, or $5,739,000
No other grants obtained
Construction cost includes remediation of dam
20 year time horizon

Current average weighted cost of purchased power - $0.1125/kWh (today's cost)
Estimated production cost - $0.1516/kWh (today's cost)



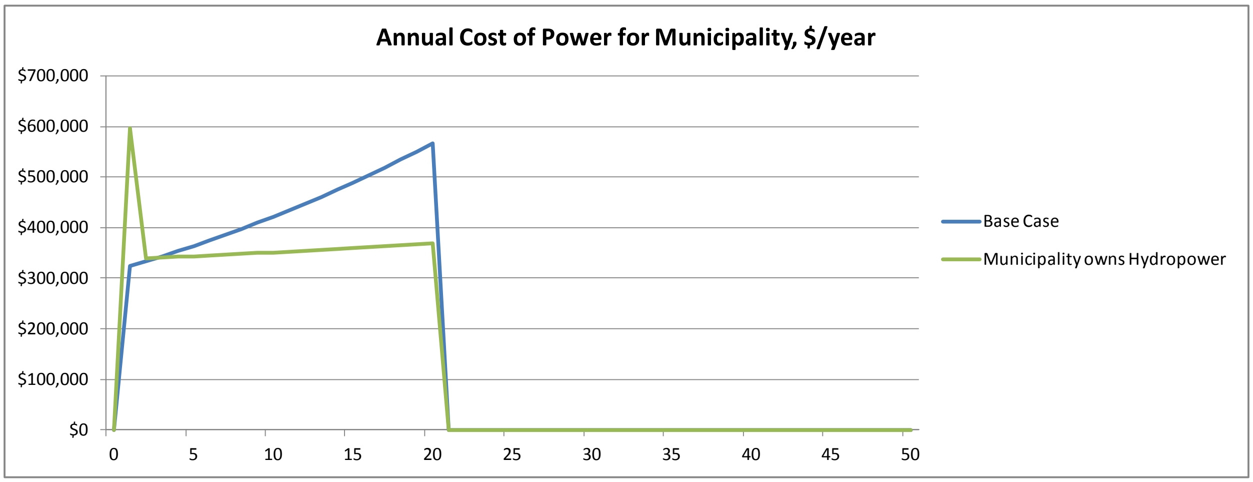


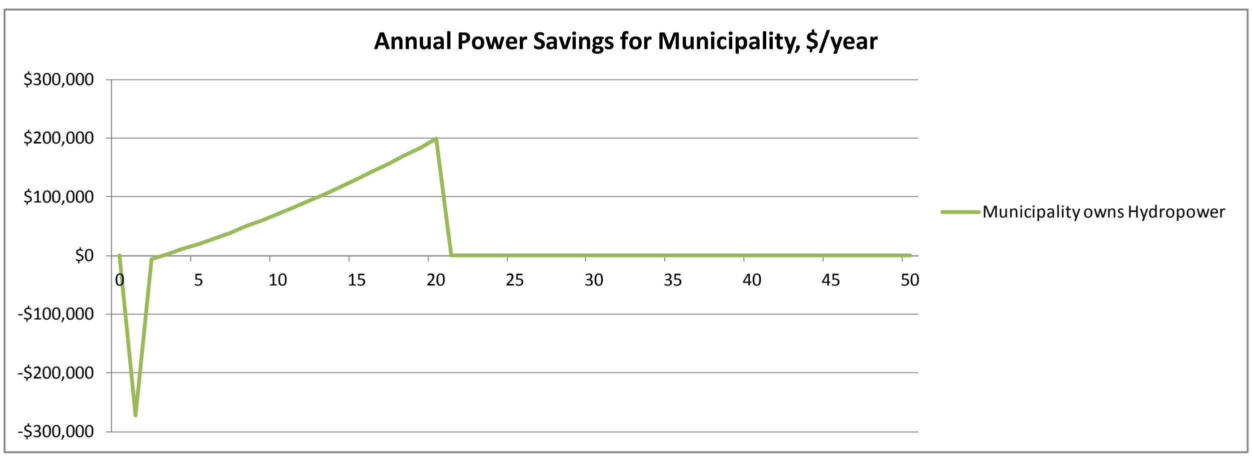
FINANCIAL METRICS FOR MUNICIPALITY - MUNICIPALITY OWNS HYDRO

COST OF POWER OVER PROJECT LIFE			
Metric	**Base Case**	**Hydropower**	**Savings**
Cumulative	**$8,687,245**	**$9,126,051**	**-$438,807**
Present Worth	**$6,363,106**	**$6,917,724**	**-$554,618**

Option #5
Mavel turbine is used at lower elevation (818')
2,829 MWh generated per year (Kleinschmidt)
Total construction cost is $6,114,000 less $375K grant from ESD, or $5,739,000
25% grant obtained, reducing total construction cost to $4,304,250
Construction cost includes remediation of dam
20 year time horizon

Current average weighted cost of purchased power - $0.1125/kWh (today's cost)
Estimated production cost - $0.1194/kWh (today's cost)



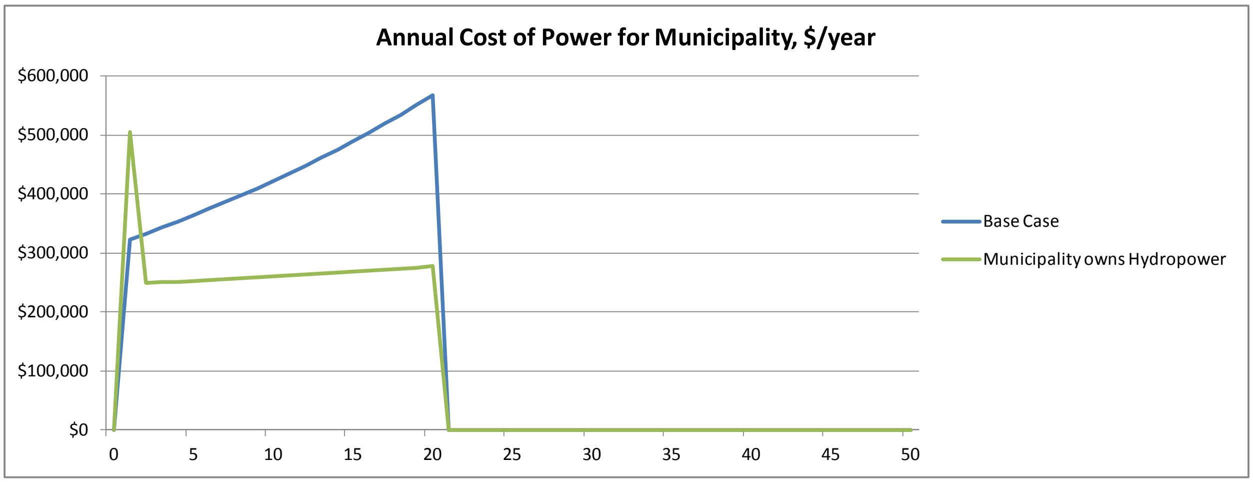


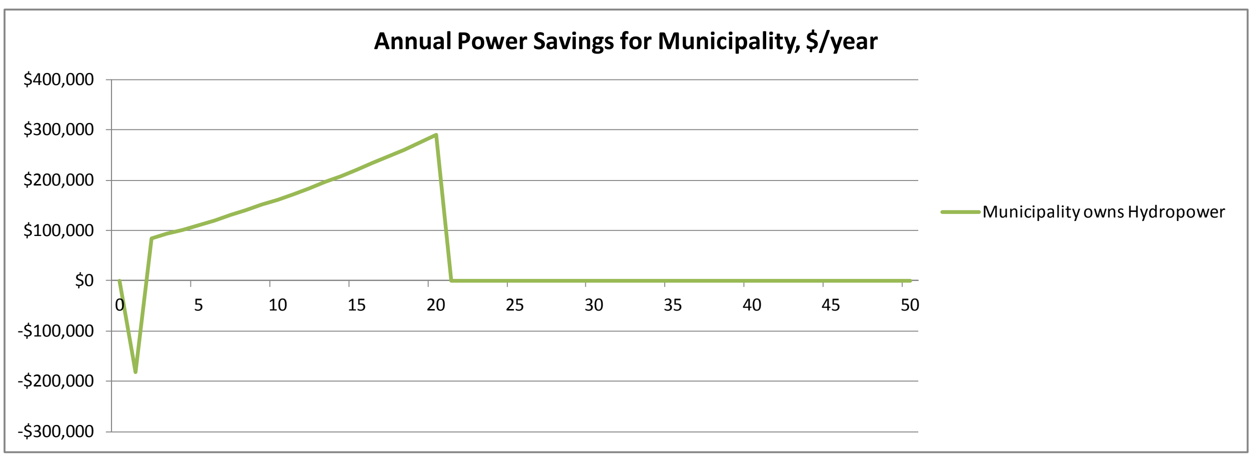
FINANCIAL METRICS FOR MUNICIPALITY - MUNICIPALITY OWNS HYDRO

COST OF POWER OVER PROJECT LIFE			
Metric	**Base Case**	**Hydropower**	**Savings**
Cumulative	**$8,687,245**	**$7,306,110**	**$1,381,135**
Present Worth	**$6,363,106**	**$5,545,402**	**$817,704**

Option #6
Mavel turbine is used at lower elevation (818')
2,829 MWh generated per year (Kleinschmidt)
Total construction cost is $6,114,000 less $375K grant from ESD, or $5,739,000
50% grant obtained, reducing total construction cost to $2,869,500
Construction cost includes remediation of dam
20 year time horizon

Current average weighted cost of purchased power - $0.1125/kWh (today's cost)
Estimated production cost - $0.0873/kWh (today's cost)





FINANCIAL METRICS FOR MUNICIPALITY - MUNICIPALITY OWNS HYDRO

COST OF POWER OVER PROJECT LIFE			
Metric	**Base Case**	**Hydropower**	**Savings**
Cumulative	**$8,687,245**	**$5,486,169**	**$3,201,076**
Present Worth	**$6,363,106**	**$4,173,080**	**$2,190,026**

Briefly, the low cost turbine case (MJ2 VLH turbine) is profitable regardless of grants received. The current weighted-average cost of purchased power (industrial and residential users) is \$0.1127/kWh; at the 0%, 25%, and 50% grant funding levels, estimated production costs of power in year 0 are \$0.1075, \$0.0865, and \$0.0653, respectively. These costs change each year due to inflation. Also, there is always a loss (i.e. cash outflow) in the first year of operation because the turbine has not yet come on line, consumers are still buying power from the utility, and DANC will have to make payments on the bond issue, proceeds from which are received in year 0. DANC can utilize the \$375K ESD grant fund to pay bond premiums in the first year. If DANC can obtain 50% grant funding, power purchasers can save more than \$4.4M over the 20-year period (cumulative dollars), or over \$3.1M in today's dollars.

