Opportunities for Utilization of Natural Gas
for
Electrical Generation

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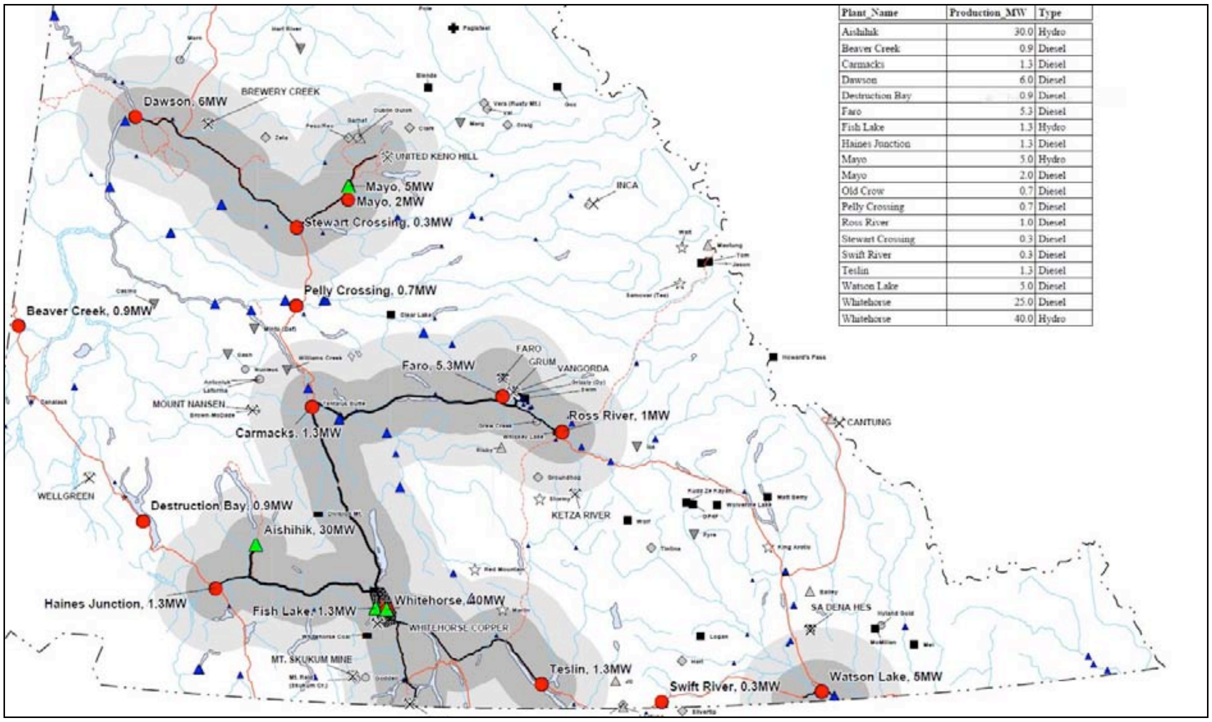
Existing Diesel Electrical Generation

YEC currently has 53.4 MW of diesel fired generating capacity used for peak shaving. Diesel is easily transported via truck giving YEC the flexibility to locate the generators at thirteen sites in the Yukon as shown by the red circles in Figure 1.



Source: Yukon Energy (www.yukonenergy.ca)

Figure 1: Yukon Electrical Grid and Generating Sites

YEC reports the marginal cost of diesel generation at $.28/kwh and that construction of additional sites is uneconomical. An example of fuel consumption for a 1 MW diesel generator is shown in Figure 2.

Load	Fuel Consumption (litre/hr)	Yukon Diesel Cost (1) ($/litre)	Cost/kwh ($/kwh)	Electrical Efficiency (%)
50%	151.1	1.26	0.38	33.3
75%	210.3	1.26	0.35	35.9
100%	271.6	1.26	0.34	37.0

Sources: Caterpillar Engines (www.catelectricpowerinfo.com)
Yukon Energy (www.yukonenergy.ca)

Figure 2: 1 MW diesel generator fuel consumption

(1) YEC is not required to pay the 7.2¢ tax on diesel used for electrical generation.

