Synopsis Report

Associated Engineering
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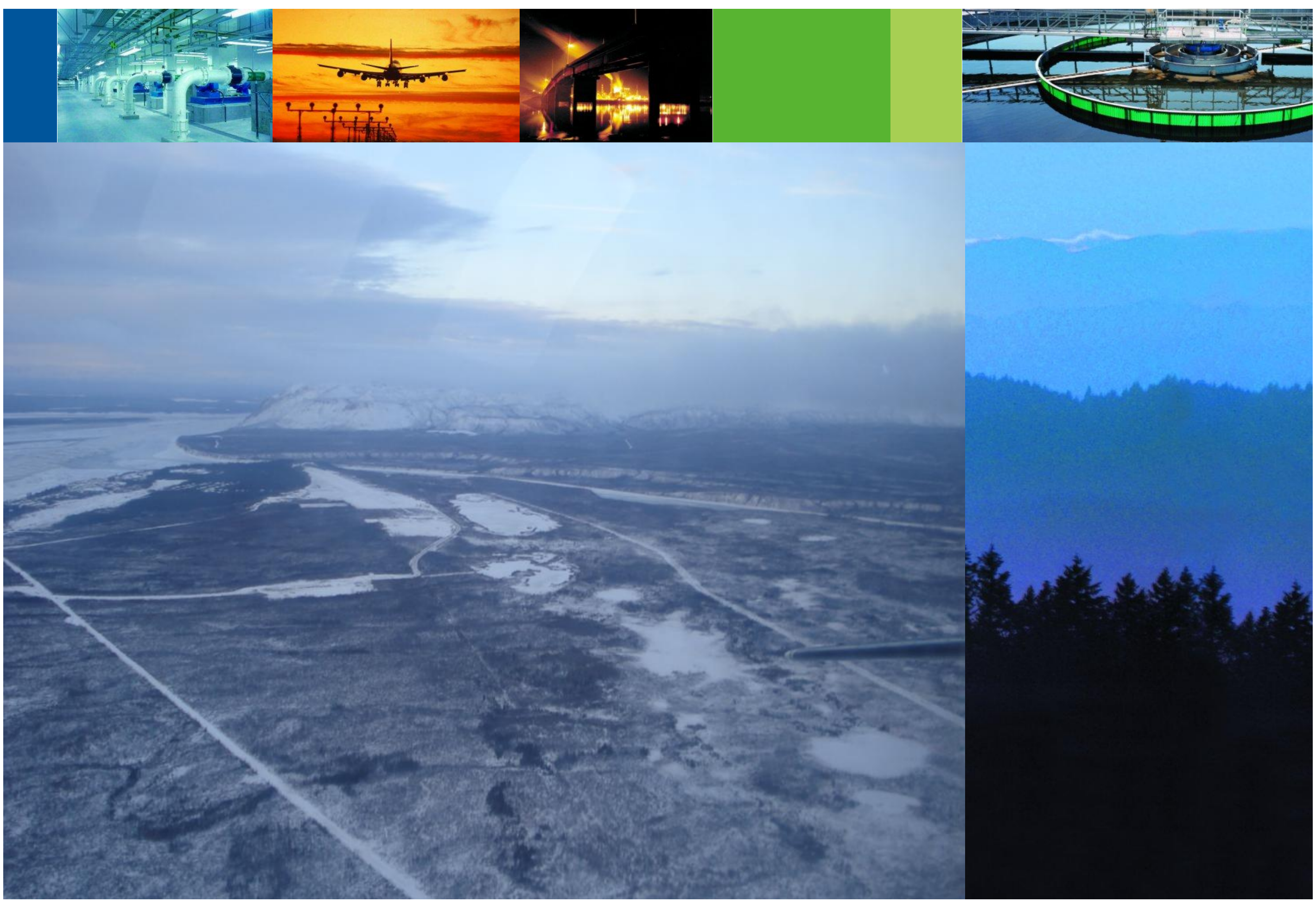
Government of the Northwest Territories

Northwest Territories Industry, Tourism and Investment

Assessment for Natural Gas Power Conversions in Fort Good Hope, NT

April 2011



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Executive Summary

The Mackenzie Gas Project presents opportunities to supply natural gas to communities along the proposed pipeline corridor. Many communities along the proposed corridor currently rely on diesel fuel to supply power generation systems for electricity. The diesel is supplied from southern Canada and significant transportation costs are incurred.

