LNG Feasibility for Alaska Affordable Energy Strategy Communities

Final Report

Prepared for

Alaska Energy Authority

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Prepared by

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Abbreviations

ACEP	Alaska Center for Energy and Power
AEA	Alaska Energy Authority
AFDC	Alternate Fuels Data Center
AHFC	Alaska Housing Finance Corporation
AIDEA	Alaska Industrial Development and Export Authority
AkAES	Alaska Affordable Energy Strategy
BCA	Benefit-cost Analysis
BCR	Benefit-cost Ratio
BEES	Alaska Building Energy Efficiency Standard
CAPEX	Capital Expense
CCHRC	Cold Climate Housing Research Center
FNG	Fairbanks Natural Gas
FOB	Freight on Board
GINA	Geographic Information Network of Alaska
IEP	Interior Energy Plan
IGU	Interior Gas Utility
ISER	Institute of Social and Economic Research
LNG	Liquefied Natural Gas
MMBtu	Million British thermal units
NEI	Northern Economics Inc.
NPV	Net Present Value
O&M	Operations and Maintenance
OPEX	Operating Expense
PURPA	Public Utility Regulatory Policies Act of 1978
WW	Water and wastewater

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Executive Summary

The potential for liquefied natural gas (LNG) to prove a cost saving solution to non-Railbelt Alaska's energy needs has induced a diversity of entities—including the State of Alaska, local and regional utilities, and fuel distribution companies—to investigate its economic and logistical feasibility. The prospective construction of the Alaska LNG Project, in particular, has galvanized public and private interest in assessing what savings, if any, LNG may hold for the thousands of Alaskans burdened by high electricity and/or heating costs.

Under a contract with the Alaska Energy Authority (AEA), and in accordance with the mandate of the Alaska Affordable Energy Strategy (AkAES) program, Northern Economics, Inc. (NEI) conducted an extensive, reconnaissance-level qualitative and quantitative assessment of the logistical, regulatory, and economic feasibility of LNG for areas of the state that will lack direct access to the proposed North Slope natural gas pipeline (hereafter "non-Railbelt communities"; The Alaska State Legislature 2014). Quantitative analyses were performed for all ice-free non-Railbelt communities for which all necessary cost and energy demand inputs were available, as well as two ice-bound communities, Bethel and Akiachak. NEI's analyses revealed the following:

- Notwithstanding the substantial interest in LNG that persists among utilities and fuel distribution companies, the study team failed to identify any AkAES study area communities or energy applications for which LNG would prove economically feasible for either electrical generation or space heating (including hot water and the use of some appliances) alone.
- Put differently, the study team estimates that the costs associated with LNG adoption for electrical generation or space heating would exceed the fuel cost savings for all communities.
- However, the quantitative analyses did not conclusively demonstrate universal infeasibility of LNG for non-Railbelt Alaska: analysis results suggested that LNG could prove economically feasible for three communities if used for electrical generation, space heating, and water/wastewater treatment (WW), the three sources of energy demand considered in this analysis.
- Significant logistical and technical hurdles exist with respect to LNG's suitability for smaller, rural communities.
- LNG presents unique challenges to ice-bound communities, as the fuel's maximum holding (storage) time of 30–110 days precludes these communities' exclusive use of LNG for heating or generation. This translates to higher reliance on diesel (and/or other existing fuels) by these communities relative to ice-free communities and, consequently, reduced fuel cost savings (assuming the delivered price of LNG is lower than the delivered price of diesel), with no reduction in LNG system capital costs.

Based on results of the quantitative analyses, this study does not recommend that the State of Alaska commit resources at this time to the exploration or implementation of programs or policies designed to encourage the adoption of LNG by AkAES communities. It is important to emphasize, however, that this is a reconnaissance-level study: potentially large margins of error associated with multiple cost assumptions that underpin the quantitative analyses—and preponderant conclusion of economic infeasibility—are implied in any such analysis. The study team cautions that the results of the combined energy demand analyses, in particular, should be considered in the context of the potentially sizeable variance of cost input estimates, as well as favorable cost assumptions specific to the assessment of benefits and costs for WW.

More broadly, the community- and region-specific cost and demands assessments conducted by the public and private sector entities referenced above, combined with refined energy demand projections generated by the Geographic Information Network of Alaska and AEA, could yield more precise—and, perhaps, more positive—economic feasibility results. The study team suggests that such a pooling of knowledge represents a logical next step in the exploration of the economic feasibility of LNG for non-Railbelt Alaska.

Logistical Feasibility

As noted above, NEI's feasibility analysis consisted of both a quantitative and qualitative component, with the latter consisting primarily of a series of key informant interviews with public and private sector organizations familiar with the opportunities and challenges of LNG adoption by AkAES communities. The following represents a top-level summary of the interviews:

- Several companies are actively investigating opportunities to expand the distribution of natural gas to portions of Alaska where the fuel currently is not available.
- LNG holds particular appeal to some communities because it burns more cleanly than diesel.
- Economic feasibility of LNG adoption in new areas of the state likely is contingent on the presence of a substantial and stable source of demand. This "anchor" demand could be for electrical generation, industrial use, or heating.
- Compared to diesel fuel, which is used extensively in non-Railbelt Alaska for both electrical generation and heating, LNG is more complex, requiring special processing, handling, training, and advanced safety protocols. LNG also requires higher levels of capital than diesel for processing and storage, as well as transportation and distribution.

Economic Feasibility

The study team assessed economic feasibility through the estimation of benefit-cost ratios (BCRs) for AkAES communities for three energy demand scenarios:

1. Electrical generation demand only;
2. Heating demand only;
3. Combined energy demand for electrical generation, heating, and water/wastewater plant operations

BCRs were calculated as the ratio of the net present value (NPV) of the estimated value of displaced base fuel and the NPV of estimated total alternative (LNG system) costs, including capital, operating, transportation, and LNG costs. NPV is the value in current dollars of future incoming (in this case, fuel cost savings [benefits]) and outgoing (costs) cash flows.

The benefit-cost analyses and further analysis yielded the following results:

- LNG is not an economically feasible substitute for existing fuels for any study area community for electrical generation or space heating alone. No community- and application-specific analysis yielded a benefit-cost ratio (BCR) higher than 1.0; however, two communities in the electrical generation analysis and five communities in the heating analysis were estimated to have BCRs greater than 0.8. A BCR of 1.0 indicates equivalency of benefits and costs; a BCR less than 1.0 indicates that costs exceed benefits. For all electricity- and heating-specific analyses, the study team estimates that LNG project costs would exceed benefits.

- Communities with larger populations tend to have higher BCRs and lower per-resident capital costs.
- A community's distance from its anticipated LNG source is not a strong predictor of economic feasibility in the electrical generation analysis, but it is negatively correlated with the BCR in the heating analysis.
- The method of LNG delivery (truck or barge) is not a strong predictor of the BCR in the electrical generation analysis, but it is negatively correlated with the BCR in the heating analysis.
- A community's LNG source (Nikiski or British Columbia [B.C.]) is not a strong predictor of its BCR for either electrical generation or heating.
- BCRs in both the electrical generation and heating analyses tend to increase as LNG costs constitute a greater share of total costs.
- LNG Freight on Board prices from the two assumed sources, Nikiski ($10.99/MMBtu; ADOR 2016, FNG 2013) and Vancouver ($6.89/MMBtu; Fortis 2015) are substantially lower than delivered diesel prices paid by AkAES communities on a per energy unit basis. However, capital, operating, and transportation costs bump up delivered LNG prices considerably.

Section 5 examines the relationship between cost components and BCRs, as well as the relationship between community population and capital costs, while Appendix A provides supplemental statistical analysis of the primary drivers of BCRs.

Summary of Quantitative Results

Table ES-1 identifies the top six communities—as ranked by BCR—for each of the three energy demand scenario analyses. The values in the far right column indicate the calculated weighted average price of diesel (expressed in constant 2016 dollars) from 2017–2036 that would yield economic feasibility, i.e. a BCR of 1.0. For the electrical generation and heating summaries, each of these calculated weighted average prices is higher than the actual forecasted weighted average price for the respective community.

The electrical generation demand-only and heating demand-only scenarios yielded maximum BCRs of 0.92 and 0.96, respectively, while the combined energy demand of all three LNG uses yielded a top BCR of 1.13 (Tok). Notably, the communities with the highest BCRs for each of the three scenarios possess highly variable attributes in terms of geography, level of energy demand, method of fuel transportation, and regional source of LNG (B.C. or Cook Inlet).

Table ES-1. Highest BCR Communities for the Three Energy Demand Scenario Analyses

Community	BCR	NPV Total Costs (1,000 $2016)	NPV Benefits (1,000 $2016)	Break Even Diesel Price ($2016/Gallon)
Electrical Generation Only				
Yakutat	0.92	13,261	12,235	4.68
Tok	0.85	10,591	8,955	4.77
Cordova	0.71	11,310	8,022	5.60
Bethel	0.63	67,931	42,949	8.78
Kake	0.61	3,805	2,329	6.40
Cold Bay	0.58	6,328	3,642	10.38
Heating Only				
Tok	0.96	60,921	58,382	4.25
Juneau	0.93	1,016,175	940,673	5.37
Naukati Bay	0.86	5,468	4,677	7.68
Kake	0.83	17,321	14,424	7.54
Haines	0.80	75,775	60,895	4.81
Kodiak	0.78	161,027	125,321	7.00
Combined Electrical Generation, Heating, and Water/Wastewater Treatment				
Tok	1.13	60,041	68,023	3.59
Kake	1.07	15,696	16,798	5.40
Yakutat	1.01	30,743	31,063	4.64
Bethel	0.94	202,227	190,025	5.82
Adak	0.85	10,869	9,211	7.94
Cordova	0.82	78,671	64,310	4.67

Source: Northern Economics analysis of data provided by the Alaska Energy Authority, the Alaska Department of Revenue (2016), Fairbanks Natural Gas (2012), Michael Baker International (2016), and other sources.

1 Introduction

Passed by the Alaska Legislature in 2014, Senate Bill 138 (SB 138) enabled legislation for an Alaska Liquefied Natural Gas Pipeline project and included a mandate for the Alaska Energy Authority (AEA) to propose a plan and supporting legislation to improve energy affordability for Alaska communities that will not have direct access to the proposed North Slope natural gas pipeline. As a component of the Alaska Affordable Energy Strategy (AkAES), AEA's program to fulfill this mandate, AEA issued a Request for Proposal soliciting assistance in determining if liquefied natural gas (LNG) can prove a viable, long-term energy cost reduction solution for AkAES communities.

This report presents findings that address the issue of the economic feasibility of LNG for electrical generation, heating, and water/wastewater treatment in AkAES communities. Northern Economics, Inc. (NEI) conducted the feasibility analysis based on cost and energy demand inputs provided by team partners. NEI also conducted a series of key informant interviews that provided important insights regarding the logistical, regulatory, and economic challenges associated with the implementation of LNG systems. A summary of these interviews is included with this report as Appendix B.

1.1 Study Team

NEI teamed with engineering firm Michael Baker International (Baker) to meet project objectives related to the assessment of potential LNG use for electrical generation, heating, and water/wastewater treatment in rural Alaska. In addition, the project team collaborated with Geographic Information Network of Alaska (GINA) staff, who programmed a comprehensive energy demand model for AkAES communities that AEA staff developed. AEA also assisted with analysis of key assumptions and provision of input, data, and assumptions from other AEA projects related to the same objectives and geographic scope.

1.2 Work Approach

AEA designed a five-phase process for assessing various energy affordability options considered through the AkAES:

Phase 1: Collect baseline data.

Phase 1 consisted of three main components:

1. Estimation of current energy demand by AkAES community. AEA relied on various data sources to establish energy demand baselines for AkAES communities.
2. Estimation of LNG infrastructure costs and challenges of its use. Baker developed cost estimates related to multiple components of the LNG chain, including transportation, storage, regasification, dual fuel conversion, and piped distribution for heating. Baker also identified key logistical and engineering requirements associated with LNG use—as well as implications of LNG's unique physical properties—for electrical generation and heating.
3. Identification of barriers to LNG delivery and use. NEI conducted 11 key informant interviews with utilities, fuel distribution companies, and the Regulatory Commission of Alaska to understand more fully the challenges specific to the delivery and use of LNG in AkAES communities.

Phase 2: Develop 20-year energy demand and fuel price forecasts.

Phase 2 consisted of two components:

1. Development of energy demand forecasts. GINA and AEA applied AEA forecasting assumptions to baseline demand data to develop energy demand projections by use.
2. NEI forecasted prices for LNG and biomass based on published price data from the Alaska Department of Revenue and industry sources, as well as AEA modeling assumptions. NEI obtained forecasted diesel fuel prices from AEA; these prices include input from the Alaska Center for Energy and Power and the U.S. Energy Information Administration.

Phase 3: Assess the economic feasibility of LNG for individual communities and applications.

NEI relied on output from Phase 1 and Phase 2—specifically, energy demand projections and fuel price forecasts—to conduct economic feasibility analyses for AkAES communities for three LNG demand scenarios: LNG use for electrical generation only, LNG use for heating only, and LNG use for electrical generation, heating, and water/wastewater treatment. NEI employed benefit-cost analysis (BCA) to assess economic feasibility. NEI further examined the key drivers of costs and benefit-cost ratios (BCRs) and explored the relative influence of population size, method of LNG delivery, and other factors related to estimated economic feasibility.

Phase 4: Identify logical next steps in the analysis of LNG as an energy cost reduction solution.

Based on the results from Phase 3, NEI proposed additional opportunities for exploration of the economic feasibility of LNG for AkAES communities.

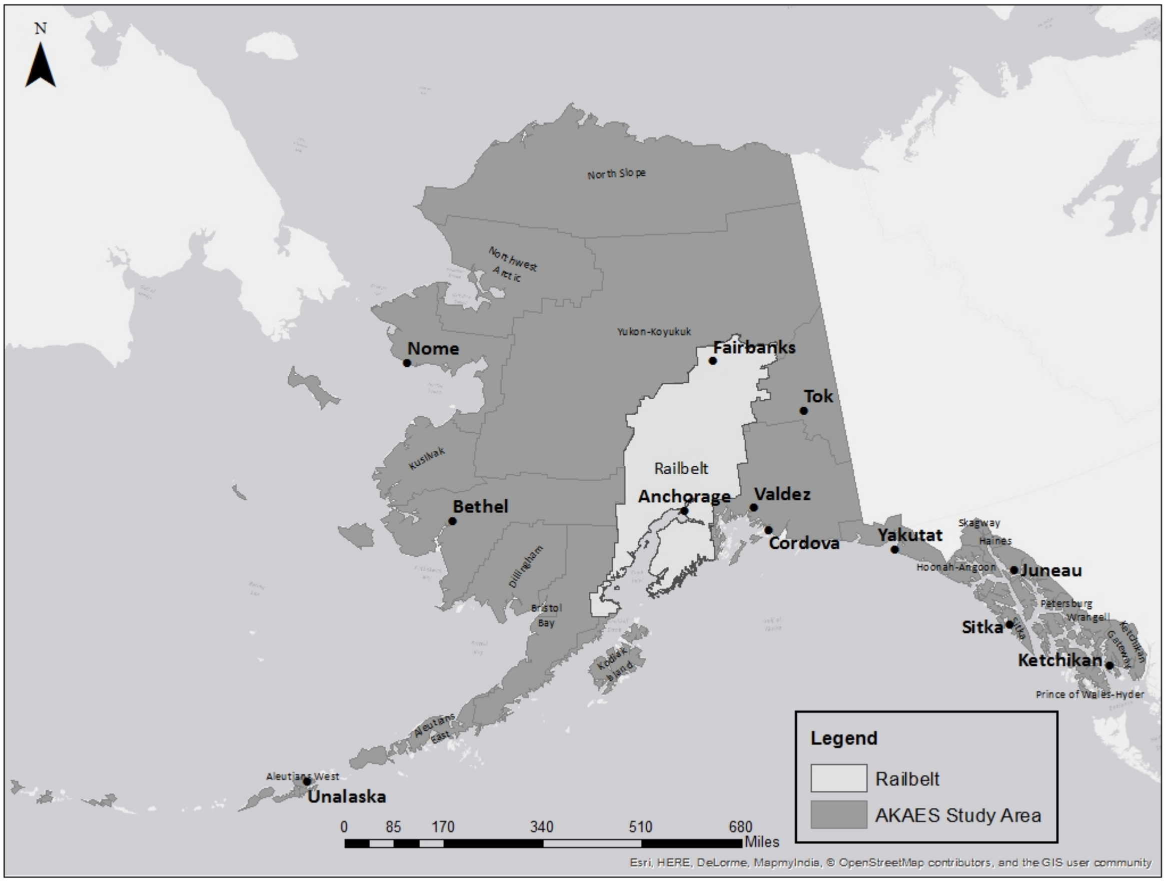
Phase 5: Prioritize Policy Options.

This final step, reserved for AEA, provides results and analysis of the first four project phases, with AEA's review and final acceptance of those options that most closely meet program objectives.

1.3 Project Geographic Scope

Non-Railbelt Alaska comprises the hundreds of communities for which the study team assessed the economic feasibility of LNG use. Figure 1 is a map of Alaska showing the geographic boundaries of the Railbelt and the vastness of the AkAES study area.

Figure 1. Railbelt Alaska and AkAES Study Area



Source: Developed by Northern Economics based on an AEA (2016) map of Alaska Affordable Energy Strategy communities and regions.

1.4 Report Layout

Section 1. This is an introductory section that provides report scope, objectives, and approach.

Section 2. This section summarizes of findings from key informant interviews conducted by the study team with utilities, fuel distribution companies, and State of Alaska agencies regarding barriers and opportunities presented by LNG use for non-Railbelt Alaska.

Section 3. Section 3 presents energy demand projections by AkAES region and fuel price forecasts for communities for which the study team conducted economic feasibility analyses.

Section 4. This section identifies feasibility analysis goals and framework, as well as key assumptions and methodologies. Section 4 also presents results of the feasibility analyses by community for the three energy use scenarios.

Section 5. Section 5 considers the feasibility analysis results in greater depth, with focus devoted to the relative influence of various factors on economic feasibility of LNG for electrical generation and heating across the AkAES community sample.

Section 6. This section suggests opportunities for further analysis of the feasibility of LNG for non-Railbelt Alaska and identifies important study limitations.

Appendix A. Supplemental analysis of economic feasibility modeling results

Appendix B. Summary of key informant interviews

Appendix C. Baker report

2 Phase 1 – Key Informant Interviews, LNG Costs and Challenges

Baker began its work by compiling cost estimates of various parts of the LNG chain. These were used as major components of the BCAs detailed in Section 4 of this report. Baker further identified logistical and engineering characteristics of LNG that represent challenges to AkAES communities when compared to fuels that are currently in use.

Meanwhile, NEI complemented Baker's efforts by conducting interviews with representatives of utilities and fuel distribution companies with operations in Alaska to understand more deeply the key barriers to LNG adoption among communities that lack access to the fuel. Per AkAES program objectives, the study team particularly attempted to discern those factors with the strongest bearing on whether LNG adoption would prove realistic and pragmatic for AkAES communities.

Several electric utilities operating outside Southcentral Alaska have devoted considerable energy to investigating the economic, logistical, and other implications of LNG use for many years; their understanding of the specific applicability of LNG to their operations offered important insights regarding the challenges, constraints, and opportunities presented by the fuel for Alaskan communities.

The following represent key takeaways from the interviews; the complete summary is included as Appendix B. Baker's report is included as Appendix C.

Big Picture

- Several companies are actively investigating opportunities to expand the distribution of natural gas to Interior Alaska and portions of the state where the fuel currently is not available. In addition to potentially lowering energy costs, LNG burns more cleanly than diesel.
- Most interviewees agree that economic feasibility of LNG adoption in new areas of the state is contingent on the presence of a substantial and stable source of demand. This "anchor" demand could be for electrical generation, industrial use, or heating.
- Compared to diesel fuel, which is used extensively in non-Railbelt Alaska for both power generation and heating, LNG is more complex, requiring special processing, handling, training, and more advanced safety procedures. It also requires more capital for processing and storage facilities, as well as transportation and distribution.
- LNG presents unique challenges to ice-bound communities, as the fuel's maximum holding (storage) time of 30–110 days precludes these communities' exclusive use of LNG for heating or generation. This translates to relatively higher reliance on diesel (and/or other existing fuels) by these communities and, consequently, reduced fuel cost savings (assuming the delivered price of LNG is lower than the delivered price of diesel), with no reduction in LNG system capital costs.

Distribution/Implementation Models

- LNG is more likely to prove more economically feasible for ice-free communities than for those that are ice-bound. This distinction is specific to communities to which LNG would be transported via barge. Economic feasibility of LNG for ice-bound communities would depend on multiple factors, including total energy demand, seasonality of demand, average annual number of ice-bound days, and other infrastructure, equipment, and conversion costs.
- ISO containers represent the ideal mode for LNG delivery and storage for most AkAES communities. ISO containers are large standardized shipping containers that are designed for

intermodal transport of a wide variety of freight. Typically 20 feet or 40 feet in length, LNG ISO containers are specially designed (with insulation, boil-off valves, and other features) for the fuel's transport and storage. Figure 2 shows three 20-foot, non-wheeled, stacked ISO tanks at the Port of Anchorage.

Figure 2. Three Stacked ISO Tanks, Port of Anchorage

Source: Northern Economics

- Moving these types of ISO tanks requires a large front-end loader or crane; smaller communities are less likely to receive enough cargo to justify the purchase of this type of equipment. Baker's report (Appendix C) analyzes larger, wheeled ISO tanks, with tractors as prime movers. Figure 3 is an image of these larger, 40-foot ISO tanks. ISO tank ownership may reside with the LNG producer, a third-party logistics/transportation company, or the utility that represents the end user.