Four refineries, each of which is capable of producing and delivering diesel fuel into Yukon, are located in British Columbia and Alaska

Location	Operator	Crude Oil Inlet Capacity (bbl/d)
Burnaby, B.C.	Chevron	55,000
Prince George, B.C.	Husky	12,000
North Pole, Alaska	Flint Hills	210,000
North Pole, Alaska	Petro Star	17,000

Currently all diesel from Burnaby is barged to Skagway and then trucked throughout the Yukon. The difference between Burnaby wholesale prices and Whitehorse retail prices for diesel is approximately $0.50/litre. Diesel from Prince George is shipped via rail to Fort Nelson and then via truck into the Yukon. Alaskan diesel is trucked from North Pole.

Natural Gas Electrical Generation

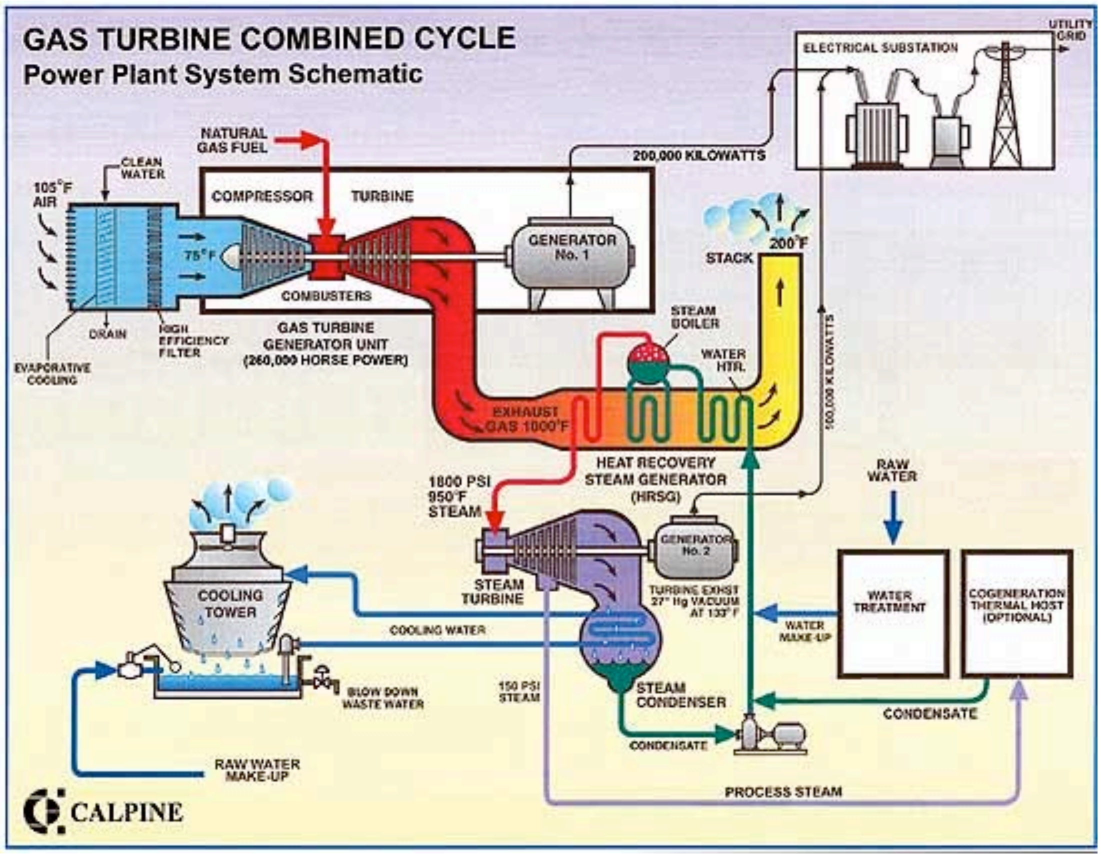
In a simple cycle process, the diesel reciprocating engine is replaced by a natural gas reciprocating engine or gas turbine. A range of examples are show in Figure 3.