The community of Fort Good Hope, NT is provided with electrical power from a single generating facility on the outskirts of the community. The generating facility is a diesel generating power facility complete with three diesel generating sets.

The Government of the Northwest Territories (GNWT) initiated this study to further evaluate the technical, economical, and environmental feasibility for the potential of converting the existing power generation systems in the community of Fort Good Hope from diesel fuel to natural gas. This conversion can be accomplished through a number of different approaches. We completed a preliminary evaluation of the following four energy generation scenarios:

- Converting the existing diesel engines to natural gas engines;
- Replacing the existing diesel engines with new natural gas turbine and reciprocating engines;
- Replacing the diesel power plant with a combined cycle power plant including new natural gas turbine generators and reciprocating engine generators; and
- Providing new natural gas engines and generators.

Of the four scenarios, **providing new natural gas engines and generators** was the most viable approach and can be achieved by the following two options:

Replacement of Three Generator Sets - This option would entail replacing the existing three diesel driven generator sets with three new gas driven reciprocity engine generator sets. The new generator sets would be provided as three equally sized 500 kW gas driven engines complete with synchronous generators. The estimated capital cost for this option is $3,930,000.

Adopting this option could lead to significant savings over the life of the project. If the status quo was maintained, the net present value would be ($18.9 million) compared to ($7.7 million) under this option. This represents a total present worth of savings of $11.2 million.

In addition, there could be significant savings in green house gas (GHG) emission. If the status quo was maintained, the GHG emissions over the life of the project would be 55,600 tonnes CO_2 equivalent. Under this option, the GHG emissions would be 43,400 tonnes CO_2 equivalent. This represents a reduction of 12,200 tonnes.

Provision of New Single Generator Set in a New Facility - This option would entail a new single gas driven reciprocity engine generator set in an enclosure located adjacent to the community's school. The new generator set would be a 750 kW unit. The existing diesel based generation systems would be retained and maintained in their current state. The diesel based system would be used as back-up to the new gas driven generator set. The waste heat from the new generator could be recovered to provide heat to the school making this a combined heat and power (CHP) facility. The estimated capital cost for this option is $3,750,000.

This option would also lead to significant savings. The net present value of this option is ($7.0 million). The total present worth savings would therefore be $11.9 million. Under this option the total GHG emissions would be 44,800 tonnes CO_2 equivalent. The total GHG reduction could be 10,800 tonnes CO_2 equivalent.

In addition to estimating the capital costs, a financial analysis was completed for each option which included the 'Business As Usual' (BAU) scenario. The financial analysis also considered the operation and maintenance costs including fuel, routine and overhaul costs over a 20 year project period starting in 2018. The financial analysis indicated that the **Provision of a New Single Generator Set** near the school was the most financially attractive option with a NPV of $6,939,545 and an average generation cost of $0.18 /kWh. A sensitivity analysis was undertaken by varying the capital and fuel costs to evaluate the impact on overall project financial outcomes. The sensitivity analysis indicated that changes in costs had no impact on the relative financial attractiveness of the options.

Further to the financial analysis, a triple bottom line analysis (TBL) was completed for the two options and BAU. Based on the TBL analysis, **Provision of New Single Generator Set** near the School is the most attractive option. This new single generator set facility is more financially economical than replacing the existing diesel three generator sets with natural gas generators set. Furthermore, this new facility has more environmental and social benefits than the BAU and the replacement of the generator sets.

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1 Introduction

1.1 BACKGROUND

The community of Fort Good Hope, NT is located approximately 150 km northwest of Norman Wells. This community is remote with a population of approximately 550 persons. The economy of the community is based on hunting, fishing, trapping, oil exploration, and tourism. This community is accessible by plane or barge.

Many communities in the North, such as Fort Good Hope, rely on independent power generation, such as diesel generating systems for electricity, and heating oil for space heating. Diesel generation systems are widely used to provide electricity in communities without connection to the power grid and as standby power supplies. For remote communities, these systems present challenges in their operation, including diesel fuel supply, fuel transportation costs, spill risks, and air emissions from diesel fuel combustion. Conversion to natural gas-based generation systems could present opportunities for significant cost savings, increased energy efficiency, and reduced greenhouse gas (GHG) emissions for these remote communities.

