GHBLP - Harbor Island Technology Study

SUMMARY REPORT

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1 Introduction

1.1 Background

Power Engineers Collaborative (PEC) was retained by the Grand Haven Board of Light and Power (GHBLP) to conduct a reciprocating internal combustion engine (RICE) technology study to determine if an economical 'right sized' technology option exists that could also be effectively coupled with the existing downtown snowmelt system on Harbor Island serving the City of Grand Haven, Michigan.

In 2019, Burns & McDonnell generated a Project Definition Report (PDR) to study and identify all costs of the power supply transition following the retirement of the J.B. Sims Generating Station and determine if the development of a 36 MW RICE facility on Harbor Island made economic sense for the community. The PDR studied and provided recommendations for various other aspects of the redevelopment effort including decommissioning of the existing generating facility, demolition and remediation of the site, reconfiguration of the substation(s), and installation of a temporary configuration to support the City of Grand Haven snowmelt system.

The conclusion of the PDR indicated that the construction of a 36MW RICE facility consisting of (4) Wartsila 20V34SG (9 MW) engines on Harbor Island was cost prohibitive. This conclusion was due to various aspects of the redevelopment effort, including the requirements for substantial natural gas service upgrades, site specific architectural and construction challenges, expensive noise mitigation requirements, and overall facility scale vs. need. While the evaluated facility could be coupled with the existing downtown snowmelt system, due to the size of the engines and heat output, it would not be cost justifiable to operate the units for the snowmelt idle mode in the winter months. GHBLP has proceeded with the recommendations from the PDR on the 'critical paths' steps which included: proceeding with demolition, site remediation, and development of a temporary snowmelt system. The recommendation to pursue potential generation on Harbor Island was to evaluate a design that may be a better fit for a reduced capacity installation.

1.2 Technology Study Scope

This technology study is intended to evaluate the installation of a smaller generating facility on Harbor Island scaled to take advantage of the existing natural gas infrastructure available on the island, the thermal load required for a permanent City of Grand Haven snowmelt system, and the co-development of general administrative and maintenance facilities planned for the overall redevelopment of the site. It has been previously concluded, during the PDR process that other means of redevelopment, such as residential, commercial or industrial on the island are not feasible due to the long history of the site and various remediation concerns from the ash used as fill on the island and the former city dump. It is GHBLP's intent to retain and redevelop the portion of the site outside of the 100 year flood plain with the overall best interests of the City of Grand Haven community in mind based on the proximity to the harbor and downtown business district. GHBLP has retained Progressive AE to coordinate the overall the master plan for site redevelopment. Progressive AE was chosen due to their historical presence in the downtown Grand Haven area with the successful development of the Lynne Sherwood Waterfront Stadium, the development of the Coast Guard Station, and their architectural design of the Holland Energy Park. PEC and Progressive AE have worked closely on the technology study effort to meld the generating facility component into the overall master plan for the site.

1.3 Snowmelt System Design Basis

The City of Grand Haven snowmelt system load was identified by the system designer (Progressive AE) to have an idle mode load of 4-5 mmbtu/hr and a melt mode load of approximately 12 mmbtu/hr. The system is a closed circuit that continuously circulates 1,100 gpm of water to prevent freezing of the distribution piping during winter conditions. For purposes of the evaluation, PEC has assumed the snowmelt system operates for (4) months on a continuous basis in idle mode (2800 hours). In melt mode, the system will generally operate for approximately 200 hours per year during necessary weather conditions. The temporary snowmelt system presently being installed consists of (5) condensing boilers, rated at a nominal 4 mmBtu/hr each. During idle mode operation, the intent is to circulate water through the system to prevent freezing and maintain the system above a certain minimum temperature.

The original concept for the snowmelt system proposed in 2008 was to potentially expand it in two additional phases in the future, if desired and supported by the community. The conceptual design for the generating facility will allow for future expansion of the Genset heat recovery system but will require additional heat exchange equipment to be installed on the engine exhaust to gain the additional heat available. Due to the costs of heat recovery equipment on the engine exhaust and the need for this heat based on the current system loads, investment of heat recovery on the exhaust of all five engines was determined not to be economical at this time. There may exist an opportunity to add heat recovery from one or two engines at this time and that can be evaluated further if the project is pursued.

2 Executive Summary

2.1 Background

In order to determine if the installation of a generating facility on Harbor Island is feasible and recommended, PEC reviewed the generating facility studied in the GHBLP Harbor Island PDR. The 36MW facility development did not make sense to pursue for GHBLP for the following primary reasons:

- Natural gas infrastructure is not available on the island to support the required volume and pressure required for the 9MW RICE engines. Upgrades are expensive and heavily impact project economics. MI Gas Utilities changed their cost projections substantially between October, 2018 and April, 2019 during the PDR process.

- The size of the proposed RICE facility does not pair well with the City of Grand Haven snowmelt system. The typical engine heat rejection from a single Wartsila 20V34SG unit, considering only jacket / oil cooler / after cooler heat recovery only, exceeds the typical idling mode duty of the snowmelt system substantially. Operating this size of unit for the sole purpose of supporting the snowmelt system is not efficient or cost effective based on current purchased energy rates.

- Complexities in construction due to the large scale of the proposed 36MW facility drive capital costs to uneconomical levels. The larger the facility, the more impact site specific aesthetic considerations and items such as noise abatement have on the overall construction cost of the facility.

- Making large scale investments into the natural gas system to support a generating asset that will operate at a projected 10% capacity factor does not make economic sense for a small municipal utility with a 36MW average load. PEC has reviewed the current economics for purchase capacity and energy in Michigan along with day ahead pricing trends for the past three years and it is PEC's opinion that the proposed 36MW facility would likely not be economic to dispatch even 900 hours per year, considering the cost of fuel delivered to Harbor Island and the heat rate of the proposed units.

The technology study contained herein addresses the issues described above regarding the development and construction of the proposed 36MW generating facility on Harbor Island and the feasibility of a "right sized" generating asset.

2.2 Technology Study Summary

Any generating facility development on Harbor Island must fully take advantage of the plant location to improve the economics. This includes interconnection with the existing local electrical distribution substation, use of the existing natural gas supply available on the island, operating as a true Combined Heat and Power (CHP) plant to support the City of Grand Haven snowmelt system, and co-development with planned administration and maintenance facilities.

PEC reviewed varying RICE technologies ranging from 2.5MW – 4 MW from a diverse set of reputable Original Equipment Manufacturers (OEMs) - (Caterpillar, MTU/Rolls Royce, Jenbacher). These smaller engines fit into the existing natural gas system pressure and volume supply capabilities, offer the GHBLP cost competitive capacity, provide for peak shaving opportunities, and more economically couple with the downtown snowmelt system. The technology comparison contained in the Attachment A provides a side by side comparison between four RICE options evaluating the electrical and thermal efficiency, heat recovery available, indicative capital and O&M costs, CHP capability (snowmelt mode economic benefits) and a simple economic screening. The results indicate that a nominal 2.5MW RICE Genset pairs well with the City of Grand Haven snowmelt system for supporting winter idle mode operation. The Caterpillar G3520H was the best fit identified during the technology study and was used as the basis of design moving forward for the evaluation after the initial prime mover screening. Comparable offerings from MTU and Jenbacher in the 2.5MW range will be further evaluated and compared during the next phase of development.

PEC evaluated heat recovery from both the engine jacket, oil cooling, and after cooler stage 1 loop (AC1), the after cooler stage 2 loop (AC2) (low temp) and the engine exhaust. Heat recovery from the engine exhaust requires a relatively expensive and maintenance intensive recovery system. Heat recovery from the engine jacket, oil cooling and AC1 loops are inexpensive and only require a set of 3-way control valves and plate and frame heat exchanger. Because the snowmelt system operates at a low temperature (110°F - hot water supply (HWS)) the AC2 loop heat recovery can also be utilized.

The total heat recovery available from a single 2.5MW Caterpillar G3520H genset is approximately 5 mmBtu/hr. This pairs nearly identically with the snowmelt system idle mode load, which is generally consistent for nearly four months through the winter. This will allow a single Genset to operate continuously to support snowmelt idle mode operation and defer operation of the condensing boilers, reducing gas usage. The engine radiator fans will not be required to operate for cooling, but will be available if needed. Additional Gensets could be operated to support melt-mode, but it will likely be more economical to cycle the condensing boilers for the limited number of annual melt-mode operating hours.

The initially identified natural gas availability on the island was communicated by Michigan Gas to be 100 mcfh at 60psig with no infrastructure upgrades required. PEC evaluated the project using this natural gas availability and it was concluded that (4) Caterpillar G3520H Gensets could be installed, with no investments in the natural gas system and additional incremental natural gas capacity to spare. The economics were evaluated for both (4) Gensets and (5) Gensets to determine the assumed benefit of a marginal increase in gas supply availability. A subsequent discussion was held with Michigan Gas to determine if the existing distribution system can support a maximum demand of 110 mcfh, which would allow for the installation of (5) Gensets. Michigan Gas confirmed in a letter to GHBLP that they can support a maximum demand of 110 mcfh on the island. The economic evaluation indicated that (5) Gensets provide a projected increased benefit to GHBLP, and therefore it is recommended that the (5) Gensets or nominal 12MW basis of design be pursued.

2.3 Economic Indicators

PEC conducted a high-level economic evaluation of the potential generating facility as a screening tool to determine generally if the Project makes sense for GHBLP to pursue and how large of a facility is best suited for Harbor Island. The economic evaluation can be summarized in the following questions and answers:

- Will (5) gensets fully utilizing the available gas on the island be more beneficial than (4) engines?

  (5) Gensets fully utilizing the available gas on the island will be more beneficial than (4) Gensets based on the incremental increase in capital cost, reducing the $/kW installed for the facility by spreading the balance of plant costs over one additional unit, while at the same time taking advantage of the offsetting of estimated future capacity purchases.

- How sensitive are the economics to energy pricing or capacity cost? Does increasing capacity factor have any impact on the economics?

  For conservativeness, the economics were evaluated by capacity cost and not energy. Data supplied by GHBLP for present capacity and energy purchase rates were reviewed. Due to the cost of delivered natural gas on the island and heat rate of the proposed units, it will likely not be economical to dispatch the units for pure electrical generation except on a peak days with energy pricing above $50/MWh. While this will serve as a benefit in hedging power prices during hot summer days, savings in energy is minimal and the project should be justified by its capacity evaluation alone. Therefore, increasing the capacity factor was considered negligible for improving the economics of this project. However, the installation of these units will provide additional flexibility in how bi-lateral power purchase agreements are structured in the future offering a benefit to future power rates.

- How does the proposed generating facility compare with simply purchasing capacity and energy from the grid?

  As discussed in the economics section of the study report, current 2020/2021 Planning Resource Auction (PRA) results indicate the Cost of New Entry (CONE) for electrical capacity Michigan Zone 7 is $7.85/kW-mo. This is due to insufficient zonal capacity to meet the local clearing requirements. This cost will fluctuate based on generation projects in the region and has not historically been at this level for long term capacity purchases, but is an indicator of the lack capacity in the region. It is expected in future years, if Michigan Zone 7 continues to reach CONE, that this cost of $7.85/kW-mo may grow as costs grow to add additional new capacity in the region. It is also possible that additional generation is added to the region driving the cost of capacity down. PEC can conclude that the proposed Harbor Island 12MW generating facility project makes economic sense with purchased capacity cost in the $5-$6 / kW-mo range. This assumes capacity, energy, natural gas and O&M costs will escalate at a nominal rate of 2% over the 30 year evaluation period .

- Does it make sense to consider a larger generating asset on the island based on increased incremental upgrades to the natural gas supply infrastructure? The first stage of incremental upgrades can provide up to 250 mcfh of gas capacity for approximately $1.5M.