Manufacturer	Model	Type	Size (MW)	Electrical Efficiency (%)
GE	J208 GS	reciprocating	0.34	35.8
CATERPILLAR	DM5496	reciprocating	1.31	34.8
GE	J624	reciprocating	4.40	46.5
GE	GE10-2	Turbine	11.98	33.3
Siemens	SGT-200	Turbine	6.75	31.0
Rolls-Royce	501-KB5S	Turbine	3.89	29.0

Figure 3: Gas fired simple cycle generators

An important benefit of simple cycle generation is that it can be started up within 15 minutes for the production of peak power.

Higher efficiency can be achieved by using a gas turbine in either a combined cycle or co-generation scenario. In a combined cycle plant, a gas fired turbine produces electricity in the first (simple cycle) stage. The high temperature exhaust gas is used, in a heat recovery boiler, to convert water into high pressure, super-heated steam which then expands and cools as it passes through a second stage steam turbine to create more electricity. The low pressure steam is subsequently cooled back into water, in a condenser, and is recycled back to the heat recovery boiler. A schematic of the combined cycle process is shown in Figure 4.

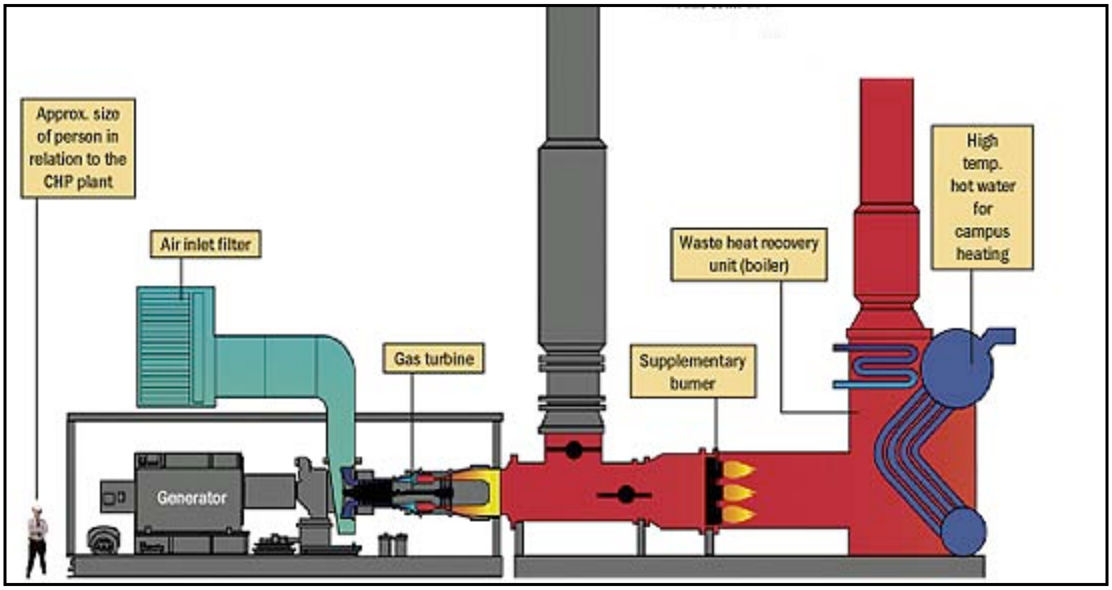


Source: www.power-technology.com

Figure 4: Gas fired combined cycle process

Economies of scale for the steam turbine process result in overall electrical efficiency of combined cycle plants ranging from 45% for small plants to 58% for large (i.e. 500 MW) plants. Due to the longer start-up time required for the steam plant, co-generation is better suited for continuous, as opposed to peak shaving, electrical supply.