The Northwest Territories has an abundance of natural gas reserves. The Mackenzie Gas Project will include supply and delivery of natural gas from three fields in the Mackenzie Delta via a new 1,196 km pipeline system along the Mackenzie Valley to north western Alberta. The Mackenzie Gas Project provides opportunities for many communities along the pipeline corridor to access natural gas. A previous study commissioned by the Government of Northwest Territories (GNWT) in 2008 showed that conversion from diesel power generation to natural gas power generation was feasible for the community of Fort Good Hope.

1.2 ASSIGNMENT OBJECTIVE AND APPROACH

The objective of this assignment is to complete a feasibility analysis of converting the existing power generation systems in the community of Fort Good Hope from diesel fuel to natural gas. This feasibility study assesses the technical and economic feasibility as well as the non-economic benefits of four power generation scenarios which include the following:

- Converting the existing diesel engines to natural gas engines;
- Replacing the existing diesel engines with new natural gas turbine and reciprocating engines;
- Replacing the diesel power plant with a combined cycle power plant including new natural gas turbine generators and reciprocating engine generators; and
- Providing new natural gas engines and generators.

The project objectives were addressed through a series of technical memoranda and are as follows:

- Technical Memorandum No. 1B – Site Visits and Data Record
- Technical Memorandum No. 2B – Diesel to Natural Gas Conversion Options
- Technical Memorandum No. 3B – Cost Estimates and Business Case Analysis

- Technical Memorandum No. 4B – Triple Bottom Line Analysis

1.3 REPORT STRUCTURE

This report begins with a summary of the key findings of each technical memorandum. Following the summaries, the conclusions and next steps are provided.

2 Site Visit and Data Record

2.1 SITE VISIT

A site visit was carried out on November 18th, 2010 with representatives from GNWT. The site visit consisted of a tour of the generating facility and the community.

2.2 ELECTRICAL FACILITIES DESCRIPTION

The community of Fort Good Hope is provided with electrical power from a single generating facility in the centre of the community. Power is distributed via two 4160 volt circuits along overhead power lines that run along existing roadway routes.

The generating facility is a diesel generating power facility complete with three diesel generating sets and all necessary ancillary equipment. Each generator set is provided with an engine monitoring panel, cooling circuit piping, heat exchanger and exhaust system. A summary of the various components of the generator sets are presented in **Table 2-1**.

Table 2-1
Generator Sets

	Genset G1	Genset G2	Genset G3
Engine			
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Type	8 cylinder reciprocating	6 cylinder reciprocating	8 cylinder reciprocating
Configuration	"V" configuration	"in-line" configuration	"V" configuration
Start Method	Battery	Battery	Battery
Exhaust Driven Turbocharger	Single	Single	n/a
Jacket Cooling	Yes	Yes	Yes
Oil Cooling	Yes	No	Yes
Generator			
Manufacturer	Reliance Electric	Marathon Electric	Reliance Electric

	Genset G1	Genset G2	Genset G3
Type	565 kW synchronous	400 kW synchronous	565 kW synchronous
Nominal speed	1200 rpm	1200 rpm	1200 rpm

2.3 ELECTRICAL CONSUMPTION

In 2008, a detailed analysis of fuel use and community electrical demand was undertaken. The information was collated by Northern Territories Power Corporation and presented in the 2008 ENCOR report titled “Mackenzie Valley Gas Conversion Feasibility Study”. Since the preparation of the 2008 report there have been few changes in the community. The data is therefore considered to be still appropriate for the basis of this study. The data shows the peak electrical load in 2010 to be 629 kW rising to 719 kW in 2037.

3 Diesel to Natural Gas Conversion Options

3.1 ELECTRICITY LOAD FORECAST

The annual electricity demand is expected to rise from 2.89 GWh in 2010 to 3.44 GWh in 2037.