  The larger engine generating facility economics on Harbor Island are sensitive to equivalent purchased capacity cost. The economics are improved by the ability of the smaller Gensets to operate in CHP mode to support the City of Grand Haven snowmelt system, but this is generally limited to operation of a single unit to supply the 4-5 mmbtu/hr in heat required for snowmelt idle mode. Operating 1 of 5 installed units in a rotating manner to equalize engine hours during the winter is a reasonable approach to utilization of installed capacity. Spending $1.5 million in additional capital to upgrade the existing natural gas distribution capacity on the island to support up to eleven 2.5 MW Gensets is cost prohibitive. PEC also does not believe it is likely a larger generating asset (for example a 9MW Genset) will be economically dispatched ~900 hours per year with $4.59/mmBtu natural gas at the proposed heat rate of these units. Additionally, this initial investment for the gas line on Harbor Island will restrict future capacity additions to a total of approximately 27 MWs. The increased costs of ~$1.5 million for only an additional 15 MWs above the proposed facility is not justifiable for a Distribution Energy Resource.

  For a pure electrical capacity asset there are less expensive alternatives to increasing the size of the Harbor Island Generating Facility with greater potential benefits to GHBLP.

2.4 Conclusions and Recommendations

This Technology Study has consisted of a detailed review of previously identified flaws determined during the PDR development for the 36 MW RICE generating facility on Harbor Island that ultimately resulted in the abandonment of further development effort.

PEC has determined that a smaller, "right sized" generating facility on Harbor Island can be a short term and long term benefit to both GHBLP and the City of Grand Haven for the following reasons:

- The nominal heat rejection from a single 2.5MW Genset is well coupled with the City of Grand Haven snowmelt system. One Genset can be operated continuously in the winter, with limited hours remaining for peaking duty should operation of the facility be deemed economical by market conditions. The Genset coupled with the snowmelt system will be operated as a true CHP system offering highly efficient use of purchased natural gas reducing the amount of gas required for the snowmelt condensing boilers.

- The 12MW generating facility can be developed in conjunction with the overall master plan for Harbor Island redevelopment including the proposed GHBLP administration and maintenance facilities in a cohesive manner. Integration of the smaller scale generating plant can be done more economically than the larger scale 36MW facility, largely due to the cost avoidance of the natural gas infrastructure upgrades, foundation requirements, noise mitigation controls, and auxiliary requirements necessary to support a larger plant.

- GHBLP remains an electrical generator, with 12MW of dispatchable capacity as a hedge against future capacity purchases and retains the potential for peak shaving opportunities should market conditions warrant. Long term electric capacity pricing in the region cannot be definitively projected, but it can be reasonably concluded that the economics of the 12MW project will likely be generally comparable to purchased capacity and will provide additional overall fringe benefits to GHBLP. This also results in a "generation mix" of purchased capacity and self-generation in GHBLP's portfolio while leaving options open for future opportunities in the renewable and peaking power space. This complies with the GHBLP's direction to develop a sustainable, economical, and diversified power supply portfolio as outlined in their 2017-2012 Strategic Plan.

- GHBLP has existing operations and maintenance staff that can effectively operate and maintain the facility. Additional staffing is un-necessary due to the simplistic operation of the proposed Gensets.

- PEC believes this smaller scale generating plant portion of the facility can be constructed for approximately $1300-1,400/kW (using a 15% contingency factor in installation costs). While the heat rate on the smaller Gensets is not as low as the Wartisila 20V34SG evaluated in the PDR (~7900 btu/kWh vs. ~7400 btu/kWh), the anticipated operating profile does not warrant the substantially higher capital investment for slightly better efficiency.

2.5 Path Forward

PEC recommends the following next steps for GHBLP's consideration regarding the continued development of the Harbor Island Generating Facility.

- Refine and finalize the master plan for Harbor Island redevelopment.
- Publish a planned overall project execution schedule.
- Determine the desired project execution approach best suited for the Project.
- Finalize RICE selection based on discussions between GHPLP and proposed equipment suppliers (OEMs).
- Advance conceptual engineering for the combined GHBLP administration and maintenance facilities and the generating plant to the schematic design stage to allow for the assembly of a +/- 10% grade cost estimate. Refine the design based on the cost estimate to meet budget requirements.
- Develop a complete utility interface schedule to finalize all required services needed to support the administration and generating facility (water, sewer, natural gas, fire water, communications).
- Refine site specific design criteria that will impact the overall capital cost of the Project such as site geotechnical conditions (re-use of existing piles which will be evaluated once exposed), noise abatement, and overall aesthetics of the proposed buildings and structures.
- Determine path forward for snowmelt regarding the potential relocation to new facility building along with an actual schematic design for engine heat recovery integration.
- Determine air permitting requirements for the Gensets. Begin discussions with permitting consultant for development of permit applications and related documents.
- Finalize design concept for the electrical interconnection and determine requirements for any studies or agreements necessary.

PEC anticipates the activities above will lead into detailed design development of construction documents to be used for construction bidding and installation of the facility.

3 Prime Mover Review

3.1 General

PEC reviewed the performance of several reciprocating engines of varying sizes from industry reputable OEMs to determine:

- Optimal engine sizing and quantity of units that can be supported by the existing available natural gas supply. Conclude if any minor incremental increases in gas availability improve the economics for the project.
- Ideal engine size to fully utilize the heat recovery component to displace the condensing boilers and serve snowmelt idle mode loads.
- High level Genset efficiency and operating cost comparison.
- Operating profile sensitivity based on simple payback analysis.

The purpose of the prime mover review was not to solicit firm proposals from Genset OEMs with the intent of selecting a final Genset model for the Project. The prime mover review was intended to be a screening tool to narrow the field to three options in the correct size range that will be fully vetted during the next phase of the Project in terms of capital cost, operating cost, serviceability, etc.

3.2 Results Discussion

The prime mover review summary of results can be found in Attachment A. Tabulated are Genset options from Caterpillar (2.5MW & 4MW), MTU/Rolls Royce (2.5MW), and Jenbacher (3.3MW). Based on previous experience, local service capability and efficiency evaluations PEC recommends the prime movers for the Project be selected from the current line of the OEMs listed above.

Upon initial review, preliminary findings suggest that utilization of heat recovery should be focused on the engine jacket water, oil cooler, and after cooler loops only due to capital costs. There is a future option of adding in heat recovery from the engine exhaust but the costs to include that on all engines does not warrant it based on the current system needs. There may exist an opportunity to add heat recovery from one or two engines at this time and that can be evaluated further if the project is pursued. Snowmelt loads for idling operation are projected to be in the range of 4-5 mmbtu/hr. This generally equates to a single condensing boiler or two condensing boilers operating at partial load assuming a specific hot water temperature does not need to be maintained.

Projected engine heat recovery from the 2.5MW units is in the 4-5 mmbtu/hr range for both the Caterpillar 3520H and MTU 20V4000. This couples well with the snowmelt system, as it will generally displace the projected snowmelt idle mode load from the condensing boilers. If heat recovery is added to the engine exhaust, another 2-3 mmbtu/hr is available to be added to the system for each engine. The larger engine options will require operation of the radiators in parallel to the heat recovery exchangers to partially reject heat during operation at full load.

The recommended operating profile of the facility, based on the target 10% capacity factor, would be to operate a single Genset during the winter to support the operation of the snowmelt system. Continuous operation is projected from mid-November through mid-March for a period of approximately 2800 hours in the analysis. Credit is taken for displacing the natural gas usage of the condensing boilers for this snowmelt heating load. The remaining operating hours are grouped into “peak shaving” mode, which is anticipated to be in the summer when electricity prices are highest. An energy cost of $50/MWh was used in this analysis for peak shaving energy cost.

The following components of the prime mover analysis were varied to determine sensitivities:

- Capacity factor >10%, increasing peak shaving hours.
- Capacity charge, starting point of $6/kW-mo. No escalation considered in this part of the screening.
- Gas availability, 100 mcfh up to 110 mcfh.

3.3 Conclusions

The prime mover screening indicated that the ideal size Genset for the project are the 2.5MW units. These units will allow for operation of a single Genset during the winter to support snowmelt idle mode operation using only the jacket, oil cooler and aftercooler heat recovery leaving limited operating hours for peak shaving during high energy cost periods. PEC reviewed higher capacity factors, thereby increasing peak shaving operating hours, and the overall economics were virtually unaffected using a cost of energy of $50/MWh. For this reason it can be concluded that higher capacity factors will not be economical on Harbor Island, primarily due to the cost of delivered fuel and heat rate associated with the units.

The overall economics are generally driven by the assumed costs of purchased capacity. A more detailed review of the capacity economics is included in Section 4 of this summary report. For purposes of the prime mover evaluation, a fixed average capacity cost of $6/kW-mo was utilized. An indicative capital cost was also utilized in the screening based on the generating facility component only and related historical data. It should be noted that the prime mover review considers a point in time only, and is intended to be a comparison tool between technologies. The economics section provides further review and analysis of the evaluated capacity, capital recovery and operating costs escalated over time.

Existing natural gas availability of 100 mcfh at 60 psig on Harbor Island was originally stated in the PDR as an overall project constraint which would have to be mitigated at a significant expense to support engines requiring 125 psig. The analysis conducted by PEC sought to fully capitalize on the availability of the existing natural supply system by changing technology options to smaller engines. After discussions with Michigan Gas Utilities indicated an incremental additional volume of 10 mcfh was available, the analysis was run using 110 mcfh of available natural gas. This greatly improved the economics increasing the recommended number of 2.5MW gensets to five (5) with a nominal facility output of 12MW. This result indicated the evaluation sensitivity to the cost of capacity and also reinforced the fit of the 2.5MW gensets as the incremental benefit was highest for this particular Genset size.

It can be concluded that the 2.5MW Gensets are the best prime mover fit for the Harbor Island Generating Facility and that the installation of 5 units makes the most sense for GHBLP. This reduces the options to be further evaluated to the Caterpillar G3520H, MTU/Rolls Royce 20V4000 and the Jenbacher J616. For purposes of the technology study conceptual design, PEC has selected the Caterpillar G3520H as the basis of design due to the fact that it provided the best value based on the initial screening. PEC used very preliminary capital and O&M cost data. This data will need to be fully vetted during the next phase of the Project.

4 Economic Evaluation

4.1 General

An economic analysis was performed to compare the impact of installing a new generating facility versus purchasing capacity and energy from the grid. Economic feasibility for the facility was evaluated for the 4-unit and 5-unit options using the recommended nominal 2.5 MW Genset. This economic analysis performed is based on a variety of assumptions and is to be considered a general screening tool only.

4.2 Basis and Methodology

A cash flow analysis was created for each of the two options and incorporated the following parameters:

- Cost of capital is 4%, equivalent to the estimated rate of municipal bonds over a term of 30 years.
- Year 1 capacity charges at intervals of $5/kW-mo to $8/kW-mo at $1/kW-mo increments were considered.
- Year 1 natural gas fuel cost of $4.59/mmBtu.
- Year 1 purchased energy costs of $30/MWh during the snow melt mode (winter), and $50/MWh during peak shaving mode (summer).
- Year 1 genset O&M cost of $20/Op-hr
- Over a 30-year evaluation period, an escalation rate of 2% was applied to the capacity charge, fuel cost, energy charge and Genset O&M costs. It should be noted that 2% is an extremely conservative number. Forward projections show that 3% may be more realistic and the analysis has been provided for information purposes only.
- Estimated capital cost is $1325/kW for a 4-unit facility and $1300/kW for a 5-unit facility (includes a 15% contingency).
- A "break-even point" was determined where the capacity charge resulted in a positive cash flow at Year 1.

4.3 Results

The resulting cash flow trend charts are located in Exhibit B. As illustrated by the graphs, investing in a generating facility on Harbor Island is generally driven by the cost of capacity. For the 4-unit generating facility, the year one estimated positive cash flow point is approximately $6.87/kW-mo. At this rate and higher, a positive cash flow for the evaluation period is anticipated based on the escalation assumptions stated above. For the 5-unit generating facility, the year 1 positive cash flow point is approximately $6.54/kW-mo, illustrating the advantage of the 5-unit facility over the 4-unit facility. Additional capacity charges are plotted to illustrate the projected cash flow trends based on differing values.