Another option is co-generation in which the exhaust heat from the gas turbine is used to heat hot water instead of steam. The hot water is then distributed for building heat, typically in an industrial or high density office tower setting. The University of Calgary is in the process of installing a 12 MW co-gen facility to supply electricity and building heat to the entire campus. Their co-gen schematic is shown in Figure 5.



Source: University of Calgary
(http://www.ucalgary.ca/news/uofcpublications/oncampus/november2008/power)

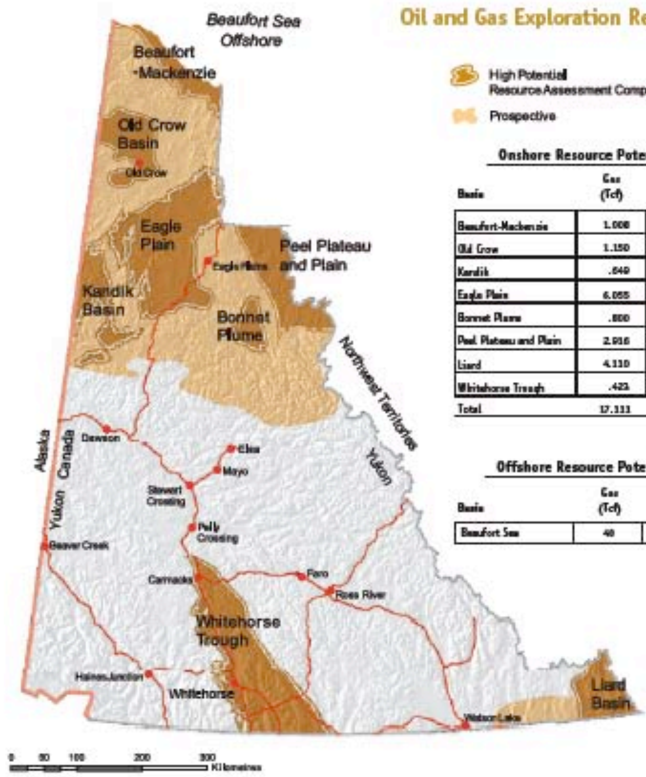
Figure 5: Co-generation process

In a co-generation process, 30% of the resultant energy is electricity and 40% is used for heating. The problem with this method is that the electrical efficiency drops slightly below the efficiency of a simple cycle generator. The total energy efficiency of this type of plant is usually greater than 70% depending on how much of the thermal energy is used. In summer, when the excess heat is not needed, the total efficiency will be lower but the electrical efficiency will be unchanged. A co-generation process may be applicable for site specific mining operations in the Yukon.

Natural Gas Sources

Figure 6 is the summary of number of resource studies conducted by the Yukon Geological Survey and the National Energy Board and shows the ultimate oil and gas resource potential of the sedimentary basins within the Yukon. The term "resource potential" refers to the total volumes of oil and gas that are inferred, from available geological and engineering data, to exist underground. Resource potential includes those volumes discovered to date plus those volumes that remain undiscovered. Three basins highlighted as potential sources for natural gas supply; Liard Basin, Eagle Plains and the Whitehorse Trough.

Oil and Gas Exploration Regions



Onshore Resource Potential

Basin	Gas (Tcf)	Oil (MMbbls)
Beaufort-Mackenzie	1.008	216.7
Old Crow	1.150	0
Kandik	.649	99.3
Eagle Plain	6.055	436.7
Bonnet Plume	.800	0
Peel Plateau and Plain	2.916	0
Liard	4.110	0.1
Whitehorse Trough	.423	19.2
Total	17.111	772.0

Offshore Resource Potential

Basin	Gas (Tcf)	Oil (MMbbls)
Beaufort Sea	40	4,500

Oil and Gas Resource Potential

Basin	Mean Gas Play Potential (Tcf)	Mean Oil Play Potential (MMbbls)	Discovered Resource Gas (Tcf)	Discovered Resource Oil (MMbbls)	Wells to date
Kandik	.649	99			3
Beaufort-Mackenzie	1.008	217			3
Bonnet Plume	.800	0			0
Eagle Plain *	6.054	436	.084	11	34
Liard *	4.110	0.1	.417		13
Old Crow	1.149	0			0
Peel Plateau and Plain	2.916	0			19
Whitehorse Trough	.423	19			0
Other					1
Total	17.111	771.1	.501	11	73