3.2 ENGINE CONVERSION SCENARIOS

There are a number of approaches to converting the community from diesel power generation to natural gas power generation. We completed a preliminary evaluation of the four energy generation scenarios. Our preliminary evaluations of the following three scenarios indicated that they were not suitable and were therefore not evaluated in further detail:

1. **Converting the existing diesel engines to natural gas engines** - Natural gas engines are designed to run at the far higher temperatures associated with a spark ignition based engine. Diesel engines are not. If a diesel engine is run with a spark based fuel, the engine will see accelerated wear. For an engine which is intended to be used continuously in a power generation role, the on-going maintenance costs will be significant.

2. **Providing new natural gas driven turbines and generators** - Turbine engines can be more efficient than conventional reciprocating engines. This efficiency comes from a combination of optimized selection for steady state operation and the application of heat recovery techniques. In the case of Fort Good Hope, the power generation will not be steady state as the loads will vary diurnally and seasonally. This would not be an optimum arrangement for a turbine application. In addition, the load requirement for Fort Good Hope is less than most commercially available gas turbine generator sets as they are typically manufactured for capacities of 1 MW or higher. As well, the load requirements at Fort Good Hope are less than the loads at Fort Simpson. An assessment was previously completed for Fort Simpson indicating that using a turbine resulted in the lowest return of investment. This would suggest that the economic viability of a turbine option in Fort Good Hope would be even more unfavourable. Furthermore, micro turbines are relatively new and unproven and would require specialist attention which is not ideal for remote locations.

3. **Providing a combined cycle power plant** – Combined cycle power plants are electrical generation systems where more than one power cycle is used to create electricity. A typical combined cycle power plant would have a gas turbine generator as the primary power source, with waste heat from the gas turbine being used to raise steam to drive a steam turbine generator. Although combined cycle power plants can achieve high levels of efficiency, the systems are complicated and best suited to large scale power generation. Combined power plants typically start in the 50 MW range which far exceeds the anticipated load requirements for Fort Good Hope.

3.3 VIABLE ENGINE CONVERSION OPTIONS

From our preliminary evaluation, the most viable approach to engine conversion is by providing new natural gas reciprocity engines and generator sets. This can be achieved by replacing the existing diesel engines and generator set with natural gas engines and generator sets or by constructing a new power generation facility complete with a single natural gas generator set. The “Business As Usual” (BAU) is presented as Option 1 for baseline comparison purposes.

Option 1: Business As Usual

Under the BAU option, the existing diesel based generation systems would be retained and maintained in their current state. There is no need to upgrade the units as the existing generator capacities are suitable for meeting the power requirements for the community through to 2035.

Option 2: Replacement of Three Generator Sets

Under this option, the existing three diesel driven generator sets would be replaced with new gas driven reciprocity engine generator sets. The existing building and other ancillary systems would be retained. Some systems would need to be modified and others replaced, but the intent would be to use as much of the existing installation as possible.

The new generator sets would be provided as three equally sized gas driven engines complete with synchronous generators. The units would typically be provided at a nominal size of 500 kW. For the purposes of this study, a Caterpillar G3512 gas engine generator set has been selected. This unit includes a V-12 spark ignition engine and a self-excited brushless generator. The generators will generate at 4160 volt and the units will run at a nominal operating speed of 1200 rpm. The proposed engine is provided with twin turbochargers and after-cooling systems.

There would be no additional cold climate requirements for the installation of the generator sets. However, the external works will require appropriate attention in regard to the installation of gas piping and other services. It may be necessary for gas lines and other services to be provided in a utility corridor (utilidor).

Option 3: Provision of New Single Generator Set in New Facility

Under this option a new single gas driven reciprocity generator set would be provided. This set would be provided in an enclosure and would be located adjacent to the community’s school. The existing diesel based generation system would be retained and maintained in their current state. The diesel based system would be used as back-up to the new gas driven generator set.

The new generator set would be provided as a gas driven engine complete with synchronous generator. The unit would be provided at a nominal size of 750 kW. This size unit would be suitable for meeting community energy loads through to the year 2037. For the purposes of this study, a Caterpillar G3516 gas engine generator set has been selected. This unit includes a V-16 spark ignition engine and a self-excited brushless generator. The generators will generate at 4160 volt and the units will run at a nominal operating speed of 1200 rpm. The proposed engine is provided with twin turbochargers and after-cooling systems.