Typically, the economic success of a project is not driven by positive cash flow from day 1, but rather the overall benefit of the project over the evaluation term. Therefore, PEC conducted an analysis of projected expenditures to determine the estimated 'break even' point day 1 capacity charge. The expenditures for each option were compared over a period of 30 years to arrive at an estimated present value for each option in comparison to purchased energy and capacity. For the installed capacity option, expenditures include the facility annual fuel and Genset O&M costs, plus the annual debt service used for constructing the facility. The expenditures for the power purchase option include the energy plus capacity charges, escalated over time. On a present value basis, the 5-unit option provide a greater overall savings compared to the 4-unit option.

The current cost of new entry (CONE) in Michigan Zone 7 based on 2020/2021 PRA auction results is $7.85/kW-mo. This cost will fluctuate based on generation projects in the region and has not historically been at this level for long term capacity purchases, but is an indicator of the lack of capacity in the region. CONE is based on a capacity asset for a plant that is to be used infrequently, generally a peaking plant similar to what is being considered for Harbor Island, although it's generally based on a combustion turbine vs. a reciprocating internal combustion engine. CONE is used by MISO as a maximum offer and maximum clearing price. The financial component is based on market cost of debt and normalized after tax return on equity.

It is expected in future years, if Michigan Zone 7 continues to reach CONE, that this cost of $7.85/kW-mo will grow as costs grow to add additional new capacity in the region.

The advantage GHBLP has for constructing capacity is the relatively low cost of debt based on the issuance of municipal bonds and the fact that a third party investor rate of return is not generally considered. The disadvantage for GHBLP is the economies of scale, as capacity projects are generally much larger than 12 MW to lower the overall equivalent capital and operating cost. PEC cannot conclude with certainty that it is more economical for GHBLP to build capacity vs. purchase capacity over the next 30 years. However, based on this analysis, it is reasonable to conclude that the GHBLP can construct capacity in a competitive manner to market based capacity based on existing published rate data.

The tables below have been provided to demonstrate the estimated point of economic benefit of the installed capacity option and the difference in economics based on escalation factor. It can be concluded that the 4-unit option is anticipated to be economically beneficial over the 30 year evaluation period if the year 1 cost of capacity $5.46/kW-mo or higher. The 5-unit option is anticipated to be economically beneficial if the year 1 cost of capacity is $5.16/kW-mo or higher. A 3% escalation factor (over the initial basis 2% escalation factor) improves the economics further.

Results: 2% Escalation Factor

(4) G3520H Gensets			
Year 1 Capacity Charge	PV of Total Evaluation Period Expenditures		Delta (Savings)
	Power Purchase Option	Installed Capacity Option	
$5.00/kW-mo	$19,457,000	$20,648,000	-$1,191,000
$5.46/kW-mo	$20,653,000	$20,648,000	$5,000
$6.00/kW-mo	$22,057,000	$20,648,000	$1,409,000

(5) G3520H Gensets			
Capacity Charge	PV of Expenditures		Delta (Savings)
	Power Purchase Option	Self-Generation Option	
$5.00/kW-mo	$25,079,000	$25,579,000	-$500,000
$5.16/kW-mo	$25,599,000	$25,579,000	$20,000
$6.00/kW-mo	$28,329,000	$25,579,000	$2,750,000

*Highlighted row indicates approximate break even for project expense over 30-year period in reference to YR1 capacity charge

Results: 3% Escalation Factor

(4) G3520H Gensets			
Year 1 Capacity Charge	PV of Total Evaluation Period Expenditures		Delta (Savings)
	Power Purchase Option	Installed Capacity Option	
$4.84/kW-mo	$21,703,000	$21,689,000	$14,000
$5.00/kW-mo	$22,177,000	$21,689,000	$488,000
$6.00/kW-mo	$25,141,000	$21,689,000	$3,452,000

(5) G3520H Gensets			
Capacity Charge	PV of Expenditures		Delta (Savings)
	Power Purchase Option	Self-Generation Option	
$4.55/kW-mo	$26,919,000	$26,892,000	$27,000
$5.00/kW-mo	$28,586,000	$26,892,000	$1,694,000
$6.00/kW-mo	$32,290,000	$26,892,000	$5,398,000

*Highlighted row indicates approximate break even for project expense over 30-year period in reference to YR1 capacity charge

5 Recommended Facility Conceptual Design

5.1 General

The following general descriptions are intended to describe the recommended conceptual design basis for the proposed generating facility. These descriptions are preliminary in nature and will be refined during continued design and development of the Project.

At this time it is not anticipated that emissions controls beyond a standard CO catalyst will be required for the engines. Permitting requirements will be further defined during subsequent stages of design.

5.2 General / Arrangement

The generating facility will be arranged as depicted in the preliminary general arrangement drawing 772-M-102 contained in Attachment C. The generation building will be divided into a number of spaces, including the engine hall, electrical room, battery room and communications room.

The engine hall will be designed to contain the five (5) Gensets with associated local control panels, catalytic converters and exhaust silencers arranged in a horizontal to vertical manner. The stacks will extend through the roof vertically and be supported by the roof steel. Consideration will be given to routing the flue gas exhaust ductwork to a central point with the five stacks enclosed within a single screen wall. These features will be reviewed during site architectural development.

An overhead bridge crane for cylinder and general engine maintenance will be suspended from the roof steel and designed to travel over all five engines. Roll-up doors will be installed between the units allowing for both engine removal and maintenance / parts access.

Additional space within the engine hall will be available for clean and used engine oil, glycol (coolant), compressed air equipment and low temperature and high temperature heat exchangers. Space will be allocated for snowmelt hydronic supply and return header piping to be suspended from the roof steel.

Adjacent to the engine hall will be an electrical room, containing the 15kV rated (13.2kV operating voltage) paralleling switchgear, 480V MCC's, and other distribution panels and related equipment. A dedicated battery room will enclose the 125VDC battery system. A communications and data room will contain the genset control panels, networking equipment and other operator necessary equipment for the generating facility.

Exterior to the engine hall will be dedicated individual Genset combined low temperature and high temperature radiators that are necessary to operate the Gensets when not in heat recovery mode. Also exterior to the electrical room will be 13.2kV – 480V pad mount step-down transformers to be used for auxiliary loads.

It is anticipated that the snowmelt condensing boiler room would be located directly south of the engine hall to allow for short interconnecting piping to the engine heat exchangers.

5.3 Mechanical

Natural gas will be supplied to the generating facility from the existing distribution pipeline at a minimum pressure of 30psig and a volume of 110 mcfh. It is anticipated that the gas supply piping will be routed underground and will require a single pressure regulation and metering station prior to being routed overhead to each Genset natural gas control valve train.

Engine oil will be stored within the engine room to allow for completion of oil changes in an expedited manner. Diaphragm style pumps will evacuate dirty oil from the engines to be temporarily stored in a used oil tank which will include pump-out provisions for a waste hauling truck. Separate pumps will distribute clean oil to the engines in a distribution piping system.

Coolant will be stored within the engine room in totes to facilitate changing of engine coolant.

A packaged air compressor will be installed along with a desiccant dryer package and necessary compressed air distribution piping and specialty items.

Engine heat rejection will be accomplished using a combined (2) coil radiator package. Each radiator package will include a low temp coil and a high temp coil. The forced draft fans will circulate air across both coils simultaneously. Genset mounted pumps will circulate coolant through each individual engine and out to the radiators. Each coolant circuit will include a set of 3-way control valves that will either direct coolant to the radiators or the heat recovery exchangers. The valves will maintain proper engine cooling regardless of the amount of heat recovery required by the process.

Decoupling plate and frame heat exchangers will be installed for both the low temperature and high temperature cooling circuits. The heat exchangers will be non-contact type, and will feature engine coolant on the engine side and water on the process side. The water (process) side will be part of the City of Grand Haven snowmelt system.

The snowmelt system will continue to operate as currently being installed with five (5) – 4 mmbtu/hr condensing boilers, circulating pumps and related auxiliary systems. Relocating the system from the existing pump house building will be further evaluated at a later date. The system generally supplies hot water at 110 °F to the city snow melt coils and returns water at 90 °F during melt-mode operation.

When an engine is operating and the system is in idle mode, return water will be diverted through the engine heat exchangers to displace the need to operate the condensing boilers or that particular engine's radiator fans. Snowmelt hot water temperature (HWT) will fluctuate from design, but will be sufficient to prevent potential freezing of the snowmelt system distribution piping while maintaining a constant volumetric flow rate. Additional refinement of the snowmelt system interface will be determined during design. Each Genset can generally replace the capacity of (1) condensing boiler from a heat contribution perspective.

The engine room ventilation system will be designed to provide adequate cooling for both the engines and generators during operation. This system will likely consist of roof mounted filtered fan units and either gravity dampers or exhaust fan / damper systems.

5.4 Electrical

The generating facility overall electrical system will be arranged as generally depicted in the preliminary single line drawings 772-E-101, 772-E-110 and 772-E-111 contained in Attachment D.

The generators will operate at 13.2kV to match the existing substation medium voltage distribution system. The point of interconnection will be a spare bay in the existing outdoor distribution substation. Specific requirements for metering and protection will be determined at a later date.

It is anticipated that medium voltage distribution conductors will be routed underground from the generators to the paralleling switchgear and from the paralleling switchgear main breaker to the distribution substation.

The paralleling switchgear will consist of a lineup of 15kV rated metal clad switchgear with necessary protection, synchronization and generator control provisions. Each generator will include a dedicated generator breaker. Distribution breakers will be installed within the paralleling switchgear lineup to feed auxiliary transformers.

Facility auxiliary loads will be fed from pad mounted 13.2kV – 480V transformers. The transformer secondaries will feed motor control centers to be employed for all facility motor starting and distribution requirements. Single phase distribution will be installed as required via dry type transformers and distribution panels.

5.5 Structural / Architectural

The generation building foundation design basis will be further refined during the next phase of design. It is anticipated that re-use of some of the existing piles from the former J.B. Sims Generating Station may be possible as a cost savings measure. Generally the Genset foundations will be isolated mat designs tied to deep foundation pile caps. The building will be supported by a structural slab, footings or grade beams likely tied to deep foundation pile caps.

The generation building will likely be a single high-bay design with a flat built-up roof supported by structural steel or bar joists. Exterior building walls will generally consist of pre-cast concrete stand-up panels or masonry block depending on the architectural features determined during continued project development. Screen walls and other features may be employed for improved aesthetics.

6 Indicative Cost Estimate

The following table summarizes indicative costs developed by PEC for the generating facility portion of the GHBLP Harbor Island redevelopment based on the conceptual design described in Section 5 above. Equipment costs are based on OEM budget proposals and historical cost data. Construction costs are based similar installations and have not been estimated on a commodity basis. PEC estimates the accuracy of the estimate is +/- 20% based on the present level of conceptual design completed to date and the following assumptions:

- Generating facility will be constructed in conjunction with the new GHBLP administration and maintenance building on Harbor Island.
- Civil, site development, roadways, landscaping and any remediation costs are not included.
- General utility costs are not included. These may consist of city water supply to the building, sanitary sewer and fire water laterals or fire water storage, if required. An allowance for natural gas piping already present on the island is included for tie-ins.
- Deep foundations are not included – it is assumed a strategy can be developed to re-use the existing piles from the former J.B. Simms Generating Station.
- The building envelope costs included are typical of a RICE generating facility of this type. Enhanced architectural features have not been considered. Further investigation in collaboration with Progressive AE will be required to finalize the building envelope design.
- Noise attenuation beyond standard exhaust silencers and low noise radiators have not been considered. It is believed that the small scale of the facility will greatly reduce the need for complex noise abatement on the site.
- The electrical interconnection will be to the local distribution substation already planned for the site. An allowance for an additional breaker is included.
- Relocation of the snowmelt system from the existing pump house is not included in the estimate. It is assumed that the snowmelt system will be relocated to an adjacent space to the generating facility in the new building development and simplistic tie-ins can be made to the hot water supply and return piping to reclaim the rejected heat from the Genset heat exchangers. This project component will require further study and refinement.
- Costs are stated in 2020 dollars.
- Additional Owner's costs, such as environmental permitting, insurance, financing, consumables, or management labor are not included.

