Whitehorse
Diesel LNG Conversion Project

Prepared For: Canadian Consulting Engineers Awards 2016

Submitted By:

Allnorth
1200 – 1100 Melville Street
Vancouver, BC V6E 4A6
Canada
Phone: 604-602-1175

Allnorth Contact: John Murray, P. Eng

Date: 19 April 2016

YUKON ENERGY

KGS GROUP CONSULTING ENGINEERS

Allnorth

CAP

TABLE OF CONTENTS

1 PROJECT OUTLINE

Yukon's hydro-based electrical system is isolated from North America's grid. Delivering a continuous source of electricity is challenged by spikes in demand from weather, transmission and hydro generation failures. Yukon Energy Corporation's aging diesel backup generators are increasingly a reliability risk. YEC with FN support, along with a $21 million investment from the Kwanlin Dun Band, constructed an innovative 8.8MW LNG fueled power generating station, improving reliability, reducing both power costs and environmental impacts.

2 BACKGROUND

In 2012, 99% of the Yukon's electrical grid drew power from 93 MW of renewable hydroelectric and wind power. YEC could supplement this capacity with an additional 42 MW of backup diesel capacity from the utilities aging thermal generating equipment. Backup capacity is required on the grid for three reasons:

1. Replacement power in the event of a transmission or generation failure.
2. Meeting peak winter demands when the grid peak exceeds the renewable generation capacity.
3. Supplying energy to the grid during drought years when there is insufficient hydroelectric energy available.

The flexibility and reliability of thermal generation makes it the preferred solution for the Yukon's requirement of backup power. Prior to embarking on this project, YEC's backup diesel capacity equipment ranged from 20 to 45 years old – with all diesel units effectively reaching the end of their useful service lives within the next 15 years.

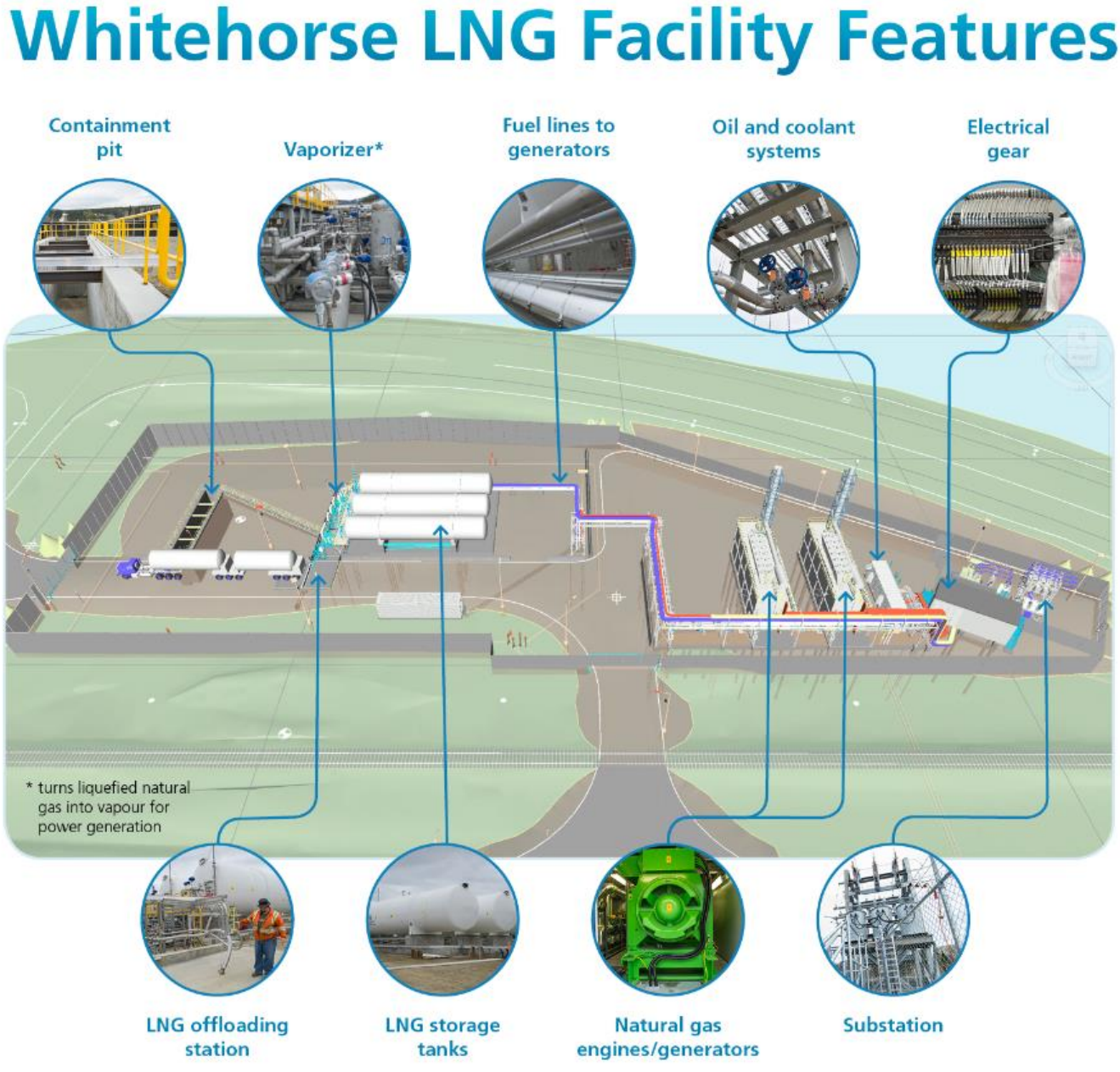
Viable thermal generation options include diesel and liquefied natural gas (LNG) as the energy source. The capital costs associated with both diesel and LNG systems were considered along with the estimated annual fuel savings that LNG would offer compared to diesel, with $1-2 million per year starting in 2015 and growing by $3-4 million by 2018. Technical, safety and environmental aspects were all thoroughly considered alongside cost. With the LNG option also offering the distinct advantage over diesel of lower greenhouse gas emissions, YEC worked to develop a project that would replace existing aging diesel backup generation capacity with new capacity generated from LNG.