Figure 3. Forty-Foot LNG ISO Tank

Source: www.lngworldnews.com

- A qualifying facility may be the best way to demonstrate proof of concept of LNG's feasibility in communities or regions where it currently lacks a presence.[1] Some of the capital cost of a qualifying facility could be passed along to customers through a cost of power adjustment.
- Numerous potential LNG sources exist, including Cook Inlet; Fortis, British Columbia (B.C.); Prince Rupert, B.C.; Alaska's North Slope; and Whitehorse (from Yukon Energy Corp.). It is conceivable that communities in different regions could source LNG from different locations.

Transportation

- LNG trucking is often outsourced to a third-party transport company, as long as sufficient demand exists to justify the outsourcing. Specialized trailers exist for the transport of LNG, with maximum capacity commonly between 9,000 and 9,500 gallons.

[1] Qualifying facilities are generating facilities—either small power production facilities or cogeneration facilities—that receive special rate and regulatory treatment by the Federal Energy Regulatory Commission, as legislated by the Public Utility Regulatory Policies Act of 1978 (PURPA). Generating facilities may be considered qualifying facilities if they achieve one or more of PURPA's stated goals, including: conservation of electric energy; increased efficiency in the use of facilities and resources by electric utilities; equitable retail rates for electric consumers; expeditious development of hydroelectric potential at existing small dams; and conservation of natural gas while ensuring that rates to natural gas consumers are equitable (FERC 2016).

- ISO tanks offer an ideal means for the marine transport of LNG. Delivery of LNG to Southeast communities could utilize the existing tug-and-barge service with LNG delivered to individual communities in ISO tanks. If sufficient demand is secured, a purpose-built LNG barge could be used instead.

Uses/Applications

- The most likely application of LNG in most non-Railbelt communities—particularly those with low population levels and densities—is power generation. However, some communities could rely on LNG primarily for industrial operations or space heating. A small number of communities may be candidates for conversion to LNG for multiple uses.
- LNG is not considered an effective backup generation fuel, as its physical properties dictate that it not be held for long periods due to in-tank vaporization (and higher pressures) from warming.

Costs

- A great deal of uncertainty exists among electrical utilities regarding the actual costs of acquiring and installing dual fuel retrofit kits. Dual fuel technology allows for the use of two fuels by a single generation unit. For purposes of this analysis, a dual fuel retrofit kit is a piece of equipment that connects to an existing diesel generator set and allows for the use of up to 60-70 percent natural gas (in terms of portion of total energy content of generation fuels) in the production of electricity. One interviewee who has investigated retrofit kits reported a cost range for acquisition and installation of $60,000 to $150,000 per retrofit kit. This range reflects the cost of retrofitting gensets with capacities between 400 kW and 2.3 MW.
- Interviewees expressed interest in taking advantage of a state tax advantage program for fuel storage that could help defray some of the costs of introducing LNG for either power generation or gas distribution service.
- The Cost of Power Adjustment is a possible mechanism to finance the purchase of LNG dual fuel systems and avoid having to undertake a General Rate Case with the Regulatory Commission of Alaska, which can consume a great deal of time and cost up to $250,000.
- Market dynamics allow for variable length contracts in the lower 48 states but not in Southcentral Alaska. Fixed-term contracts for gas sourced from Cook Inlet historically have been 10 to 20 years in length; more recently, however, contract lengths typically have ranged from 3 to 5 years. Whether contracts are longer fixed-term or shorter and more variable in length depends on the location of the LNG source and negotiations with the gas producer.
- Transportation contracts are very important in Alaska, particularly in regions where no competitive market exists. Potential LNG distributors believe that they will have to carefully negotiate transportation contracts with shippers and truckers.

LNG Handling

- The offload and connection of LNG from a truck or trailer can be highly manual in nature and may require Hazmat and other training. This especially may be the case with the conveyance of LNG from a truck or tank to a smaller generator. The offloading of LNG from a trailer to a larger storage tank or at a regasification facility may be less manual and may be performed by a trained truck driver without significant risk.
- The level of engineering/technical knowledge required for the operation of equipment involved with the storage, transfer, and use of LNG surpasses that of comparable diesel equipment. On-site expertise would be needed in Alaskan communities to handle LNG and connect it to tanks.

Storage

- The maximum holding time for LNG can vary depending on the type of tank in which the LNG is stored, as well as whether and at what frequency gas draw-down (use) occurs. Interviewees provided maximum holding times ranging from 30 days to 110 days.
- In the hub-and-spoke distribution model, LNG could be stored in larger vertical tanks in the hub communities and distributed to the smaller spoke communities via ISO tank.
- "Bullet" tanks are more permanent storage vessels than ISO tanks and are available in a wide range of sizes. They allow for some boil-off and are constructed with vacuumed steel. The largest bullet tanks can hold up to 500,000 gallons of LNG.
- Tanks that are refilled less frequently take longer to refill because they warm up more than tanks whose contents are used and then refilled more quickly. A typical faster tank refill will take about 45 minutes, while a slower refill can take around 4.5 hours.

Conversion

- Conversion to natural gas for electrical generation requires a significant capital investment. The most likely candidates for conversions to natural gas include generators that can be retrofitted with dual fuel (diesel and LNG) kits or older diesel gensets that are nearing the end of their lifetime and need to be replaced.
- Retrofitting existing diesel gensets for dual fuel use allows for reversion to exclusive use of diesel, should LNG prove economically or technically infeasible, and presents far lower capital costs than the purchase of new, exclusively gas-fired generators.
- Natural gas can provide at most 65-70 percent of the fuel consumed by dual fuel systems. The CAT 3500 series of gensets have a proven record of successful conversion to dual fuel capacity.

Community-level Expertise

- Smaller utilities may lack the capacity in terms of personnel to thoroughly evaluate and plan conversion to LNG for electrical generation. These utilities may rely on the expertise and resources of the potential LNG distributor or, if available, the state to assess the economics and technical requirements of conversion.

Regulatory Issues

- Laws and regulations pertaining to LNG storage are not anticipated to be a significant barrier. The Federal Energy Regulatory Commission could assert jurisdiction in certain cases, particularly if new material infrastructure associated with LNG transport is constructed, but the Commission's involvement is not anticipated to represent a major hurdle.
- Recently, the Alaska Railroad received regulatory permission to transport LNG when and if the demand occurs. A hub and spoke distribution system could develop at Fairbanks, for example, and provide LNG to non-Railbelt communities such as Tok.
- The Regulatory Commission of Alaska has issued several certificates of public convenience and necessity for natural gas utilities, with most specific to Railbelt areas. One certificate includes most of southeast Alaska, though no LNG utility is currently delivering or using LNG in this region.

3 Phase 2 – Energy Demand Projections and Fuel Price Forecasts

Energy demand and fuel prices are important inputs of any energy-related economic feasibility analysis. This section presents energy demand projections for electrical generation, heating, and water and wastewater (WW) at the regional level, as well as community-specific price forecasts for diesel and LNG. For ease of interpretation, energy demand volumes and fuel prices are presented in terms of both million British thermal units (MMBtu) and equivalent gallons of diesel fuel.

3.1 Energy Demand Projections

AEA, together with programming assistance from GINA, developed community-based energy demand projections for communities comprising the AkAES study area. These projections included energy demand for electrical generation, heating (including space and hot water heating and, as applicable, appliance use), and WW treatment.

The question of how to reduce energy costs among study area communities is the primary motivation behind this analysis and a critical component of the BCA: analysis results presented in Section 4.5 and further analyzed in Appendix A indicate that communities with higher energy demand generally exhibit higher BCRs.

Table 1 disaggregates projected energy demand for electrical generation into renewable[2] and non-renewable demand over the analysis period, 2017–2036, by AkAES region. The table further presents non-renewable energy demand in terms of equivalent gallons of diesel on both a 20-year and average annual basis. This analysis assumes that LNG would not replace any portion of renewable generation; thus, LNG would represent a very small portion of the electrical generation energy portfolio for communities for which the preponderant generation source is hydroelectric projects. This phenomenon is particularly evident among several Southeast communities.

Table 1. Forecasted Energy Demand for Electrical Generation by Region, 2017-2036

Region	Renewable Generation (MMBtu)	Non-Renewable Generation (MMBtu)	Total Generation (MMBtu)	Non-Renewable Generation (Diesel Equivalent, 1,000 Gallons)	Average Annual Non-Renewable Generation (Diesel Equivalent, 1,000 Gallons)
Bristol Bay	318,802	3,864,198	4,183,000	46,757	2,338
Kodiak	10,432,418	149,777	10,582,195	1,812	91
North Slope	0	6,186,075	6,186,075	74,852	3,743
Northwest Arctic	206,662	2,578,032	2,784,694	31,194	1,560
Aleutians	238,500	4,355,656	4,594,156	52,703	2,635
Lower Yukon-Kuskokwim	348,818	6,649,295	6,998,113	52,703	4,023
Yukon-Koyukuk/Upper Tanana	317	2,497,400	2,497,717	80,456	1,511
Southeast	57,963,009	2,207,285	60,170,294	30,219	1,335
Bering Straits	218,972	3,869,212	4,088,184	26,708	2,341
Copper River/Chugach	5,429,320	2,861,883	8,291,203	46,817	1,731
Total, All Regions	75,156,818	35,280,572	110,437,390	34,629	21,345

Source: Northern Economics, Inc. analysis of energy demand projections provided by GINA and AEA.

[2] The Oxford Dictionaries defines renewable energy as “energy from a source that is not depleted when used…” (Oxford Dictionaries 2016). The U.S. Department of Energy cites the following as constituting the U.S. renewable energy portfolio: solar, wind, geothermal, bioenergy, and water (hydro) (U.S. Department of Energy 2016).

Table 2 presents total 20-year and average annual energy demand projections for heating and WW in terms of both MMBtu and equivalent gallons of diesel, again by AkAES region. Unsurprisingly, the highest populated regions are projected to have the greatest heating and WW energy demand.

Table 2. Forecasted Energy Demand for Heating and WW Treatment by Region, 2017-2036

Region	Total Heat Energy Demand (MMBtu)	Annual Heat Energy Demand (MMBtu)	Annual Heat Demand (Gal Diesel)	Total WW Energy Demand (MMBtu)	Annual WW Energy Demand (MMBtu)	Annual WW Energy Demand (Gal Diesel)
Bristol Bay	7,477,130	373,857	2,769,307	360,372	18,019	133,471
Kodiak	8,854,849	442,742	3,279,574	149,466	7,473	55,358
North Slope	11,832,598	591,630	4,382,444	299,567	14,978	110,951
Northwest Arctic	7,906,132	395,307	2,928,197	346,865	17,343	128,469
Aleutians	4,234,711	211,736	1,568,411	233,358	11,668	86,429
Lower Yukon-Kuskokwim	21,022,857	1,051,143	7,786,243	1,005,351	50,268	372,352
Yukon-Koyukuk/Upper Tanana	12,364,055	618,203	4,579,280	763,574	38,179	282,805
Southeast	87,112,247	4,355,612	32,263,795	763,321	38,166	282,711
Bering Straits	10,348,558	517,428	3,832,799	510,321	25,516	189,008
Copper River/Chugach	15,595,801	779,790	5,776,223	138,682	6,934	51,364
Total, All Regions	186,748,938	9,337,447	69,166,273	4,570,877	228,544	1,692,917

Source: Northern Economics, Inc. analysis of energy demand projections provided by GINA and AEA.

3.2 Fuel Price Forecasts

Readily quantifiable benefits from the replacement of existing (primarily diesel) fuels with LNG consist entirely of the value of the displaced fuel(s). Thus, community-specific fuel price forecasts represent another critical input into the BCA.

Table 3 and Table 4 provide community-specific comparisons of forecasted 20-year weighted average diesel prices and estimated 20-year weighted average LNG prices for electrical generation and heating, respectively, on a $2016 per MMBtu basis. The communities whose diesel and LNG prices are compared in the two tables represent all study communities for which economic feasibility analysis was conducted.

Importantly, the LNG Freight on Board (FOB) prices do not compare directly to base fuel prices, as only the latter include capital, operating, and fuel transportation costs. The total LNG price (far right column), equal to the sum of the four constituent costs, does allow for a direct comparison with the base fuel price. Weighted average LNG FOB prices for electrical generation and heating can vary slightly for particular communities because of nonparallel projected energy demand for the two uses across the analysis timeframe. BCRs are not equal to the ratio of the weighted base fuel price and the weighted LNG price because differences in electrical generation and heating system efficiencies across fuel types result in variation in energy input requirements from the base fuel scenario to the LNG scenario.

A quick glance at Table 3 and Table 4 reveals that less populated communities (and, more to the point, communities with lower energy demand) tend to be burdened by high LNG system capital and operating costs. Section 4.2 identifies data sources and assumptions that underlie the price forecasts and cost projections summarized in Table 3 and Table 4. These include the constituent costs of LNG systems (fuel, transportation, capital, and operating) but do not similarly break down diesel costs, as such a disaggregation extended beyond the study scope.

Table 3. Comparison of Community-Specific 20-Year Weighted Average Base Fuel and LNG Prices for Electrical Generation

Community	Base Fuel (Diesel) Price ($2016/MMBtu)	NPV LNG System Prices ($2016/MMBtu)				
		LNG FOB Price	LNG System Capex	LNG System Opex	LNG Transportation	Total LNG Price
Adak	32.18	9.72	17.25	8.98	20.57	56.52
Akiachak	25.35	12.30	19.59	10.20	40.90	82.99
Akutan	25.04	9.75	129.31	67.33	26.31	232.71
Angoon	24.29	6.12	18.56	9.66	6.05	40.38
Bethel	29.99	9.48	2.03	1.06	30.12	42.69
Bettles	23.75	9.76	45.26	23.57	14.17	92.76
Central	20.99	9.77	55.28	28.79	12.69	106.53
Chitina	24.05	9.75	49.64	25.85	8.42	93.66
Circle	22.14	9.76	67.85	35.33	12.99	125.94
Cold Bay	32.19	9.72	13.28	6.92	20.43	50.34
Cordova	21.42	9.78	5.89	3.07	8.45	27.18
Eagle	22.15	9.77	35.40	18.44	11.27	74.88
Elfin Cove	25.18	6.12	127.14	66.20	9.58	209.05
False Pass	22.27	9.77	57.52	29.95	23.82	121.05
Kake	21.23	6.13	13.78	7.18	4.12	31.21
Karluk	22.62	9.25	132.91	69.21	6.67	218.04
Larsen Bay	26.26	9.87	1592.25	829.11	48.73	2479.95
Minto	21.22	9.77	38.09	19.83	11.50	79.19
Nelson Lagoon	29.21	9.49	77.13	40.16	23.32	150.11
Newhalen	32.51	9.21	14.26	7.42	29.01	59.90
Nikolski	33.01	9.72	173.15	90.16	31.94	304.98
Nome	20.28	9.55	2.37	1.24	34.02	47.18
Northway	21.54	9.77	10.44	5.44	8.88	34.53
Old Harbor	23.25	9.76	38.94	20.28	5.35	74.32
Ouzinkie	23.24	9.76	55.07	28.67	5.82	99.32
Pelican	25.57	6.22	1481.07	771.21	75.64	2334.14
Perryville	22.75	9.76	76.67	39.92	35.56	161.92
Port Alsworth	32.68	9.17	42.45	22.11	31.02	104.75
Saint George	41.88	8.86	47.25	24.60	21.18	101.90
Saint Paul	20.40	9.79	11.72	6.10	19.63	47.24
Sand Point	23.73	9.76	11.62	6.05	19.81	47.24
Slana	22.03	9.78	25.20	13.12	7.17	55.28
Tatitlek	27.29	9.74	67.68	35.24	10.83	123.50
Tok	21.72	9.77	3.61	1.88	7.86	23.12
Whale Pass	21.41	6.13	118.79	61.85	4.08	190.85
Yakutat	23.29	6.12	5.10	2.66	8.83	22.72

Source: Diesel fuel prices are equivalent to AEA Renewable Energy Program Round 9 forecasts. NEI developed LNG price forecasts with data from the Alaska Department of Revenue (2016), Fairbanks Natural Gas (2012), and Fortis (2015).

Table 4. Comparison of Community-Specific 20-Year Weighted Average Base Fuel and LNG Prices for Heating ($2016/MMBtu)

		NPV LNG System Prices				
Community	Base Fuel Price	LNG FOB Price	LNG System Capex	LNG System Opex	LNG Transportation	Total LNG Price
Adak	39.73	9.73	28.12	14.64	9.39	61.87
Akutan	25.46	9.80	112.68	58.68	13.46	194.62
Angoon	22.14	6.12	35.38	18.42	4.12	64.05
Atka	36.49	9.71	179.15	93.29	12.30	294.45
Bethel	29.16	9.45	19.16	9.98	13.97	52.56
Bettles	19.66	9.84	74.37	38.73	8.53	131.46
Central	17.99	9.81	23.10	12.03	5.15	50.09
Chignik	22.82	9.77	43.91	22.86	15.96	92.49
Chitina	24.08	9.73	23.61	12.29	3.31	48.95
Circle	18.57	9.75	33.90	17.65	5.60	66.90
Cold Bay	35.19	9.73	43.02	22.40	10.26	85.41
Cordova	20.62	9.78	14.40	7.50	3.97	35.66
Craig	19.81	6.12	17.99	9.37	1.69	35.16
Dillingham	20.03	9.55	14.64	7.63	13.53	45.35
Eagle	25.78	9.79	25.84	13.46	5.29	54.38
Elfin Cove	22.90	6.16	88.96	46.32	6.08	147.52
False Pass	23.77	9.76	85.63	44.59	12.48	152.46
Gustavus	21.62	6.13	24.27	12.64	4.10	47.14
Haines	20.98	6.12	12.29	6.40	5.09	29.89
Hoonah	21.34	6.14	21.20	11.04	4.04	42.41
Juneau	26.70	6.09	12.97	6.76	3.91	29.72
Kake	34.22	6.14	24.66	12.84	2.92	46.57
Karluk	32.26	9.24	101.86	53.04	2.34	166.48
Ketchikan	25.81	6.10	20.13	10.48	1.69	38.41
King Cove	22.01	9.77	27.18	14.15	9.17	60.27
Klukwan	19.90	6.13	34.61	18.02	5.74	64.51
Kodiak	29.48	9.73	18.53	9.65	2.26	40.17
Larsen Bay	30.62	9.76	45.37	23.62	2.60	81.36
Minto	17.72	9.76	21.92	11.41	5.05	48.14
Naknek	20.24	9.56	16.98	8.84	13.76	49.13
Naukati Bay	35.31	6.11	25.57	13.32	1.76	46.77
Nelson Lagoon	33.24	9.49	84.77	44.14	12.99	151.39
Newhalen	30.91	9.09	44.84	23.35	15.38	92.66
Nikolski	35.67	9.86	438.93	228.56	35.96	713.31
Nome	21.68	9.52	21.33	11.10	16.22	58.17
Northway	25.95	9.75	46.12	24.01	4.86	84.74
Old Harbor	33.66	9.76	30.38	15.82	2.40	58.36
Ouzinkie	26.15	9.76	30.16	15.70	2.52	58.13
Pelican	21.71	6.15	37.79	19.68	4.41	68.03

Community	Base Fuel Price	NPV LNG System Prices				
		LNG FOB Price	LNG System Capex	LNG System Opex	LNG Transportation	Total LNG Price
Perryville	23.71	9.77	60.96	31.74	15.60	118.07
Port Alsworth	31.65	9.13	28.51	14.84	14.84	67.33
Saint George	46.80	9.11	89.40	46.55	12.51	157.57
Saint Paul	23.76	9.82	31.16	16.23	9.56	66.77
Sand Point	25.94	9.75	24.61	12.82	9.22	56.40
Sitka	28.04	6.10	18.48	9.62	3.38	37.59
Skagway	21.69	6.12	12.56	6.54	5.08	30.30
Slana	20.20	9.80	17.28	9.00	3.28	39.37
Tatitlek	26.99	9.72	23.53	12.25	4.20	49.71
Tenakee Springs	21.65	6.16	35.35	18.41	4.35	64.27
Tok	22.04	9.77	8.69	4.52	3.67	26.65
Unalaska	24.31	9.79	22.92	11.94	9.09	53.74
Whale Pass	31.91	6.14	54.19	28.22	2.23	90.79
Yakutat	26.90	6.13	20.94	10.91	6.32	44.30

Source: Diesel fuel prices are equivalent to AEA Renewable Energy Program Round 9 forecasts. NEI developed LNG price forecasts with data from the Alaska Department of Revenue (2016), Fairbanks Natural Gas (2012), and Fortis (2015).

4 Phase 3 – Benefit-Cost Analysis

This section presents the framework, underlying assumptions, and results of a series of BCAs conducted to assess the economic feasibility of LNG in AkAES communities for electrical generation, heating, and the combined demand of electrical generation, heating, and WW plant operation. The study team conducted these three sets of analysis for all AkAES communities for which the full complement of required inputs was available.

Analysis results suggest that LNG would not prove an economically feasible substitute for existing fuels for electrical generation or heating alone in any of the study area communities; however, LNG may promise fuel cost savings to a few communities if used for electrical generation, heating, and WW plant operation. While it is important to consider these more positive results in the dual context of the substantial margins of error associated with cost inputs and the favorable cost assumptions specific to the WW analysis, they also underscore the strong relationship between the increase in energy demand (for LNG) and the reduction of capital costs per unit of fuel.

No community- and application-specific analysis yielded a benefit-cost ratio (BCR) higher than 1.0; however, two communities in the electrical generation analysis and five communities in the heating analysis were estimated to have BCRs greater than 0.8, and combined demand analysis (for all three fuel uses) yielded BCRs slightly higher than 1.0 for three communities. In light of the large margins of error associated with the many cost estimates that informed the BCAs, these results suggest that more rigorous, community- or region-specific analyses could more accurately assess the likelihood of LNG offering cost savings relative to existing fuels.

4.1 Goal and Framework

BCAs typically attempt to capture all benefits and costs accruing to members of society for the various project alternatives. For this analysis, the baseline scenario represents the world as-is (i.e. continued consumption by study communities of fuels that are currently available [diesel fuel and renewables for electrical generation; a combination of diesel, biomass, and electricity for heating; and diesel for WW), while the alternative implies the substitution of all or some portion of existing fuel demand with LNG. Estimated benefits under the alternative consist of the value of the base fuel displaced by LNG.