Generating Facility Indicative Cost Estimate Table

ITEM	DESCRIPTION	ITEM COST	EXTENDED COST
1	Equipment Procurement		$ 7,838,000
2	Plant Electrical Interconnection Upgrade Allowance		$ 100,000
4	Engineering & Project Management		$ 852,000
5	Construction		$ 4,997,000
6	Civil / General / Foundations	$ 798,000	
7	Generation Building	$ 1,080,000	
8	Mechanical Erection & Piping	$ 1,758,000	
9	Electrical Assembly & Wiring	$ 1,361,000	
10	Startup & Testing - By Genset OEM – Labor Allowance Only		$ 60,000
11	**Total Estimated Cost**		**$ 13,847,000**
12	*Contingency 15.0%*		*$ 2,078,000*
13	**Total Plant Extended Cost**		**$ 15,925,000**
14	*Total Installed Cost per kW based on nominal 12,250 kW*		*$ 1,300*

7 Attachments

Attachment A – Prime Mover Evaluation Data
Attachment B – Cash Flow Trend Charts
Attachment C – Generating Facility Conceptual General Arrangement
Attachment D – Generating Facility Conceptual Single Line Diagrams

Attachment A

Prime Mover Evaluation Data

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HARBOR ISLAND GENERATION EVALUATION

TABLE A: 100 MCF GAS AVAILABILITY

PRIME MOVER EVALUATION DATA	Unit	CAT G3520H	CAT CG260	MTU 20V4000	JENBACHER J620
SITE DESIGN DATA					
Ambient Temp	°F	59	59	59	59
Relative Humidity	%	60	60	60	60
Site Elevation	ft	587	587	587	587
GENSET DATA					
Genset Power Output - EA	kW	2491	4000	2454	3329
Fuel Consumption (LHV) - OEM, ISO 3046	Btu/ekW-hr	7672	7792	8083	7693
Fuel Consumption (LHV) - OEM, ISO 3046	MBtu/hr	19.11	31.17	19.83	25.61
Efficiency (LHV) - OEM, ISO 3046	%	44.5%	43.8%	42.2%	44.4%
Fuel Flow (LHV) - OEM, ISO 3046	cfm	352	574	367	472
Fuel Consumption (HHV), OEM, ISO 3046	MBtu/hr	21.88	35.68	22.83	29.32
Fuel HHV	Btu/cf	1036	1036	1036	1036
Heat Rate (LHV), OEM, ISO 3046	Btu/kWh	7672	7792	8083	7693
Heat Rate (HHV), OEM, ISO 3046	Btu/kWh	8439	8571	8891	8462
Fuel Cost	$/Mbtu	$4.59	$4.59	$4.59	$4.59
Per Unit O&M Cost - 10% Cap Factor	$/Op-hr	$40.00	$40.00	$60.00	$60.00
Per Unit O&M Cost - 10% Cap Factor	$/kWh	$0.0161	$0.0100	$0.0244	$0.0180
Heat Rec. - Jacket + Oil Cooler + 1 AC	Mbtu/hr	3.92	7.08	5.01	5.29
Heat Rec. - 2 AC	Mbtu/hr	1.02	1.21	0.53	0.71
Heat Rec. - Exhaust	Mbtu/hr	3.36	7.34	4.34	4.44
Heat Rec Potential - Total	Mbtu/hr	8.30	15.63	9.88	10.44

CONFIGURATION A: EXISTING AVAILABLE GAS - HARBOR ISLAND: NOMINAL 10MW FACILITY	Unit	G3520H	CAT CG260	MTU 20V4000	JENBACHER J620
CONFIGURATION DESIGN INPUT					
Fuel Quantity Available	mcfh	100	100	100	100
Fuel Quantity Available	Mbtu/hr	103.6	103.6	103.6	103.6
Fuel Heating Value (HHV)	Btu/cf	1036	1036	1036	1036
Fuel Quantity Available (HHV)	cfm	1667	1667	1667	1667
Fuel Pressure Available	psig	75	75	75	75
CONFIGURATION					
Quantity of Units based on Available Fuel - Coincident Operation @ 100% Load	No.	4	2	4	3
Facility Power Generating Capacity - Gross	kW	9964	8000	9816	9987
Aux Load Allowance @ 1.5%	kW	149	120	147	150
Facility Power Generating Capacity - Net	**kW**	**9815**	**7880**	**9669**	**9837**
Genset O&M Cost Per Unit - 10% Cap	$/Op-hr	$20.00	$25.00	$30.00	$30.00
Genset O&M Cost - 10% Cap	$/kWh	$0.0082	$0.0127	$0.0124	$0.0122
Genset O&M Cost - Annual	$	$70,080	$70,080	$105,120	$78,840
Facility Capacity Factor	%	10%	16%	10%	10%
Total Facility Full Load Equivalent Operating Hours	Hrs	876	1402	876	876
Facility Annual NET Generation	kWh	8,597,537	11,044,608	8,469,834	8,617,383
Facility Fuel Consumption Rate (HHV)	MBtu/hr	87.51	71.36	91.33	87.95
Facility Annual Fuel Consumption (HHV)	Mbtu/yr	76,658	100,014	80,004	77,045
Facility NET Electrical Efficiency (HHV)	%	38.3%	37.7%	36.1%	38.2%
Facility Net Heat Rate (LHV)	Btu/kWh	8106	8232	8587	8128
Facility Net Heat Rate (HHV)	Btu/kWh	8916	9055	9446	8941
Additional Available Fuel, Based on ISO 3046 Genset Consumption	Mbtu/hr	16	32	12	16
Potential Additional Generation Capability - Additional Unit / Max Fuel Avail.	kW	*1649*	*3253*	*1187*	*1599*
SNOW MELT					
Snow Melt Hours of Operation - Idle Mode	Hrs	2,800	2,800	2,800	2,800
Condensing Boiler Units Operating Concurrently	No	2	2	2	2
Snow Melt Energy Input - Idle Mode	Mbtu/hr	5.00	5.00	5.00	5.00
Condensing Boiler Fuel Input - 90% HHV Overall Efficiency	Mbtu/hr	5.56	5.56	5.56	5.56
Snow Melt Boiler Gas Cost - Idle Mode	$	$71,400	$71,400	$71,400	$71,400
OPERATING COST SUMMARY					
Natural Gas Fuel Cost	$/Mbtu	$4.59	$4.59	$4.59	$4.59
Genset Operating Cost - Fuel Only	$/kWh	$0.0403	$0.0409	$0.0427	$0.0404
Per Unit Fuel + Genset O&M - 10% Cap Factor	$/kWh	$0.0485	$0.0536	$0.0551	$0.0526
Facility Annual Fuel Cost	$	$351,860	$459,063	$367,220	$353,638
Snowmelt Idle Mode Fuel Cost Credit	$	($71,400)	($71,400)	($71,400)	($71,400)
Facility Net Annual Fuel Cost	$	$280,460	$387,663	$295,820	$282,238
Facility Net Annual Fuel Cost	$/kWh	$0.0326	$0.0351	$0.0349	$0.0328
Facility Net Fuel & Genset O&M Cost	$/kWh	$0.0408	$0.0478	$0.0473	$0.0450
FACILITY COST					
Total Facility Installed Cost PRELIM	$	$13,202,300	$11,400,000	$13,006,200	$13,232,775
Total Facility Installed Cost PRELIM	$/kW	$1,325	$1,425	$1,325	$1,325
GHBLP ELECTRICITY COST COMPARISON					
Capacity Charge - Long Term	$/kW-mo	$6.00	$6.00	$6.00	$6.00
Generating Facility Capacity	kW	9,815	7,880	9,669	9,837
Capacity Charge for Generating Facility Net Output - Annual	$	$706,647	$567,360	$696,151	$708,278

PEC Power Engineers Collaborative, L.L.C.

GRAND HAVEN BOARD OF LIGHT AND POWER

HARBOR ISLAND GENERATION EVALUATION

TABLE A: 100 MCF GAS AVAILABILITY

PRIME MOVER EVALUATION DATA					
	Unit	CAT G3520H	CAT CG260	MTU 20V4000	JENBACHER J620
SITE DESIGN DATA					
Ambient Temp	°F	59	59	59	59
Relative Humidity	%	60	60	60	60
Site Elevation	ft	587	587	587	587
GENSET DATA					
Genset Power Output - EA	kW	2491	4000	2454	3329
Fuel Consumption (LHV) - OEM, ISO 3046	Btu/ekW-hr	7672	7792	8083	7693
Fuel Consumption (LHV) - OEM, ISO 3046	MBtu/hr	19.11	31.17	19.83	25.61
Efficiency (LHV) - OEM, ISO 3046	%	44.5%	43.8%	42.2%	44.4%
Fuel Flow (LHV) - OEM, ISO 3046	cfm	352	574	367	472
Fuel Consumption (HHV), OEM, ISO 3046	MBtu/hr	21.88	35.68	22.83	29.32
Fuel HHV	Btu/cf	1036	1036	1036	1036
Heat Rate (LHV), OEM, ISO 3046	Btu/kWh	7672	7792	8083	7693
Heat Rate (HHV), OEM, ISO 3046	Btu/kWh	8439	8571	8891	8462
Fuel Cost	$/Mbtu	$4.59	$4.59	$4.59	$4.59
Per Unit O&M Cost - 10% Cap Factor	$/Op-hr	$40.00	$40.00	$60.00	$60.00
Per Unit O&M Cost - 10% Cap Factor	$/kWh	$0.0161	$0.0100	$0.0244	$0.0180
Winter Snow Melt Mode					
Winter Generation Snowmelt Operating Hours - Single Engine Operation	Hrs	2,800	2,800	2,800	2,800
Winter Generation Snowmelt Single Engine Electrical Output - Net	kW	2,454	3,940	2,417	3,279
Winter Generation - Snowmelt Coupled	kWh	6,870,178	11,032,000	6,768,132	9,181,382
Purchased Energy Charge	$/MWh	$30	$30	$30	$30
Purchased Energy Charge	$/kWh	$0.030	$0.030	$0.030	$0.030
Equivalent Purchased Energy Charge	$	$206,105	$330,960	$203,044	$275,441
Total Equivalent Purchased Energy + Interpolated Capacity Charge	$	$770,778	$897,672	$759,329	$841,417
Snow Melt Mode Purchased Energy Total Cost	$/kWh	$0.1122	$0.0814	$0.1122	$0.0916
Peak Shaving Mode					
Peak Shaving Generation Facility Operating Hours	Hrs	176	2	176	235
Peak Shaving Generation Facility Electrical Output	kW	9,815	7,880	9,669	9,837
Peak Shaving Generation	kWh	1,727,359	12,608	1,701,702	2,308,462
Purchased Energy Charge	$/MWh	$50	$50	$50	$50
Purchased Energy Charge	$/kWh	$0.050	$0.050	$0.050	$0.050
Equivalent Purchased Energy Charge	$	$86,368	$630	$85,085	$115,423
Total Equivalent Purchased Energy + Interpolated Capacity Charge	$	$228,343	$1,278	$224,951	$257,726
Peak Shaving Mode Purchased Energy Total Cost	$/kWh	$0.1322	$0.1014	$0.1322	$0.1116
Generating Facility vs. Market Purchased Electric Comparison					
Total Generation Facility Annual Equivalet Engine Operating Hours	Hrs	3,504	2,803	3,504	3,504
Total Generation Facility Annual Equivalent Generation	kWh	8,597,537	11,044,608	8,469,834	11,489,844
Capacity Charge for Generating Facility Net Output - Annual	$	$706,647	$567,360	$696,151	$708,278
Energy Charge for Generating Facility Net Output - Annual	$	$292,473	$331,590	$288,129	$390,865
Total Projected Purchased Annual Electrical Cost	$	$999,120	$898,950	$984,280	$1,099,143
Total Projected Purchased Annual Electrical Rate	$/kWh	$0.116	$0.081	$0.116	$0.096
Generating Facility Annual Fuel + Genset O&M Cost	$	$350,540	$527,823	$400,940	$516,477
Staffing & General O&M Annual Allowance	$	$0	$0	$0	$0
Generating Facility Annual Equivalent Electric Rate	$/kWh	$0.041	$0.048	$0.047	$0.045
Potential Year 1 Pre-Capital Recovery Annual Savings vs. Purchased Capacity and Energy (Capacity @ $6/kW-mo)	**$**	**$648,580**	**$371,128**	**$583,340**	**$582,665**

GRAND HAVEN BOARD OF LIGHT AND POWER

PEC Power Engineers Collaborative, L.L.C.