The high cost turbine case (Mavel turbine) will require grants to be profitable. The current weighted-average cost of purchased power (industrial and residential users) is \$0.1125/kWh (slightly different from the low cost turbine case because slightly less power is generated). The 0% grant funding case loses money, 25% is somewhat profitable, and 50% is quite profitable. At the 0%, 25%, and 50% grant funding levels, estimated production costs of power in year 0 are \$0.1516, \$0.1194, and \$0.0873, respectively. As noted above, these costs change each year due to inflation. As before, there is always a loss (i.e. cash outflow) in the first year of operation because the turbine has not yet come on line, consumers are still buying power from the utility, and DANC will have to make payments on the bond issue, proceeds from which are received in year 0. DANC can utilize the \$375K ESD grant fund to pay bond premiums in the first year. If DANC can obtain 50% grant funding, power purchasers can save more than \$3.2M over the 20-year period (cumulative dollars), or over \$2.1M in today's dollars.

As stated previously in this report, the hydroturbine represents only a portion of the microgrid project. The entire \$5.53M project assumes funding from the NY Prize program to cover costs for the following: hydroturbines (to be partially funded by a Community Distributed Generation program to include critical facilities and other members of the community), electrical interconnection, protection and control gear, cabling, battery energy storage, etc. One potential financing structure to execute this project through development, construction, and initial operation would include the following,

- 50% funding from NY Prize
- 25% funding from DANC
- 25% financed via loan (debt to be serviced by customer revenue)

In addition to funding from NY Prize, other funding and financing vehicles exist for DANC to pursue to obtain the necessary resources:

- The USDA Rural Energy for America Program (REAP) will fund up to 25% of capital costs (a maximum of $500,000)
- The NY Green Bank program has numerous options for financing, including credit enhancements, lending (senior, mezzanine, subordinated, etc.), and warehouse provider, among others

Once the system is operational, the fixed costs to operate and maintain the system will hover around 2.5% of the initial capital costs or between $22.5k and $25k.

The timing of this project is impacted by the dam rehabilitation, potential NY Prize funding, and other available incentives such as those available from USDA REAP and NY Green Bank.

VI. TASK 4 - BENEFIT COST ANALYSIS

The costs associated with the development of the microgrid, as well as those associated with power outage, and backup generator operations, have been estimated through a collaborative process between the Development Authority of the North Country, its contractors and partners, the Village of Croghan, and the critical facilities included. Information was provided to the New York State Energy Research and Development Authority for third-party Cost-Benefit Analysis and final documentation, analysis, and recommendations. These recommendations are enclosed as Appendix F. To summarize, this third party effort identified a benefit-cost ratio of 1.0 in years in which the community (including critical facilities) experience at least 1.9 days of significant power outage. This analysis includes a higher project cost ($10.3M versus the projected costs of $5.53M) than that finally developed by the project team, a difference due to a variance in project costs included. The BCA analysis was conducted on a construction project which includes dam rehabilitation and installation of hydroelectric facilities, an effort that can be financed by implementing the system under Community Distributed Generation as discussed in Task 3.5.

Task 4.1 Facility List and Customer Description

The following table summarizes the critical facilities that have been identified, analyzed, and included in the Croghan microgrid. Each of these facilities represents a single meter/ratepayer providing a governmental, economic, residential, or other important function in the community. Several of these facilities are centers of community activity and could serve as a place of refuge during a severe and/or long-term emergency. These include Shekinah Mennonite Fellowship, St. Stephen's Catholic Church, and the American Legion Post. This final list of critical facilities was established through a process that prioritized criticality to both the community's immediate emergency resiliency and the economic wellbeing of the region, and as such the functions and electrical needs of these facilities are key to understanding the as-proposed microgrid's overall benefit.

Facility Name	Rate Class	Facility/Customer Description	Economic Sector Code	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Supply Required Per Day During Major Power Outage
Croghan Fire Hall	Small Commercial/Industrial (<50 annual MWh)	Fire Hall	*All other industries*	0.343	.001	100%	24
Croghan Library	Small Commercial/Industrial (<50 annual MWh)	Library	*All other industries*	0.983	.004	100%	6
Steepleview Courts	Residential	Apartment complex	*Residential*	58.822	.027	100%	24

Facility Name	Rate Class	Facility/Customer Description	Economic Sector Code	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Supply Required Per Day During Major Power Outage
Village of Croghan Municipal Bldg	Small Commercial/Industrial (<50 annual MWh)	Municipal facility	*All other industries*	16.715	.012	100%	24
Croghan Wastewater treatement	Small Commercial/Industrial (<50 annual MWh)	Water treatment facility	*All other industries*	1.661	.002	100%	24
Croghan Convenience	Large Commercial/Industrial (>50 annual MWh)	Grocery/convenience store	*All other industries*	260.833	.05	100%	16
American Maple Museum	Small Commercial/Industrial (<50 annual MWh)	Museum	*All other industries*	10.023	.004	100%	6
Monnat's	Large Commercial/Industrial (>50 annual MWh)	Grocery/convenience store	*All other industries*	135.939	.05	100%	12
Croghan Island Mill	Small Commercial/Industrial (<50 annual MWh)	Mill/production facility	*Manufacturing*	9.203	.008	100%	10

Facility Name	Rate Class	Facility/Customer Description	Economic Sector Code	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Supply Required Per Day During Major Power Outage
Grand Slam Safety	Large Commercial/Industrial (>50 annual MWh)	Factory/production facility	*Manufacturing*	60.000	.03	100%	10
Croghan Railroad Museum	Small Commercial/Industrial (<50 annual MWh)	Museum	*All other industries*	12.000	.005	100%	10
Shekinah Mennonite Fellowship	Small Commercial/Industrial (<50 annual MWh)	Religious institution	*All other industries*	4.266	.003	100%	24
St. Stephens Catholic Church	Small Commercial/Industrial (<50 annual MWh)	Religious institution	*All other industries*	32.133	.017	100%	24
American Legion Post 1663	Small Commercial/Industrial (<50 annual MWh)	Event center/ American Legion post	*All other industries*	37.445	.029	100%	10
Joseph Lyndaker Farm	Large Commercial/Industrial (>50 annual MWh)	Dairy farm	*All other industries*	53.641	.050	100%	24

Facility Name	Rate Class	Facility/Customer Description	Economic Sector Code	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Supply Required Per Day During Major Power Outage
Croghan Reservoir Water Production	Small Commercial/Industrial (<50 annual MWh)	Water production facility	*All other industries*	24.967	.018	100%	24
Croghan Lift Stations	Small Commercial/Industrial (<50 annual MWh)	Wastewater lift stations. 9 meters	*All other industries*	13.132	.024	100%	24

Task 4.2 Distributed Energy Resources

The microgrid relies on two fundamental components to provide direct power to critical facilities during an emergency grid outage. These assets are summarized in the table below. Additionally, the microgrid will leverage existing standby generators at some of the facilities as needed if the microgrid control mechanisms determine that the pre-islanding load exceeds DER capability.

Distributed Energy Resource Name	Facility Name	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Average Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
						Quantity	Unit
Hydro-Electric	*Croghan Dam*	*Hydro*	*0.5*	*2480*	*12*	*0*	Choose an item.
Microgrid Batteries	Croghan ESS	*Electrochemical*	0.5	0	0	0	Choose an item.

Task 4.3 Capacity Impacts and Ancillary Services

It is anticipated that adding 500kW of DER, though the actual power generation is to be financed and designed through a process separate from the NY Prize, will have a net positive impact on the regional capacity of the grid. As this power source is intended to provide power to the grid through a remote net metering arrangement, the utility will be able to use the DER as a resource for balancing peak load.

The following resources are available for peak load support.

Distributed Energy Resource Name	Facility Name	Available Capacity (MW / year)	Does distributed energy resource currently provide peak load support?
Hydro-Electric	*Croghan Dam*	0.5	☐ Yes

There would be no Demand Response resources available.

Further, no emission allowances will be purchased for the operation of the DER's. The emission rates for the equipment are as follows:

Emissions Type	Emissions per MWh	Unit
CO_2	0	lb
SO_2	0	lb
NO_x	0	lb
PM	0	lb

Task 4.4 Project Costs

A key figure for determining the Croghan microgrid's overall value is the cost of the project. This includes all necessary power generation assets as well as outlying microgrid assets such as power distribution, control systems and software, and any necessary infrastructure upgrades. The installed cost for all the capital equipment is shown in the below table, totaling $10.3M.