The study team conducted BCAs of more than 100 Alaskan communities that currently lack access to LNG (or natural gas). These analyses included all road-accessible and ice-free AkAES communities, as well as the seasonally ice-bound cities of Bethel and Nome. The goal of these analyses was to assess the economic feasibility of LNG use for these communities for electrical generation, heat,[3] and WW plant operation at as high a level of accuracy as available data and projections allow for this reconnaissance-level study.

BCAs were conducted for each community to estimate the economic feasibility of LNG for:

- Electrical generation only;
- Heat only; and
- Electrical generation, heat, and WW plant operation.

[3] Heat energy includes energy consumption for space and hot water heating, as well as appliance use such as kitchen ranges and clothes dryers.

Analyses were not conducted for WW alone, as this sector's consumption is far lower than that of the other two sectors and would not justify minimum project costs. This is considered a realistic constraint.

In accordance with AEA assumptions regarding the economic lifetime of natural gas projects, this analysis estimated benefits and costs over a 20-year timeframe.

The BCAs assumed a discount rate of three percent, which was applied to all costs over the 20-year analysis timeframe and allowed for the estimation of the net present value (NPV) of all costs and benefits.

4.2 Data Sources

Multiple data sources informed the BCA. The Baker report documents sources and rationale for estimated capital, transportation, and operating costs. Baker notes that its cost estimates are Class 5 estimates as defined by the Association for the Advancement of Cost Engineering. A Class 5 estimate typically is applied to a project whose design is 0-2 percent complete and whose expected accuracy range is +50 percent to -30 percent. The following sources provided the fuel cost and demand forecasts critical to the analyses:

- Heating, electrical, and WW energy demand forecasts for each community and each year over the analysis period were provided by AEA/GINA. NEI vetted these projections and considers them reasonable, realistic, and useful.
- The price estimate for LNG from Cook Inlet in 2017 reflects the average Cook Inlet natural gas price for Q1 2016, as reported by the Alaska Department of Revenue (ADOR 2016), plus an assumed cost of liquefaction of $4.33 per MMBtu (FNG 2013).
- The price estimate for LNG out of Vancouver, B.C. (Fortis) in 2017 of $6.89 per MMBtu reflects the LNG price for the lowest volume demand tier from Fortis Energy Inc.'s Rate Schedule 46 (Fortis 2015).
- LNG fuel prices from both sources are assumed to increase in parallel with the U.S. Energy Information Administration Brent Spot Crude forecast.
- Diesel fuel price forecasts are set equivalent to the AEA renewable Energy Round 9 forecasts.
- Wood fuel was assumed to remain at a real price of $250 per cord ($2016) through the analysis timeframe. While the study team acknowledges that both the price and heat content of firewood can vary by community or region, insufficient data were available to assign community-specific prices. Roundwood fuel (only) was considered due to limited use of wood pellets or wood chips in non-Railbelt communities.

4.3 Assumptions

The BCAs discussed in this section rely on numerous assumptions related to costs, system and fuel properties, relative efficiencies of various heating and electrical generation systems, project financing, and rates of conversion to LNG-based systems. Section 4.4 documents the majority of the assumptions related to costs; the remainder are presented below and organized topically.

4.3.1 System Efficiencies and Properties

System efficiencies differ between electrical generation and thermal uses, as noted in the following two subsections.

Electricity Production

This analysis assumes the following regarding conversion from diesel-only to dual fuel systems:

- LNG constitutes 60 percent of the energy content of the LNG/diesel mix used to operate dual fuel electrical generation systems.
- A diesel genset that is retrofitted for dual fuel capacity experiences a 10 percent loss in efficiency. This means that a retrofitted dual fuel genset will require 10 percent more energy than a diesel-only genset to generate the same amount of electricity.

Heating Fuel

Heating fuel systems are not uniformly efficient. Table 5 identifies the assumed average efficiencies of heating systems included in this analysis. A particular system's efficiency percentage indicates the portion of its fuel's energy content that is converted into usable heat and not lost during combustion. By this standard, electrical heat is the most efficient while wood fuels may be the least efficient due to high water content that must be driven off during combustion.

The natural gas efficiency multipliers for heating oil, electricity, and wood systems denote the proportional natural gas energy content required to produce the same amount of heat as these base systems. For example, since heating oil- and wood-fired heating systems typically are less efficient than gas systems, less natural gas (in terms of energy content) than heating oil or wood is required to produce the same amount of heat.

Table 5. Heating System Efficiency by Fuel Type

Fuel	System Efficiency	Natural Gas Efficiency Multiplier
Heating oil	85%	0.94
Natural gas	90%	1.00
Electricity	98%	1.09
Wood	64%	0.71

Source: Developed by Northern Economics, in collaboration with AEA staff.

4.3.2 Fuel Properties

This analysis considered both the relative fuel contents of LNG and other fuels and other properties related to the logistical feasibility of LNG for rural Alaskan communities. Table 6 compares the energy content of the different fuels considered in this analysis.

Table 6. Energy Content of Various Fuels

Fuel	Unit	Energy Content (Btu/Unit)	Gal LNG/Unit
Diesel	Gallon	135,000	1.6
Wood	Cord	16,000,000	214.8
Electricity	kWh	3,413	0.04
Natural gas	MMBtu	1,000,000	12.1
LNG	Gallon	82,645	1.0

Source: Developed by Northern Economics based on data from the Alternative Fuels Data Center (2014).

As noted in Baker report, the maximum assumed holding time for LNG is 90 days, due to vaporization known as boil-off. This affects the analysis in two ways:

1. A community must receive a minimum of four deliveries of LNG per year to maintain use of the fuel year-round.
2. Communities that are ice-bound for more than 90 days per year will lack access to LNG for a length of time equal to the number of ice-bound days minus 90 days. As a result, ice-bound communities that adopt LNG for dual fuel diesel/LNG electrical generation will rely exclusively on diesel for the portion of the year when LNG is unavailable. For ice-bound communities that use LNG for heating, piped distribution of natural gas is only feasible for buildings with secondary (non-natural gas) heating systems; alternatively, these communities can employ a hot water distribution system in which hot water could be generated with multiple fuels (most likely at the WW plant) and then piped to buildings on the system.

BCAs for each community explicitly account for both of these constraints specific to LNG.

4.3.3 Electrical Demand for Intertied Communities

The BCAs consider energy demand forecasts for electrical energy at the generation level, rather than the end-user level. As such, all energy demand for electricity for stand-alone and intertied communities was assigned to the community where generation takes place, and all communities intertied with the generation community (if any), but that generate no electricity, are assumed to have no electrical (generation) demand.

4.4 Costs

The Baker report identifies most of the capital, operating, and transportation cost assumptions used in the BCA. This section augments those assumptions with documentation of how those assumptions were applied in the BCA.

4.4.1 Capital

The BCA applied the capital costs identified in the Baker report in the following ways to reflect the realities of the scenarios considered in this analysis:

- As documented in the Baker report, this analysis assumed that LNG is either transported to and stored at communities in portable 12,000 gallon ISO tanks suitable for truck or tractor-trailer configuration or is transported via specialized barge and stored in permanent 5 million gallon tanks. There are smaller ISO tanks, such as those shown in Figure 2, but this analysis considered 12,000-gallon tanks only.
- For each community, this analysis estimated the number of ISO tanks required for delivery and storage above which it would be less costly to purchase a permanent 5 million gallon tank. This threshold number varied between 279 and 291 tanks, with variations due to delivery distance and transportation cost.
- The number of actual ISO tanks required per community/sector was determined based on the maximum single-year demand for LNG over the 20-year analysis timeframe, as detailed in the schedule in Table 7. Each "tankful" is the equivalent of 12,000 gallons of demand, so a community with the equivalent energy demand of 96,000 gallons of LNG would require eight tankfuls. In general, and as indicated in Table 7, the study team assumed that the frequency of

deliveries will increase as total energy demand increases and that road deliveries will occur more frequently than barge deliveries. The number of actual 12,000-gallon tanks required for a particular community is determined by dividing the community's equivalent energy demand (in tankfuls) by the assumed number of deliveries per year and adding two. As explained in the far right column, it is anticipated that one of these additional two tanks will be the reserve fuel tank, while the second tank will be in transit and will replace the tank that is in use.

Table 7. Energy Content of Various Fuels

Delivery Method	"Tankfuls"	Number of Tanks	Rationale
Truck	26 or fewer	3	1 tank in use; 1 tank in reserve; 1 tank in transit
Truck	27 or more	Tankfuls/26† + 2	26 deliveries/year; 1 tank in reserve; 1 tank in transit
Barge	19 or fewer	Tankfuls/4† + 2	4 deliveries/year; 1 tank in reserve; 1 tank in transit
Barge	20 to 49	Tankfuls/6† + 2	6 deliveries/year; 1 tank in reserve; 1 tank in transit
Barge	50 or more	Tankfuls/12† + 2	12 deliveries/year; 1 tank in reserve; 1 tank in transit

Notes: † Rounded up to the nearest whole number.
Source: Northern Economics assumptions, in consultation with AEA project management.

- Analyses that assumed and incorporated LNG demand for all three purposes (electrical generation, heating, and WW) applied the estimated cost of one vaporizer, which would convert the LNG from a cryogenic liquid to natural gas state for all uses.
- As noted in the Baker report, the assumed cost of conversion to an LNG-fired heating system is $9,000 per residential or non-residential building. In addition to the system conversion cost, Baker provided per-building capital cost estimates for pipes (see Table 8). Both the system conversion and piping costs can vary substantially, depending on factors such as type of existing system, distribution line costs, level of energy demand for a particular building, geographic concentration of buildings, the amount of piping and other natural gas plumbing required within a building, and local availability of required services and materials.

Table 8. Estimated Heat Distribution Piping Costs per Building

Distribution System Component	Cost
Distribution line	$7,600
Service line	$3,400
Other piping	$8,000
Total	**$19,000**

Source: Baker (2016).

- This analysis implicitly assumes that replacement of diesel with LNG for WW facility operation incurs no capital or operating costs (other than the potential need to purchase additional ISO tanks). In reality, it is likely that a WW facility's switch from diesel to LNG would require that existing equipment or systems be retrofitted or new equipment be purchased.
- This analysis implicitly assumes that diesel storage costs are included in the diesel price paid by an electric utility when the fuel distributor owns the storage infrastructure but that these costs are excluded when the infrastructure is owned by the utility.

4.4.2 Operating

An industry source with experience operating LNG systems provided a range of 2–5 percent for annual operating costs as a percentage of capital costs. This analysis applied the midpoint of this range, 3.5 percent, to estimate annual operating and maintenance costs.

4.4.3 Transportation

Three factors influenced the calculation of estimated delivery costs:

1. The transportation cost for communities on the road system but not part of the Railbelt (i.e., Tok, Valdez) was estimated at $0.00013 per lb-mile, while the cost for transportation to the remaining communities via barge was estimated at $0.0020 per lb-mile.
2. The transportation cost for communities whose likely storage method is ISO tanks includes the weight of the tanks, while the analysis assumes that the transportation costs for the few communities whose demand warrants storage in five million gallon tanks will include only the fuel weight.
3. Mileage from the LNG source for each community was determined based on whether it is more likely that a community would receive LNG from Vancouver or Cook Inlet. Yakutat is the community furthest to the north that is anticipated to receive LNG from Fortis in B.C.

4.4.4 Fuel

Section 4.2 identifies the sources for fuel prices used in the BCA. The BCA calculated fuel cost savings as the difference in total fuel cost for a community between the baseline and alternative.

For electrical generation, the analysis assumed that LNG would replace no portion of renewable generation such as wind or hydro energy. Therefore, fuel cost savings for electrical generation were calculated as the estimated volume of energy from diesel that would be replaced by LNG, per the assumptions above, multiplied by the difference in price per unit of energy between diesel and LNG.

For the heating analysis, each community's baseline fuel price was calculated as the weighted average of all heating fuels projected to be used within the community. Similarly to the electrical generation methodology, fuel cost savings for heating were calculated as the estimated volume of heating fuel to be displaced multiplied by the difference in price per unit between the baseline fuel(s) and LNG.

4.5 Benefit-Cost Ratio Results

The study team estimated BCRs for AkAES communities for three energy demand scenarios:

1. Electrical generation only;
2. Heating demand only;
3. Combined energy demand for electrical generation, heating, and water/wastewater plant operations

BCRs were calculated as the ratio of the NPV of displaced base fuel and the NPV of estimated total costs, including capital, operating, transportation, and alternative fuel (LNG) costs.

NPV analysis measures the present value of future savings and expenditures, taking into account forecasted discount rates. BCRs greater than 1.0 imply financial feasibility, i.e. that a project's benefits are greater than its costs.

Table 9, Table 10, and Table 11 present estimated BCRs by community for the three energy demand scenarios. Each of the tables includes the following metrics for each community under analysis: estimated BCR, constituent and total alternative scenario (LNG system) costs, value of displaced base fuel, and the estimated weighted average 20-year price of diesel/heating oil that would yield a BCR of 1.0 (i.e. LNG project feasibility). In other words, the break even diesel price for a particular community is the average price at which diesel would have to be sold over the 20-year analysis timeframe to justify economically the replacement of existing fuel systems with LNG systems. Thus, if a community's BCR is greater than 1.0, its break even diesel price will be lower than the actual forecasted prices; conversely, break even prices are higher than forecasted prices for all communities with BCRs lower than 1.0.

BCA results suggest universal economic infeasibility of LNG systems across the sample of analyzed AkAES communities for electrical generation or heating alone. Electrical generation- and heating-only analyses for a handful of communities, however, yielded BCRs of 0.8 or higher. As shown in Table 9, the study team estimates that the replacement of existing electrical generation systems with dual fuel-fired generation (diesel and LNG) would not prove economically feasible for any of the communities under analysis. These reconnaissance-level estimates indicate that the implementation of dual fuel electrical generation systems would yield BCRs greater than 0.7 for Yakutat, Tok, and Cordova.

Table 10 suggests that the replacement of existing heating fuels with LNG would yield BCRs of at least 0.7 for ten communities, with the Tok and Juneau analyses yielding BCRs greater than 0.9. Finally, three communities—Tok, Kake, and Yakutat—are estimated to have BCRs greater than 1.0 (but none higher than 1.13) in a scenario in which LNG replaces existing fuels for electrical generation, heating, and WW (see Table 11).

Table 9. Estimated BCR, Costs, and Fuel Savings for LNG-Fired Electrical Generation

		NPV LNG System Costs (1,000 $2016)					NPV	
Community	BCR	Capital	Operating	Transport.	LNG	Total	Displaced Base Fuel (1,000 $2016)	Break Even Diesel Price ($2016)
Yakutat	0.92	2,980	1,552	5,157	3,572	13,261	12,235	4.68
Tok	0.85	1,655	862	3,600	4,475	10,591	8,955	4.77
Cordova	0.71	2,450	1,276	3,517	4,067	11,310	8,022	5.60
Bethel	0.63	3,229	1,681	47,929	15,091	67,931	42,949	8.78
Kake	0.61	1,680	875	502	748	3,805	2,329	6.40
Cold Bay	0.58	1,669	869	2,568	1,222	6,328	3,642	10.38
Northway	0.56	1,258	655	1,070	1,177	4,160	2,336	7.14
Angoon	0.54	1,594	830	519	525	3,468	1,878	8.31
Adak	0.51	1,829	953	2,181	1,030	5,994	3,072	11.65
Newhalen	0.49	1,826	951	3,715	1,180	7,672	3,747	12.15
Sand Point	0.45	1,941	1,011	3,309	1,630	7,890	3,568	9.74
Saint Paul	0.39	2,062	1,074	3,456	1,723	8,315	3,232	9.71
Nome	0.39	2,538	1,322	36,384	10,212	50,456	19,519	9.72
Saint George	0.37	1,508	785	676	283	3,252	1,203	20.85
Slana	0.36	1,223	637	348	475	2,683	962	11.31
Old Harbor	0.28	1,492	777	205	374	2,847	802	15.32
Port Alsworth	0.28	1,447	753	1,057	312	3,569	1,002	21.46
Akiachak	0.27	1,574	819	3,285	988	6,666	1,833	17.27
Eagle	0.27	1,174	611	374	324	2,483	661	15.43

Minto	0.24	1,217	634	367	312	2,529	610	16.36
Chitina	0.23	1,153	600	195	226	2,175	503	19.34
Bettles	0.23	1,212	631	379	261	2,484	572	19.09
Ouzinkie	0.21	1,435	747	152	254	2,588	545	20.49
Tatitlek	0.20	1,419	739	227	204	2,590	515	25.47
Central	0.18	1,191	620	273	211	2,295	407	22.01
Nelson Lagoon	0.18	1,425	742	431	175	2,774	486	30.86
False Pass	0.17	1,437	748	595	244	3,025	501	24.96
Circle	0.16	1,141	594	218	164	2,119	335	26.00
Perryville	0.13	1,448	754	671	184	3,057	387	33.40
Elfin Cove	0.11	1,432	746	108	69	2,355	255	42.72
Whale Pass	0.10	1,408	733	48	73	2,262	228	39.29
Nikolski	0.10	1,399	728	258	78	2,464	240	62.81
Akutan	0.10	1,435	747	292	108	2,582	250	47.93
Karluk	0.09	1,398	728	70	97	2,294	214	44.62
Pelican	0.01	1,529	796	78	6	2,410	24	445.42
Larsen Bay	0.01	1,459	759	45	9	2,272	22	483.80

Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

Table 10. Estimated BCR, Costs, and Fuel Savings for LNG-Fired Heating

		NPV LNG System Costs (1,000 $2016)					NPV Displaced Base Fuel (1,000 $2016)	Break Even Diesel Price ($2016)
Community	BCR	Capital	Operating	Transport.	LNG	Total		
Tok	0.96	19,863	10,343	8,388	22,327	60,921	58,382	4.25
Juneau	0.93	443,520	230,946	133,563	208,145	1,016,175	940,673	5.37
Naukati Bay	0.86	2,990	1,557	206	715	5,468	4,677	7.68
Kake	0.83	9,173	4,777	1,087	2,284	17,321	14,424	7.54
Haines	0.80	31,145	16,218	12,903	15,508	75,775	60,895	4.81
Kodiak	0.78	74,289	38,683	9,059	38,997	161,027	125,321	7.00
Skagway	0.77	17,307	9,012	6,996	8,438	41,754	32,209	5.22
Sitka	0.77	124,002	64,570	22,668	40,907	252,147	192,984	6.75
Bethel	0.76	69,936	36,416	50,992	34,510	191,853	145,684	7.16
Ketchikan	0.70	112,838	58,756	9,491	34,194	215,279	150,237	6.82
Adak	0.68	3,741	1,948	1,250	1,294	8,232	5,584	10.82
Yakutat	0.66	13,135	6,839	3,966	3,842	27,782	18,354	7.54
Cordova	0.65	34,779	18,110	9,596	23,625	86,110	55,628	5.87
Craig	0.64	18,932	9,858	1,779	6,439	37,008	23,623	5.75
Old Harbor	0.61	5,091	2,651	402	1,636	9,779	5,983	10.20
Tatitlek	0.61	2,750	1,432	491	1,136	5,808	3,522	8.30
Nome	0.60	44,780	23,318	34,057	19,996	122,151	73,742	6.71
Hoonah	0.58	13,343	6,948	2,544	3,862	26,697	15,372	6.77
Slana	0.57	3,682	1,917	700	2,088	8,388	4,807	6.42
Eagle	0.55	2,781	1,448	569	1,054	5,853	3,216	8.58

Community	BCR	NPV LNG System Costs (1,000 $2016)					NPV Displaced Base Fuel (1,000 $2016)	Break Even Diesel Price ($2016)
		Capital	Operating	Transport.	LNG	Total		
Chitina	0.55	3,142	1,636	441	1,295	6,514	3,579	8.18
Gustavus	0.52	8,963	4,667	1,516	2,266	17,413	9,136	7.50
Port Alsworth	0.51	3,020	1,573	1,572	968	7,133	3,647	11.49
Sand Point	0.49	10,735	5,590	4,022	4,252	24,599	12,017	9.88
Dillingham	0.48	32,378	16,860	29,912	21,119	100,268	48,178	7.73
Unalaska	0.48	37,816	19,691	15,002	16,149	88,659	42,355	9.41
Ouzinkie	0.48	3,741	1,948	312	1,210	7,212	3,440	10.16
Minto	0.44	3,352	1,745	773	1,492	7,363	3,241	7.47
Cold Bay	0.44	3,741	1,948	893	846	7,427	3,250	14.86
Naknek	0.44	10,372	5,401	8,407	5,838	30,018	13,136	8.56
Central	0.43	3,112	1,620	694	1,322	6,747	2,900	7.59
Larsen Bay	0.40	3,110	1,620	179	669	5,578	2,226	14.03
Whale Pass	0.40	2,089	1,088	86	237	3,500	1,394	14.64
Angoon	0.40	7,792	4,057	908	1,349	14,106	5,580	10.29
King Cove	0.39	8,992	4,682	3,035	3,232	19,941	7,737	10.52
Tenakee Springs	0.39	4,400	2,291	542	766	7,999	3,083	10.07
Saint Paul	0.38	7,191	3,745	2,207	2,266	15,409	5,790	11.52
Pelican	0.37	3,651	1,901	426	594	6,571	2,400	10.72
Newhalen	0.36	3,260	1,698	1,118	661	6,738	2,445	15.95
Northway	0.35	2,271	1,182	239	480	4,173	1,481	13.65
Klukwan	0.35	3,140	1,635	521	556	5,853	2,067	10.30
Circle	0.33	2,661	1,386	440	766	5,252	1,744	10.37
Saint George	0.31	2,870	1,494	402	293	5,059	1,587	26.26
Chignik	0.27	3,441	1,792	1,250	766	7,248	1,945	15.70
Nelson Lagoon	0.23	2,329	1,213	357	261	4,160	970	26.37
Perryville	0.22	3,140	1,635	803	503	6,082	1,329	20.07
Karluk	0.21	1,939	1,010	45	176	3,169	651	28.93
Bettles	0.18	1,580	823	181	209	2,793	500	19.55
Elfin Cove	0.18	2,059	1,072	141	143	3,415	607	23.07
False Pass	0.17	2,450	1,276	357	279	4,361	722	26.76
Akutan	0.14	2,990	1,557	357	260	5,164	718	33.16
Atka	0.13	2,600	1,354	179	141	4,273	559	51.75
Nikolski	0.05	2,179	1,135	179	49	3,542	187	117.40

Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

Table 11. Estimated BCR, Costs, and Fuel Savings for All LNG Uses

		NPV LNG System Costs (1,000 $2016)					NPV	
Community	BCR	Capital	Operating	Transport.	LNG	Total	Displaced Base Fuel (1,000 $2016)	Break Even Diesel Price ($2016)
Tok	1.13	14,960	7,790	10,180	27,111	60,041	68,023	3.59
Kake	1.07	7,377	3,841	1,433	3,045	15,696	16,798	5.40
Yakutat	1.01	10,193	5,308	7,703	7,539	30,743	31,063	4.64
Bethel	0.94	51,550	26,842	73,885	49,950	202,227	190,025	5.82
Adak	0.85	3,936	2,049	2,391	2,492	10,869	9,211	7.94
Cordova	0.82	25,858	13,465	11,355	27,994	78,671	64,310	4.67
Old Harbor	0.77	4,332	2,256	534	2,163	9,284	7,149	7.55
Tatitlek	0.74	2,584	1,346	647	1,502	6,080	4,493	6.82
Cold Bay	0.74	3,776	1,966	2,142	2,232	10,117	7,438	8.42
Chitina	0.71	2,497	1,300	520	1,571	5,888	4,203	6.29
Northway	0.71	2,012	1,048	727	1,684	5,470	3,876	6.06
Nome	0.71	33,184	17,279	51,915	30,465	132,843	94,090	5.63
Eagle	0.70	2,274	1,184	733	1,406	5,598	3,941	6.52
Newhalen	0.66	3,337	1,738	3,214	2,026	10,315	6,844	8.86
Saint George	0.66	2,486	1,294	825	729	5,334	3,514	12.04
Sand Point	0.64	8,697	4,529	5,679	6,099	25,004	16,113	7.31
Ouzinkie	0.62	3,272	1,704	402	1,613	6,991	4,338	7.62
Minto	0.61	2,704	1,408	1,056	2,076	7,244	4,442	5.61
Angoon	0.61	6,353	3,308	1,319	1,978	12,958	7,872	6.89
Saint Paul	0.54	6,145	3,200	3,977	4,195	17,517	9,450	7.59
Larsen Bay	0.53	2,599	1,353	218	829	5,000	2,648	10.30
Circle	0.52	2,160	1,125	711	1,201	5,197	2,694	7.05
Pelican	0.48	3,037	1,581	486	688	5,793	2,788	8.32
Nelson Lagoon	0.43	2,036	1,060	714	577	4,388	1,891	13.37
Karluk	0.37	1,744	908	134	405	3,191	1,187	13.40
Perryville	0.34	2,609	1,358	1,339	849	6,156	2,092	12.72
Akutan	0.30	2,494	1,299	638	581	5,012	1,515	15.30
Nikolski	0.27	1,908	993	357	280	3,538	946	22.95

Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

5 Analysis of BCRs and Costs

This section considers BCR results in greater depth, with focus devoted to the relative influence of various factors on economic feasibility of LNG for electrical generation and heating across the AkAES community sample. This section elaborates on the following conclusions:

- Communities with higher population tended to have higher BCRs and lower per-resident capital costs.
- A community's distance from its anticipated LNG source is not a strong predictor of economic feasibility for the electrical generation analysis, but it is for the heating analysis and is negatively correlated with BCR.
- The method of LNG delivery (truck or barge) is not a strong predictor of the BCR in the electrical generation analysis, but it is negatively correlated with the BCR in the heating analysis.
- A community's LNG source (Nikiski or B.C.) is not a strong predictor of its BCR for either electrical generation or heating.
- BCRs in both the electrical generation and heating analyses tend to increase as LNG costs constitute a greater share of total costs.
- Ice-bound communities have lower BCRs than ice-free communities that otherwise possess similar characteristics. Ice-bound communities are likely to experience high capital, operating, and transportation costs relative to fuel cost savings because of their seasonal lack of access to LNG.

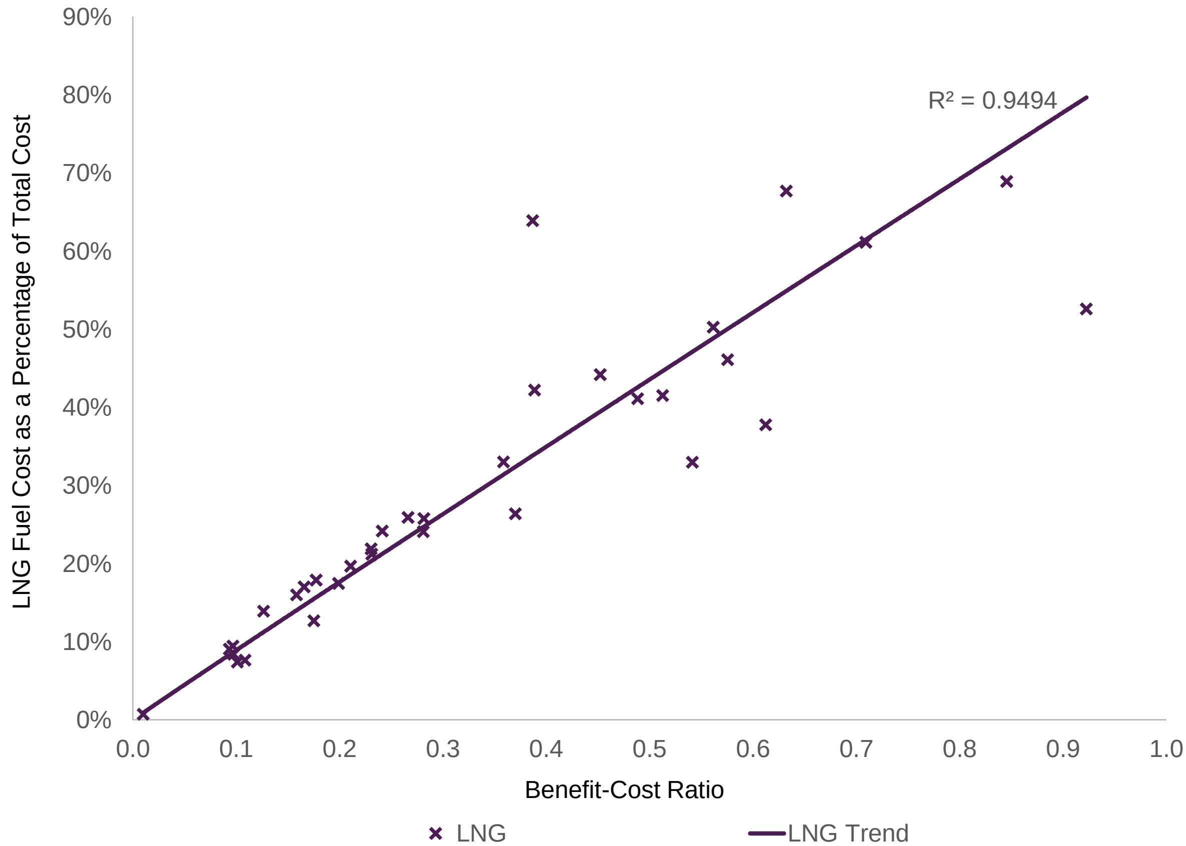
5.1 Costs Relative to BCRs

For all three sets of BCAs—electrical generation only, heating only, and all energy demand combined—higher BCRs tend to be correlated with LNG fuel costs representing a higher share of total costs. Conversely, communities for which higher capital and operating expenditures account for larger portions of total LNG system-related expenditures tend to have lower estimated BCRs.

Figure 4, Figure 5, and Figure 6 illustrate these trends for the electrical generation-only analyses, with each chart showing the relationship between an individual cost component (or, in the case of Figure 5, between both capital and operating expenditures) and BCRs. In the data plots, each symbol denotes a community, and each data plot includes a line of best fit for each of the four cost components, with the accompanying R-squared indicating tightness of fit (i.e. strength of correlation) between cost and BCR. CAPEX and OPEX are combined in a single chart because OPEX is calculated as a function of CAPEX and the two costs' lines of best fit have identical tightness of fit. Appendix A (Correlation between Costs and BCRs) further explains the correlations between costs and BCRs, with each of the four cost components for each of the analyses (electricity-only and heating-only) juxtaposed in a single chart.

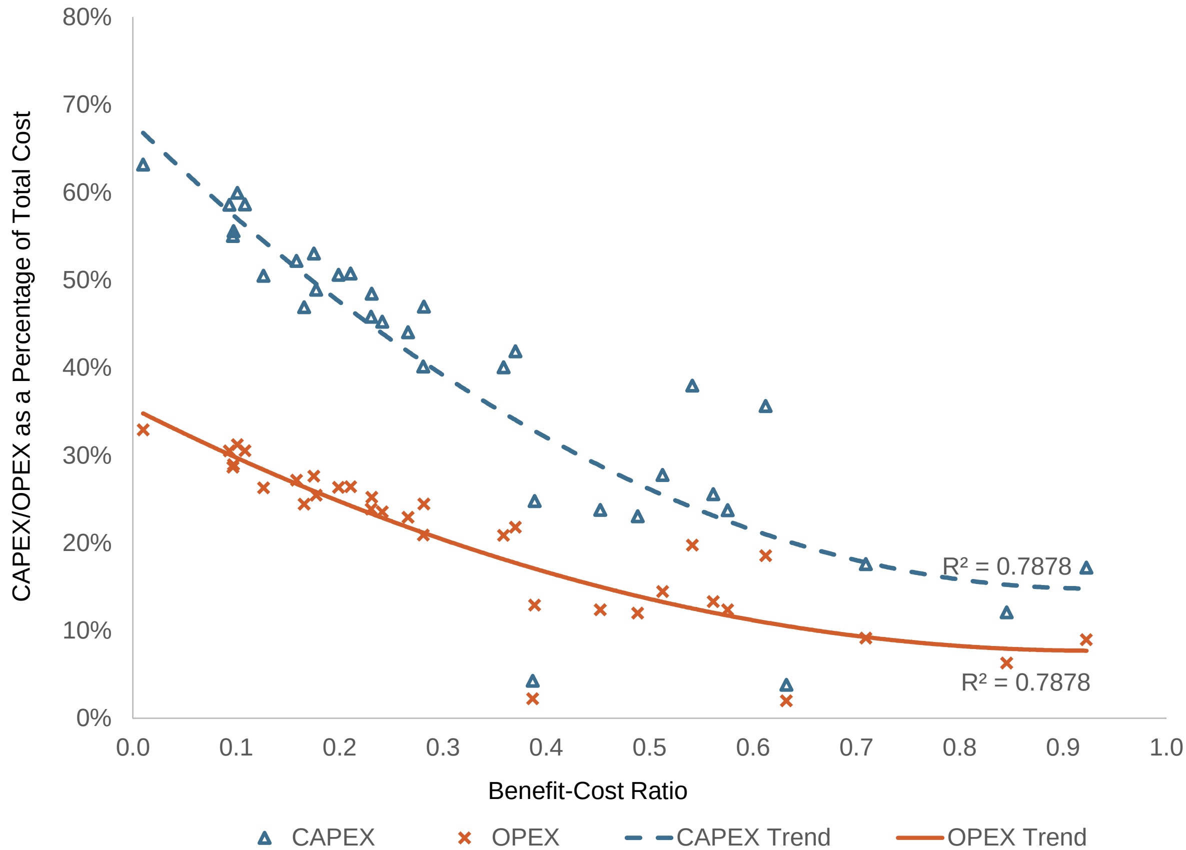
Figure 4 demonstrates a strong positive correlation between LNG cost as a share of total cost and electrical generation-only BCR, while Figure 5 indicates an overall negative correlation between capital and operating expenditures as shares of total cost and BCR. While less strongly correlated with the BCR than LNG, capital, and operating costs, LNG transportation costs are positively correlated with BCR overall (see Figure 6).

Figure 4. Relationship between LNG Fuel Cost for LNG-Fired Electrical Generation and BCR



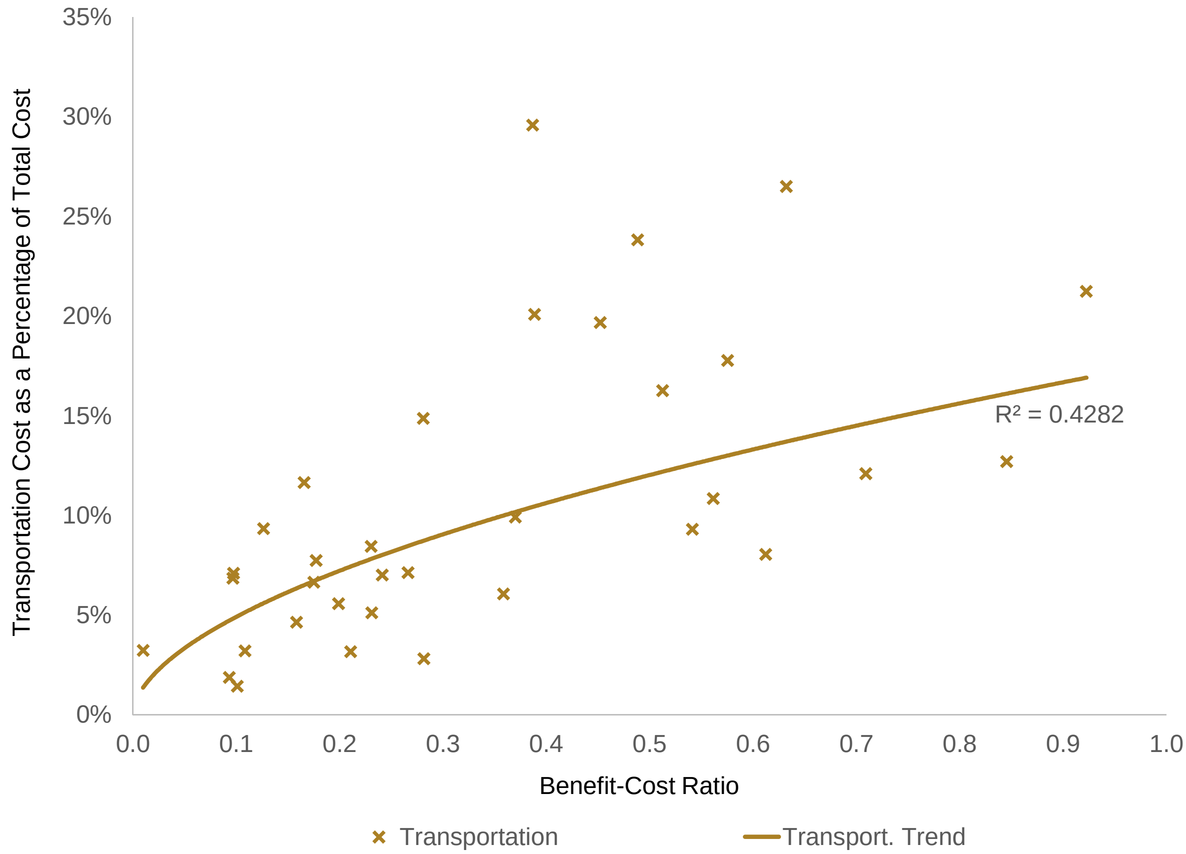
Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

Figure 5. Relationship between CAPEX and OPEX for LNG-Fired Electrical Generation and BCR



Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

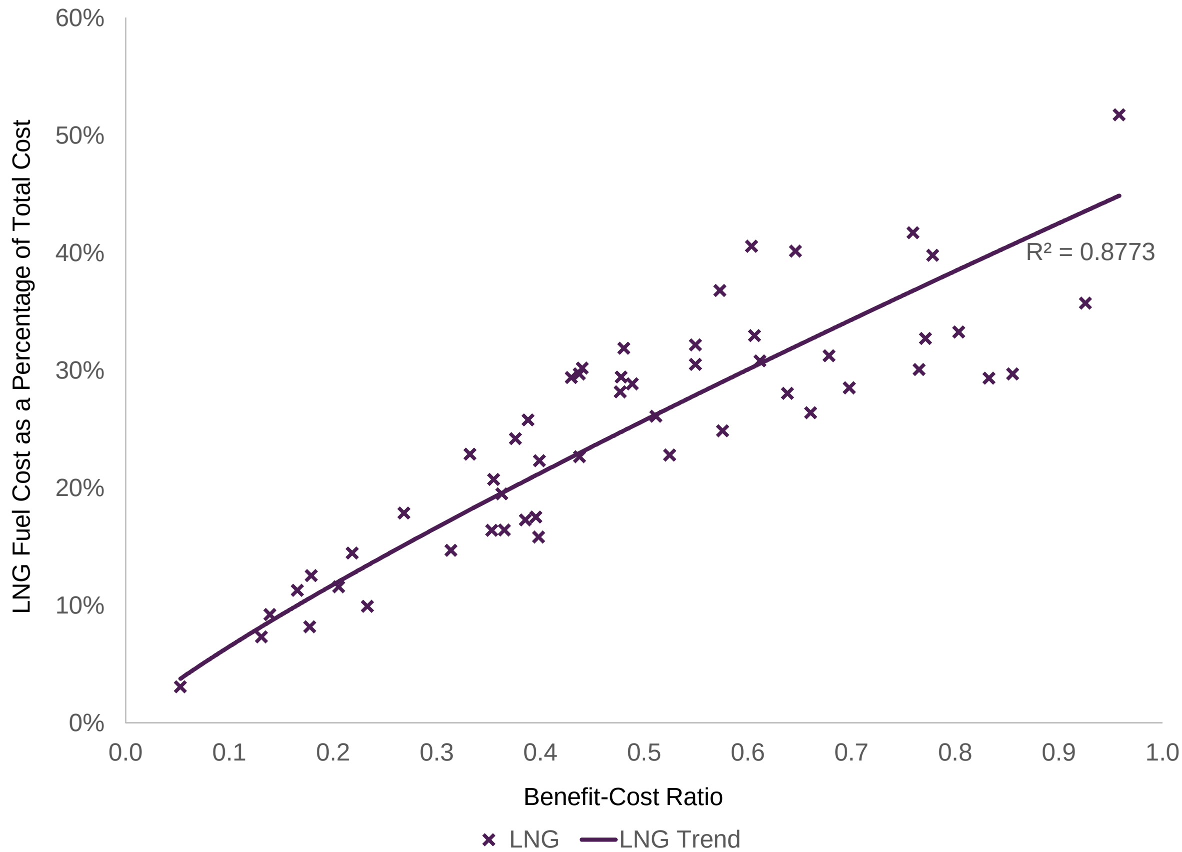
Figure 6. Relationship between LNG Transportation Costs for LNG-Fired Electrical Generation and BCR



Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

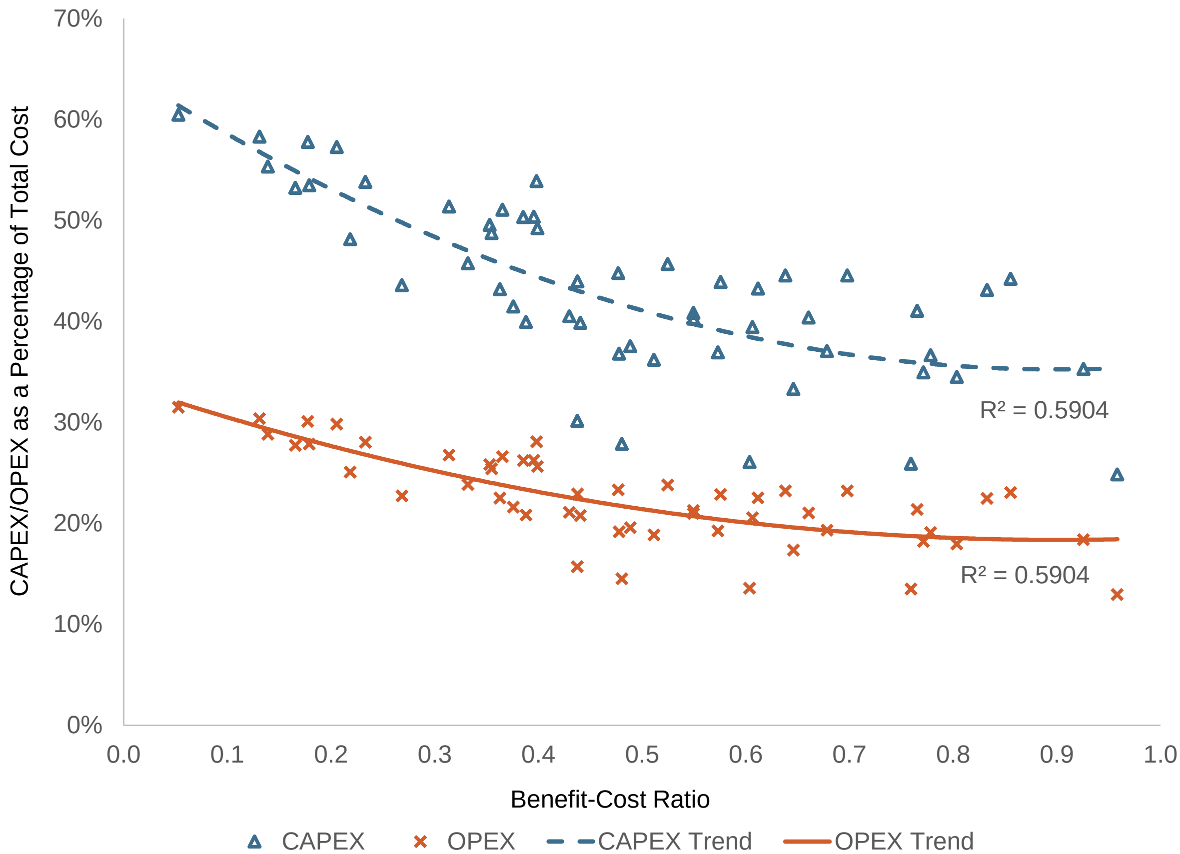
For the heating analysis, the direction of influence on the BCR of LNG costs remains positive (Figure 7), while those of CAPEX and OPEX remain negative, though at a decreasing rate as BCRs approach 1.0 (Figure 8). However, the lines of best fit for each of these costs are less strongly correlated with the BCR than the respective curves from the electrical analysis. Statistical analysis proved that transportation costs are a poor predictor of BCR for the heating system analyses.