HARBOR ISLAND GENERATION EVALUATION

TABLE B: 110 MCF GAS AVAILABILITY

PRIME MOVER EVALUATION DATA					
	Unit	CAT G3520H	CAT CG260	MTU 20V4000	JENBACHER J620
SITE DESIGN DATA					
Ambient Temp	°F	59	59	59	59
Relative Humidity	%	60	60	60	60
Site Elevation	ft	587	587	587	587
GENSET DATA					
Genset Power Output - EA	kW	2491	4000	2454	3329
Fuel Consumption (LHV) - OEM, ISO 3046	Btu/ekW-hr	7672	7792	8083	7693
Fuel Consumption (LHV) - OEM, ISO 3046	MBtu/hr	19.11	31.17	19.83	25.61
Efficiency (LHV) - OEM, ISO 3046	%	44.5%	43.8%	42.2%	44.4%
Fuel Flow (LHV) - OEM, ISO 3046	cfm	352	574	367	472
Fuel Consumption (HHV), OEM, ISO 3046	MBtu/hr	21.88	35.68	22.83	29.32
Fuel HHV	Btu/cf	1036	1036	1036	1036
Heat Rate (LHV), OEM, ISO 3046	Btu/kWh	7672	7792	8083	7693
Heat Rate (HHV), OEM, ISO 3046	Btu/kWh	8439	8571	8891	8462
Fuel Cost	$/Mbtu	$4.59	$4.59	$4.59	$4.59
Per Unit O&M Cost - 10% Cap Factor	$/Op-hr	$40.00	$40.00	$60.00	$60.00
Per Unit O&M Cost - 10% Cap Factor	$/kWh	$0.0161	$0.0100	$0.0244	$0.0180
Heat Rec. - Jacket + Oil Cooler + 1 AC	Mbtu/hr	3.92	7.08	5.01	5.29
Heat Rec. - 2 AC	Mbtu/hr	1.02	1.21	0.53	0.71
Heat Rec. - Exhaust	Mbtu/hr	3.36	7.34	4.34	4.44
Heat Rec Potential - Total	Mbtu/hr	8.30	15.63	9.88	10.44
CONFIGURATION B: EXISTING AVAILABLE GAS WITH INCREMENTAL 10 MCF MARGIN - HARBOR ISLAND: NOMINAL 12MW FACILITY					
	Unit	G3520H	CAT CG260	MTU 20V4000	JENBACHER J620
CONFIGURATION DESIGN INPUT					
Fuel Quantity Available	mcfh	110	110	110	110
Fuel Quantity Available	Mbtu/hr	113.96	113.96	113.96	113.96
Fuel Heating Value (HHV)	Btu/cf	1036	1036	1036	1036
Fuel Quantity Available (HHV)	cfm	1833	1833	1833	1833
Fuel Pressure Available	psig	75	75	75	75
CONFIGURATION					
Quantity of Units based on Available Fuel - Coincident Operation @ 100% Load	No.	5	3	4	3
Facility Power Generating Capacity - Gross	kW	12455	12000	9816	9987
Aux Load Allowance @ 1.5%	kW	187	180	147	150
Facility Power Generating Capacity - Net	**kW**	**12268**	**11820**	**9669**	**9837**
Genset O&M Cost Per Unit - 10% Cap	$/Op-hr	$20.00	$25.00	$40.00	$30.00
Genset O&M Cost - 10% Cap	$/kWh	$0.0065	$0.0085	$0.0165	$0.0122
Genset O&M Cost - Annual	$	$87,600	$105,120	$140,160	$78,840
Facility Capacity Factor	%	10%	16%	10%	10%
Total Facility Full Load Equivalent Operating Hours	Hrs	876	1402	876	876
Facility Annual NET Generation	kWh	10,746,921	16,566,912	8,469,834	8,617,383
Facility Fuel Consumption Rate (HHV)	MBtu/hr	109.39	107.04	91.33	87.95
Facility Annual Fuel Consumption (HHV)	Mbtu/yr	95,823	150,021	80,004	77,045
Facility NET Electrical Efficiency (HHV)	%	38.3%	37.7%	36.1%	38.2%
Facility Net Heat Rate (LHV)	Btu/kWh	8106	8232	8587	8128
Facility Net Heat Rate (HHV)	Btu/kWh	8916	9055	9446	8941
Additional Available Fuel, Based on ISO 3046 Genset Consumption	Mbtu/hr	5	7	23	26
Potential Additional Generation Capability - Additional Unit / Max Fuel Avail.	kW	*469*	*699*	*2189*	*2658*
SNOW MELT					
Snow Melt Hours of Operation - Idle Mode	Hrs	2,800	2,800	2,800	2,800
Condensing Boiler Units Operating Concurrently	No	2	2	2	2
Snow Melt Energy Input - Idle Mode	Mbtu/hr	5.00	5.00	5.00	5.00
Condensing Boiler Fuel Input - 90% HHV Overall Efficiency	Mbtu/hr	5.56	5.56	5.56	5.56
Snow Melt Boiler Gas Cost - Idle Mode	$	$71,400	$71,400	$71,400	$71,400
OPERATING COST SUMMARY					
Natural Gas Fuel Cost	$/Mbtu	$4.59	$4.59	$4.59	$4.59
Genset Operating Cost - Fuel Only	$/kWh	$0.0403	$0.0409	$0.0427	$0.0404
Per Unit Fuel + Genset O&M - 10% Cap Factor	S/kWh	$0.0468	$0.0494	$0.0593	$0.0526
Facility Annual Fuel Cost	$	$439,825	$688,594	$367,220	$353,638
Snowmelt Idle Mode Fuel Cost Credit	$	($71,400)	($71,400)	($71,400)	($71,400)
Facility Net Annual Fuel Cost	$	$368,425	$617,194	$295,820	$282,238
Facility Net Annual Fuel Cost	S/kWh	$0.0343	$0.0373	$0.0349	$0.0328
Facility Net Fuel & Genset O&M Cost	$/kWh	$0.0408	$0.0457	$0.0515	$0.0450
FACILITY COST					
Total Facility Installed Cost PRELIM	$	$16,191,500	$16,800,000	$12,760,800	$12,983,100
Total Facility Installed Cost PRELIM	$/kW	$1,300	$1,400	$1,300	$1,300
GHBLP ELECTRICITY COST COMPARISON					
Capacity Charge - Long Term	$/kW-mo	$6.00	$6.00	$6.00	$6.00
Generating Facility Capacity	kW	12,268	11,820	9,669	9,837
Capacity Charge for Generating Facility Net Output - Annual	$	$883,309	$851,040	$696,151	$708,278

PEC Power Engineers Collaborative, L.L.C.