3 DESCRIPTION

The Project consisted of the construction of a new natural gas-fired thermal generating station and associated infrastructure adjacent to Yukon Energy's existing primary power generating station, the Whitehorse Rapids Hydroelectric Dam & Thermal Generating Station. The Expanded Site Area as commissioned in 2015 includes two reciprocating generators for a total of 8.8 MW capacity. Infrastructure and physical space have been allocated to allow installation of a third generator that will bring the total capacity up to 13.2 MW. This brings an additional 4.1 MW to the Yukon electrical grid upon the decommissioning of the two diesel generators (9.1 MW capacity) that were at the end of their normal service lives. The Expanded Site Area also includes truck offloading, LNG storage and vaporization facilities as well as an electrical substation to support the future generation needs.

4 MAJOR COMPONENTS

Natural Gas Generating Units and Related Infrastructure – Includes three new 4.4 MW natural gas-fired modular reciprocating generating units and related facilities. Two of the units are in service, as of 2015, and one additional unit will be installed within a few years. The related infrastructure includes a fluid (oil/glycol) transfer station, a small electrical substation to receive power from the generating units, and a switchgear module.



- LNG Storage and Vaporization – The LNG storage station includes three horizontal single containment vacuum jacketed bullet tanks and foundations. These tanks have a stainless steel inner tank and carbon steel outer tank and are considered the primary containment system.
- Vapour Fence – A new 12 foot high fence was design based on vapor dispersion modeling to allow LNG vapor to be contained within the fenced area in the event of a release.
- Related Infrastructure – Construction of related infrastructure between YEC's main power station and the expanded site area included electrical services for streetlights and security systems as well as a utility trench and piping network for natural gas, fire suppression water, glycol/water heating system and hydrants. Other infrastructure included a distribution line and communication line to bring power from the new substation to the existing substation and out to the grid. Roads, security gates and electrical grounding grid were also required.

- Impoundment Pit and Trenching – Heavily reinforced concrete trenching that directs any spill from the storage, vaporization or offloading areas towards the impoundment pit. The impoundment pit itself is heavily reinforced to enable it to withstand the extreme low temperatures that would be associated with direct sustained contact with LNG.