The new gas driven generator set complete with enclosure and ancillary systems would be assembled as a packaged set. The packaged set would be factory tested and then transported to site for installation on an elevated footing to prevent perma-frost thawing below the facility. The new unit would be connected to the existing transmission wires with piping between the facility and the school using an utilidor and then field tested. On successful completion of the field testing, the unit would be considered commissioned.

Under Option 3 the waste heat from the new generator would be recovered to provide heat to the school making this a combined heat and power (CHP) facility. In order to allow the waste heat to be effectively used, it will be necessary to include a number of additional systems including: pumping equipment, heat exchangers, piping systems and control equipment. Some modifications to the school heating systems would also be required. These modifications would be implemented in such a way that the existing school heating systems would be retained. By taking this approach the school will still be able to be heated even when the new generator set is out of service.

4 Cost Estimate and Business Case Analysis

4.1 COST ESTIMATE

Class C capital costs and operations and maintenance (O&M) costs were estimated for the following options:

- Option 2: Replacement of Three Generator Sets
- Option 3: Provision of New Single Generator Set in New Facility

As per the requirements of a Class C cost estimate, the cost estimates are based on pricing of similar project components from other comparable projects except for the engine driven generator sets where specific quotes were obtained for the major components. The capital cost estimate includes a 20% contingency.

The O&M costs were estimated based on the project period of 2018 to 2037 and included the following components:

- Annual Fuel Cost
- Annual Routine O&M Costs
- Overhaul Costs (over 20 year project period)

4.2 FINANCIAL ANALYSIS

A financial analysis was completed for each of the three options. The financial model was based on a 20 year project period starting in 2018. The analysis included all capital expenditures as well as all O&M costs.

The financial assumptions used in the analysis included:

- Cumulative cost includes amortized investment and overhaul costs plus recovered costs.
- Discount interest rate of 5%.
- Annual O&M escalation rate of 2%.
- Annual overhaul escalation rate of 2%.
- Annual O&M cost of $50/kW in 2011 dollars
- Overhaul cost of $150,000 in 2011 dollars.
- Greenhouse Gas Emissions valued at $30/tCO_2$.
- No residual equipment value.

The financial analysis showed Option 3 to be the most financially attractive approach with an average generation cost of $0.18/kWh. This was followed by Option 2 at $0.20/kWh and Option 1 at $0.49/kWh.

Adopting Option 3 would lead to significant savings over the life of the project. Compared to maintaining the status quo of using diesel generator sets, this option would lead to a total present worth saving of $11.9M.

A sensitivity analysis was undertaken by varying the capital and fuel costs to evaluate the impact on overall project financial outcomes. For each of the options investigated, the capital cost was increased by 25%, 50% and 100%. Similarly, the cost of fuel was increased by an additional 100%, 200% and 300% over the project period.

Cost estimates and business case analysis have been conducted for the three options identified. The capital cost estimate for Option 2 is $3,930,000 and the capital cost estimate for Option 3 is $3,750,000. The business case analysis identifies Option 3 to be the most attractive option with an NPV of ($6,939,545) and an average price of generation of $0.18 kW.

A sensitivity analysis has also been conducted. The sensitivity analysis shows that Option 1 will be significantly impacted by changes in fuel cost. The sensitivity analysis indicates that changes in costs will be unlikely to change the order of preference of the options. And Option 3 remains as the most financially attractive option.

5 Triple Bottom Line Analysis

The TBL analysis provided a comparison of economic, social, and environmental factors associated with implementing each of the three described options.

The analysis did not consider TBL factors related to the implementation of the Mackenzie gas pipeline which would supply natural gas to the proposed engine generators.

Summarized in Table 5-1 are the TBL analysis results.

Table 5-1
Triple Bottom Line Assessment Results

Criteria	Option 1	Option 2	Option 3
Economic Factors			
Project construction cost	$ 0	$ 3,930,000	$ 3,750,000
Net Present Value	($ 18,875,008)*	($ 7,708,830)*	($ 6,939,545)*
Environmental Factors			
GHG Emissions (tonnes)			
CO_2	2779	2171	2239
CH_4	0.11	0.04	0.04
N_2O	0.23	0.004	0.004
Non-GHG Emissions (tonnes)			
NOx	31	84	86
SOx	24	0.01	0.01
CO	14	10	6
TPM	2	0.13	0.13
Social Factors			
Fuel security	Medium	Medium	High
Additional Employment Opportunities	No	No	Yes
Risk Factors			
Spill or leakage	Medium	Low	Low

* Note: Brackets around figure indicates a negative number. Option 1 (maintaining the status quo) has the lowest NPV and is therefore the least attractive option.