GRAND HAVEN BOARD OF LIGHT AND POWER

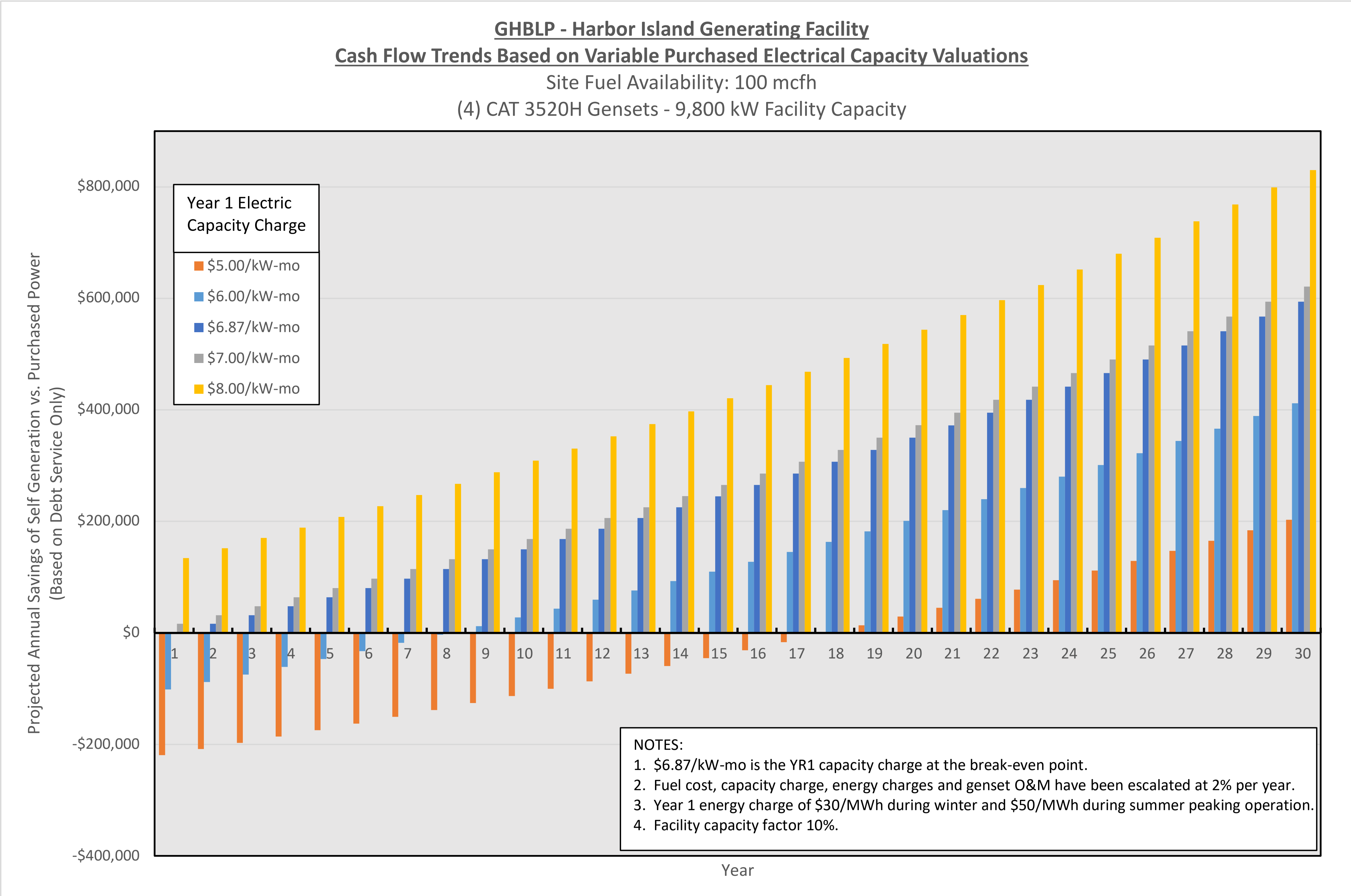
HARBOR ISLAND GENERATION EVALUATION

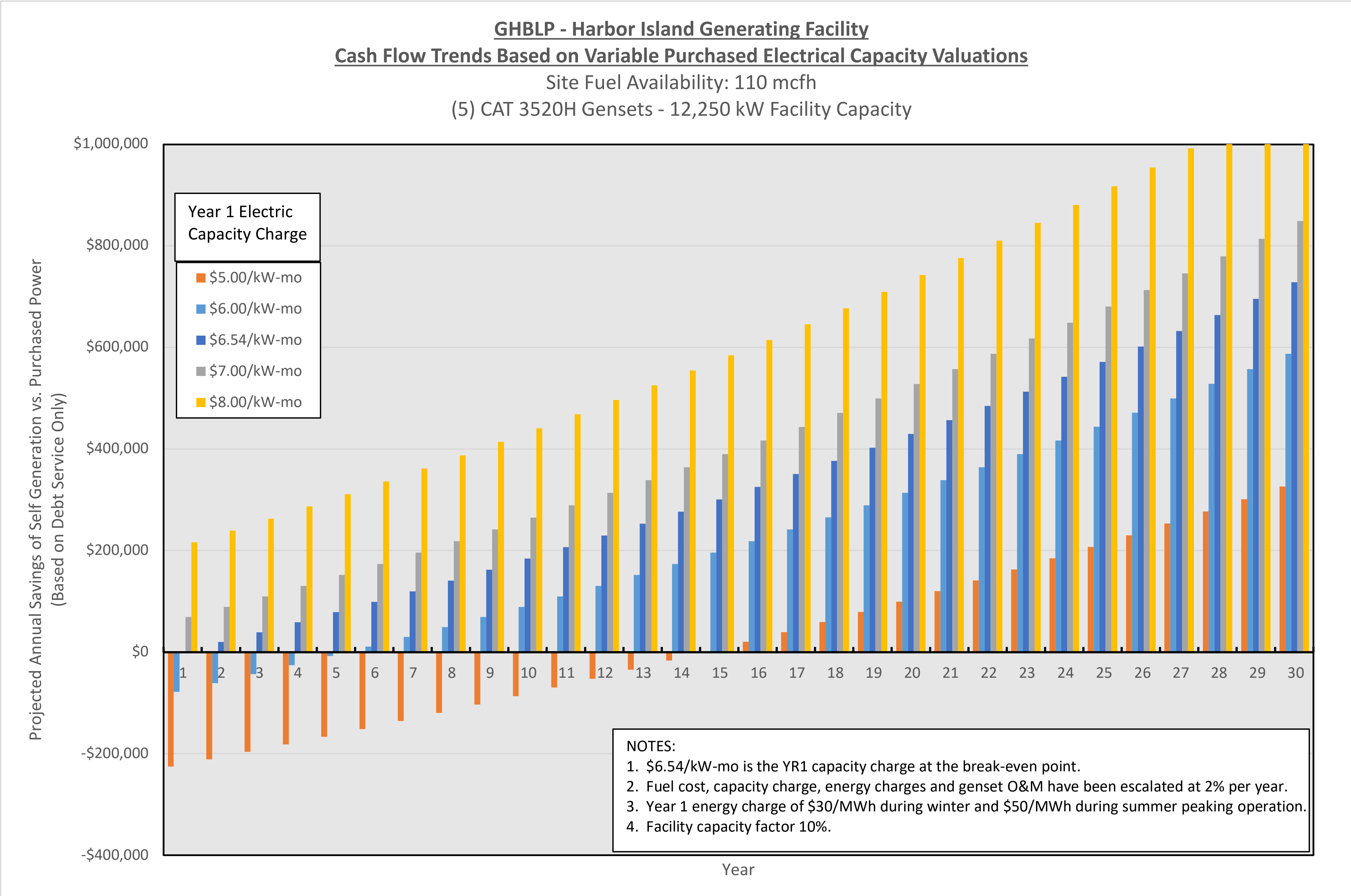
TABLE B: 110 MCF GAS AVAILABILITY

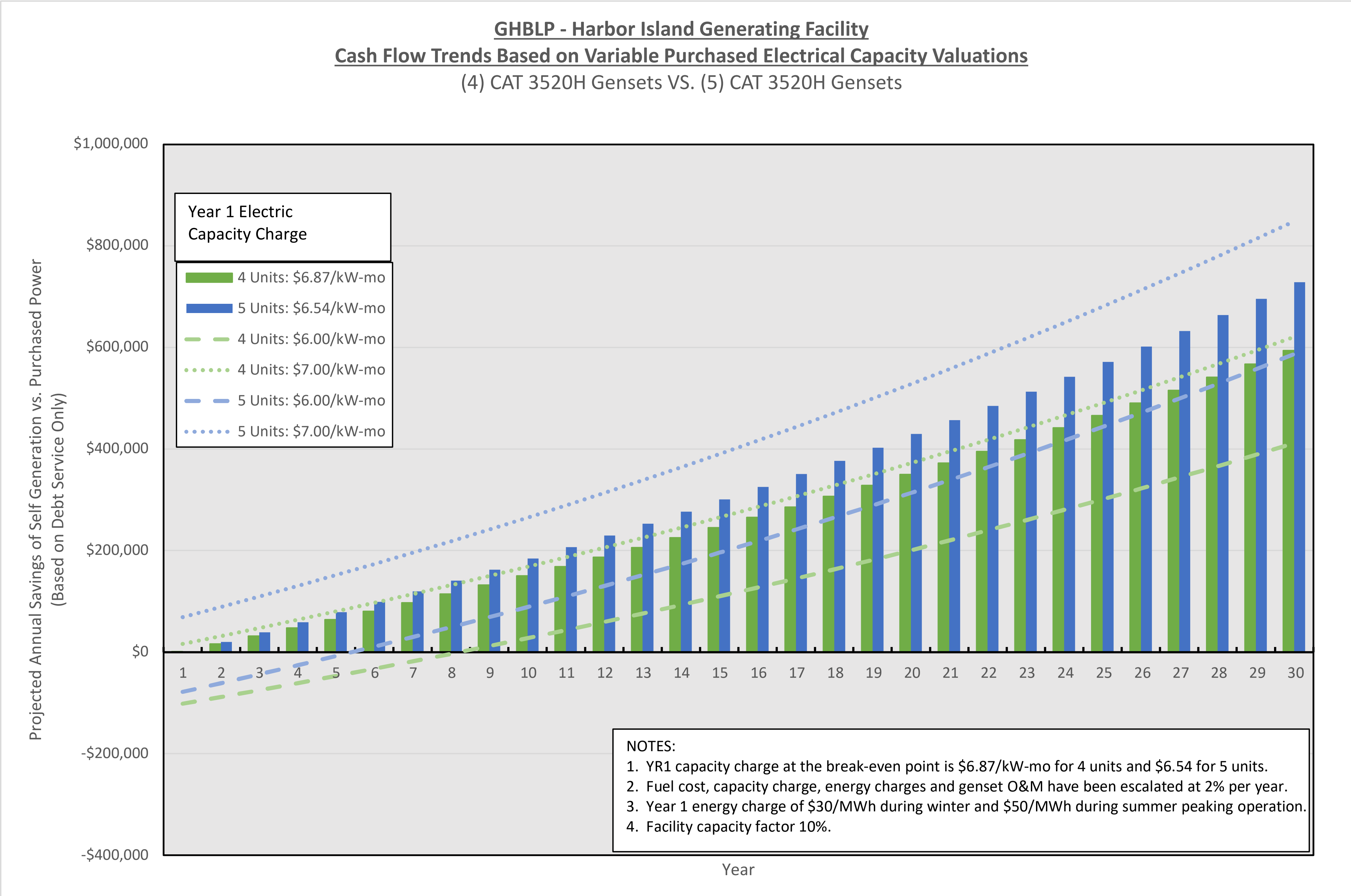
PRIME MOVER EVALUATION DATA					
	Unit	CAT G3520H	CAT CG260	MTU 20V4000	JENBACHER J620
SITE DESIGN DATA					
Ambient Temp	°F	59	59	59	59
Relative Humidity	%	60	60	60	60
Site Elevation	ft	587	587	587	587
GENSET DATA					
Genset Power Output - EA	kW	2491	4000	2454	3329
Fuel Consumption (LHV) - OEM, ISO 3046	Btu/ekW-hr	7672	7792	8083	7693
Fuel Consumption (LHV) - OEM, ISO 3046	MBtu/hr	19.11	31.17	19.83	25.61
Efficiency (LHV) - OEM, ISO 3046	%	44.5%	43.8%	42.2%	44.4%
Fuel Flow (LHV) - OEM, ISO 3046	cfm	352	574	367	472
Fuel Consumption (HHV), OEM, ISO 3046	MBtu/hr	21.88	35.68	22.83	29.32
Fuel HHV	Btu/cf	1036	1036	1036	1036
Heat Rate (LHV), OEM, ISO 3046	Btu/kWh	7672	7792	8083	7693
Heat Rate (HHV), OEM, ISO 3046	Btu/kWh	8439	8571	8891	8462
Fuel Cost	$/Mbtu	$4.59	$4.59	$4.59	$4.59
Per Unit O&M Cost - 10% Cap Factor	$/Op-hr	$40.00	$40.00	$60.00	$60.00
Per Unit O&M Cost - 10% Cap Factor	$/kWh	$0.0161	$0.0100	$0.0244	$0.0180
Winter Snow Melt Mode					
Winter Generation Snowmelt Operating Hours - Single Engine Operation	Hrs	2,800	2,800	2,800	2,800
Winter Generation Snowmelt Single Engine Electrical Output - Net	kW	2,454	3,940	2,417	3,279
Winter Generation - Snowmelt Coupled	kWh	6,870,178	11,032,000	6,768,132	9,181,382
Purchased Energy Charge	$/MWh	$30	$30	$30	$30
Purchased Energy Charge	$/kWh	$0.030	$0.030	$0.030	$0.030
Equivalent Purchased Energy Charge	$	$206,105	$330,960	$203,044	$275,441
Total Equivalent Purchased Energy + Interpolated Capacity Charge	$	$770,778	$897,672	$759,329	$841,417
Snow Melt Mode Purchased Energy Total Cost	$/kWh	$0.1122	$0.0814	$0.1122	$0.0916
Peak Shaving Mode					
Peak Shaving Generation Facility Operating Hours	Hrs	316	468	176	235
Peak Shaving Generation Facility Electrical Output	kW	12,268	11,820	9,669	9,837
Peak Shaving Generation	kWh	3,876,743	5,534,912	1,701,702	2,308,462
Purchased Energy Charge	$/MWh	$50	$50	$50	$50
Purchased Energy Charge	$/kWh	$0.050	$0.050	$0.050	$0.050
Equivalent Purchased Energy Charge	$	$193,837	$276,746	$85,085	$115,423
Total Equivalent Purchased Energy + Interpolated Capacity Charge	$	$512,474	$561,073	$224,951	$257,726
Peak Shaving Mode Purchased Energy Total Cost	$/kWh	$0.1322	$0.1014	$0.1322	$0.1116
Generating Facility vs. Market Purchased Electric Comparison					
Total Generation Facility Annual Equivalet Engine Operating Hours	Hrs	4,380	4,205	3,504	3,504
Total Generation Facility Annual Equivalent Generation	kWh	10,746,921	16,566,912	8,469,834	11,489,844
Capacity Charge for Generating Facility Net Output - Annual	$	$883,309	$851,040	$696,151	$708,278
Energy Charge for Generating Facility Net Output - Annual	$	$399,943	$607,706	$288,129	$390,865
Total Projected Purchased Annual Electrical Cost	$	$1,283,251	$1,458,746	$984,280	$1,099,143
Total Projected Purchased Annual Electrical Rate	$/kWh	$0.119	$0.088	$0.116	$0.096
Generating Facility Annual Fuel + Genset O&M Cost	$	$438,505	$757,354	$435,980	$516,477
Staffing & General O&M Annual Allowance	$	$0	$0	$0	$0
Generating Facility Annual Equivalent Electric Rate	$/kWh	$0.041	$0.046	$0.051	$0.045
Potential Year 1 Pre-Capital Recovery Annual Savings vs. Purchased Capacity and Energy (Capacity @ $6/kW-mo)	**$**	**$844,746**	**$701,391**	**$548,300**	**$582,665**