*discovered resource based on NEB resource assessment report

Source: Yukon Energy, Mines and Natural Resources

Figure 6: Yukon Oil and Gas Resources

The Liard Basin has the only natural gas production to date. Wells in the Kotaneelee field produced via the Spectra Pointed Mountain pipeline into British Columbia. The production rate has declined due to water production and the discovered gas resource is significantly depleted. A photo of the Kotaneelee gas plant is shown in Figure 7 and a photo of a typical wellhead is shown in Figure **8**.

Source: Yukon News

Figure 7: Kotaneelee Gas Plant

Source: Applied Petroleum Engineering Expertise

Figure 8: Kotaneelee Well Head

The Whitehorse Trough is estimated to have 0.423 Tcf (trillion cubic feet) of natural gas in place; close to the existing electrical infrastructure. There have been no wells drilled in this basin and the demand for natural gas would need to be significant for energy producing companies to risk exploration capital on seismic and drilling in an untested area.

With an estimated 6.054 Tcf of gas-in-place, Eagle Plains is regarded as the area most likely to be developed first for commercial production. To date, 34 exploratory wells have been drilled and significant gas productivity has been demonstrated in 5 wells (average 5 MMcf/d per well). The wells have the productivity needed (estimated at ~12 MMcf/d depending on load factor) to fuel all of the Yukon's electrical demand. It is quite conceivable that additional exploration drilling in the area would yield sufficient gas to maintain the needed supply for many years.

Gas Economics

To bring 10, 20 or 50 GWh of generation online, the sizing of an appropriate generator will be dependent on the utilization rate which, as shown in Figure **9**, has been estimated to be between 10% and 50%.

Yearly generation (GWh)	Yearly Utilization (%)	Generator size (MW)
10	90%	1.26
10	50%	2.28
10	25%	4.57
10	10%	11.42
20	90%	2.52
20	50%	4.57
20	25%	9.13
20	10%	22.83
50	90%	6.30
50	50%	11.42
50	25%	22.83
50	10%	57.08

Figure 9: Generator sizing

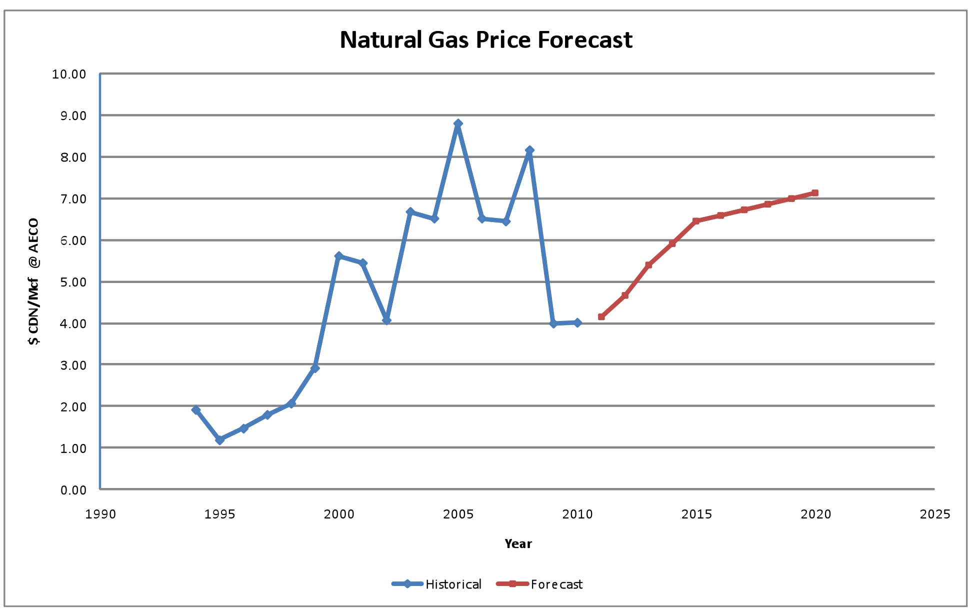
Natural gas is an economically attractive fuel source for electrical generation in North America both in terms of its high heat of combustion as well as the current situation of low gas prices in comparison to oil derivative fuels. Figure 10 illustrates the operating economics for both a simple cycle and a combined cycle scenario.