Figure 7. Relationship between LNG Cost for LNG-Fired Heating Systems and BCR



Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

Figure 8. Relationship between CAPEX and OPEX for LNG-Fired Heating Systems and BCR



Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

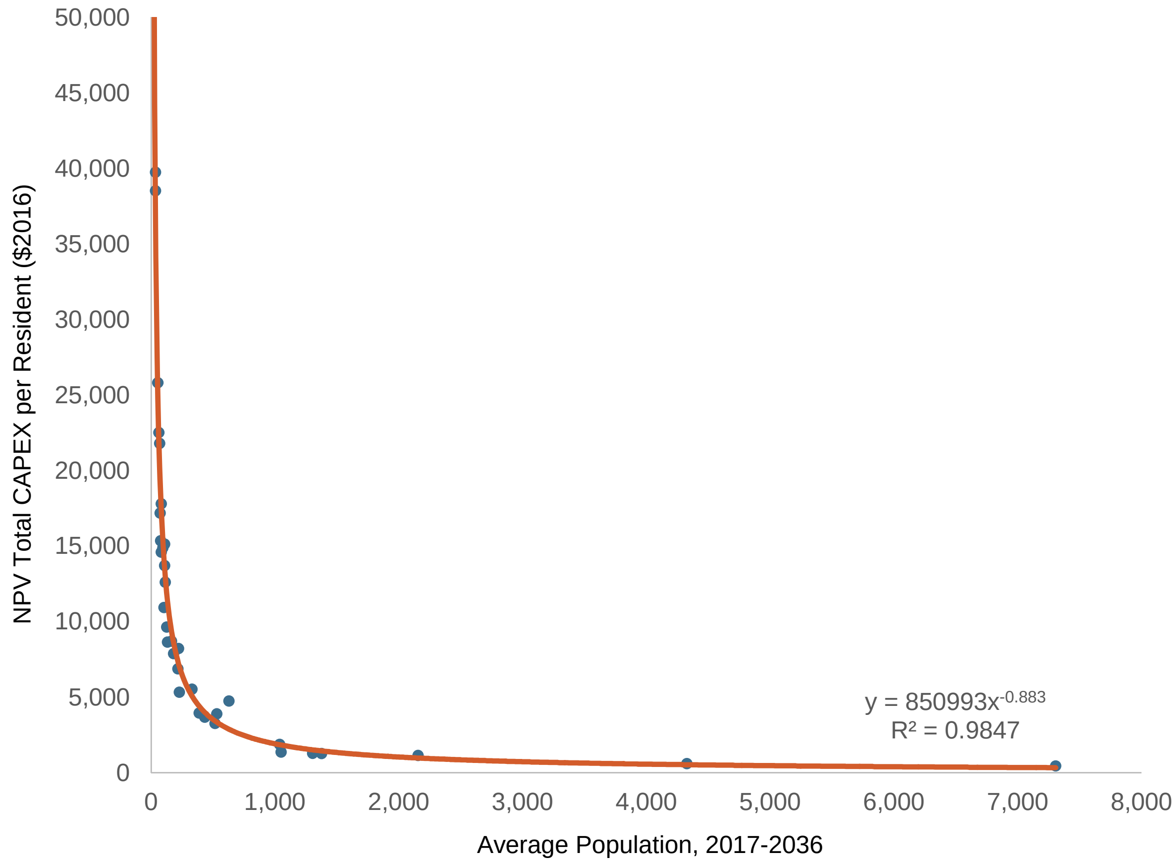
5.2 Community Population and CAPEX

The data plots in Section 5.1 depict how capital expenditures tend to account for a particularly large share of total costs among communities with low estimated BCRs. In addition, capital expenditures per resident generally are far higher among communities with low BCRs. This latter trend is evident when CAPEX per resident is plotted against BCRs from the electrical generation and heating analyses (see Figure 9 and Figure 10).

For electrical generation, in particular, population size is an excellent predictor of capital costs per resident. For both the electrical generation and heating analyses, however, capital costs per resident rise precipitously as population size falls under a few hundred.

Not surprisingly, the communities exhibiting the highest BCRs in both analyses generally are those with higher populations relative to the AkAES community sample as a whole. Each of the five communities in the electrical analysis with a BCR greater than 0.6 has a population greater than 500.

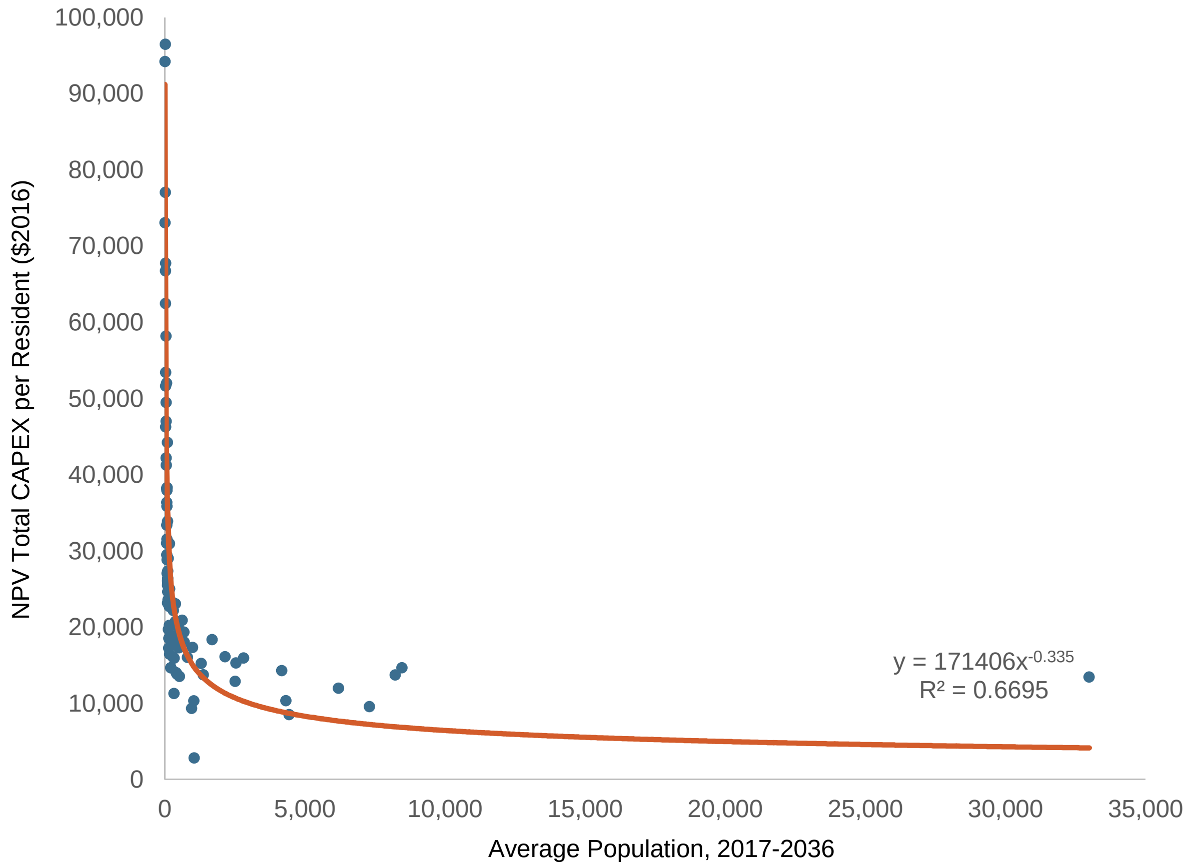
Figure 9. Community Population and CAPEX per Resident: LNG-Fired Electrical Generation



Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

Meanwhile, only one of the nine communities in the heating analysis with estimated BCRs greater than 0.75 is home to fewer than 500 residents, and seven of these nine are home to at least 1,000 residents. In comparison, 26 of the 53 communities for which the study team estimated heating BCRs have fewer than 200 residents.

Figure 10. Community Population and CAPEX per Resident: LNG-Fired Heating Systems



Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

6 Phase 4 – Next Steps

Primary among the goals of this project is the identification of communities that are likely to fall into each of the three categories of economic feasibility with respect to implementation of LNG systems:

- High (BCR substantially higher than 1)
- Medium (BCR close to 1)
- Low (BCR substantially lower than 1)

As documented previously, no application-specific analysis (electrical generation or heating alone) yielded a BCR greater than 1.0. However, three communities (Yakutat, Tok, Cordova) in the electrical generation analysis and ten communities (Tok, Juneau, Naukati Bay, Kake, Haines, Kodiak, Skagway, Sitka, Bethel, Ketchikan) in the heating analysis were estimated to have BCRs of 0.7 or higher. Given that this is a reconnaissance-level study, these communities—as well as the 13 communities in the combined analyses with BCRs of at least 0.7—should be considered Medium feasibility communities and may warrant more in-depth quantitative and qualitative analysis. For example, conversion of existing diesel-fired generator sets to dual fuel capacity for communities with some of the highest electrical generation BCRs may be prohibitively costly or technically impractical, depending on the type and condition of existing generating units. The absence of any High category communities renders project goals related to LNG system implementation—in particular, the identification of policies likely to encourage the adoption of LNG by study area communities—premature at this time.

Further Analysis

Given that this study's findings represent the results of a reconnaissance level analysis, additional analysis at the community- or region-specific level may yield more positive results. Over a period of many years, multiple entities from both the public and private sectors—including fuel distribution companies and electric utilities—have investigated the feasibility of LNG as a cost-effective substitute for diesel in various communities and regions of Alaska. These entities may have more highly refined cost data or energy demand estimates (possibly including sectors not considered in this analysis, such as mining) that, in combination with the data and forecasts developed for this study, could help answer the question of economic feasibility of LNG in communities and regions of Alaska that currently lack access to the fuel. In addition to development of more highly refined estimates of the economic feasibility of LNG, a project that demonstrates proof-of-concept is a prudent step in LNG development prior to widespread adoption.

One of the key takeaways from the informant interviews is that LNG systems, from transportation through actual fuel use, are more complex and require higher levels of training and sophistication on the part of users than diesel systems. For electrical generation alone, a proof-of-concept project would demonstrate that LNG transportation, delivery, and storage, as well as conversion of diesel-fired generation units to dual fuel capacity, are logistically feasible and replicable. In general, community-specific logistical and technical nuances and challenges of LNG system implementation must be evaluated prior to concluding from a favorable quantitative assessment alone that LNG will prove a cost-saving fuel.

Key Study Limitations

In addition to the opportunity to refine assessment of the economic feasibility of LNG through public-private knowledge sharing and/or community- or region-specific analysis, several important limitations of this study justify closer examination of the economics of LNG in non-Railbelt Alaska. These limitations include the following:

- This analysis assumes that no economies of scale exist with respect to LNG transportation costs. Transportation cost data were difficult to obtain, and the assumption of economies of scale would have represented conjecture. However, it is conceivable that larger LNG demand volumes would justify the purchase of a purpose-built articulated tug and barge, which, in turn, could lower LNG shipping costs on a per-unit basis.
- The current analysis constrains the portion of existing (and projected) energy demand for electrical generation that can be converted to LNG-fired generation to 60 percent, reflecting the widely accepted maximum ratio of LNG-to-diesel by dual fuel generators. Separate analysis could test the sensitivity of the BCR to 100 percent conversion of energy demand for electrical generation to LNG, contingent on incorporation of higher capital costs for the purchase of LNG-only generating units.
- The current analysis does not reflect the possible provision of LNG to communities in the Yukon-Koyukuk (Y-K) region via the Donlin Gold Mine. Donlin has publicly stated an intent to construct a gas pipeline from Cook Inlet to the mine to provide a natural gas supply for mining operations. The cost of shipping to Y-K communities could fall dramatically if the fuel is sourced from the mine and if Donlin does not pass along any of the pipeline construction and maintenance costs to these communities. Enhanced economic feasibility would further be contingent on consideration of Donlin as a non-Alaskan entity; otherwise, subsidization of fuel costs by an Alaskan entity to Alaskan fuel consumers would be considered a transfer payment.

7 References

Alaska Department of Revenue. Cook Inlet Prevailing Value of Natural Gas. Available at http://www.tax.alaska.gov/programs/oil/prevailing/cook.aspx. May 2016.

Alaska Energy Authority. Map of Alaska Affordable Energy Strategy Communities and Regions. April 2016.

Alternative Fuels Data Center. 2014. Fuel Properties Comparison. Available at http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf. Accessed April 2016.

Fairbanks Natural Gas. 2012 Annual Report. Available at rca.alaska.gov. March 29, 2013.

Federal Energy Regulatory Commission (FERC). What is a Qualifying Facility? June 30, 2016. Available at http://www.ferc.gov/industries/electric/gen-info/qual-fac/what-is.asp. Accessed July 26, 2016.

Fortis Energy Inc. Rate Schedule 46. Liquefied Natural Gas Sales, Dispensing and Transportation Service. Effective January 1, 2015. Available at https://www.fortisbc.com/About/RegulatoryAffairs/GasUtility/NatGasTariffs/Documents/RateSchedule_46.pdf. June 2016.

Oxford Dictionaries. Renewable energy definition. Available at www.oxforddictionaries.com. June 24, 2016.

The Alaska State Legislature. SB 138 Alaska Senate Bill. 2014. Available at http://openstates.org/ak/bills/28/SB138/. Accessed July 27, 2016.

U.S. Department of Energy. Renewable Electricity Generation. Available at energy.gov/eere/renewables. June 24, 2016.

Appendix A: Supplemental Analysis of Economic Feasibility Results

Drivers of BCRs: Regression Results

The study team conducted regression analysis to determine the relative influence on BCRs of several variables correlated with the four primary costs. Separate regressions measured the impacts of the following five variables on electrical generation-only and heating system-only BCRs, with the BCR in both regressions the dependent variable:

- ln Population: Natural log of each community's average projected population over the 2017–2036 timeframe
- ln Distance: Natural log of the distance (in miles) from a community's LNG source
- ln ConsPerRes: Natural log of the forecasted average energy consumption (for electricity or heating) per resident over the 2017–2036 timeframe
- Barge: Dummy variable that is activated for communities that would receive LNG deliveries via barge
- B.C: Dummy variable that is activated for communities that would source LNG from B.C., instead of Cook Inlet

A log-log model specification was used, with the natural logs of the three continuous variables (as well as the two binary dummy variables) regressed against the natural log of the BCR.

The regression results in Table 12 indicate that the model explains 81.7 percent of the variation in electrical generation-only BCRs on an adjusted R-squared basis, with high overall model significance. Four of the five independent variables expected signs that agree with a priori expectations, with the sourcing of LNG from B.C. surprisingly negatively correlated with BCR. Population and energy consumption per resident exhibit statistically significant correlations with the BCR at 95 percent confidence levels; these variables' coefficients suggests that a 1 percent increase in a community's population is correlated with a 0.49 percent increase in the BCR, while a 1 percent increase in energy consumption per resident predicts a 0.69 percent increase in the BCR. The lack of statistical significance of the other three variables—distance from the LNG source, whether LNG would be delivered via barge, and whether a community would source LNG from B.C.—is indicative of their variable and minor impact on the BCR relative to other factors.

Table 12. Regression Results: Electrical Generation BCR

Regression Statistics	
Multiple R	0.919
R Square	0.844
Adjusted R Square	0.817
Standard Error	0.442
Observations	35

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	30.67	6.13	31.35	<0.01
Residual	29	5.67	0.20		
Total	34	36.35			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-7.11	0.92	-7.75	0.00	-8.99	-5.24	-8.99	-5.24
ln Population	0.49	0.05	9.02	0.00	0.38	0.60	0.38	0.60
ln Distance	-0.13	0.15	-0.86	0.40	-0.44	0.18	-0.44	0.18
ln ConsPerRes	0.69	0.07	9.67	0.00	0.54	0.84	0.54	0.84
Barge	-0.18	0.19	-0.95	0.35	-0.55	0.20	-0.55	0.20
B.C.	-0.12	0.23	-0.52	0.61	-0.59	0.35	-0.59	0.35

Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

The regression results provided in Table 13 indicate that the same five independent variables explain 67.8 percent of the variation in electrical heating-only BCRs, with high overall model significance. The signs of each of the five independent variables agree with a priori expectations, and four of the five variables (not whether LNG is sourced from Nikiski or B.C.) are significant at a 90 percent confidence level in predicting the BCR (with population, distance from LNG source, and consumption per resident significant at a 95 percent confidence level). The coefficients for the population, transportation distance, and consumption per resident variables indicate that 1 percent increases in each predict a 0.23 percent increase, 0.22 percent decrease, and 0.35 percent increase in the BCR, respectively. The coefficient for the barge dummy variable suggests that a community that receives LNG deliveries via barge is predicted to have a BCR 0.25 percent lower than the mean.

Table 13. Regression Results: Heating System BCR

Regression Statistics	
Multiple R	0.842
R Square	0.709
Adjusted R Square	0.678
Standard Error	0.325
Observations	53

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	12.13	2.43	22.93	<0.01
Residual	47	4.97	0.11		
Total	52	17.10			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2.89	0.80	-3.61	0.00	-4.50	-1.28	-4.50	-1.28
ln Population	0.23	0.03	8.90	0.00	0.18	0.28	0.18	0.28
ln Distance	-0.22	0.08	-2.66	0.01	-0.39	-0.05	-0.39	-0.05
ln ConsPerRes	0.35	0.08	4.48	0.00	0.19	0.50	0.19	0.50
Barge	-0.25	0.13	-1.90	0.06	-0.52	0.01	-0.52	0.01
B.C.	0.02	0.13	0.12	0.90	-0.24	0.27	-0.24	0.27

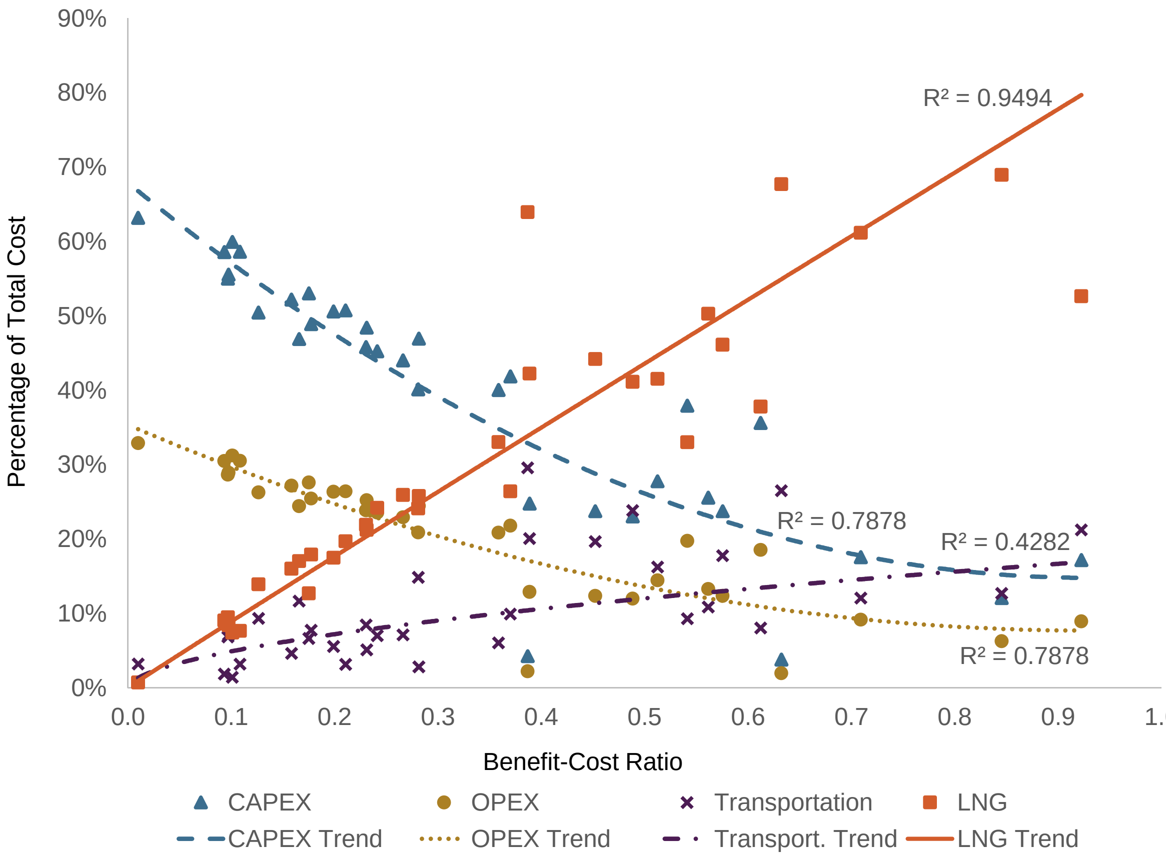
Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

Correlation between Costs and BCRs

As documented in Section 5.1, higher BCRs tend to be correlated with LNG costs representing a higher share of total costs. Conversely, communities for which higher capital and operating expenditures account for larger portions of total LNG system-related expenditures tend to have lower estimated BCRs. Section 5.1 illustrates these trends with a series of charts showing the relationships between individual cost components and BCRs for the electricity-only and heating-only analyses. In Figure 11 and Figure 12, however, these charts are combined into single graphics (one each for the electrical and heating analyses) that show how each of the four costs' shares of total costs tend to change as BCRs increase. As with the data plots in Section 5.1, each symbol denotes a community; in Figure 11 and Figure 12, however, each community is represented by four symbols (one for each of the four cost components). Again, each plot includes a line of best fit for each of the four cost components, with the accompanying R-squared indicating tightness of fit (i.e. strength of correlation) between cost and BCR.