Attachment B

Cash Flow Trend Charts

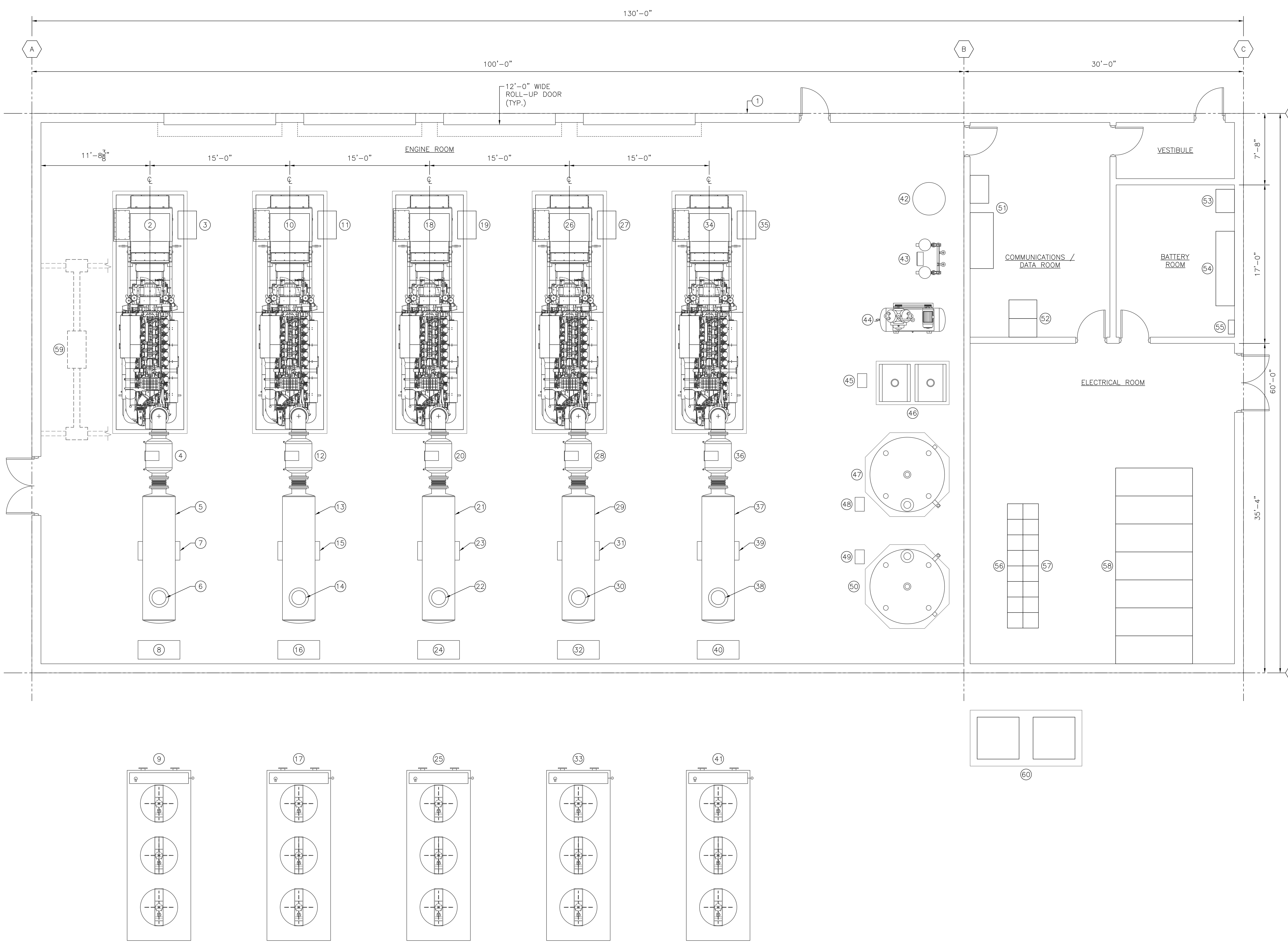

GHBLP - Harbor Island Generating Facility
Cash Flow Trends Based on Variable Purchased Electrical Capacity Valuations
Site Fuel Availability: 100 mcfh
(4) CAT 3520H Gensets - 9,800 kW Facility Capacity
Projected Annual Savings of Self Generation vs. Purchased Power
(Based on Debt Service Only)
$800,000
$600,000
$400,000
$200,000
$0
-$200,000
-$400,000
Year 1 Electric
Capacity Charge
$5.00/kW-mo
$6.00/kW-mo
$6.87/kW-mo
$7.00/kW-mo
$8.00/kW-mo
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Year
NOTES:
1. $6.87/kW-mo is the YR1 capacity charge at the break-even point.
2. Fuel cost, capacity charge, energy charges and genset O&M have been escalated at 2% per year.
3. Year 1 energy charge of $30/MWh during winter and $50/MWh during summer peaking operation.
4. Facility capacity factor 10%.


GHBLP - Harbor Island Generating Facility
Cash Flow Trends Based on Variable Purchased Electrical Capacity Valuations
Site Fuel Availability: 110 mcfh
(5) CAT 3520H Gensets - 12,250 kW Facility Capacity
Projected Annual Savings of Self Generation vs. Purchased Power (Based on Debt Service Only)
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
-$200,000
-$400,000
Year 1 Electric Capacity Charge
$5.00/kW-mo
$6.00/kW-mo
$6.54/kW-mo
$7.00/kW-mo
$8.00/kW-mo
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Year
NOTES:
1. $6.54/kW-mo is the YR1 capacity charge at the break-even point.
2. Fuel cost, capacity charge, energy charges and genset O&M have been escalated at 2% per year.
3. Year 1 energy charge of $30/MWh during winter and $50/MWh during summer peaking operation.
4. Facility capacity factor 10%.


GHBLP - Harbor Island Generating Facility
Cash Flow Trends Based on Variable Purchased Electrical Capacity Valuations
(4) CAT 3520H Gensets VS. (5) CAT 3520H Gensets
Year 1 Electric Capacity Charge
4 Units: $6.87/kW-mo
5 Units: $6.54/kW-mo
4 Units: $6.00/kW-mo
4 Units: $7.00/kW-mo
5 Units: $6.00/kW-mo
5 Units: $7.00/kW-mo
Projected Annual Savings of Self Generation vs. Purchased Power (Based on Debt Service Only)
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
-$200,000
-$400,000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Year
NOTES:
1. YR1 capacity charge at the break-even point is $6.87/kW-mo for 4 units and $6.54 for 5 units.
2. Fuel cost, capacity charge, energy charges and genset O&M have been escalated at 2% per year.
3. Year 1 energy charge of $30/MWh during winter and $50/MWh during summer peaking operation.
4. Facility capacity factor 10%.

Attachment C

Generating Facility Conceptual General Arrangement



LEGEND

1. GENERATION BUILDING
2. GENSET-1 CATERPILLAR 3520H
3. GENSET-1 CONTROL PANEL
4. GENSET-1 CATALYTIC CONVERTER
5. GENSET-1 EXHAUST SILENCER
6. GENSET-1 EXHAUST STACK
7. GENSET-1 LOW TEMP CIRCUIT HEAT EXCHANGER
8. GENSET-1 HIGH TEMP CIRCUIT HEAT EXCHANGER
9. GENSET-1 RADIATOR
10. GENSET-2 CATERPILLAR 3520H
11. GENSET-2 CONTROL PANEL
12. GENSET-2 CATALYTIC CONVERTER
13. GENSET-2 EXHAUST SILENCER
14. GENSET-2 EXHAUST STACK
15. GENSET-2 LOW TEMP CIRCUIT HEAT EXCHANGER
16. GENSET-2 HIGH TEMP CIRCUIT HEAT EXCHANGER
17. GENSET-2 RADIATOR
18. GENSET-3 CATERPILLAR 3520H
19. GENSET-3 CONTROL PANEL
20. GENSET-3 CATALYTIC CONVERTER
21. GENSET-3 EXHAUST SILENCER
22. GENSET-3 EXHAUST STACK
23. GENSET-3 LOW TEMP CIRCUIT HEAT EXCHANGER
24. GENSET-3 HIGH TEMP CIRCUIT HEAT EXCHANGER
25. GENSET-3 RADIATOR
26. GENSET-4 CATERPILLAR 3520H
27. GENSET-4 CONTROL PANEL
28. GENSET-4 CATALYTIC CONVERTER
29. GENSET-4 EXHAUST SILENCER
30. GENSET-4 EXHAUST STACK
31. GENSET-4 LOW TEMP CIRCUIT HEAT EXCHANGER
32. GENSET-4 HIGH TEMP CIRCUIT HEAT EXCHANGER
33. GENSET-4 RADIATOR
34. GENSET-5 CATERPILLAR 3520H
35. GENSET-5 CONTROL PANEL
36. GENSET-5 CATALYTIC CONVERTER
37. GENSET-5 EXHAUST SILENCER
38. GENSET-5 EXHAUST STACK
39. GENSET-5 LOW TEMP CIRCUIT HEAT EXCHANGER
40. GENSET-5 HIGH TEMP CIRCUIT HEAT EXCHANGER
41. GENSET-5 RADIATOR
42. AIR RECEIVER
43. AIR DRYER
44. AIR COMPRESSOR
45. COOLANT TRANSFER PUMPS
46. COOLANT TRANSFER TOTES
47. CLEAN OIL STORAGE TANK
48. CLEAN OIL TRANSFER PUMP
49. WASTE OIL STORAGE PUMP
50. WASTE OIL TRANSFER TANK
51. WORK STATION / STORAGE
52. MAIN CONTROL PANELS
53. BATTERY CHARGER
54. DC BATTERY RACK
55. DC DISTRIBUTION PANEL
56. 480V MCC-1
57. 480V MCC-2
58. 13.2KV SWITCHGEAR
59. BRIDGE CRANE
60. AUXILIARY TRANSFORMERS 13.2KV-480V

REV	DATE	DESCRIPTION	DWN	DGN	CHK	APP
A	06-16-20	PRELIMINARY	-	-	-	-

SCALE: 1/4"=1'-0"

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

PEC

E SIZE 42"x30"

Power Engineers Collaborative, L.L.C.