	Simple Cycle	Combined Cycle
Size (MW)	7	57
Hours per day	24	24
Energy output (KWh/d)	168,000	1,368,000
Conversion (MJ per KWh)	3.6	3.6
Energy output: MJ/d	604,800	4,924,800
Efficiency	35%	55%
Fuel Requirement (MJ/d)	1,728,000	8,954,182
Gas Heat Content (MJ/MMcf)	1,050,000	1,050,000
Gas Supply (MMcf/d)	1.65	8.53
Gas Price ($/Mcf)	7.75	7.75
Fuel Cost ($/KWh)	0.08	0.05

Figure 10: Fuel cost for natural gas fired co-generation

The 7 MW size in Figure 10 was selected as a representative size that may be considered for additional electricity in the Yukon. The 57 MW size is the largest unit calculated in Figure **9**.

A natural gas price of $7.75/Mcf was used in Figure 10 as being representative of forecasted natural gas prices in year 2015 as shown in Figure 11. Clearly the prices in Figure 11 reflect an interconnected market whereas the any supply from Eagle Plains would deliver into a closed marketplace within the Yukon. Notwithstanding, the price is estimated to be a reasonable cost of delivered gas. Inherent in the forecast is the prediction that natural gas prices will escalate at a rate above inflation until 2015, thereby narrowing the price gap between natural gas and oil.



Source: Fekete Associates Inc.

Figure 11: Natural Gas Price Forecast

To this point, the cost advantage of natural gas fired electrical generation has been assessed based on fuel price only. Construction costs have quoted by various sources to be between $1,000/KWh and $2,000/KWh.

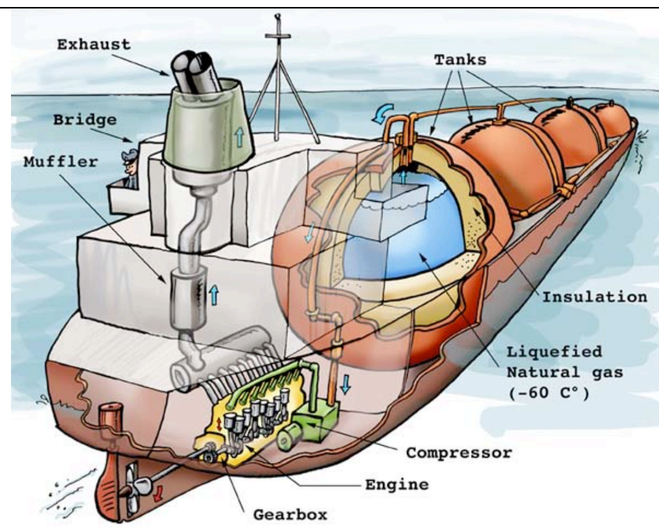
Further, the economics herein have assumed that an existing gas supply is proximal to the proposed electrical generation site. With no gas infrastructure in place in the Yukon, significant capital will be required to bring the gas to market. A pipeline route from Eagle Plains, along the Dempster Highway, to the closest point on the Yukon electrical grid at Glenboyle Stewart Crossing is a distance of 500 km. Scoping cost for a 12 inch line, capable of transporting 69 MMcf/d of gas, would be in the order of 864 MM$. While a 12 inch pipeline is larger than needed to deliver 12 MMcf/d (rate needed to fuel all of the Yukon's electrical demand), the major portion of pipelining costs is associated with route preparation and excavation whereas the cost of a smaller pipe reduces the total cost by only ~15%.