Capital Component	Installed Cost ($)	Component Lifespan (round to nearest year)	Description of Component
Hydro-Turbine	4.77*	20	Cost/ install provided by others. Includes support equip
Batteries	$1.2M	15	ESS system complete
Microgrid OH distribution	$2.7M	25	Overhead microgrid separate from utility
Microgrid controls	$0.53M	20	Control panels, software, comms
Main electrical switchgear	$1.1M	25	Switching for sources, microgrid, utility

Of course, the above table does not represent all necessary expenditures to bring the functional microgrid into operation. The initial planning and design cost for this microgrid, as proposed, is estimated at $630,000. The fixed O&M costs are projected to be $65.5 k per year. There are no non-fuel variable O&M costs. Dam and hydro-generation costs are included, but as separate financing, design, and construction is being considered by the dam owners, leveraging separate revenue streams, the overall Benefit-Cost ratio of this microgrid project should be considered substantially better than that depicted in third-party assessment. In short, during normal operation the dam and hydro-electric generation are intended to be a self-sustaining energy asset, financed through a Community Distributed Generation model, while serving as the anchor energy resource for the microgrid during emergency operation. The financing details of this dam rehabilitation and hydroelectric project are discussed under Task 3.5

Distributed Energy Resource Name	Facility Name	Duration of Design Event (Days)	Quantity of Fuel Needed to Operate in Islanded Mode for Duration of Design Event	Unit
Hydro-Electric	*Croghan Dam*	30	0	Choose an item.
Microgrid Batteries	Croghan ESS	30	0	Choose an item.

Task 4.5 Costs to Maintain Service During a Power Outage

The value any microgrid design is challenging to quantify. While financial costs for designing and constructing the necessary assets can be readily estimated and the approximations of the system's necessity, in terms of people served and the likelihood of a triggering event, the benefit to the community is much further reaching. The economic impact of a major power outage to an area's businesses and livelihoods must be taken into account. One means of applying a number to this microgrid benefit is to examine the avoided costs of having a microgrid in place during a major outage. This section attempts to tabulate the costs to be incurred by both businesses and municipal entities during a power outage in order to maintain services. It can be assumed that a functional microgrid designed to serve the critical facilities herein would avoid these costs during a power outage. And, because the Croghan microgrid utilizes hydroelectric power, these costs would not be replaced with other fuel or mobilization costs—though operation of the hydrelectric facilities will incur some nominal per kWh cost.

Within the Croghan microgrid are four existing generators with a total nameplate capacity of .1425MW. Their specific locations, capacities, and associated costs are tabulated below. These generators would be employed during a regional outage.

Facility Name	Generator ID	Energy Source	Nameplate Capacity (MW)	Standard Operating Capacity (%)	Avg. Daily Production During Power Outage	Fuel Consumption per Day		One-Time Operating Costs ($)	Ongoing Operating Costs ($/day)
						Quantity	Unit		
Water Treatment Facility and lift stations	*Unit 1*	*Diesel*	*.0125*	*100 %*	*0.3*	*22*	*Gallons/ day*	-	*450 (includes mobile staff)*
Croghan Fire Department	Unit 2	*Diesel*	.05	80%	1	77	Gallons/ day	-	$165
Monnat's Country Store	Unit 3	*Diesel*	.04	80%	.8	78	Gallons/ day	-	$165
Steepleview Courts	*Unit 4*	*Natural Gas*	*.04*	*50%*	*.5*	*8000*	*Ft3/day*	-	*$100*
Joseph Lyndaker farm	Unit 5	*Diesel*	.04	80%	.8	78	Gallons/ day	-	$165

Further, a regional power outage would burden the microgrid's critical facilities with other costs, in terms of lost revenue, emergency measures, and/or equipment rental to maintain power. These estimated costs are tabulated below and have been included in third-party Benefit-Cost Analysis enclosed as Appendix F.

Facility Name	Type of Measure (One-Time or Ongoing)	Description	Costs	Units	When would these measures be required?
Wastewater Treatment Facility and Lift Stations	*Ongoing measures*	*Generator rental*	*250*	*$/day*	*Year-round*
Croghan Library	*One-time measures*	*Evacuating staff and patrons.*	*1,000*	*$/day*	*Year-round, but only necessary five days per week*
Monnat's Country Store	*Ongoing Measures*	*Loss of inventory*	*2,000*	*$/day*	*Year-round*
Steepleview Courts	*One-time measures*	Evacuating residents	1,000	$/day	One-time, only in extreme weather
Croghan Convenience	*Ongoing Measures*	*Loss of inventory*	*2,000*	*$/day*	*Year-round*
Village Municipal Building	*One-time measures*	Evacuating staff, lost productivity	500	$/day	Year-round
American Legion Post 1663	*Ongoing measures*	*Cancelling reservations*	*$500*	*Per day*	*During power outage*
Shekinah Mennonite Fellowship Church	*One-time measures*	*During occasional evening events, services would have to be cancelled.*	*0*	*$*	*During two Sunday evenings a month for two hours, 7pm-9pm*
St. Stephens Catholic Church	*One-time measures*	*During occasional evening events, services would have to be cancelled.*	0	$	Sunday mornings, Saturday evenings, occasional midweek events
American Maple Museum	*One-time measures*	Cancelling or postponing major seasonal fundraiser due to power outage	4,500	$/day	Four times in the spring.
American Maple Museum	*Ongoing measures*	Lost revenue and productivity	250	$/day	Spring-through fall, five days a week

Facility Name	Type of Measure (One-Time or Ongoing)	Description	Costs	Units	When would these measures be required?
Railroad Museum	*One-time measures*	*Lost food supplies (refrigeration)Food in refrigeration for special events (BBQs) lost due to lack of refrigeration.*	*1000*	*$*	*~6 times per year*
Railroad Museum	*One-time measures*	*Lost revenue Entrance fees for one business day*	*500*	*$*	*Memorial day to Labor day during normal business horus*
Grand Slam Safety	*Ongoing measures*	*Closing operations for the period of power outage. Loss of revenue. Loss of welding and fundamental fabrication ability*	*17,500*	*$/day*	5 days a week, year-round
Croghan Island Mill	*Ongoing measures*	*Closing operations for the period of power outage. Loss of revenue . Loss of fabrication ability*	*500*	*$/day*	*If outage happened during normal hours of business operation. 5 days a week, year-round*
Joseph Lyndaker Farm	*Ongoing Measures*	*Generator rental, when available. More information necessary for farm operations.*	*500*	*$/day*	*Year round. Increased necessity during winter months*
Croghan Reservoir Water Production Facility	*Ongoing Measures*	*Generator rental*	*500*	*$/day*	*Year round.*

Based on the above assumptions, the total costs to maintain service at critical facilities during a power outage ranges from $26,500 to $31,500 per day, depending on planned events and time of year.

Task 4.6 Critical Facilities Supported by the Microgrid

The critical and emergency facilities supported by the microgrid are fully detailed in Appendix A. The list includes the following:

1. Waste Water Treatment Plant (serving 5,500. Backup generation provides 100% of service)
2. Croghan Free Library
3. Croghan Fire Hall (serving 5,500. Backup generation provides 100% of service)
4. Monnat’s Country Store
5. Steepleview Courts (50 residents left without electricity during a power outage)
6. Croghan Convenience
7. Village of Croghan Municipal Building
8. American Legion Post 1663
9. Shekinah Mennonite Fellowship Church
10. St. Stephens Catholic Church & Monastery
11. American Maple Museum
12. Railway Historical Society, Railroad Museum
13. Grand Slam Safety
14. Croghan Island Mill
15. Joseph Lyndaker Farm

In addition, 9 wastewater lift stations will be supported by the proposed microgrid. The locations for all these facilities are noted in the system map in Appendix B.

VII. TASK 5 – SUMMARY AND CONCLUSIONS

This section will summarize some of the observations made by the project team during the development of the Croghan microgrid. It will also note some of the lessons learned while noting key landmarks in the project's evolution, recommending actions to be taken whether or not the microgrid is awarded grant funding, and identifying economic and environmental benefits of deploying the project as specified above.

Observations and recommendations

Methodology and flexibility

As a unique microgrid project, the Croghan microgrid benefitted greatly from the expertise, enthusiasm, and innovative thinking of its project team, including direct contributors to the design as well as community stakeholders, the local utility, and NYSERDA. Unlike a project involving the deployment of a single power generation source, or the design of a microgrid localized to a group of adjacent parcel or assets, the Croghan microgrid seeks to provide overall community resiliency by directly benefitting governmental operations, residential need, and economic vitality. As such, the project team was required to cultivate an open stance on new ideas, historical trends, and design considerations. By working from brainstormed concepts to feasibility, the project team was able to carry the project through a number of increasingly feasible scenarios to deliver the preliminary microgrid design documented in this report. This involved using a wide range of resources and specialties, combining data analysis, electrical design, historical research, innovative financing, institutional knowledge, and renewable energy expertise. The final Croghan microgrid concept simply could not have been developed through a rigid, stepwise process that attempted to fit a design around initiatory ideas, but rather came about as a result of the careful evolution of a project executed with the flexibility required to adapt to new information as it was identified.

Utility Involvement

The involvement of the local utility, in this case National Grid, is critical for collecting the necessary information for developing a right-sized and economically feasible microgrid. Coordination with National Grid was useful to the project along two fundamental avenues: information about the consumption history of critical facilities, and reconnaissance regarding transmission and distribution within the microgrid service area. These information sets, along with data gathering efforts between stakeholders and within the project team, served as the fundamental source of information for design decisions throughout the project. To illustrate how utility information was used as a primary coordination point, some depiction of the project's evolution must be considered (for more details, see above). Early stages of the project considered the integration of a large solar array, along with storage, for the generation of power to critical facilities during an emergency grid shutdown. Careful analysis of the power requirements, including average electrical consumption as well as average peak demands, determined that the inclusion of a large, expensive solar array was unnecessary to augment a microgrid which already includes 500kW of hydroelectric power, a power source that, though variable, provides a more continuous and predictable source of energy for the community. Furthermore, as the project team explored means for distributing and delivering power during a shutdown, the transmission and distribution information provided by National Grid allowed the consideration of sharing grid resources in the area. An early project iteration studied the possibility of using National Grid-owned distribution circuits, controlled through strategically deployed switching equipment. While this design was eventually discarded as cumbersome and expensive, the provision of information about available resources allowed the project team to treat this method of power delivery as viable while the ultimate design was developed A separate power grid within the Village could, potentially, be used for the development of a local electric co-op. The feasibility, capacity, and community interest of this effort were not studied; however, a future project under such an initiative could increase the local value of the microgrid substantially. The involvement of a cooperative utility, in this case National Grid, was key for the project team developing a feasible microgrid serving a wide geographic area and diverse constituency.