5 INNOVATION

- LNG had not previously been stored, nor had natural gas been used as a fuel for electrical power generation, in a greenfield facility of this scale in Yukon.
- This was a ground-breaking project for oil and gas regulators in Yukon contributing to new natural gas and LNG related standards for fuel storage and LNG power generation.
- YEC assembled a comprehensive inclusive team including project managers (Allnorth and CAP) and design consultants (KGS) and the YEC in-house engineering team to engage in design and construction phases.
- The site is adjacent to one of the major road accesses to the City of Whitehorse and in the vicinity of the YEC headquarters demanded extraordinary vapour dispersion computer modeling effort, used as the design basis for spill containment and vapour walls design.
- Granular subsoil and high water table conditions were a challenge for all foundations. Foundations also had to account impacts of a cryogenic LNG spill. Rock socketed piles were utilized for engine, tank and transformer foundations. Aggressive dewatering was required for the LNG spill containment structure.
- The project footprint was very limited. Through the use of 3D modeling and intense project management the geotechnical, environmental, civil, structural, mechanical, electrical and instrumentation, and GIS team

worked together in a coordinated manner to complete designs and coordinate work on site. Up to eight contractors and suppliers were active on project at the peak of construction.

- Small adjustments in design which impacted component locations required major redesigns due to the constrained site area. The use of the 3D modeling facilitated the redesign work.
- Supply chain development was done in partnership with mining companies and Alaska Power and Telephone to share LNG knowledge and optimize economies of scale.
- Equipment for the power station was procured from the global marketplace with LNG storage tanks

fabricated in China, generators from Germany and the UK, LNG offload and reload equipment from the US, with most large loads delivered to the Port of Skagway in Alaska and transported over the Coast Mountains to Whitehorse. Scheduling of deliveries, timed to fit with on-site construction progress, was critical.

- Power generation modules used were GE's state of the art GEJ 624 Series, representing the cutting edge of LNG power generation efficiency. Efficiency testing during operations have surpassed expectations.
- The experience gained in delivering this LNG power generating project has advanced the subject matter knowledge within the Yukon Government and within YEC which will have great value in permitting and delivering future greenfield LNG generation units or in natural gas conversions of existing diesel generators.

6 COMPLEXITY

- This greenfield stand-alone LNG fueled power station was a first for the Yukon and was the subject of public concern, close scrutiny from government regulators and the Oil and Gas Branch of the Yukon Government. Small LNG facilities are regulated under CSA Z276 and as this project progressed, several new items were encountered which required Constructions Standards Association(CSA) input. This project helped shape the small LNG facility guidelines for Canada.

- Structural designs accommodated the stresses and strains imposed by potential cryogenic LNG spills.
- Generators, tanks and transformers were supported on rock socketed piles, a requirement to design for seismic conditions.
- Challenging dewatering of the granular materials was required to construct the deep well LNG spill containment structure.
- The project was executed using 3D modeling to ensure equipment items fit as well and as a tool to coordinate efficient delivery through both design and construction phases.
- LNG vapour dispersion modeling on this project was extensively used to refine the design
- The client's intention was to deliver the project maximizing Yukon and First Nation resources which created a challenging construction environment with multiple contractors and suppliers working on a congested site.
- Knowledge and application of Arctic construction techniques were required through construction
- The project design had to balance the needs of the Oil and Gas Branch, YEC, the City of Whitehorse, and the historic White Pass Railway all while achieving full compliance with all design codes within the spatial constraints of an extremely small site.

7 SOCIAL AND ECONOMIC BENEFITS

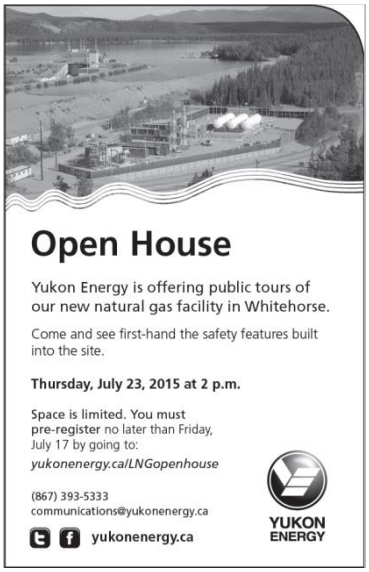
The project has had a positive effect on the quality of life in Yukon:

- The project was located in the Traditional Territories of the Kwanlin Dun First Nation and the Ta'an Kwach'an Council and successfully met land claim obligations and provided First Nations contracting, employment and investment opportunities, including a $21 million investment in the LNG project by the Kwanlin Dun First Nation.
- Local Yukon companies and First Nation companies were preferentially selected for construction where qualified.