Figure 11, which plots costs' shares of total costs for each community in the electrical generation analysis, demonstrates a strong positive correlation between LNG cost as a share of total cost and BCR, as well as a strong negative correlation between capital and operating expenditures as shares of total cost and BCR. While less strongly correlated with the BCR, transportation cost is positively correlated with BCR overall.

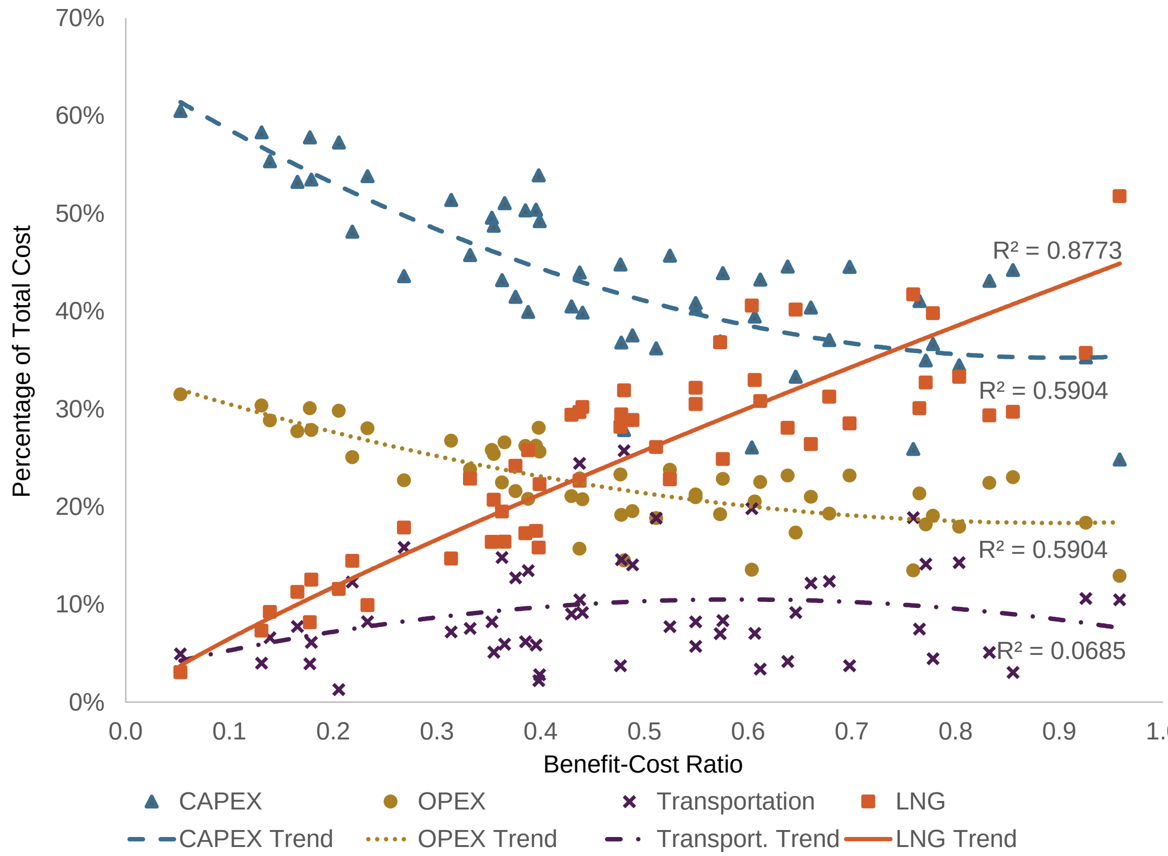
Figure 11. Relationship between LNG-Fired Electrical Generation Cost Components and BCR



Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

For the heating analysis, the direction of influence on the BCR of LNG costs remains positive, while those of CAPEX and OPEX remain negative except for those communities with the highest BCRs. However, the lines of best fit for each of these costs are less strongly correlated with the BCR than the respective curves from the electrical analysis. Moreover, Figure 12 indicates that transportation costs are a poor predictor of BCR for the heating system analyses.

Figure 12. Relationship between LNG-Fired Heating System Cost Components and BCR



Source: Northern Economics analysis of data provided by the Alaska Energy Authority.

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Appendix B: Interview Summaries

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Memorandum

Date: December 18, 2015

To: Neil McMahon, Alaska Energy Authority

From: Cal Kerr & Dave Weiss, Northern Economics, Inc.

Re: Summary of Interviews for LNG Feasibility Study for Rural Alaska

This memorandum summarizes interviews conducted by Northern Economics staff with Alaskan electric and gas utilities, fuel distribution companies, and the RCA to evaluate the opportunities and barriers to the expanded adoption of LNG in non-Railbelt Alaska. Interviewees' responses have been anonymized and are organized topically, following the list of interviewed organizations.

List of Interviews

1. FNG
2. Clean Energy
3. Crowley Marine
4. Regulatory Commission of Alaska
5. Copper Valley Electric Association
6. Inside Passage Electric Cooperative
7. Alaska Power and Telephone
8. Avista Corporation
9. WesPac Midstream
10. Interior Gas Utility
11. ENSTAR

Big Picture: LNG for Non-Railbelt Alaska

Several companies are actively investigating opportunities to expand the distribution of natural gas to Interior Alaska and portions of the state where the fuel currently is not available. This is largely a matter of public knowledge, in light of proposals submitted to AIDEA for the distribution of natural gas to the Interior. Conversely, there is considerable interest in LNG on the part of communities and utilities with either limited or no current access to natural gas if the fuel lowers energy costs and if the source proves reliable. In addition to potentially lowering energy costs for non-Railbelt communities, LNG burns more cleanly than diesel.

In general, the consensus among LNG suppliers and distribution companies that the study team interviewed is that LNG does represent a potential energy cost saving fuel for portions of the state where the fuel currently is unavailable. However, the economic feasibility of the expansion of LNG distribution to non-Railbelt Alaskan communities is contingent on the presence of a substantial and stable source of demand, among other factors. This "anchor" demand could be for electrical generation, industrial (e.g. from a large mine), or for thermal use. For example, LNG could present cost-saving potential to Southwest communities with large fish processing operations such as Dillingham and Naknek, but possibly only if industrial and electric demand in Unalaska serves as the anchor demand for the region. In this model, Unalaska would be the demand "hub," and the Bristol Bay communities would be the "spokes." Similarly, a number of smaller communities in Southeast Alaska may benefit from the regional presence of LNG for purposes of electrical generation if a piped natural gas distribution system is constructed in Juneau. Only through the conversion of significant anchor demand to LNG – whether the demand be for power production, industrial operations, or space heating (or a combination thereof) – will adequate economies of scale be achieved to justify the high costs of LNG-related infrastructure and equipment and the further distribution of LNG to smaller communities with lower levels of energy demand.

Models of Distribution/Implementation

Regional Feasibility: Fuel distribution companies agreed that a community's location in an ice-free region would strengthen the economics of that community's adoption of LNG but that a community need not be ice-free for LNG to prove economically feasible. Instead, economic feasibility will be determined by a number of factors, including total energy demand, seasonality of demand, LNG storage capacity and maximum allowable storage duration, seasonal duration of ice presence, proximity to other demand that could be served by LNG (thereby potentially reducing transportation costs), and costs of conversion. These criteria would particularly apply in the analysis of feasibility of LNG for communities with seasonal access (e.g. Bethel) and communities with large seasonal fish processing operations. Interviewees also indicated interest in exploring the feasibility of LNG for electrical generation for non-Railbelt Interior communities that are located on the road system, as well as for Valdez. For these communities, Tok would likely serve as the hub, with distribution to other communities on the road system via ISO tanks. However, depending on the LNG source, Tok also could represent a component of another utility's demand.

Ownership of ISO tanks: Both fuel distribution companies and utilities generally agreed that ISO containers present the ideal mode for LNG delivery and storage in most communities. Multiple models exist with regard to the ownership of ISO containers used for the transport and storage of LNG. Ownership may reside with the LNG producer, a third-party logistics/transportation company, or the utility that represents the end user. Crowley supplies LNG to Coca-Cola Bottlers (and possibly other customers) in Puerto Rico with gas that is produced in Georgia, trucked to Jacksonville, transported to Puerto Rico by barge or steam ship, and then delivered to customers. Crowley has outsourced transport of the LNG from the port in Puerto Rico to customers to a third-party logistics company, which is responsible for training and safety education of its staff. Crowley owns the ISO tanks in which the fuel is transported, with each tank's capacity approximately 10,000 gallons.[1]

Proof of Concept: A qualifying facility (QF) may be the best way to demonstrate proof of concept of LNG's feasibility in communities or regions where it currently has no presence. Some of the capital cost for a QF could be passed along to customers through a cost of power adjustment (COPA). However,

[1] http://www.crowley.com/News-and-Media/Press-Releases/Crowley-to-Supply-LNG-to-Coca-Cola-Bottlers-CC1-Companies-LLC-in-Puerto-Rico.

capital costs for such a facility would be recovered through an addition to the rate base, assessed on a cost per kilowatt-hour basis, equivalent to the annual amount of depreciation of the facility.

LNG Sources: Interviewees mentioned numerous potential sources of LNG, including Cook Inlet, Fortis (B.C.), Prince Rupert (B.C.), Alaska's North Slope, and Whitehorse (from Yukon Energy Corp.). Given the vast distances between regions of Alaska that could adopt LNG, as well as the availability of multiple sourcing options, it is conceivable that communities in different regions could source LNG from different locations.

Methods of Transportation

It is common where LNG trucking occurs for the trucking to be outsourced to a third-party transport company, as long as sufficient demand exists to justify the outsourcing. Truck drivers likely require Hazardous Materials (Hazmat) certification and specific training in the handling of LNG.

Specialized trailers exist for the transport of LNG. Maximum capacity for these trailers can depend on the weight of the trailer itself and highway weight restrictions but commonly it is between 9,000 and 9,500 gallons, with other trailers holding up to 13,000 gallons. The tankers with approximately 9,000 gallons of capacity and which currently are in use in Alaska weigh between 25,000 lbs. and 40,000 lbs. unloaded. There is an 80,000 lb. weight limit to truck, trailer, and cargo across the U.S., except in Washington and Oregon, and ISO tank specifications can vary significantly from one design to another.

Hawaii Gas receives LNG that is sourced from southern California, transported via ISO container to Long Beach, and then shipped to Port of Hawaii. From there, the LNG is vaporized and distributed to Hawaii Gas customers. ISO containers currently offer the best method for transporting LNG to Hawaii. The ISO tanks that carry the LNG to Hawaii are alternately 40 feet and 53 feet in length, with the former proving more traditional and also the standard size for a container ship. Cycle time to Hawaii is approximately 20 days, using Matson-line ISO beds to deliver tanks to the port of Long Beach for loading. Once the tanks are loaded, the trailer is cycled back for another container (or ISO tank). Multiple versions of LNG ISO tanks exist and are produced by multiple manufacturers. The range of volumes for these LNG ISO containers is around 7,500 gallons to 9,500 gallons.

Delivery of LNG to Southeast communities could utilize the existing tug-and-barge service, with LNG delivered to individual communities in ISO tanks. If sufficient demand is secured, a purpose-built LNG barge could be used instead.

Uses/Applications

The most likely use of LNG in most non-Railbelt communities is power generation. This is especially the case for smaller rural communities with low population levels and densities. However, some communities could rely on LNG primarily to satisfy industrial demand. This may be the case for communities with fish processing facilities. In addition, the primary use of LNG in other communities, such as Juneau, Sitka, and Ketchikan, may be for space heating.

Some communities, such as Valdez, may be candidates for conversion to LNG for multiple uses, including electrical generation, industrial use associated with refinery operations and fish processing facilities, and space heating.

Natural gas utilities in Alaska currently operate small utility trucks that run on CNG, as well as tractor trailers that haul and run on LNG.

LNG is not considered a good backup generation fuel, as its physical properties dictate that it not sit for long periods of time. However, LNG could be used as a backup fuel for utilities or communities where hydropower predominates if it is used along with diesel in a dual fuel system.

The RCA is not aware of any LNG-fueled power production in Alaska, whether for single- or dual-fuel generation.

Costs

Capital Costs: Equipment and infrastructure required for the storage, transport, and use of LNG can prove prohibitively expensive in the absence of adequate demand. Forty-foot LNG ISO containers used for both barge and truck delivery cost approximately $175,000 to $250,000 each.

A great deal of uncertainty exists among utilities regarding the actual costs of acquiring and installing dual fuel retrofit kits. However, one interviewee who has investigated retrofit kits reported a cost range for acquisition and installation of $60,000 to $150,000 per retrofit kit. This range reflects the cost of retrofitting gensets with capacities between 400 kW and 2.3 MW.

Fuel Costs: Current low diesel prices have made the fuel price differential between diesel and LNG much smaller than it has been historically. The current relative lack of savings associated with LNG acts as a disincentive to conversion.

Incentives & Financing Mechanisms: Interviewees expressed interest in taking advantage of a state tax advantage program for fuel storage that could help defray some of the costs of introducing LNG either for power generation or gas distribution service in communities with population levels and densities that justify piped distribution.

The Cost of Power Adjustment (COPA) is a possible mechanism to finance the purchase of LNG dual fuel systems. This could avoid having to undertake a General Rate Case with the RCA, which can consume a great deal of time and cost up to $250,000. The COPA could essentially pay for the installation of the dual fuel kit and then be used to pass along fuel cost savings to ratepayers.

In cases in which the adoption of LNG for electric generation will lower or eliminate PCE payments, the utility may seek offsetting financial support from the state for the capital cost of converting existing diesel-fired generators to dual fuel capacity.

Fuel & Transportation Contracts: Market dynamics allow for variable length contracts in the lower 48 states but not in southcentral Alaska. Fixed-term contracts for gas sourced from Cook Inlet typically are 10-20 years in length. Whether contracts are longer fixed-term or shorter and more variable in length depends on the location of the LNG source. The credit-worthiness of utilities taking LNG is important.

Transportation contracts are very important in Alaska, particularly in regions where no competitive market exists. Potential LNG distributors believe that they will have to carefully negotiate transportation contracts with shippers and truckers to prevent them from extracting a higher margin than a competitive market would yield.

Similarly, local utilities may wish to negotiate the costs of customer-level heating system conversions with HVAC contractors in communities that adopt natural gas for space heating and other thermal uses.

Logistical Issues

Handling: The offload of LNG can be highly manual in nature and may require Hazmat and other training. This especially may be the case with the conveyance of LNG from a truck or tank to a smaller generator. The offloading of LNG from a trailer to a larger storage tank or at a regasification facility may be less manual and may be performed by a trainer truck driver without significant risk.

The level of engineering/technical knowledge required for the operation of equipment involved with the storage, transfer, and use of LNG surpasses that of comparable diesel equipment. One interviewee stated, “You don’t want to handle LNG any more than absolutely necessary.” On-site expertise would be needed in Alaskan communities to handle LNG, connect it to tanks, etc. Operators or engineers who currently operate diesel-fired units are the most likely candidates for the long-term operation of LNG-fired units, but initial training on LNG or dual fuel systems and access to technical support from the company installing the retrofit kit or new LNG or dual fuel system would probably be required.

Storage: In Alaska, vapor dispersion and heat radiation calculations determine the minimum radius around storage/vaporization facilities. FERC, AK DOTPF, and National Fire Protection Association (NFPA 59A) codes all can influence these calculations. A few interviewees indicated that finding appropriate storage locations likely would not be difficult in most Alaskan communities.

The maximum holding time for LNG can vary depending on the type of tank in which the LNG is stored, as well as whether and at what frequency gas draw-off (use) occurs. Interviewees provided maximum holding times ranging from 30 days to 110 days. For LNG to hold for a longer period of time, an ISO tank with additional insulation can be procured. However, this reduces the volume of LNG that can be shipped. However, ISO tanks can include technology that provides automated digital reporting that alerts off-site engineers if there is a problem with tank pressure (or another issue). The off-site engineer can then contact the on-site operator to address the issue.

In the hub-and-spoke model, LNG also could be stored in larger vertical tanks in the hub communities and distributed to the smaller spoke communities via ISO tank.

“Bullet” tanks are more permanent storage vessels than ISO tanks and are available in a wide range of sizes. They allow for some boil-off and are constructed with vacuumed steel. The largest bullet tanks can hold up to 500,000 gallons of LNG; those up to 250,000 gallons in capacity can be moved around. Bullet tanks typically allow for longer storage times of up to 110 days.

Refilling ISO tanks: Tanks that are refilled less frequently take longer to refill because they warm up more than tanks whose contents are used and then refilled more quickly. A typical faster tank refill will take about 45 minutes, while a slower refill can take around 4.5 hours.

Conversion: Conversion to natural gas for electrical generation requires a significant capital investment. The most likely candidates for conversions to natural gas include generators that can be retrofitted with dual fuel (diesel and LNG) kits or older diesel gensets that are nearing the end of their lifetime and need to be replaced. Dual fuel systems can accommodate variable loads more effectively than straight gas-fired systems, but natural gas can provide at most 65-70 percent of the fuel consumed by dual fuel systems. The CAT 3500 series of gensets have a proven record of successful conversion to dual fuel capacity. The retrofit kits can use propane, as well as LNG.

Community-level Expertise: Smaller utilities may lack the capacity in terms of personnel to thoroughly evaluate and plan conversion to LNG for electrical generation. These utilities may rely on the expertise and resources of the potential LNG distributor or, if available, the state to assess the economics and technical requirements of conversion.

Regulatory/Other Barriers

There is a lack of consistency with respect to units of measure for LNG. MMBtu’s are used across the LNG industry, with Mcf are used in Cook Inlet, joules in Canada, and gallons elsewhere.

Primarily because commercial buildings/accounts receive no PCE funding, the energy demand of commercial buildings in many Alaskan communities is largely unknown. Other members of the project team are developing a model among whose goals is the estimation of energy demand for commercial buildings in study communities. In addition, AHFC has conducted extensive energy audits that may provide initial commercial demand estimates.

The RCA likely is to be reactive rather than proactive in its regulation of LNG as a potential fuel for power generation outside the Railbelt.

Laws and regulations pertaining to LNG storage are not anticipated to be a significant barrier. FERC could assert jurisdiction in certain cases, particularly if new material infrastructure associated with LNG transport is constructed, but the Commission's involvement is not anticipated to represent a major hurdle. Generally, FERC defers to local and state regulations governing the transportation of hazardous materials if they address the full extent of the supply chain. Standardized protocols associated with the handling of LNG ISO tanks do exist.

Even though natural gas burns more cleanly than diesel, utilities can encounter significant delays in obtaining air quality permits for LNG/diesel dual fuel use from the Alaska Department of Environmental Conservation (ADEC). It is believed that these delays are due to variability in the ratio of the two fuels burned over time; however, the study team will seek clarification on this matter from ADEC directly. The attainment of ADEC air quality permits by first-time users of LNG in dual fuel systems may need to be outsourced to third-party consultants familiar with the permitting process, which would incur a cost to the utility.

Appendix C: Phase 1 Methodology Basis of Estimate

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PHASE 1 METHODOLOGY
BASIS OF ESTIMATE

Prepared for:

Alaska Energy Authority

Liquefied Natural Gas

Feasibility Study

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June 6, 2016

REVISION HISTORY

Rev.	Date	Comments	Prepared by:	Checked by:	Approved by:
1	5/25/2016	Final to NEI	J. Suttie	V. Fernandez	D. Christianson
2	6/06/2016	AEA comments addressed	J. Suttie	V. Fernandez	D. Christianson

TABLE OF CONTENTS

Attachment 2 Detailed Transportation, Capital, and Operational Costs, Full Residential Energy Demand, CY 2017

1. Introduction

The purpose of this report is to complete designated Phase 1: Liquefied Natural Gas (LNG) Storage Cost and Requirements Analysis. This task is a component of the request from the Alaska Energy Authority (AEA) to create a cost model for supply of LNG to be sited in Alaska communities located off the Rail belt. LNG supply will be trucked and/or barged to locations for use as the primary fuel source for residential heating and/or electrical generation. This report addresses:

1. LNG CAPEX and OPEX storage costs, including infrastructure, boil-off constraints, and regulatory requirements.
2. CAPEX and OPEX costs of LNG for energy, including regasification, generator conversion, piped distribution systems, and furnace/boiler conversion.
3. Other potential benefits of LNG such as fish processing refrigeration.
4. Barriers to LNG delivery and use.

The cost estimate presented in this report is a Class 5 cost estimate as defined by the Association for the Advancement of Cost Engineering (AACE). A Class 5 estimate is typically applied for a project where the design is 0-2% complete and has an expected accuracy range of +50% to -30%.

2. LNG Storage Costs And Requirements

2.1 Infrastructure

Infrastructure includes tankage, regasification equipment, pads and/or foundations, associated equipment such as headers and manifolds to allow for distribution, and fencing. Two LNG tank options were considered: 1) portable International Organization for Standardization (ISO) tanks and, 2) permanent tanks. The capacity, weights, and hold times (the time of the pressure increase in the tank measured from the starting pressure up to the maximum allowable working pressure (MAWP) of the tank) for each LNG tank option are described below:

2.1.1 LNG ISO Tank

LNG ISO tanks are insulated, pressure rated, modular containers designed to hold low-temperature LNG (Figure 1). Their modular nature allows them to be transported by rail, water, and road. For this study, the ISO tanks are assumed to be 40 feet in length with a 12,000-gallon capacity, and with unloaded and loaded weights of 30,000 pounds and 72,000 pounds, respectively. The hold time of the ISO tanks are typically 70 to 90 days. A price quote for a 12,000 gallon LNG ISO tank provided by Cryotech is shown in Table 1.