The pipeline costs assume a single line to Stewart Crossing where a one gas fired generator could be located to provide all of the additional electrical supply. Upgrading of the existing electrical system may be required to distribute the electricity however the costs of power lines to small load centres is lower than the cost of an extensive natural gas pipeline system. In summary, pipelining costs remain the major hurdle to commercial development of the Yukon's natural gas resources and no timeline is foreseeable.

LNG

Liquified natural gas ("LNG") provides an opportunity to utilize natural gas reserves, such as Eagle Plains, which are stranded without a pipeline. LNG consists of 90% or more methane with the remainder being small amounts of ethane, propane and butane. Natural gas is cooled in a cryogenic liquefaction plant and becomes liquid at a temperature of -162° C. In the process, the volume of natural gas shrinks by 630 times. The resultant super-cooled liquid can be transported in trucks or ocean tankers that have thermos-style insulation as shown in Figure 12.

LNG Truck (56 m3)



LNG Tanker (135,000 m3)

Figure 12: LNG Truck and Tanker

LNG plants benefit from economics of scale and most projects are very large, up to 15 MTPA (million tonnes per annum). The closest LNG terminal is at Kenai, Alaska however on February 10, 2001, the plant's owners, ConocoPhillips and Marathon Oil, announced that the 1.5 MTPA plant would be mothballed as they were unable to renew new contracts with customers in Japan.

The remaining option would then be to construct a micro-LNG plant at Eagle Plains. Based on the gas supply estimates in Figure 10, a micro-LNG plant of 11 to 61 KTPA would be required. Between 2 and 7 trucks per day would transport the LNG to demand centres. Micro-LNG is a developing technology with a few plants installed worldwide. One example is the 18 KTPA plant constructed by BOC in Tasmania. A photo of a micro-LNG plant is shown in Figure 13.

Source: Kryopak

Figure 13: Micro-LNG Plant

At the demand centres, the LNG needs to be stored in insulated tanks and then re-gassified before being burned in the generator engines. Re-gassification is achieved by warming the gas to -5° C in a heat exchanger which requires a steady supply of ambient temperature water to provide heat.

Reliable cost estimates for a micro-LNG are not easily available. The quoted cost for the BOC plant was 150 MM$ AUS however that included 6 distribution centres.

Regulatory Issues

Any natural gas pipeline with the Yukon can be expected to undergo the same regulatory and environmental process that was experienced by the MVP. From conception to completion, a pipeline project schedule is estimated to be between 5 and 7 years.

Extraterritorial Gas Sources

Three possible gas pipeline scenarios are contemplated. The first would be a gas pipeline from the Spectra Pipeline interconnection at Pointed Mountain to Teslin, a distance of approximately 650 km. The economics would be similarly unattractive as a pipeline from Eagle Plains. The recent federal government approval of the McKenzie Valley Pipeline brings that project one step closer to actuality however, given the low gas price, the Producers Group has made no pronouncements as to a construction schedule. Whenever the MVP proceeds, the potential exists for further exploration and development at Eagle Plains, sufficient to fill a pipeline that would interconnect with MVP at Inuvik or Little Chicago. The Yukon would realize economic development but there are no identified synergies to bring gas south for electrical generation. The Alaska Highway Pipeline Project provides the best opportunity for natural gas off-take at various points along the pipeline's route through the Yukon. While there is no timeline for the AHPP, it would ultimately deliver an ample supply of gas at market prices, resulting in very competitive electrical generation costs.

Emissions

Natural gas generates the lowest emissions of any fossil fuel source as shown in Figure 14.
(Note 1 billion BTU= 1MMcf of gas).

Fossil Fuel Emission Levels
- Pounds per Billion Btu of Energy Input

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: EIA - Natural Gas Issues and Trends 1998

Figure 14: Fossil fuel emissions