Recommendations

Whether or not the full microgrid is deployed as specified, the findings of this process provide value to Development Authority of the North Country. Firstly, the economic analysis conducted on the hydroelectric deployment presents a highly favorable case for operating a revitalized, 500kW hydroelectric facility as a Community Distributed Generation asset during everyday grid operations. This report recommends further study and eventual implementation of the Croghan dam as a full-time hydroelectric power source, delivering fixed-cost power to community members, including critical facilities. Maximizing the potential of this strategy will require identifying further funding sources, such as USDA and other grants or loan guarantees, but the fundamental analysis made possible by this design effort will serve as the first step.

Additionally, the Village of Croghan would benefit from financing and implementing energy storage for its sewerage lift stations, whether the full microgrid is funded or not. The relatively low power demands of these pump stations, the criticality of their function, and the challenges associated with maintaining power to them during a grid outage, strongly implicates the deployment of storage to facilitate wastewater service during an outage. As the cost of energy storage continues to decrease, this strategy will become increasingly feasible and beneficial.

Lessons Learned

As the project was developed, some notable project aspects were considered but finally removed from the final concept:

- Solar: Various iterations of solar PV were considered during the project. This included small stationary units at sewerage lift stations, a rooftop unit at government-owned facilities, and a large array (up to 2MW) to be operated as a Community Distributed Generation asset during everyday grid operations. It was ultimately determined that the deployment of new hydroelectric facilities at the to-be-rehabilitated dam site would deliver more than enough power during a grid outage to satisfy the peak needs of the microgrid's critical facilities.
- Secondary utilization of grid facilities: One stage of the microgrid's design included using existing grid conductors as the microgrid network. The notion was to deploy switching gear at each critical facility, as well as all microgrid power sources, to create a secondary, emergency-only grid between critical facilities during an outage. The project's electrical design partnershave prior experience with such efforts and have determined that this concept, as it involves shared ownership and access with National Grid, was likely to incur excessive project cost and limited project independence.
- Critical facilities: Due to geographic constraints, some facilities initially included in the study group were ultimately removed. These include, but are not limited to, the Beaver River Elementary School

and the Beaver River Medical Center. While these facilities could not be included in the microgrid, as their distance from power generation would incur prohibitive connection costs, these facilities should be kept in mind in the future as potential users of back-up power generation, energy storage, or renewable energy deployment as such projects could significantly and positively affect regional energy resiliency.

- Underground power distribution: After determining that the Croghan microgrid would be required to provide its own distribution, the project team worked to estimate costs for underground power distribution. Because of existing infrastructure, and the complications associated with burying new conduit and conductor, this was determined to be overly costly for the resiliency benefits such an effort would garner. Final project design may opt to revisit this effort.

Environmental impact and economic benefits

The Croghan microgrid relies on the rehabilitation of a local dam coupled with the deployment of new hydroelectric turbines. As this effort is financed separately from the microgrid itself, with the dam rehabilitation a partially-financed DEC requirement, the financial considerations of such an effort, while significant, do not directly bear on the feasibility of the Croghan microgrid. To summarize this paradigm, as further explained in previous tasks, the microgrid as conceptualized here requires the hydroelectric facilities, but the hydroelectric facilities do not require the microgrid. By considering this power source as a functional part of the Croghan microgrid, clear economic and environmental benefits become clear. By delivering 500kW of capacity to the area, serving potentially dozens of facilities during everyday operation and providing energy resiliency during a grid outage, the project could contribute 2,480,000kWh or more of renewable electricity every year. This represents a carbon offset equivalent (according to the EPA's Greenhouse Equivalencies Calculator) to that produced by nearly 200 homes (over 1,600 metric tons of carbon dioxide). The project incurs environmental benefit during a grid outage as well, by minimizing or eliminating the need for critical facilities to use diesel- or natural gas-fueled generators to stand-in for grid power.

The economic benefit of the Croghan microgrid was a key consideration at all stages of conceptualization and preliminary design. By carefully balancing the economic value of critical facilities, in conjunction with their direct benefit to residents during an outage, the Croghan microgrid was able to generate a favorable BCA (the full details of this analysis are included as Appendix F). Including the proposed hydroelectric deployment as part of the microgrid realizes even larger economic benefit. By operating this power source under a Community Distributed Generation arrangement, the Development Authority of the North Country, will be able to finance this significant construction effort through power sales and deliver fixed-cost power to interested rate-payers (including critical facilities) with the eventual goal of delivering considerable cost savings on energy. Task 3.5 details the full economic benefit of this arrangement.

APPENDICES

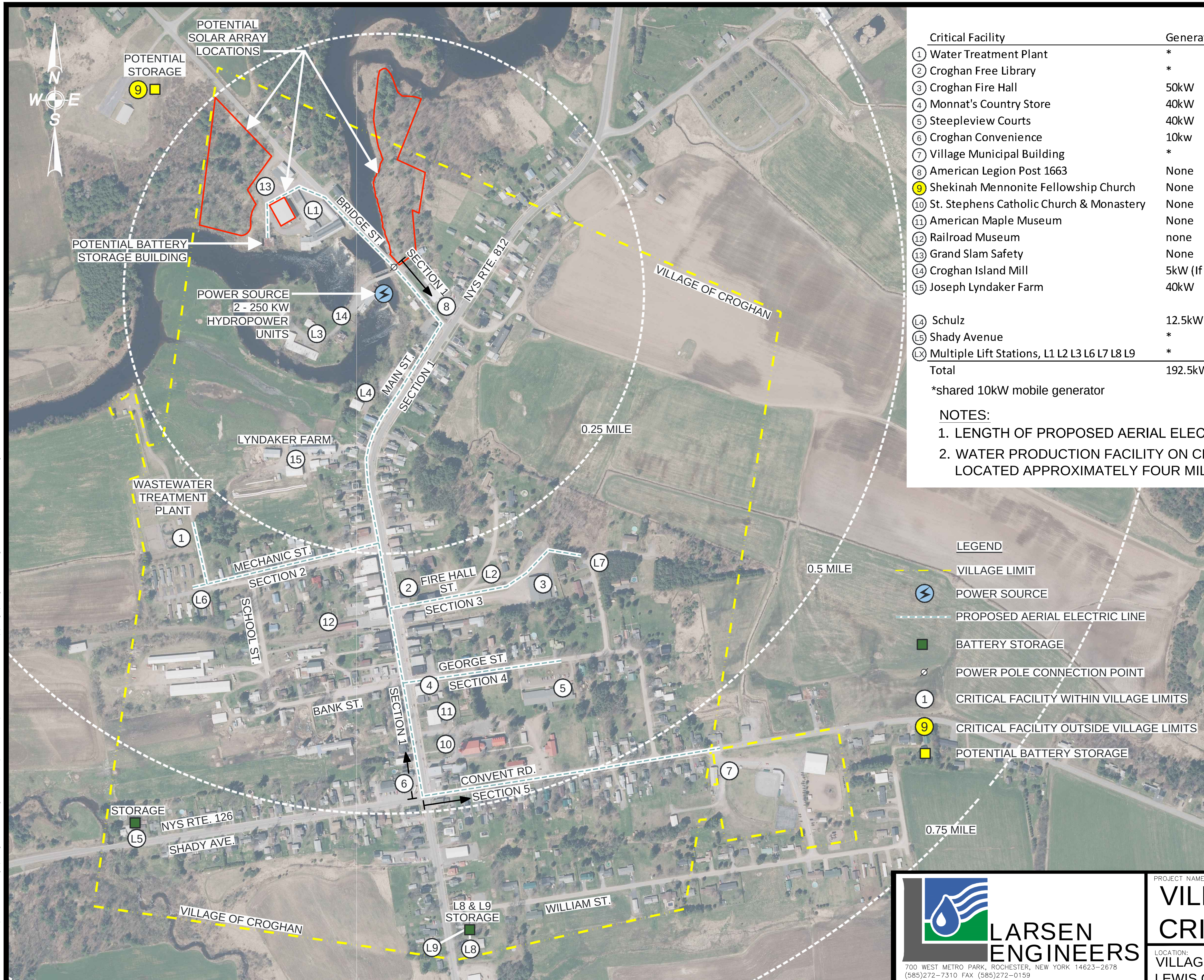
APPENDIX A – CRITICAL AND EMERGENCY FACILITIES