Signing of the Kwanlin Dun First Nation's $21 million investment in the Yukon LNG project

Left to Right: Premier Darrell Pasloski, Chief Doris Bill and Minister Responsible for the Yukon Development Corporation Brad Cathers.

- Long term local jobs will be maintained due to requirements for ongoing LNG facility operation and maintenance.
- Annual fuel savings of LNG over an equivalent diesel facility are estimated at $1.3 million per year post commissioning, growing to $3 to $4 million by 2018.
- Reduced occurrence of electrical outages through a more reliable system. Over time load growth on the Yukon grid is depleting surplus hydro availability requiring additional peak period power on demand. During a cold Yukon winter electricity is a necessity for most residents.
- Potential for additional local training and employment as LNG use is adopted as a fuel source throughout the Yukon.
- Positions the Yukon as an innovator in the use of LNG fuel and conversion projects – local knowledge and expertise can be leveraged to other future adopters across Canada.
- The Yukon will be seen as a leader in environmentally progressive energy generation reinforcing positive perceptions to the benefit of the tourism industry.
- A significant YEC public relations effort related to the use of LNG as a fuel source on this project resulted in a broader public understanding of the benefits of LNG as a cleaner fuel than diesel.



8 ENVIRONMENTAL BENEFITS

- The LNG fueled generators are replacing aging diesel generators with associated reductions in emissions. Reported reductions in pollutants when changing from diesel to LNG include greenhouse gas reduction of between 11% and 20%, NOx emissions reduced up to 80% and particulate emissions reduction of up to 75%.
- Due to the choice of location and the design implemented at this location, there are no significant adverse effects on the biophysical environment. The site was previously disturbed.
- The new generators are quieter and more reliable than the aging diesel generators.
- The potentially hazardous environmental consequences of an LNG spill were mitigated through the use of LNG vapor dispersion modeling as the basis for selecting size and location of the spill containment structure and the placement of vapor walls around the site. The environmental impact of a LNG spill if managed appropriately is considered to have less impact than a similar sized diesel spill.
- The new LNG fueled power station gives YEC the option of generating power using LNG while storing water in its reservoirs for hydro power generation for times of extreme cold, disasters or drought conditions which have the potential to create a negative ecological impact if water is not maintained at or above prescribed minimum levels.
- Yukon's isolated electrical grid has no access to external North American power grids to secure extra power when it is needed, or to sell surplus power when it is available. This project provides reliable and flexible clean thermal generation to the Yukon grid.

9 MEETING THE CLIENT'S NEEDS

- Economic Solution - When assessing replacement options for aging diesel generators YEC selected LNG fueled generators on the basis of life cycle costing, long term savings for rate payers and environmental benefits.
- Project Costs - The project design, project management and construction management amounted to 11% of the final project cost.
- Schedule - The project was delivered on schedule with commissioning completed in July, 2015.
- Project Management– Allnorth provided rigorous project management from project inception to closeout. Their management of multiple regulatory bodies, authorities having jurisdiction, client stakeholders, designers, vendors and contractors was the essential control that held the project together. CAP worked closely with Allnorth as on-site Construction Managers.
- Quality Management – Quality management was critical on this project at the design phase, in all procurement activities, in the contractor selection and through into the construction and commissioning phases. This was rigorously applied through the cooperative efforts of CAP and KGS under the direction of Allnorth and YEC to manage impact on schedule and cost on this complex project.
- Risk Management – HAZID, FMEA and HAZOP processes were implemented early then monitored throughout the course of the project. Client Overall Requirements – YEC's mandate requires four priorities when it comes to electricity, it has to be flexible, affordable, reliable and environmentally responsible (F.A.R.E). This project successfully meets all four of these objectives.

10 PROJECT TEAM

Client / Engineering Resources: Yukon Energy Corp.

Project Management: Allnorth Consultants Limited

Balance of Plant Engineering: KGS Group

Construction Site Management: CAP Management Services