Economically, Options 2 and 3 present a strong alternative to the existing diesel generators when comparing net present value of the three options. In terms of environmental factors, the natural gas options also provide considerable reductions in GHG and most non-GHG emissions (mono-nitrogen oxides are an exception). GHG and non-GHG emissions levels for Options 2 and 3 are similar. When considering social factors, Option 3 has the additional benefits of potentially higher fuel security and the possibility for additional employment opportunities within the community. Risk factors, most significantly the risk of a leakage or spill, are considered to be lower for Options 2 and 3 which rely principally on fuel transport by natural gas pipeline.

6 Conclusion

The two most viable options to engine conversion for the community of Fort Good Hope are as follows:

Replacement of Three Generator Sets (Option 2) - This option will entail replacing the existing three diesel driven generator sets with three new gas driven reciprocating engine generator sets. The new generator sets will be provided as three equally sized 500 kW gas driven engines complete with synchronous generators. The estimated capital cost for this option is $3,930,000.

Adopting this option could lead to significant savings over the life of the project. Compared to maintaining the status quo of using diesel generator sets, this option could lead to a total present worth of savings of $11.2 million.

In addition, there could be significant savings in green house gas (GHG) emission. Over the project life, the GHG reduction would be 12,200 tonnes CO_2 equivalent.

Provision of New Single Generator Set in New Facility (Option 3) - This option will entail a new single 750 kW gas driven generator set in an enclosure located adjacent to the community's school. The existing diesel based generation systems will be retained and maintained in their current state. The diesel based systems will be used as back-up to the new gas driven generator set. The waste heat from the new generator could be recovered to provide heat to the school making this a combined heat and power (CHP) facility. The estimated capital cost for this option is $3,750,000.

This option would also lead to significant savings. The total present worth savings would be $11.9 million. The total GHG reduction could be 10,800 tonnes CO_2 equivalent.

Based on the triple bottom line analysis (Option 3) - Provision of New Single Generator Set in a New Facility is the most attractive option. Option 3 is more economical than Option 2 and has more environmental and social benefits than the 'Business As Usual' (Option 1) and Option 2.

7 Next Steps

Based on the findings of this feasibility study, the following items are recommended for GNWT to perform during the next phase of this project:

- Continue to monitor fuel pricing as the increases or decreases to fuel pricing can make the project more or less financially attractive.
- Continue to monitor energy use in the community which will provide better baseline data for energy consumption projections.
- Investigate governance strategies (e.g. Neighbourhood Energy Utility (NEU)) associated with distributing the electricity and heating from natural gas to the community.
- Develop and implement a stakeholder engage plan which should also include public consultation. The likely success of proceeding with this project will be highly dependent on public support and a well thought-out communications plan will help navigate GNWT through the challenging yet necessary process.
- Proceed with preliminary design of the preferred option. This will allow for more detailed capital cost estimating as well as presentation material, such as site plans and concept designs, at public engagement events. As part of the preliminary design, a more detailed assessment of the environmental and social consequences as well as risk associated with this project should be completed.

In addition, as part of pre-design the GNWT may wish to consider:

- The cost of pipeline and gas reception facilities. These additional costs may impact the economic viability of the conversion from diesel to natural gas.
- A hybrid option where two of the existing diesel sets are replaced and the third diesel set is retained. This option would likely be cheaper to implement and would allow the diesel set to act as standby when gas is not available.
- A detailed assessment of the O&M costs of the relative options. This assessment would be based on experience of running the existing plant and other similar installations.
- If Option 3 is adopted, what will be the diesel fuel requirements to provide standby to the gas engine? This should be assessed during preliminary design.
- If Option 3 is adopted, what will be the efficiency of the engine considering that the unit will be run at low load factors for much of the time?