Critical Facilities		Address		Distance From Dam	Energy KWh/yr	Estimated KW Demand
1	Waste Water Treatment Plant	6823 Mechanic Street	Croghan, NY 13327	within village	1,317	2
2	Croghan Free Library	9794 State Route 812	Croghan, NY 13327	within village	8,362	4
3	Croghan Fire Hall	6860 Fire Hall St.	Croghan, NY 13327	within village	22,825	2
4	Monnat's Country Store	9762 State Route 812	Croghan, NY 13327	within village	135,939	50
5	Steepleview Courts (apartments)	6926 George St.	Croghan, NY 13327	within village	16,773	12
6	Croghan Convenience(ATM, gas, grocery)	9741 State Route 812	Croghan, NY 13327	within village	204,000	50
7	Village of Croghan Municipal Building	9578 Park Drive	Croghan, NY 13327	within village	30,129	12
8	American Legion Post 1663	9883 State Route 812	Croghan, NY 13327	within village	37,445	29
9	Shekinah Mennonite Fellowship Church	6720 Swiss Road	Castorland, NY	approx 1/4 mile	4,266	3
10	St. Stephens Catholic Church & Monastery	9748 State Route 812	Croghan, NY 13327	within village	32,133	17
11	American Maple Museum	8756 State Route 812	Croghan, NY 13327	within village	10,685	4
12	Railway Historical Society, Railroad Museum	9781 State Route 812	Croghan, NY 13327	within village	1,200	5
13	Grand Slam Safety	9793 Bridge St.	Croghan, NY 13327	within village adjacent to dam	60,000	30
14	Croghan Island Mill	9746 S. Bridge St.	Croghan, NY 13327	within village adjacent to dam	9,203	8
15	Joseph Lyndaker Farm	9843 State Route 812	Croghan, NY 13327	within village	53,641	50
16	Water production facility	0 Croghan Reservoir Road	Croghan, NY 13327	Outside village limits	24,967	18

Lift Stations for Waste Water						
1-3, 6-9	Sewerage lift pump stations L1-L3.	Various	Croghan,NY 13327	various	Included in #7	14
4	Schulz - L4 - Main lift station	9857 State Route 812	Croghan, NY 13327	within village	Included in #7	5
5	Sewerage lift pump stations	Various	Croghan, NY 13327	various	Included in #7	5
	TOTAL				606,928	320

The water production facility located on Croghan Reservoir Road, approximately four miles east of downtown Croghan, is critical for ongoing water services. This facility will be managed during emergencies by a separate self-contained energy production unit comprised of solar and storage, or a generator, with 20kW capacity.

APPENDIX B – MICROGRID MAP WITH CRITICAL FACILITIES



Critical Facility	Generator	Approximate Annual Consumption (kWh)	Estimated kW Demand
(1) Water Treatment Plant	*	1,317	2
(2) Croghan Free Library	*	8362	4
(3) Croghan Fire Hall	50kW	22,825	2
(4) Monnat's Country Store	40kW	135,939	50
(5) Steepleview Courts	40kW	16773	27
(6) Croghan Convenience	10kw	204,000	50
(7) Village Municipal Building	*	30,129	12
(8) American Legion Post 1663	None	37,455	29
(9) Shekinah Mennonite Fellowship Church	None	4,266	3
(10) St. Stephens Catholic Church & Monastery	None	32,133	17
(11) American Maple Museum	None	10,685	4
(12) Railroad Museum	none	1,200	5
(13) Grand Slam Safety	None	39,000	33
(14) Croghan Island Mill	5kW (If Available)	9,203	8
(15) Joseph Lyndaker Farm	40kW	53,641	50
(L4) Schulz	12.5kW	inc. in #7	5
(L5) Shady Avenue	*		5
(LX) Multiple Lift Stations, L1 L2 L3 L6 L7 L8 L9	*	inc. in #7	14
Total	192.5kW	606,928	320

*shared 10kW mobile generator

NOTES:

1. LENGTH OF PROPOSED AERIAL ELECTRIC LINE SHOWN IS 8,581± FEET.
2. WATER PRODUCTION FACILITY ON CROGHAN RESERVOIR ROAD NOT SHOWN. LOCATED APPROXIMATELY FOUR MILES EAST OF DOWNTOWN CROGHAN.

LEGEND

- VILLAGE LIMIT
- POWER SOURCE
- PROPOSED AERIAL ELECTRIC LINE
- BATTERY STORAGE
- POWER POLE CONNECTION POINT
- CRITICAL FACILITY WITHIN VILLAGE LIMITS
- CRITICAL FACILITY OUTSIDE VILLAGE LIMITS
- POTENTIAL BATTERY STORAGE

0 500 1000 1500

SCALE IN FEET

LARSEN ENGINEERS
700 WEST METRO PARK, ROCHESTER, NEW YORK 14623-2678
(585)272-7310 FAX (585)272-0159
www.larsen-engineers.com

PROJECT NAME:

VILLAGE OF CROGHAN CRITICAL FACILITIES MAP

LOCATION: VILLAGE OF CROGHAN, LEWIS COUNTY, NEW YORK

DATE: 4/13/16

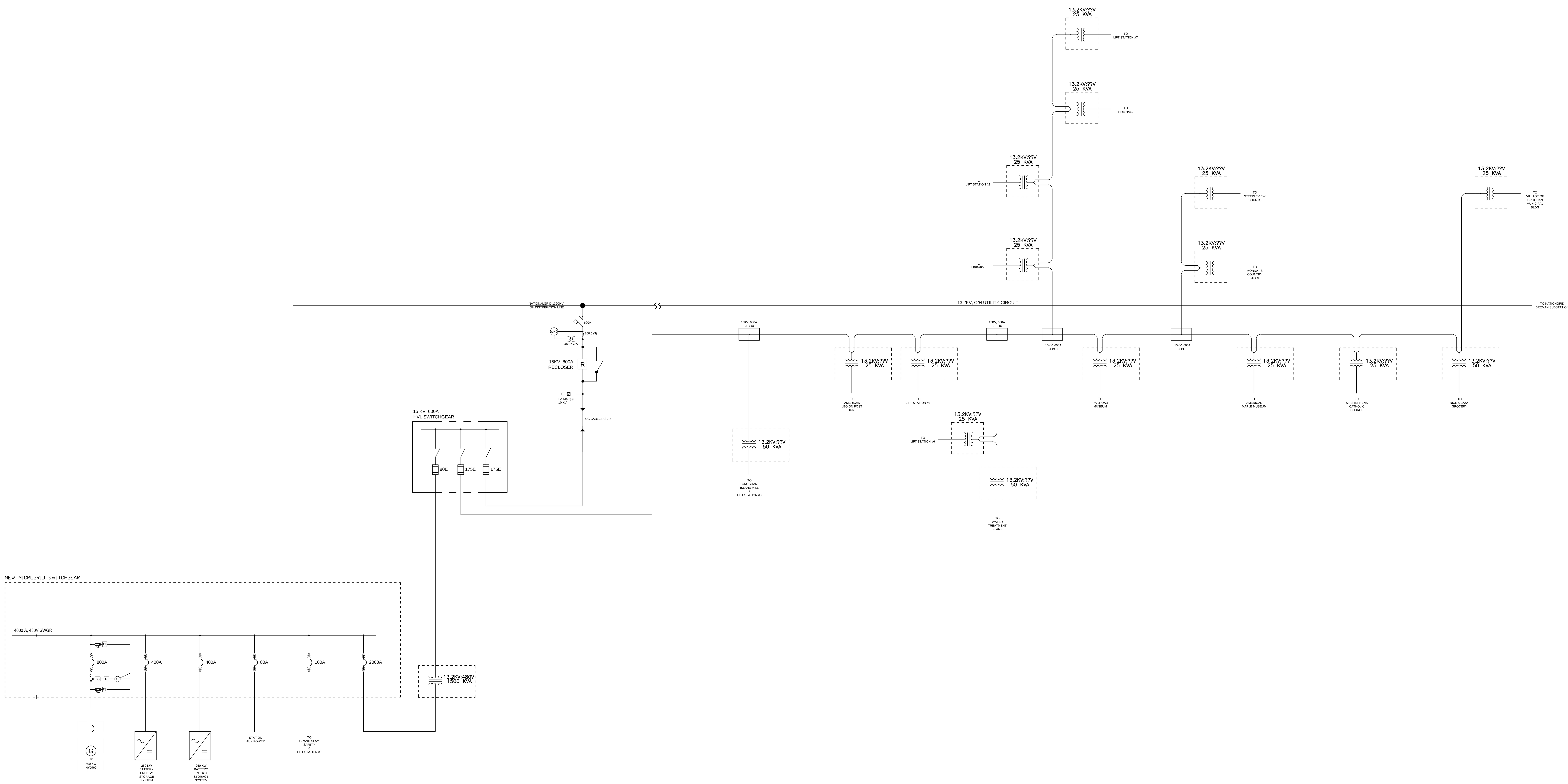
PAGE 1 OF 1

Cadd File: H:\Lewis County\Croghan Microgrid Solar\060 CAD\Critical Facilities Mapping\Croghan Village Critical Facilities.dwg
Plot Date: Apr 13, 2016

APPENDIX C – ENERGY USAGE FOR VILLAGE

ID	Facility Name	Annual Electricity Usage (kWh, estimated)	Peak Demand (kW, estimated)	Annual Energy Costs ($, estimated)
1	Water Treatment Plant	1,317	2	$600
2	Croghan Free Library	8,362	4	$1,450
3	Croghan Fire Hall	22,825	2	$5,250
4	Monnat's Country Store	135,939	50	$13,750
5	Steepleview Courts	16,773	27	$4,750
6	Croghan Convenience	204,000	50	$28,500
7	Village Municipal Building	30,129	12	$8,000
8	American Legion Post 1663	37,455	29	$4,250
9	Shekinah Mennonite Fellowship Church	4,266	3	$450
10	St. Stephens Catholic Church and Monastery	32,133	17	$3,600
11	American Maple Museum	10,685	4	$1,550
12	Railroad Museum	12,000	5	$450
13	Grand Slam Safety	39,000	33	$7,600
14	Croghan Island Mill	9,203	8	$1,550
15	Joseph Lyndaker Farm	53,641	50	$9,400
	Lift stations: L1-L3, L6-L8	Included in Number 7	14	Included in Number 7
	L4 - Schulz Lift Station	Included in Number 7	5	Included in Number 7
	L5 - shady Avenue Lift Station	Included in Number 7	5	Included in Number 7
	TOTALS	Annual System Electricity Usage (kWh, estimated)	Peak System Demand (kw, estimated)	Annual System Energy Costs ($, estimated)
		617,728	320	$91,150