Figure 1. LNG ISO Tank and Tractor Trailer

Source: http://lngisocontainer.com/

Table 1. LNG ISO Tank Cost

Tank Capacity	Capital Cost
12,000 Gallons	$175,000

2.1.2 Permanent LNG Tank with Cryopumps

A permanent LNG tank consists of a tank erected and permanently installed on site. The tank is assumed to include cryopumps that indefinitely limit the hold time of the tanks. The estimate is based upon a "Full Containment" type as the most cautious cost approach. Full containment LNG tanks are configured as: Inner open topped main tank of 9% Ni Steel and a secondary fully enclosed concrete tank bottom, walls, and cover. The outer concrete tank provides primary vapor containment and the inner tank provides liquid containment. Full containment tanks are significantly more expensive than single containment LNG tanks. However, full containment tanks do not require land areas for external lined earthen dikes needed to meet regulatory requirements for secondary containment, which present added costs, nor do they usually have significant associated siting and permitting risks.

Supply and installation cost estimates for LNG storage tanks were developed from historical total installed cost data points that were provided by a world-scale designer, manufacturer and constructor of its own line of proprietary-engineered LNG storage tanks systems. A 5,000,000-gallon tank is assumed to be the smallest practical and cost-effective size. Cost data was estimated from the data points and related factored facility costs as shown in Table 2. The data represents Alaskan installed costs.

Table 2. Permanent LNG Tank Price Points

Description	m^3	Gallons	Capital Cost	Cost / Gallon
LNG Storage Tank Full Containment w/ cryopumps	166,540	44,000,000	$135,000,000	$3.07
LNG Storage Tank Full Containment w/ cryopumps	28,388	7,500,000	$60,000,000	$8.00

Cost estimates for permanent tanks are shown in Table 3.

Table 3. Permanent LNG Tank Costs

Description	Capital Cost
5,000,000 Gal LNG Tank	$40,000,000

2.1.3 Supporting Infrastructure

Supporting infrastructure comprises the site development needed to allow the LNG ISO tanks to function as intended. This includes labor, materials, and freight to construct the pad, foundation, manifold, vaporizer, and security fencing. The supporting infrastructure cost only applies to the LNG ISO tank applications. These costs are accounted for differently for the permanent tanks as described below in the Associated Balance of Plant section. Thermax, Incorporated provided cost data for the vaporizers. The estimated costs for supporting infrastructure are shown in Table 4.

Table 4 Supporting Infrastructure Costs

Description	Capital Cost
Labor and Materials per ISO Tank	$13,000
Manifold (1 per site)	$30,000
Vaporizer (2 per site)	$35,000 each; $70,000 total per site

2.1.4 Associated Balance of Plant

The associated balance of plant covers the site development needed to allow the permanent LNG tanks to function as intended. It includes items such as the pad, foundation, yard piping, manifold, vaporizer, and security fencing. The estimated cost is shown in Table 5.

Table 5. Associated Balance of Plant Cost

Description	Capital Cost
Associated Balance of Plant	25% of Tank Cost

2.1.5 Ground Conditioning

Ground conditioning mitigates unsatisfactory soil conditions at the permanent LNG tank locations. Potential unsatisfactory soil conditions include subsurface ice or permafrost, surcharging and related soil consolidation measures, and liquefaction during a seismic event. The cost for a 5,000,000 gallon tank is shown in Table 6.

Table 6. Ground Conditioning Cost for 5,000,000 Gallon Tank

Description	Capital Cost
Ground Conditioning	$5,000,000

2.1.6 Distribution Piping

The distribution piping includes the distribution lines and services lines needed to distribute the gas from the tanks to individual structures. The costs were based on the 2012 Fairbanks North Star Borough Gas Distribution System Analysis. The costs were adjusted to 2016 prices and were increased by 40% due to the additional costs of working off the Rail belt. The costs per structure, inclusive of pipes and valves, are shown in Table 7.

Table 7. Distribution Piping Costs

Description	Capital Cost per Structure
Distribution Lines	$16,800
Service Lines	$7,000
Total	$23,800

2.1.7 Unknown Cost

The unknown cost calculation is used to cover the uncertainty and variability associated with a cost estimate, as well as unforeseeable elements of cost within the defined project scope. The unknown cost covers field uncertainties, inadequacies in complete project scope definition, estimating methods, and estimating data. Unknown cost specifically excludes changes in project scope and unforeseen major events such as earthquakes, prolonged labor strikes, weather delays, etc. The amount of unknown cost is based on the AACE class 5 estimate and is shown in Table 8.

Table 8. Unknown Cost

Description	Capital Cost
Unknown Cost	30%

2.1.8 Boil Off Constraints

Boil-off occurs as the LNG warms, expands, and increases pressure in the tank. LNG ISO tanks have typical boil-off rates of 0.2% to 0.3% per day, depending on how well they are insulated. A 0.3% per day boil-off rate equates to 36 gallons per day for a full 12,000-gallon tank. The boil-off product loss decreases as the tank empties, through either product use or boil-off.

2.1.9 LNG ISO Tank Cost Summary

Table 9 summarizes the cost components for an LNG ISO tank. The table does not include the distribution and service piping costs since they vary depending on the number of service connections. The table does not total the costs since two of the items are a function of the number of tanks and one item is a function of the number of sites. Totaling the values would not provide a meaningful number.

Table 9. Permanent LNG Tank Cost Summary

Description	Capital Cost	Notes
LNG ISO Tank	$175,000	Each per tank
Supporting Infrastructure – labor and materials	$13,000	Each per tank
Supporting Infrastructure – Manifold and Vaporizer	$100,000	Each per site

2.1.10 Permanent LNG Tank Cost Summary

Table 8 summarizes the cost components for a permanent LNG tank. The table does not include the distribution and service piping costs since they vary depending on the number of service connections.

Table 10. Permanent LNG Tank Cost Summary

Description	Capital Cost	Notes
5,000,000 Gal LNG Tank	$40,000,000	Each
Associated Balance of Plant	$10,000,000	25% of Tank Cost
Ground Conditioning	$5,000,000	Each per tank
Subtotal Capital Costs	$55,000,000	
Unknown Cost	$16,500,000	30% of Capital Cost
Subtotal Capital Costs	$71,500,000	
Permitting & Engineering	$7,150,000	5% each, 10% total
Total CAPEX	**$78,650,000**	

2.2 Regulatory and Engineering Requirements and Costs

These costs cover labor and fees for regulatory permits and labor for engineering. Regulatory requirements will vary from site to site depending on specific impacts and federal, state and local regulations. Potential required permits are listed below.

1. State of Alaska, Division of Mining Land and Water: Temporary Land Use Permit and Right of Way (ROW) across state land
2. Alaska Department of Transportation and Public Facilities (ADOT&PF): ROW permit for construction on or across DOT&PF ROW
3. Alaska Department of Fish and Game: Fish Habitat Permits for Water Withdrawal, mechanized stream crossing or work within stream channel
4. Alaska Department of Environmental Conservation: Alaska Pollutant Discharge Elimination System Construction General Permit, Excavation Dewatering, Contained Water (Hydrostatic test water)
5. Section 401 Water Quality Certification of the USACE Section 404/10 permit
6. Mental Health Trust ROW
7. University of Alaska ROW
8. ROW permission from individual landowners

Additionally, by definition, any ISO tank should comply with United States Coast Guard (USCG) and DOT requirements for safe transport. These requirements are detailed in CG-ENG Policy Letter 02-15, entitled *Design Standards for U.S. Barges intending to Carry Liquefied Natural Gas in Bulk*, and can be accessed via the World Wide Web[1].

Safety of LNG facilities is provided by four features:

1. Primary containment provided by appropriately designed and constructed tanks.
2. Secondary containment which isolates spilled LNG from the public.

[1] CG-ENG Policy Letter 02-15 (http://www.uscg.mil/hq/cg5/lgcncoe/designLNGfuel.asp)

3. Operational safety systems incorporated into the facilities such as alarms, leak detection, fire suppression, and shut down systems.
4. Separation distances between LNG facilities and the public, as regulated by CFR 49, Part 193. This regulation includes requirements for a thermal radiation protection zone and a flammable vapor dispersion exclusion zone.

The estimated regulatory and engineering costs are shown in Table 10.

Table 10. Regulatory and Engineering Costs

Description	Capital Cost
Regulatory Cost	5%
Engineering Cost	5%
Total	10%

3. Using LNG for Energy

3.1 Regasification

Regasification is the process of converting LNG to natural gas. Regasification is accomplished using LNG vaporizers which are heat exchangers that are able to increase the temperature of the LNG beyond its boiling point. Common vaporizer types include ambient air heated, steam heated, water heated, gas or diesel fire heated, open rack, and submerged combustion. Vaporizers can be either permanently installed units or mobile truck mounted units. The appropriate vaporizer type depends on climate, available heating source, and site regulations.

An ambient air heated vaporizer is an appealing option for small rural communities as it has no moving parts, requires no external energy, and requires little maintenance. However, the efficiency of these systems in Alaska is severely constrained due to the state's colder climate. A trim heater will be required to make the ambient air vaporizer functional during the winter. The trim heater operation will increase the energy demand for each community. Bill Carter of Thermax, Incorporated indicated that two of their SG95HF vaporizers would be appropriate for a community with a demand of 100,000 gal LNG/year and that two of their SG1150HF vaporizers would be appropriate for a community with a demand of 1,000,000 gal LNG/year. An ambient air vaporizer is shown in Figure 2. A mobile vaporizer is shown in Figure 3.

Figure 2. Ambient Air Vaporizer

Source: http://cryonorm.com/en/t/lng-ambient-air-vapor

Figure 3. Mobile Vaporizer

Source: http://cryonorm.com/en/t/lng-mobile-vaporizing-unit/175

3.2 Electricity

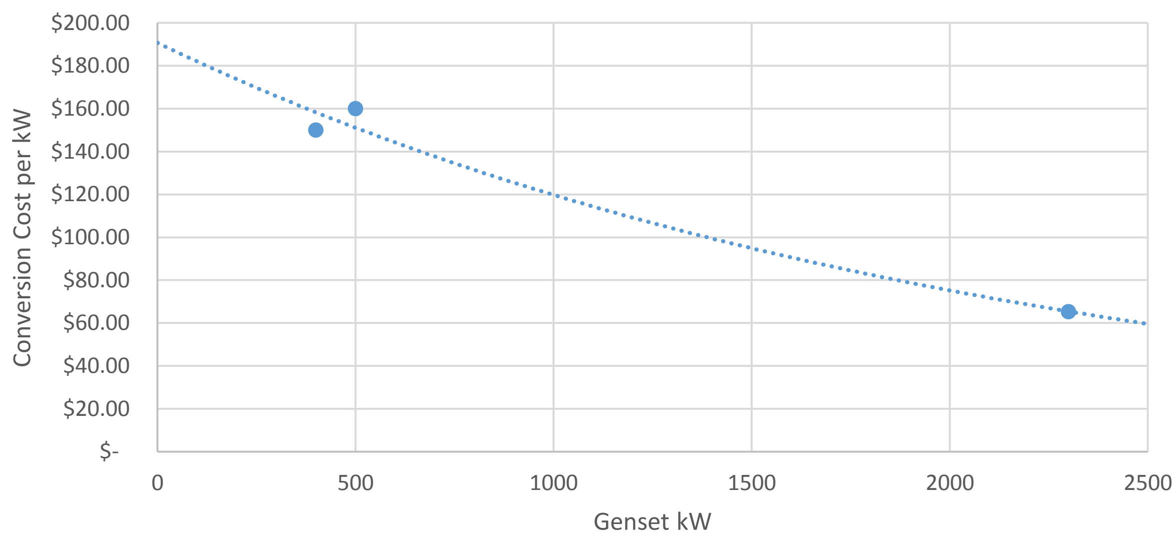
Considerations and costs for converting existing diesel generators to dual fuel systems were investigated. Eden Innovations has developed a dual fuel kit that allows a generator to run on both diesel and natural gas fuels. They have used this kit on a 500 kW Caterpillar generator. The cost of the kit is approximately $40,000 and the installation cost is approximately $40,000. Another interviewee reported a cost range for acquisition and installation of $60,000 to $150,000 per retrofit kit for capacities between 400 kW and 2.3 MW, respectively. According to Eden Innovations, conversion installation is relatively complicated. Cost data points for conversion kits are shown in Table 11.

Table 11. Generator Conversion Costs

Description	Capital Cost	Cost/kW
400 kW	$60,000	$150
500 kW	$80,000	$160
2.3 MW	$150,000	$65

A trend line was fitted to the data in Table 11 to produce an equation that could be used to estimate the conversion cost based on the size of generator. The trend line and its equation are shown in Figure 3 (note: the generator capacity variable uses kW for units in the equation). The equation was applied to a list of known generators by community as provided by AEA provided to estimate the capital cost of conversion.

Figure 3. Genset Conversion Costs Estimator



$$\textit{Conversion Cost} = 190.71e^{-0.0005\,\textit{Generator Capacity}}\ x\ \textit{Generator Capacity}$$

Caterpillar has identified specific manufacturers for dual fuel conversion kits for their range of engine sizes. Dual fuel combustion requires engines to run at least 50 degrees Fahrenheit hotter than normal and places a greater demand on the engine cooling system that may exceed the capacity of the as-manufactured engine. An efficiency de-rating factor of 10% to 15% occurs when running a dual fuel generator. Dual fuel generators also sometimes experience “methane slip,” an incomplete combustion where a portion of the natural gas stream is not ignited and is released as methane. Conversion from diesel to nearly exclusive spark ignition natural gas combustion will have a high unit cost, de-rated thermal efficiency, and higher operations and maintenance (O&M) cost that may make more economical the initial replacement of the entire in-place generator, especially in the case of lower kW units.

Information was not available for the conversion kit costs for generators of other sizes, specific O&M costs, or the impact to existing diesel generator heat recovery systems. The conversion kits do not appreciably change the size of the generators and therefore no new powerhouses are assumed to be required.

3.3 Heat

A piped distribution system would consist of a low pressure (i.e. 60 psi) distribution line and service lines. The distribution lines would carry natural gas from the tanks to the service lines that connect to individual structures. Meters and valves would be installed at service lines near the individual structures. The pipe would likely be 5/8-inch to 1-inch high density polyethylene (HDPE) pipe. The estimated costs for the distribution system were discussed previously, in Section 1 of this report.

Costs for businesses and homeowners to convert to a natural gas heating system are estimated at $9,000 each[2]. This cost only applies to natural gas heating systems with distributed supply.

4. Other Potential Benefits

Norman Van Vactor, CEO of the Bristol Bay Economic Development Corporation (BBEDC) was contacted to discuss the feasibility of using LNG for powering chillers at seafood processing plants. Before coming to BBEDC ~3 years ago, Mr. Vactor worked in the seafood processing industry for 30 years, much of that time for Peter Pan Seafoods (N. Van Vactor, personal communication, March 2016). According to Mr. Vactor, most of the seafood processors in Bristol Bay power their facility off the local grid and using LNG for chilling probably would not be a viable option.

Mr. Vactor also mentioned that two processors in Naknek, Trident Seafoods and Red Salmon are still producing their own power with diesel: Attempts to contact them were not successful. Remote fish processing plants rely exclusively on diesel for all energy generation. Attempts to contact Peter Pan Seafoods were not successful.

LNG use for refrigeration at seafood processing plants is technically feasible, but data regarding the demand and costs was not available.

Using waste cold from regasification for refrigeration is not realistic due to the small scale.

5. Barriers to LNG Delivery

5.1 Logistics

The most significant constraint to using LNG ISO tanks as an energy source for communities off the Rail belt is the limited hold time. The maximum hold time of the ISO tanks is approximately 90 days, meaning 90 days after filling the tank, the LNG will warm and expand to the point that the pressure in the tank exceeds the MAWP of the tank and the pressure relief valve opens releasing the product to the atmosphere. As a result, ice-bound communities without road access are poor candidates for year-round energy via LNG ISO tanks only. ISO tanks delivered to these communities in the fall will exceed their MAWP early in the following year before replacement ISO tanks can be delivered. The minimum

[2] Source: Interior Energy Project (http://www.interiorenergyproject.com/conversion_faqs.html#two)

number of ice-free days required for feasibility is assumed to be 280 to 320 when accounting for hold and transport time.

6. Cost Summary

6.1 Demand

Community heating and electricity demand estimates in annual MMBtu were provided by AEA. These were converted to gallons of LNG at 12.1 gallons of LNG per MMBtu. Communities with a minimum annual demand of 5,000,000 gallons of LNG were assumed to receive a permanent tank with cryopumps. Five communities met this criteria: Juneau, Sitka, Ketchikan, Kodiak and Valdez. Communities with lesser demand were assumed to receive LNG ISO tanks.

6.2 Quantity of Tanks

The five communities with demand greater than 5,000,000 gallons can be serviced by a single 5,000,000-gallon tank. These communities have year round ice-free ports and can be supplied at regular intervals by ships.

The quantity of tanks required at other communities was determined based on the number of 12,000 gallon ISO tanks required to meet the estimated demand. This quantity was adjusted based the 90-day hold time constraint and the assumption that one tank should always to be on-line, i.e. turning off the local supply of LNG when replacing tanks is not desirable. Consequently, the minimum number of ISO tanks per community is five or the demand based number plus one. The number of ISO tanks per community was further reduced based on redundancy of ISO tanks that are exchanged on a regular basis, i.e. a community may require 20 ISO tanks per annum, but in reality they may only need a maximum of nine ISO tanks for the coldest three months of the year. Consequently, the actual number of tanks required per community was estimated at one-half the minimum number based on demand.

6.3 Transportation Costs

Annual transportation costs were estimated based on a haul cost of $0.00020/lb.-mile for barging and $0.00013/lb.-mile for trucking. These costs include either the LNG and ISO tanks or just the LNG depending on the tank type. These costs cover the labor and equipment to load, transport and handle the materials. Travel distances were estimated using Google Earth. The LNG source was assumed to be Nikiski for communities west of Yakutat. Communities east of Yakutat were assumed to be served by a source in British Columbia (B.C.). It should be noted, that the distance from both B.C. and Nikiski to Yakutat is about 550 miles.

6.4 Capital Costs

Capital costs are estimated based on the information provided in section 1 of this report. They include the tank costs, associated balance of plant, supporting infrastructure, on-site installation, distribution piping, generator dual fuel conversion, and unknown costs.

6.5 Operational Costs

Annual operational costs are estimated at 5% of the capital costs.

Attachment 1 and Attachment 2 summarize and detail, respectively, estimated transportation, capital, and operational costs in CY 2017 for LNG-based heating and electrical generation systems for all non-ice-bound communities. These estimates reflect residential demand only and are based on output from an earlier iteration of the Residential (demand) Model, provided to Northern Economics Incorporated (NEI) and Michael Baker by Neil McMahon. They differ from NEI's transportation, capital, and operational cost estimates because the latter incorporate non-residential demand, as well as energy demand for water/wastewater plant operations. Further, Michael Baker's estimates implicitly assume the complete substitution of existing fuels for heating and electrical generation with LNG, while NEI's estimates factor in technical constraints and assumptions that limit the amount of energy supplied by LNG.

Michael Baker generated their cost estimates with the best (and only) data available to them. NEI adapted the per-unit costs and methodologies provided by Michael Baker to a more comprehensive estimation of costs (based on residential *and* non-residential demand, as well as forecasted annual demand), with the benefit of robust demand forecasts from AEA.

7. References

Bill Carter. (May 6, 2016) Personal Interview.

Cryonorm BV. Accessed on April 14, 2016. http://cryonorm.com/en/t/lng-ambient-air-vapor

Interior Energy Project. Conversion FAQs. Accessed on April 15, 2016. http://www.interiorenergyproject.com/conversion_faqs.html#two

LNG ISO Containers. Corb Energy Group. Accessed on April 13, 2016. http://lngisocontainer.com/

Norman Van Vactor. (March 25, 2016) Personal Interview.

Northern Economics. Fairbanks North Star Borough Gas Distribution System Analysis. June 29, 2012.