2215 South York Road, Suite 202, Oak Brook, Illinois 60523

150 North Sunny Slope Road, Suite 375, Brookfield, Wisconsin 53005

WWW.PECLLC.COM

GRAND HAVEN BOARD OF LIGHT & POWER
1700 EATON DR.
GRAND HAVEN, MI 49417

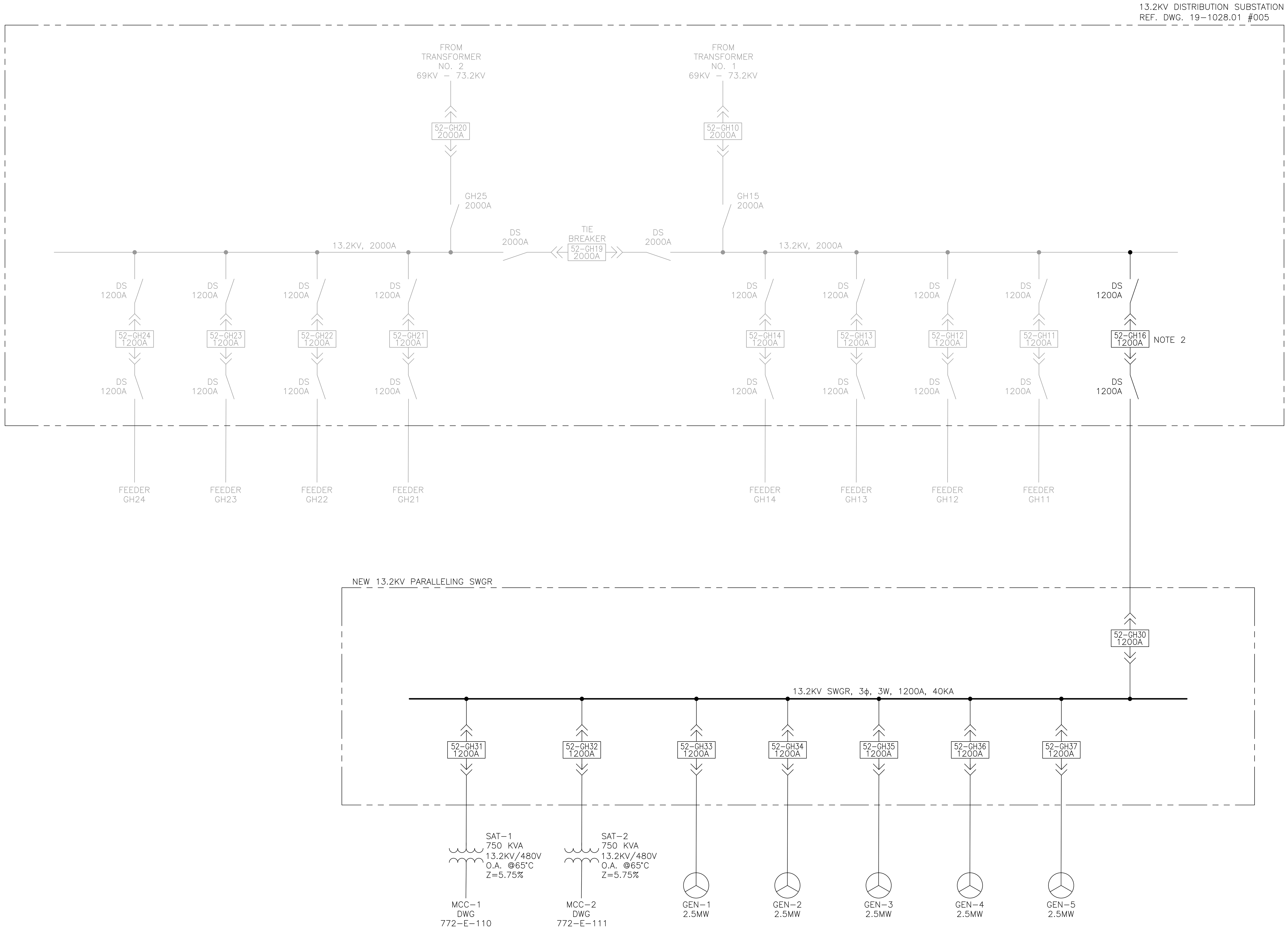
HARBOR ISLAND GENERATING FACILITY
GENERAL ARRANGEMENT
EQUIPMENT LAYOUT

DWG# 772-M-102

REV. A

Attachment D

Generating Facility Single Line Diagrams



NOTES:

1.) EXISTING PLANNED DISTRIBUTION SUBSTATION INDICATED IN GRAY SCALE.

2.) SPARE POSITION IS AVAILABLE FOR THE GENERATING FACILITY INTERCONNECTION IN THE PLANNED 13.2KV DISTRIBUTION SUBSTATION.

REV	DATE	DESCRIPTION	DWN	DGN	CHK	APP
A	07-01-20	PRELIMINARY	-	-	-	-

SCALE: -

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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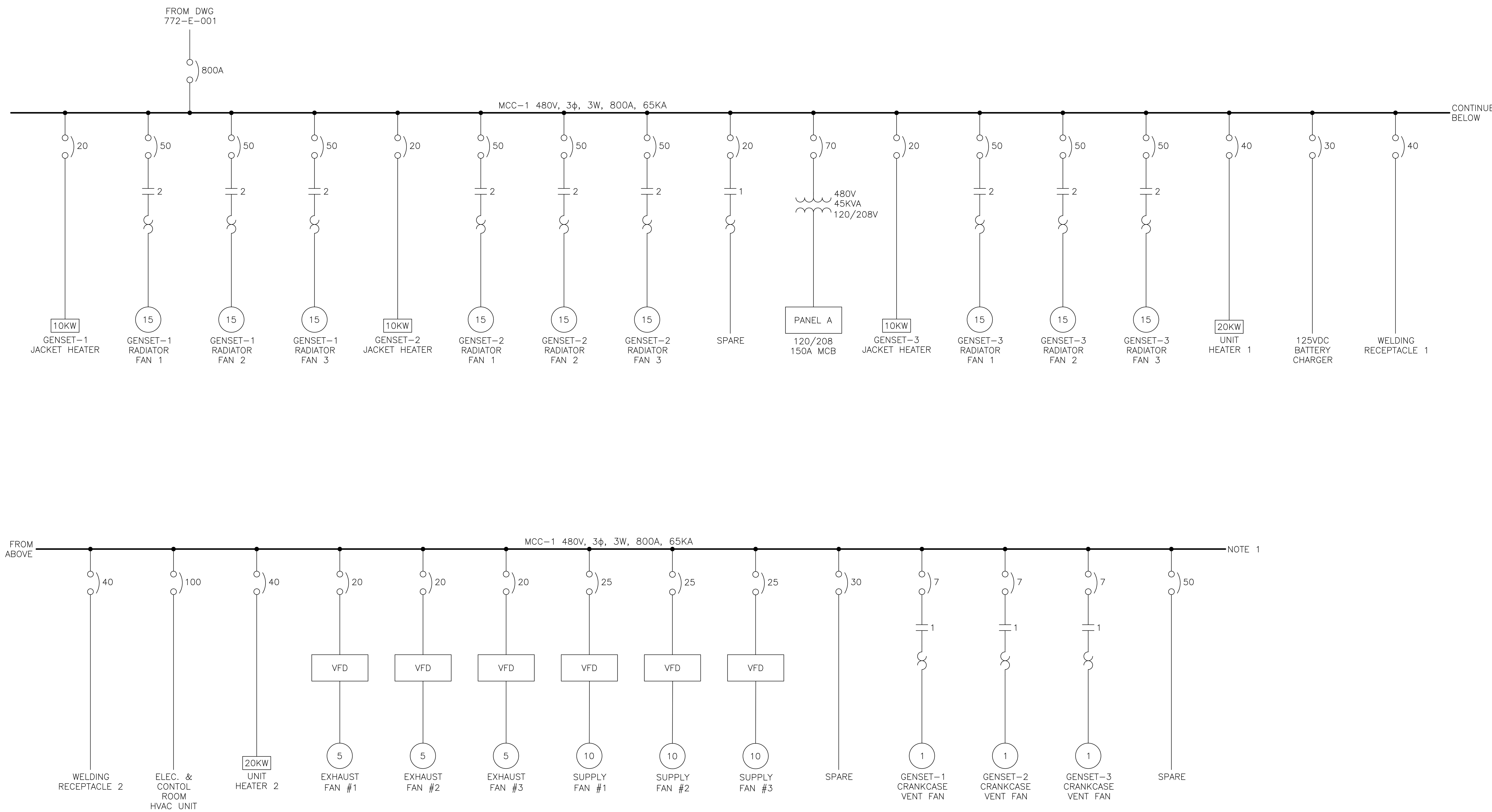
GRAND HAVEN, MI 49417

HARBOR ISLAND GENERATING FACILITY
SINGLE LINE DIAGRAM

DWG# 772-E-101

REV. A

772-E-110



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A	07-01-20	PRELIMINARY	-	-	-	-

SCALE: -

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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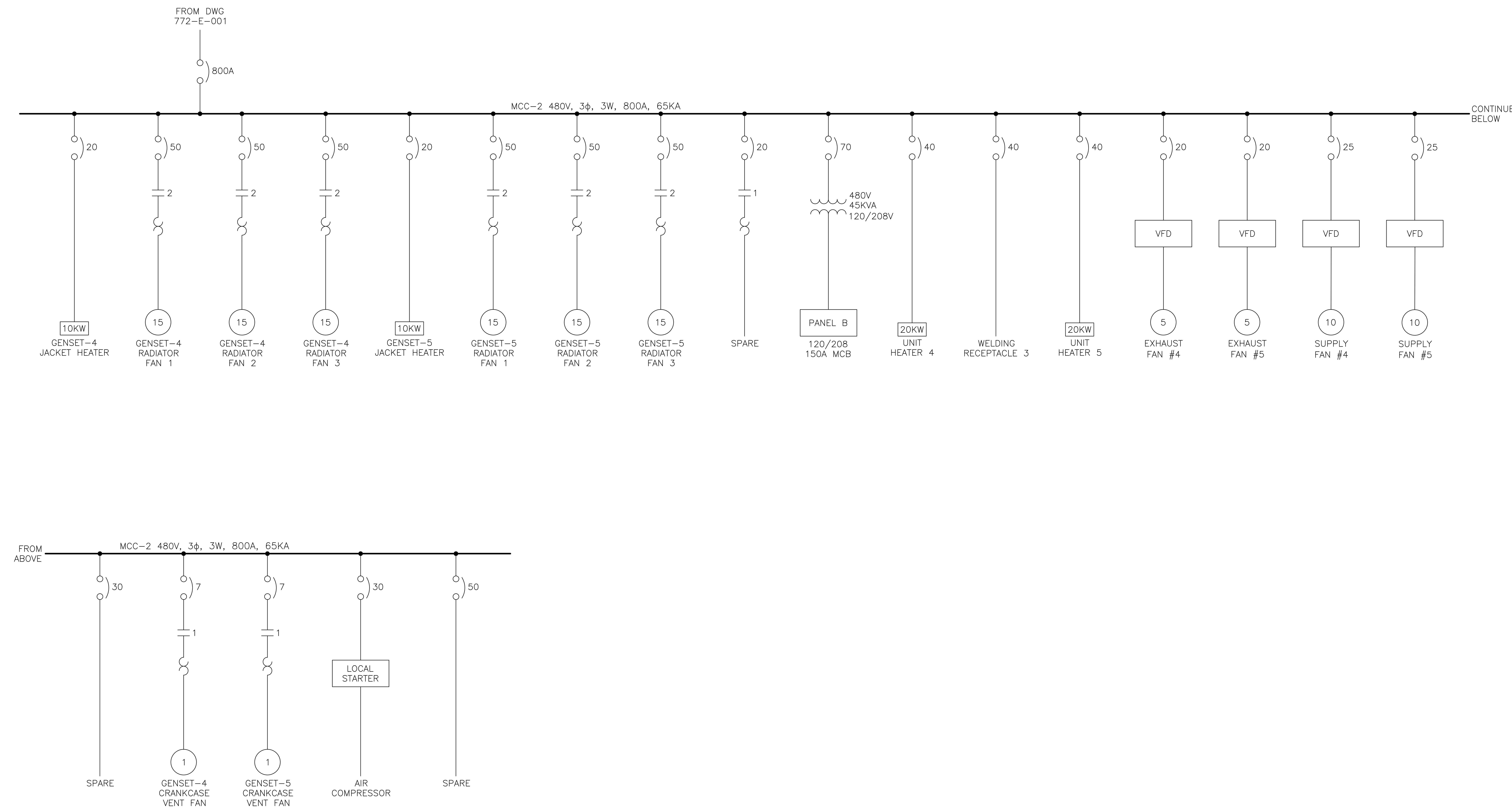
GRAND HAVEN, MI 49417

HARBOR ISLAND GENERATING FACILITY
SINGLE LINE DIAGRAM
480V MCC-1

DWG# 772-E-110

REV. A



REV	DATE	DESCRIPTION	DWN	DGN	CHK	APP
A	07-01-20	PRELIMINARY	-	-	-	-

SCALE: -

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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GRAND HAVEN, MI 49417

HARBOR ISLAND GENERATING FACILITY
SINGLE LINE DIAGRAM
480V MCC-2

DWG# 772-E-111

REV. A