APPENDIX D – CONCEPTUAL ONE-LINE DIAGRAM



PRELIMINARY

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Schneider Electric

SCHNEIDER ELECTRIC ENGINEERING SERVICES, LLC
1010 AIRPARK CENTER DR.
NASHVILLE, TN 37217
(615) 836-8400

PROFESSIONAL SEALS

NO.	DESCRIPTION	DATE
1	.	.
2		
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4		
5		
6		
7		
8		
9		
10		

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CROGHAN MICROGRID

CROGHAN
NEW YORK

MICROGRID CONCEPTUAL ONE-LINE DIAGRAM

SEES PROJECT NO.	XXXXXXXX-XXX
CUSTOMER PROJECT NO.	.
DATE	1/28/2016
CURRENT REVISION DRAWN BY	MJE
CURRENT REVISION CHECKED BY	MJE
CURRENT REVISION APPROVED BY	XXX

E-4001

APPENDIX E – AVAILABLE LOAD INFORMATION AND ESTIMATES

Facility Name	Croghan Fire	Croghan Library	Steepleview Courts	Village of Croghan Barn	Wastewater Treatment	Croghan Convenience	American Maple Museum	Monnat's Country Store	Croghan Island Mill	Grand Slam Safety	Railroad Museum	Shekinah Mennonite Fellowship	St. Stephens Catholic Church and Monastery	American Legion Post 1663	Jopseph Lyndaker Farm	Lift Stations
HISTORICAL USAGE DATA (kWh)																
Nov-14	23	558	4026	569	116	20224	505	9952	1054	4500	44	384	2522	2889	No data	936
Dec-14	26	822	6066	1294	157	20401	762	10553	1103	5700	44	441	2484	2786	No data	1126
Jan-15	27	836	6735	2072	103	18096	912	9989	911	5100	29	435	3330	3258	No data	1240
Feb-15	26	983	7798	2131	118	15625	1039	9498	490	4800	20	432	2953	2721	No data	1218
Mar-15	22	910	8313	2038	125	16277	847	10022	764	4200	23	419	2459	2724	No data	1160
Apr-15	27	831	6068	1120	131	17563	1141	9284	590	2400	28	391	2184	2616	No data	1444
May-15	31	596	4255	766	164	18100	340	9158	372	2400	108	431	2158	3784	No data	1259
Jun-15	27	583	3169	1366	84	24049	781	11382	362	2400	176	296	2264	3460	No data	1083
Jul-15	29	475	2313	1834	113	23107	687	11324	596	2700	259	279	2705	3990	No data	1202
Aug-15	24	634	1800	1480	79	22656	986	12023	914	1500	143	286	2765	3960	No data	876
Sep-15	30	570	1976	923	92	25535	897	13292	1009	3300	126	259	1875	3106	No data	844
Oct-15	26	494	2161	553	188	20301	770	10007	915	5400	52	311	1925	2579	No data	831
Nov-15	25	540	4142	569	191	18899	861	9455	1038	5700	101	407	2106	2939	No data	863
Total Annual Usage:	**343**	**8832**	**58822**	**16715**	**1661**	**260833**	**10023**	**135939**	**10118**	**50100**	**1153**	**4771**	**31730**	**40812**	**53641**	**14082**
Monthly Peak Usage (Highest historical or conservative estimate)	31	983	8313	2131	191	25535	1141	13292	1517.7	7515	115.3	715.65	4759.5	6121.8	8046.15	2112.3

Facility Name	Croghan Fire	Croghan Library	Steepleview Courts	Village of Croghan Barn	Wastewater Treatment	Croghan Convenience	American Maple Museum	Monnat's Country Store	Croghan Island Mill	Grand Slam Safety	Railroad Museum	Shekinah Mennonite Fellowship	St. Stephens Catholic Church and Monastery	American Legion Post 1663	Jopseph Lyndaker Farm	Lift Stations
Actual or **Estimated** DEMAND (kW)																
Nov-14	0.08	1.86	20.20	2.85	0.39	46.60	1.68	22.10	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Dec-14	0.09	2.74	22.10	6.47	0.52	42.00	2.54	21.20	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Jan-15	0.09	2.79	22.40	10.36	0.34	39.70	3.04	21.60	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Feb-15	0.09	3.28	24.60	10.66	0.39	34.70	3.46	20.90	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Mar-15	0.07	3.03	26.20	10.19	0.42	35.50	2.82	21.30	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Apr-15	0.09	2.77	24.50	5.60	0.44	38.00	3.80	20.10	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
May-15	0.10	1.99	24.20	3.83	0.55	45.50	1.13	20.10	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Jun-15	0.09	1.94	21.60	6.83	0.28	48.60	2.60	28.80	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Jul-15	0.10	1.58	19.80	9.17	0.38	47.00	2.29	31.20	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Aug-15	0.08	2.11	14.60	7.40	0.26	47.60	3.29	31.00	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Sep-15	0.10	1.90	14.50	4.62	0.31	47.70	2.99	31.20	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Oct-15	0.09	1.65	19.10	2.77	0.63	47.50	2.57	31.80	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Nov-15	0.08	1.80	21.00	2.85	0.64	41.00	2.87	20.90	7.59	25.05	0.38	2.39	15.87	24.49	32.18	8.4492
Peak Demand Estimate used for preliminary system design	2.00	4.00	27.00	12.00	2.00	50.00	4.00	50.00	8.00	30.00	5.00	3.00	17.00	29.00	50.00	24.00

The above table documents the best available information related to each of the critical facilities' electrical usage. Fields with red text indicate estimates of peak monthly demand. Peak Demand Estimate is the number used to determine the system's overall electrical demand during microgrid operation. Note that safety factors are included in both upsized electrical usage and peak demand for most facilities.

APPENDIX F – THIRD PARTY BENEFIT COST ANALYSIS

Benefit-Cost Analysis Summary Report

Site 61 – Village of Croghan

PROJECT OVERVIEW

As part of NYSERDA's NY Prize community microgrid competition, the Village of Croghan has proposed development of a microgrid that would enhance the resiliency of electric service for the following facilities in this Lewis County community:

- Croghan Fire Hall, which houses both the Croghan Volunteer Fire Department and an ambulance that, as of April 3, 2016, will be operated by Lewis County Search & Rescue;[1]
- Croghan Free Library, a public library located in the former Croghan Opera House;[2]
- Steepleview Court, a federally funded housing development with 20 one-bedroom units designed to provide assisted living services to elderly, low-income residents;[3]
- The Croghan Municipal Building;
- The village's wastewater treatment plant;
- The water lift stations that serve the village's water supply system;
- Two village retail establishments, Croghan Convenience and Monnat's Country Store;
- The American Maple Museum and the Croghan Depot Museum, which is operated by the Railroad Historical Society of Northern New York;[4]
- Two local churches, St. Stephen's Catholic Church and Shekinah Mennonite Fellowship;
- The local American Legion hall, home of Beaver River Memorial Post 1663;[5]
- A dairy farm owned by the Joseph Lyndaker family;
- Grand Slam Safety, LLC, which manufactures flexible fencing systems for baseball and softball fields, field houses, tennis courts, and other sport facilities;[6] and
- Croghan Island Mill, the last remaining water-powered commercial lumber mill in New York State, which manufactures custom windows, doors, and moldings.[7]

[1] http://www.scribd.com/doc/303482627/LCSR-and-Croghan-Ambulance-Merger.
[2] https://www.croghanfreelibrary.org/node/62.
[3] http://section-8-housing.credio.com/l/5268/Steepleview-Court.
[4] http://www.newyorktrains.com/.
[5] http://americanlegionpost1663.org/index.html.
[6] http://www.grandslamsafety.com/
[7] http://northcountryfolklore.org/rvsp/index.php?id=137.

The microgrid would be powered by the redevelopment of 0.5 MW of hydroelectric generating capacity at Croghan Dam.[8] A 0.5 MW battery system would provide energy storage capabilities. The operating scenario submitted by the project's consultants anticipates that the dam would generate 2,480 MWh of electricity annually, roughly 3.5 times the amount required to meet the average energy requirements of the facilities listed above. During a major outage, the project's consultants indicate that the system would fully meet the energy needs of the facilities the microgrid would serve.[9]

To assist with completion of the project's NY Prize Stage 1 feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis, which is based on the methodology outlined below.

METHODOLOGY AND ASSUMPTIONS

In discussing the economic viability of microgrids, a common understanding of the basic concepts of benefit-cost analysis is essential. Chief among these are the following:

- *Costs* represent the value of resources consumed (or benefits forgone) in the production of a good or service.
- *Benefits* are impacts that have value to a firm, a household, or society in general.
- *Net benefits* are the difference between a project's benefits and costs.
- Both costs and benefits must be measured relative to a common *baseline* - for a microgrid, the "without project" scenario - that describes the conditions that would prevail absent a project's development. The BCA considers only those costs and benefits that are *incremental* to the baseline.

This analysis relies on an Excel-based spreadsheet model developed for NYSERDA to analyze the costs and benefits of developing microgrids in New York State. The model evaluates the economic viability of a microgrid based on the user's specification of project costs, the project's design and operating characteristics, and the facilities and services the project is designed to support. The model analyzes a discrete operating scenario specified by the user; it does not identify an optimal project design or operating strategy.

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[10] It also

[8] The microgrid would also be supported by a new 0.5 MW photovoltaic (PV) array, which is to be developed independently. The analysis does not consider the costs of this system, nor, for consistency, does it treat its generating capacity or the energy it would produce as potential benefits of the microgrid.

[9] The project team indicates that stream flow at the dam is sufficient to provide full capacity power around the clock in all but extreme dry weather conditions. Flow at the dam is managed by weirs and the operations of hydroelectric facilities upstream.

[10] The seven percent discount rate is consistent with the U.S. Office of Management and Budget's current estimate of the opportunity cost of capital for private investments. One exception to the use of this rate is the calculation of environmental damages. Following the New York Public Service Commission's (PSC) guidance for benefit-cost analysis, the model relies on temporal projections of the social cost of carbon (SCC), which were developed by the U.S. Environmental Protection Agency (EPA) using a three percent discount rate, to value CO_2 emissions. As the PSC notes, "The SCC is distinguishable from other measures because it operates over a very long time frame, justifying use of a low discount rate specific to its long term effects." The model also uses EPA's temporal projections of social damage values for SO_2, NO_x, and $PM_{2.5}$, and therefore also applies a three percent discount rate to the calculation of damages associated with each of those pollutants. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.]

calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

With respect to public expenditures, the model's purpose is to ensure that decisions to invest resources in a particular project are cost-effective; i.e., that the benefits of the investment to society will exceed its costs. Accordingly, the model examines impacts from the perspective of society as a whole and does not identify the distribution of costs and benefits among individual stakeholders (e.g., customers, utilities). When facing a choice among investments in multiple projects, the "societal cost test" guides the decision toward the investment that produces the greatest net benefit.

The BCA considers costs and benefits for two scenarios:

- Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).
- Scenario 2: The average annual duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[11]

RESULTS

Table 1 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 1.9 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 1. BCA Results (Assuming 7 Percent Discount Rate)

ECONOMIC MEASURE	ASSUMED AVERAGE DURATION OF MAJOR POWER OUTAGES	
	SCENARIO 1: 0 DAYS/YEAR	SCENARIO 2: 1.9 DAYS/YEAR
Net Benefits - Present Value	-$7,050,000	$2,320
Benefit-Cost Ratio	0.4	1.0
Internal Rate of Return	-6.5%	6.4%

Scenario 1

Figure 1 and Table 2 present the detailed results of the Scenario 1 analysis.

[11] The New York State Department of Public Service (DPS) requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

Figure 1. Present Value Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

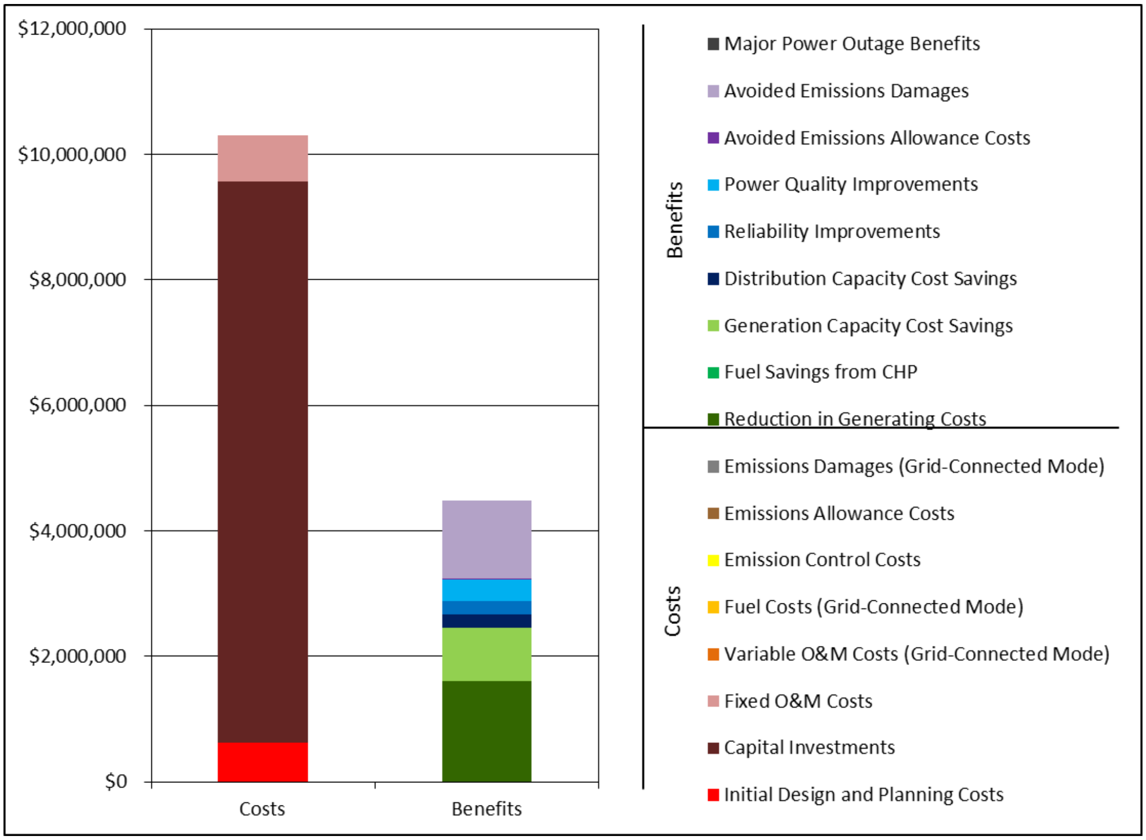

Table 2. Detailed BCA Results, Scenario 1 (No Major Power Outages; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$630,000	$55,600
Capital Investments	$8,930,000	$737,000
Fixed O&M	$742,000	$65,500
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$0	$0
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$0	$0
Total Costs	**$10,300,000**	
Benefits		
Reduction in Generating Costs	$1,610,000	$142,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$850,000	$75,000
Distribution Capacity Cost Savings	$207,000	$18,300
Reliability Improvements	$221,000	$19,500
Power Quality Improvements	$346,000	$30,500
Avoided Emissions Allowance Costs	$841	$74
Avoided Emissions Damages	$1,250,000	$81,600
Major Power Outage Benefits	$0	$0
Total Benefits	**$4,480,000**	
Net Benefits	**-$5,830,000**	
Benefit/Cost Ratio	**0.4**	
Internal Rate of Return	**-5.3%**	

Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $630,000. The present value of the project's capital costs is estimated at approximately $8.9 million, including costs associated with the energy storage system, microgrid controls, electrical switchgear, and overhead distribution network. This total also includes approximately $3.0 million to redevelop the dam.[12] The present value of the microgrid' s fixed operations and maintenance (O&M) costs (i.e., O&M costs that do not vary with the amount of energy produced) is estimated at $742,000, based on an annual cost of $65,500.

[12] The project team notes that redevelopment of the dam is being actively explored independent of the microgrid, and that the costs of dam reconstruction, a new hydroelectric generator, and other associated equipment would be borne by outside parties. The analysis includes these costs because independent redevelopment of the dam is not a certainty but is essential to the successful operation of the microgrid. Consistent with this approach, the analysis treats the dam's generating capacity and the energy it would produce as benefits of the microgrid.

Variable Costs

Because the project would rely solely on renewable energy sources, it would incur no fuel costs. Similarly, operation of the dam would generate no air pollutants; thus, the emissions damages attributable to the project would be zero.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. These include generating cost savings resulting from a reduction in demand for electricity from bulk energy suppliers. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $1.6 million. The reduction in demand for electricity from bulk energy suppliers would also reduce the emissions of air pollutants from such facilities, yielding emissions allowance cost savings with a present value of approximately $800 and avoided emissions damages with a present value of approximately $1.2 million.[13]

In addition to the savings noted above, development of a microgrid could yield cost savings by avoiding or deferring the need to invest in expansion of the conventional grid's energy generation or distribution capacity.[14] Based on the generating capacity of the dam and the energy storage system, the analysis estimates the overall impact of the project on generating capacity requirements to be approximately 1.0 MW. Over a 20-year operating period, the present value of these benefits is estimated at approximately $850,000. Similarly, the project team estimates that the investment in underground distribution will reduce the need for local distribution capacity by approximately 0.5 MW. Over a 20-year period, the present value of this benefit is estimated to be approximately $207,000.

Power Quality Benefits

Beyond the benefits noted above, the project team indicates that the microgrid would enable the facilities it serves to avoid approximately seven power quality events a year, including four voltage sags and three momentary outages. The analysis estimates the benefit of these power quality improvements to be approximately $30,500 annually. Over a 20-year operating period, the present value of these benefits would be $346,000.[15]

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce facilities' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $19,500 per year, with a present value of $221,000 over a 20-year operating period. This estimate was developed

[13] Following the New York Public Service Commission's (PSC) guidance for benefit-cost analysis, the model values emissions of CO_2 using the social cost of carbon (SCC) developed by the U.S. Environmental Protection Agency (EPA). [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.] Because emissions of SO_2 and NO_x from bulk energy suppliers are capped and subject to emissions allowance requirements in New York, the model values these emissions based on projected allowance prices for each pollutant.

[14] Impacts to transmission capacity are implicitly incorporated into the model's estimates of avoided generation costs and generation capacity cost savings. As estimated by NYISO, generation costs and generating capacity costs vary by location to reflect costs imposed by location-specific transmission constraints.

[15] The project team notes that the additional generating capacity the project would provide would create upstream impedance that would buffer the local area from distant utility voltage sags, thus providing power quality benefits to all customers in the area, not just those directly served by the microgrid. The scope of this impact is unclear, however, and the information necessary to quantify the potential economic benefits is not available.

using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[16]

- System Average Interruption Frequency Index (SAIFI) – 0.96 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 116.4 minutes.[17]

The estimate takes into account the number of residential and small or large commercial or industrial customers the project would serve; the distribution of commercial or industrial customers by economic sector; average annual electricity usage per customer, as provided by the project team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[18] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

It is important to note that the analysis of reliability benefits assumes that development of a microgrid would insulate the facilities the project would serve from outages of the type captured in SAIFI and CAIDI values. The distribution network within the microgrid is unlikely to be wholly invulnerable to such interruptions in service. All else equal, this assumption will lead the BCA to overstate the reliability benefits the project would provide.

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.4; i.e., the estimate of project benefits is approximately 40 percent that of project costs.[19] Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2

Benefits in the Event of a Major Power Outage

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[20,21]

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[16] www.icecalculator.com.

[17] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for National Grid.

[18] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.

[19] We examined the sensitivity of these findings to our treatment of the costs and benefits associated with redevelopment of the dam. We found that excluding these costs and benefits would reduce the net benefits of the microgrid project by approximately $310,000. As a result, the project's benefit/cost ratio would fall to approximately 0.2.

[20] The methodology used to estimate the value of lost services was developed by the Federal Emergency Management Agency (FEMA) for use in administering its Hazard Mitigation Grant Program. See: FEMA Benefit-Cost Analysis Re-Engineering (BCAR): Development of Standard Economic Values, Version 4.0. May 2011.

[21] As with the analysis of reliability benefits, the analysis of major power outage benefits assumes that development of a microgrid would insulate the facilities the project would serve from all outages. The distribution network within the microgrid is unlikely to be wholly invulnerable to service interruptions. All else equal, this will lead the BCA to overstate the benefits the project would provide.

The Village of Croghan' s proposed microgrid project would serve a variety of facilities – some of which are critical to public health and safety – during an extended outage. The project's consultants indicate that several of these facilities are currently served by backup generators. Table 3 summarizes the estimated daily cost of operating the generators at each facility; the estimate includes the cost of fuel as well as other costs. Table 3 also indicates the loss in service capabilities that occurs while relying on these units, as well as the loss in service capabilities that would occur should these generators fail.

Table 3. Costs and Level of Service Maintained by Current Backup Generators, Scenario 2

FACILITY	OPERATING COSTS ($/DAY)	PERCENT LOSS IN SERVICE CAPABILITIES DURING AN OUTAGE	
		WITH BACKUP GENERATOR	WITHOUT BACKUP GENERATOR
Croghan Wastewater Treatment & Water Lift Stations	$484	0%	100%
Steepleview Court	$152	0%	25%
Croghan Fire Department	$283	0%	25%
Monnat's Country Store	$284	0%	75%
Joseph Lyndaker Farm	$284	0%	75%

In the event of a generator failure, some of the facilities listed above – i.e., the wastewater treatment plant, the water supply lifts, and the dairy farm – would attempt to rent a portable generator to maintain operations. The cost of operating these generators would range from $250 to $500 per day. The availability of rental units, however, is uncertain, particularly in the event of a prolonged, widespread outage.

The project team did not identify the presence of a backup generator at any of the other 10 facilities the microgrid would serve, nor did it indicate that any of these facilities would rent a generator in the event of an outage. Table 4 summarizes the anticipated loss in service capabilities at each of these facilities should a power failure occur.

Table 4. Level of Service Maintained by Facilities without Backup Generators, Scenario 2

FACILITY	PERCENT LOSS IN SERVICE CAPABILITIES DURING AN OUTAGE
American Maple Museum	50%
Shekinah Mennonite Fellowship	50%
St. Stephen's Catholic Church	50%
Croghan Convenience	75%
American Legion Post 1663	100%
Croghan Depot Museum	100%
Croghan Free Library	100%
Croghan Island Mill	100%
Croghan Municipal Building	100%
Grand Slam Safety	100%

The information provided above serves as a baseline for evaluating the benefits of developing a microgrid. Specifically, the assessment of Scenario 2 makes the following assumptions to characterize the impacts of a major power outage in the absence of a microgrid:

- All facilities currently equipped with backup generators would rely on them, experiencing no loss in service capabilities while the generators operate. If their backup generators fail, these facilities would experience the loss in service capabilities specified for them in Table 3.
- Facilities that are not equipped with backup generators would experience the loss in service capabilities specified for them in Table 4.
- Should Steepleview Court lose power during the winter, it would be necessary to evacuate its residents at a one-time cost of $1,000.
- Should the library lose power during regular operating hours, it would be necessary to evacuate its staff and patrons at a one-time cost of $1,000.
- The supply of fuel necessary to operate backup generators at the facilities equipped with them would be maintained indefinitely.
- In all cases, there is a 15 percent chance that the backup generator would fail.

The consequences of a major power outage also depend on the economic costs of a sustained interruption of service at the facilities of interest. The analysis calculates the impact of a loss in the village's fire, sewage, water supply, and emergency medical services using standard FEMA methodologies. The impact of a loss in service at other facilities is based on the value of service estimates shown in Table 5. For Steepleview Court, the figure is based on an estimate of assisted living costs in Lewis County, as indicated by the Lewis County Office for the Aging.[22] In all other cases, these figures were estimated using the ICE Calculator, taking into account the nature of each facility, their estimated daily use of electricity, and the extent of service (hours/day) they would require during an outage.[23]

Table 5. Value of Maintaining Service, Scenario 2

FACILITY	VALUE PER DAY
Steepleview Court	$4,350
Joseph Lyndacker Farm	$26,700
Monnat's Country Store	$20,000
American Maple Museum	$2,400
Shekinah Mennonite Fellowship	$12,200
St. Stephen's Catholic Church	$13,600
Croghan Convenience	$31,800
American Legion Post 1663	$5,700
Croghan Depot Museum	$5,000

[22] http://lewiscountyny.org/content/Generic/View/182.

[23] http://icecalculator.com/

FACILITY	VALUE PER DAY
Croghan Free Library	$1,700
Croghan Island Mill	$9,300
Croghan Municipal Building	$12,700
Grand Slam Safety	$26,800

Based on these values and the other assumptions outlined above, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the facilities of interest is approximately $271,000 per day.

Summary

Figure 2 and Table 6 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 1.9 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

Figure 2. Present Value Results, Scenario 2 (Major Power Outages Averaging 1.9 Days/Year; 7 Percent Discount Rate)

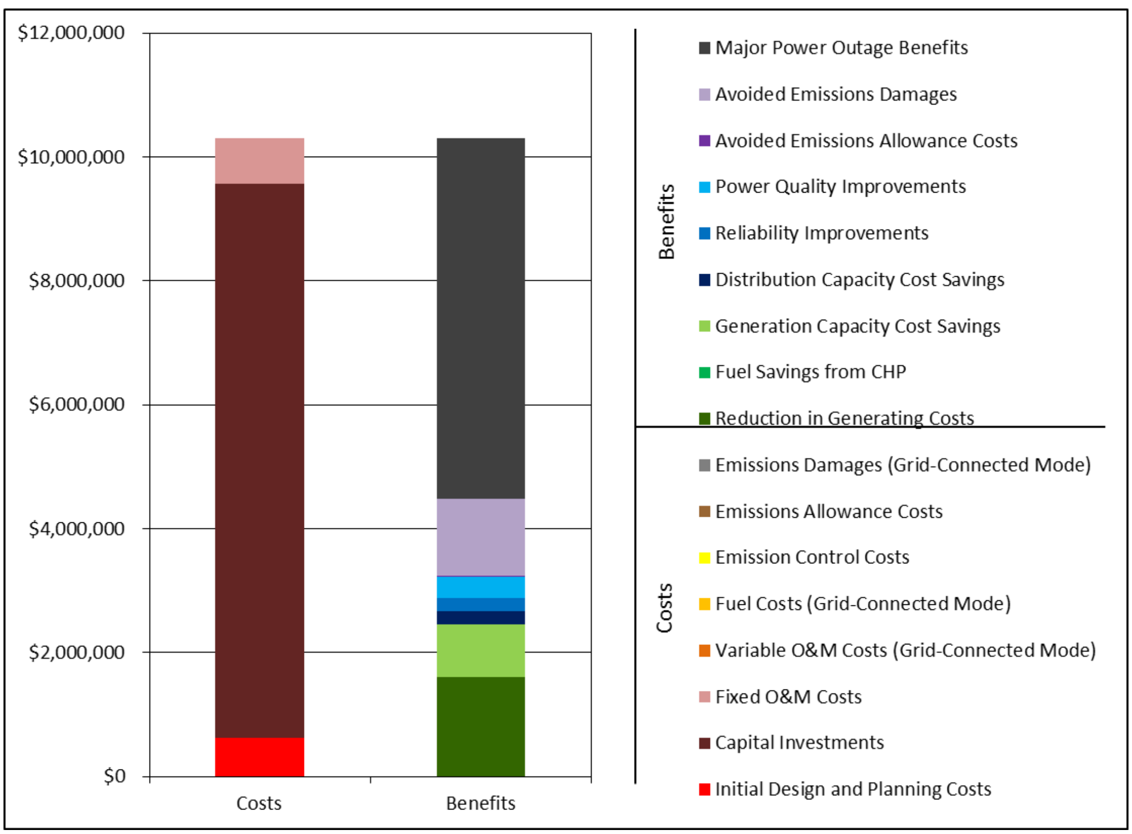

Table 6. Detailed BCA Results, Scenario 2 (Major Power Outages Averaging 1.9 Days/Year; 7 Percent Discount Rate)

COST OR BENEFIT CATEGORY	PRESENT VALUE OVER 20 YEARS (2014$)	ANNUALIZED VALUE (2014$)
Costs		
Initial Design and Planning	$630,000	$55,600
Capital Investments	$8,930,000	$737,000
Fixed O&M	$742,000	$65,500
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$0	$0
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$0	$0
Total Costs	**$10,300,000**	
Benefits		
Reduction in Generating Costs	$1,610,000	$142,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$850,000	$75,000
Distribution Capacity Cost Savings	$207,000	$18,300
Reliability Improvements	$221,000	$19,500
Power Quality Improvements	$346,000	$30,500
Avoided Emissions Allowance Costs	$841	$74
Avoided Emissions Damages	$1,250,000	$81,600
Major Power Outage Benefits	$5,830,000	$514,000
Total Benefits	**$10,300,000**	
Net Benefits	**$2,320**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.4%**	