United States Coast Guard. Design of Ships Using LNG as Fuel. Design Standards for U.S. Barges Intending to Carry Liquefied Natural Gas in Bulk, CG-ENG Policy Letter 02-15. Accessed on April 13, 2016. http://www.uscg.mil/hq/cg5/lgcncoe/designLNGfuel.asp

Attachment 1:

Summary of Transportation, Capital, and Operational Costs, Full Residential Energy Demand, CY 2017

Community	Annual Demand in Gallons LNG	Actual No. Tanks Req'd per Community	Size of Tank	Annual Transport Cost	Tank, Piping and Related Improvements Cost	Dual Fuel Conversion Cost	30% Unknown Cost	Permitting and Engineering Cost	CAPEX -50%	CAPEX	Capex +30%	OPEX
Adak	132,556	7	12,000 Gal	$ 149,760	$ 2,463,200	$ 504,000	$ 890,160	$ 385,736	$ 2,121,548	$ 4,243,096	$ 5,516,025	$ 212,155
Akhiok	44,299	3	12,000 Gal	$ 14,400	$ 1,116,200	$ 71,000	$ 356,160	$ 154,336	$ 848,848	$ 1,697,696	$ 2,207,005	$ 84,885
Akutan	41,392	3	12,000 Gal	$ 57,600	$ 1,616,000	$ 72,000	$ 506,400	$ 219,440	$ 1,206,920	$ 2,413,840	$ 3,137,992	$ 120,692
Alcan Border	53,544	3	12,000 Gal	$ 32,573	$ 1,044,800	$ -	$ 313,440	$ 135,824	$ 747,032	$ 1,494,064	$ 1,942,283	$ 74,703
Aleneva	20,984	3	12,000 Gal	$ 14,400	$ 878,200	$ -	$ 263,460	$ 114,166	$ 627,913	$ 1,255,826	$ 1,632,574	$ 62,791
Angoon	272,944	12	12,000 Gal	$ 120,960	$ 6,330,600	$ 232,000	$ 1,968,780	$ 853,138	$ 4,692,259	$ 9,384,518	$ 12,199,873	$ 469,226
Atka	21,801	3	12,000 Gal	$ 57,600	$ 1,235,200	$ 60,000	$ 388,560	$ 168,376	$ 926,068	$ 1,852,136	$ 2,407,777	$ 92,607
Bettles	30,119	3	12,000 Gal	$ 36,036	$ 878,200	$ 104,000	$ 294,660	$ 127,686	$ 702,273	$ 1,404,546	$ 1,825,910	$ 70,227
Central	173,900	8	12,000 Gal	$ 97,344	$ 2,865,400	$ 100,000	$ 889,620	$ 385,502	$ 2,120,261	$ 4,240,522	$ 5,512,679	$ 212,026
Chenega Bay	106,803	5	12,000 Gal	$ 36,000	$ 1,777,800	$ 60,000	$ 551,340	$ 238,914	$ 1,314,027	$ 2,628,054	$ 3,416,470	$ 131,403
Chicken	16,733	3	12,000 Gal	$ 26,676	$ 783,000	$ -	$ 234,900	$ 101,790	$ 559,845	$ 1,119,690	$ 1,455,597	$ 55,985
Chignik	168,214	8	12,000 Gal	$ 276,480	$ 3,912,600	$ 267,000	$ 1,253,880	$ 543,348	$ 2,988,414	$ 5,976,828	$ 7,769,876	$ 298,841
Chistochina	119,226	6	12,000 Gal	$ 41,184	$ 2,084,800	$ 40,000	$ 637,440	$ 276,224	$ 1,519,232	$ 3,038,464	$ 3,950,003	$ 151,923
Chitina	174,651	8	12,000 Gal	$ 62,899	$ 2,841,600	$ 62,000	$ 871,080	$ 377,468	$ 2,076,074	$ 4,152,148	$ 5,397,792	$ 207,607
Circle	123,007	6	12,000 Gal	$ 78,624	$ 2,180,000	$ 40,000	$ 666,000	$ 288,600	$ 1,587,300	$ 3,174,600	$ 4,126,980	$ 158,730
Coffman Cove	219,799	10	12,000 Gal	$ 43,200	$ 4,098,200	$ 107,000	$ 1,261,560	$ 546,676	$ 3,006,718	$ 6,013,436	$ 7,817,467	$ 300,672
Cold Bay	85,750	5	12,000 Gal	$ 103,680	$ 2,134,800	$ 321,000	$ 736,740	$ 319,254	$ 1,755,897	$ 3,511,794	$ 4,565,332	$ 175,590
Coldfoot	20,079	3	12,000 Gal	$ 36,738	$ 806,800	$ -	$ 242,040	$ 104,884	$ 576,862	$ 1,153,724	$ 1,499,841	$ 57,686
Copper Center	540,789	24	12,000 Gal	$ 160,571	$ 7,539,400	$ -	$ 2,261,820	$ 980,122	$ 5,390,671	$ 10,781,342	$ 14,015,745	$ 539,067
Cordova	2,735,382	115	12,000 Gal	$ 1,154,160	$ 43,663,600	$ 630,000	$ 13,288,080	$ 5,758,168	$ 31,669,924	$ 63,339,848	$ 82,341,802	$ 3,166,992
Covenant Life	89,005	5	12,000 Gal	$ 58,320	$ 1,873,000	$ -	$ 561,900	$ 243,490	$ 1,339,195	$ 2,678,390	$ 3,481,907	$ 133,920
Craig	973,941	42	12,000 Gal	$ 179,280	$ 19,182,000	$ 469,000	$ 5,895,300	$ 2,554,630	$ 14,050,465	$ 28,100,930	$ 36,531,209	$ 1,405,047
Dillingham	2,093,439	88	12,000 Gal	$ 3,041,280	$ 36,993,000	$ -	$ 11,097,900	$ 4,809,090	$ 26,449,995	$ 52,899,990	$ 68,769,987	$ 2,645,000
Dot Lake	87,011	5	12,000 Gal	$ 46,332	$ 1,658,800	$ -	$ 497,640	$ 215,644	$ 1,186,042	$ 2,372,084	$ 3,083,709	$ 118,604
Dry Creek	97,049	5	12,000 Gal	$ 51,480	$ 1,730,200	$ -	$ 519,060	$ 224,926	$ 1,237,093	$ 2,474,186	$ 3,216,442	$ 123,709
Eagle	236,700	11	12,000 Gal	$ 128,747	$ 3,881,600	$ 80,000	$ 1,188,480	$ 515,008	$ 2,832,544	$ 5,665,088	$ 7,364,614	$ 283,254
Edna Bay	45,774	3	12,000 Gal	$ 10,800	$ 1,092,400	$ -	$ 327,720	$ 142,012	$ 781,066	$ 1,562,132	$ 2,030,772	$ 78,107
Elfin Cove	33,059	3	12,000 Gal	$ 25,200	$ 973,400	$ 710,000	$ 505,020	$ 218,842	$ 1,203,631	$ 2,407,262	$ 3,129,441	$ 120,363
Excursion Inlet	15,258	3	12,000 Gal	$ 25,200	$ 806,800	$ -	$ 242,040	$ 104,884	$ 576,862	$ 1,153,724	$ 1,499,841	$ 57,686
False Pass	28,085	3	12,000 Gal	$ 57,600	$ 1,021,000	$ 73,000	$ 328,200	$ 142,220	$ 782,210	$ 1,564,420	$ 2,033,746	$ 78,221
Gakona	231,277	11	12,000 Gal	$ 72,727	$ 4,214,800	$ -	$ 1,264,440	$ 547,924	$ 3,013,582	$ 6,027,164	$ 7,835,313	$ 301,358
Game Creek	17,801	3	12,000 Gal	$ 25,200	$ 830,600	$ -	$ 249,180	$ 107,978	$ 593,879	$ 1,187,758	$ 1,544,085	$ 59,388
Glennallen	419,987	18	12,000 Gal	$ 67,392	$ 8,315,400	$ -	$ 2,494,620	$ 1,081,002	$ 5,945,511	$ 11,891,022	$ 15,458,329	$ 594,551
Gulkana	110,911	6	12,000 Gal	$ 37,066	$ 2,084,800	$ -	$ 625,440	$ 271,024	$ 1,490,632	$ 2,981,264	$ 3,875,643	$ 149,063
Gustavus	469,746	21	12,000 Gal	$ 206,640	$ 9,093,600	$ 138,000	$ 2,769,480	$ 1,200,108	$ 6,600,594	$ 13,201,188	$ 17,161,544	$ 660,059
Haines	2,761,389	116	12,000 Gal	$ 1,503,360	$ 40,519,600	$ -	$ 12,155,880	$ 5,267,548	$ 28,971,514	$ 57,943,028	$ 75,325,936	$ 2,897,151
Hobart Bay	2,543	3	12,000 Gal	$ 23,040	$ 687,800	$ -	$ 206,340	$ 89,414	$ 491,777	$ 983,554	$ 1,278,620	$ 49,178
Hollis	99,837	5	12,000 Gal	$ 21,600	$ 2,087,200	$ 69,000	$ 646,860	$ 280,306	$ 1,541,683	$ 3,083,366	$ 4,008,376	$ 154,168
Hoonah	778,840	33	12,000 Gal	$ 332,640	$ 13,563,000	$ -	$ 4,068,900	$ 1,763,190	$ 9,697,545	$ 19,395,090	$ 25,213,617	$ 969,755
Hydaburg	191,724	9	12,000 Gal	$ 36,720	$ 4,838,400	$ 255,000	$ 1,528,020	$ 662,142	$ 3,641,781	$ 7,283,562	$ 9,468,631	$ 364,178
Hyder	122,064	6	12,000 Gal	$ 34,560	$ 2,370,400	$ -	$ 711,120	$ 308,152	$ 1,694,836	$ 3,389,672	$ 4,406,574	$ 169,484
Ivanof Bay	4,141	3	12,000 Gal	$ 86,400	$ 711,600	$ 60,000	$ 231,480	$ 100,308	$ 551,694	$ 1,103,388	$ 1,434,404	$ 55,169
Juneau	31,367,469	1	5,000,000 Gal	$ 7,663,073	$ 345,050,600	$ -	$ 103,515,180	$ 44,856,578	$ 246,711,179	$ 493,422,358	$ 641,449,065	$ 24,671,118
Kake	486,209	21	12,000 Gal	$ 151,200	$ 9,117,400	$ 304,000	$ 2,826,420	$ 1,224,782	$ 6,736,301	$ 13,472,602	$ 17,514,383	$ 673,630
Karluk	21,406	3	12,000 Gal	$ 14,400	$ 949,600	$ 40,000	$ 296,880	$ 128,648	$ 707,564	$ 1,415,128	$ 1,839,666	$ 70,756
Kasaan	18,964	3	12,000 Gal	$ 10,800	$ 1,211,400	$ 62,000	$ 382,020	$ 165,542	$ 910,481	$ 1,820,962	$ 2,367,251	$ 91,048

Community	Annual Demand in Gallons LNG	Actual No. Tanks Req'd per Community	Size of Tank	Annual Transport Cost	Tank, Piping and Related Improvements Cost	Dual Fuel Conversion Cost	30% Unknown Cost	Permitting and Engineering Cost	CAPEX -50%	CAPEX	Capex +30%	OPEX
Kenny Lake	369,896	16	12,000 Gal	$ 119,808	$ 6,559,000	$ -	$ 1,967,700	$ 852,670	$ 4,689,685	$ 9,379,370	$ 12,193,181	$ 468,969
Ketchikan	7,719,425	1	5,000,000 Gal	$ 808,224	$ 132,564,200	$ -	$ 39,769,260	$ 17,233,346	$ 94,783,403	$ 189,566,806	$ 246,436,848	$ 9,478,340
King Cove	356,506	16	12,000 Gal	$ 357,120	$ 7,415,800	$ 543,000	$ 2,387,640	$ 1,034,644	$ 5,690,542	$ 11,381,084	$ 14,795,409	$ 569,054
King Salmon	444,244	20	12,000 Gal	$ 673,920	$ 7,596,600	$ -	$ 2,278,980	$ 987,558	$ 5,431,569	$ 10,863,138	$ 14,122,079	$ 543,157
Klawock	513,513	22	12,000 Gal	$ 95,040	$ 11,304,600	$ -	$ 3,391,380	$ 1,469,598	$ 8,082,789	$ 16,165,578	$ 21,015,251	$ 808,279
Klukwan	104,263	5	12,000 Gal	$ 64,800	$ 2,015,800	$ -	$ 604,740	$ 262,054	$ 1,441,297	$ 2,882,594	$ 3,747,372	$ 144,130
Kodiak	5,014,449	1	5,000,000 Gal	$ 700,017	$ 103,528,200	$ -	$ 31,058,460	$ 13,458,666	$ 74,022,663	$ 148,045,326	$ 192,458,924	$ 7,402,266
Kupreanof	38,145	3	12,000 Gal	$ 18,000	$ 1,021,000	$ -	$ 306,300	$ 132,730	$ 730,015	$ 1,460,030	$ 1,898,039	$ 73,002
Larsen Bay	74,907	4	12,000 Gal	$ 23,040	$ 1,661,200	$ 68,000	$ 518,760	$ 224,796	$ 1,236,378	$ 2,472,756	$ 3,214,583	$ 123,638
Livengood	23,426	3	12,000 Gal	$ 28,548	$ 830,600	$ -	$ 249,180	$ 107,978	$ 593,879	$ 1,187,758	$ 1,544,085	$ 59,388
Lutak	63,575	4	12,000 Gal	$ 45,360	$ 1,447,000	$ -	$ 434,100	$ 188,110	$ 1,034,605	$ 2,069,210	$ 2,689,973	$ 103,461
McCarthy	66,496	4	12,000 Gal	$ 31,450	$ 1,328,000	$ -	$ 398,400	$ 172,640	$ 949,520	$ 1,899,040	$ 2,468,752	$ 94,952
Mendeltna	65,460	4	12,000 Gal	$ 20,966	$ 1,304,200	$ -	$ 391,260	$ 169,546	$ 932,503	$ 1,865,006	$ 2,424,508	$ 93,250
Mentasta Lake	174,622	8	12,000 Gal	$ 67,392	$ 2,698,800	$ -	$ 809,640	$ 350,844	$ 1,929,642	$ 3,859,284	$ 5,017,069	$ 192,964
Metlakatla	659,240	28	12,000 Gal	$ 80,640	$ 17,097,400	$ -	$ 5,129,220	$ 2,222,662	$ 12,224,641	$ 24,449,282	$ 31,784,067	$ 1,222,464
Minto	167,661	8	12,000 Gal	$ 91,260	$ 3,151,000	$ 120,000	$ 981,300	$ 425,230	$ 2,338,765	$ 4,677,530	$ 6,080,789	$ 233,877
Mosquito Lake	350,933	16	12,000 Gal	$ 200,880	$ 6,392,400	$ -	$ 1,917,720	$ 831,012	$ 4,570,566	$ 9,141,132	$ 11,883,472	$ 457,057
Mud Bay	264,471	12	12,000 Gal	$ 155,520	$ 4,831,200	$ -	$ 1,449,360	$ 628,056	$ 3,454,308	$ 6,908,616	$ 8,981,201	$ 345,431
Naknek	332,354	15	12,000 Gal	$ 501,120	$ 8,417,800	$ -	$ 2,525,340	$ 1,094,314	$ 6,018,727	$ 12,037,454	$ 15,648,690	$ 601,873
Naukati Bay	116,875	6	12,000 Gal	$ 23,760	$ 2,394,200	$ 86,000	$ 744,060	$ 322,426	$ 1,773,343	$ 3,546,686	$ 4,610,692	$ 177,334
Nelson Lagoon	14,120	3	12,000 Gal	$ 57,600	$ 1,187,600	$ 67,000	$ 376,380	$ 163,098	$ 897,039	$ 1,794,078	$ 2,332,301	$ 89,704
Newhalen	82,428	4	12,000 Gal	$ 138,240	$ 2,042,000	$ 241,000	$ 684,900	$ 296,790	$ 1,632,345	$ 3,264,690	$ 4,244,097	$ 163,235
Nikolski	12,994	3	12,000 Gal	$ 57,600	$ 973,400	$ 60,000	$ 310,020	$ 134,342	$ 738,881	$ 1,477,762	$ 1,921,091	$ 73,888
Nondalton	77,644	4	12,000 Gal	$ 138,240	$ 2,208,600	$ -	$ 662,580	$ 287,118	$ 1,579,149	$ 3,158,298	$ 4,105,787	$ 157,915
Northway	223,911	10	12,000 Gal	$ 102,960	$ 3,098,600	$ 165,000	$ 979,080	$ 424,268	$ 2,333,474	$ 4,666,948	$ 6,067,032	$ 233,347
Old Harbor	175,391	8	12,000 Gal	$ 46,080	$ 3,603,200	$ 118,000	$ 1,116,360	$ 483,756	$ 2,660,658	$ 5,321,316	$ 6,917,711	$ 266,066
Ouzinkie	122,876	6	12,000 Gal	$ 34,560	$ 2,560,800	$ 73,000	$ 790,140	$ 342,394	$ 1,883,167	$ 3,766,334	$ 4,896,234	$ 188,317
Paxson	74,562	4	12,000 Gal	$ 31,824	$ 1,375,600	$ -	$ 412,680	$ 178,828	$ 983,554	$ 1,967,108	$ 2,557,240	$ 98,355
Pelican	130,914	6	12,000 Gal	$ 60,480	$ 2,203,800	$ 149,000	$ 705,840	$ 305,864	$ 1,682,252	$ 3,364,504	$ 4,373,855	$ 168,225
Perryville	68,257	4	12,000 Gal	$ 120,960	$ 1,756,400	$ 83,000	$ 551,820	$ 239,122	$ 1,315,171	$ 2,630,342	$ 3,419,445	$ 131,517
Petersburg	2,907,661	122	12,000 Gal	$ 878,400	$ 52,833,600	$ -	$ 15,850,080	$ 6,868,368	$ 37,776,024	$ 75,552,048	$ 98,217,662	$ 3,777,602
Point Baker	37,697	3	12,000 Gal	$ 10,800	$ 854,400	$ -	$ 256,320	$ 111,072	$ 610,896	$ 1,221,792	$ 1,588,330	$ 61,090
Pope-Vannoy Landing	6,212	3	12,000 Gal	$ 86,400	$ 735,400	$ -	$ 220,620	$ 95,602	$ 525,811	$ 1,051,622	$ 1,367,109	$ 52,581
Port Alexander	47,079	3	12,000 Gal	$ 10,800	$ 1,187,600	$ -	$ 356,280	$ 154,388	$ 849,134	$ 1,698,268	$ 2,207,748	$ 84,913
Port Alsworth	91,258	5	12,000 Gal	$ 155,520	$ 2,087,200	$ 82,000	$ 650,760	$ 281,996	$ 1,550,978	$ 3,101,956	$ 4,032,543	$ 155,098
Port Lions	170,863	8	12,000 Gal	$ 46,080	$ 3,436,600	$ -	$ 1,030,980	$ 446,758	$ 2,457,169	$ 4,914,338	$ 6,388,639	$ 245,717
Port Protection	61,724	4	12,000 Gal	$ 15,120	$ 1,470,800	$ -	$ 441,240	$ 191,204	$ 1,051,622	$ 2,103,244	$ 2,734,217	$ 105,162
Saint George	62,673	4	12,000 Gal	$ 80,640	$ 1,851,600	$ 164,000	$ 604,680	$ 262,028	$ 1,441,154	$ 2,882,308	$ 3,747,000	$ 144,115
Saint Paul	337,484	15	12,000 Gal	$ 345,600	$ 6,775,600	$ 395,000	$ 2,151,180	$ 932,178	$ 5,126,979	$ 10,253,958	$ 13,330,145	$ 512,698
Sand Point	425,934	19	12,000 Gal	$ 426,240	$ 9,526,800	$ 376,000	$ 2,970,840	$ 1,287,364	$ 7,080,502	$ 14,161,004	$ 18,409,305	$ 708,050
Saxman	227,505	10	12,000 Gal	$ 43,200	$ 4,836,000	$ -	$ 1,450,800	$ 628,680	$ 3,457,740	$ 6,915,480	$ 8,990,124	$ 345,774
Silver Springs	151,592	7	12,000 Gal	$ 45,864	$ 2,463,200	$ -	$ 738,960	$ 320,216	$ 1,761,188	$ 3,522,376	$ 4,579,089	$ 176,119
Sitka	7,726,970	1	5,000,000 Gal	$ 1,618,027	$ 139,371,000	$ -	$ 41,811,300	$ 18,118,230	$ 99,650,265	$ 199,300,530	$ 259,090,689	$ 9,965,027
Skagway	1,247,627	53	12,000 Gal	$ 680,400	$ 20,440,800	$ -	$ 6,132,240	$ 2,657,304	$ 14,615,172	$ 29,230,344	$ 37,999,447	$ 1,461,517
Slana	261,607	12	12,000 Gal	$ 91,494	$ 4,188,600	$ 123,000	$ 1,293,480	$ 560,508	$ 3,082,794	$ 6,165,588	$ 8,015,264	$ 308,279
Tanacross	124,918	6	12,000 Gal	$ 56,160	$ 2,489,400	$ -	$ 746,820	$ 323,622	$ 1,779,921	$ 3,559,842	$ 4,627,795	$ 177,992

Community	Annual Demand in Gallons LNG	Actual No. Tanks Req'd per Community	Size of Tank	Annual Transport Cost	Tank, Piping and Related Improvements Cost	Dual Fuel Conversion Cost	30% Unknown Cost	Permitting and Engineering Cost	CAPEX -50%	CAPEX	Capex +30%	OPEX
Tatitlek	118,096	6	12,000 Gal	$ 55,440	$ 2,084,800	$ 62,000	$ 644,040	$ 279,084	$ 1,534,962	$ 3,069,924	$ 3,990,901	$ 153,496
Tazlina	371,068	16	12,000 Gal	$ 106,330	$ 5,749,800	$ -	$ 1,724,940	$ 747,474	$ 4,111,107	$ 8,222,214	$ 10,688,878	$ 411,111
Tenakee Springs	182,044	9	12,000 Gal	$ 85,680	$ 3,505,600	$ -	$ 1,051,680	$ 455,728	$ 2,506,504	$ 5,013,008	$ 6,516,910	$ 250,650
Tetlin	95,794	5	12,000 Gal	$ 42,120	$ 2,063,400	$ -	$ 619,020	$ 268,242	$ 1,475,331	$ 2,950,662	$ 3,835,861	$ 147,533
Thorne Bay	520,162	23	12,000 Gal	$ 97,200	$ 9,517,200	$ 155,000	$ 2,901,660	$ 1,257,386	$ 6,915,623	$ 13,831,246	$ 17,980,620	$ 691,562
Tok	2,353,108	99	12,000 Gal	$ 926,640	$ 31,373,600	$ 702,000	$ 9,622,680	$ 4,169,828	$ 22,934,054	$ 45,868,108	$ 59,628,540	$ 2,293,405
Tolsona	62,015	4	12,000 Gal	$ 22,932	$ 1,280,400	$ -	$ 384,120	$ 166,452	$ 915,486	$ 1,830,972	$ 2,380,264	$ 91,549
Tonsina	135,196	7	12,000 Gal	$ 48,672	$ 2,344,200	$ -	$ 703,260	$ 304,746	$ 1,676,103	$ 3,352,206	$ 4,357,868	$ 167,610
Ugashik	14,495	3	12,000 Gal	$ 86,400	$ 830,600	$ -	$ 249,180	$ 107,978	$ 593,879	$ 1,187,758	$ 1,544,085	$ 59,388
Unalaska	1,717,964	73	12,000 Gal	$ 1,670,400	$ 35,886,600	$ -	$ 10,765,980	$ 4,665,258	$ 25,658,919	$ 51,317,838	$ 66,713,189	$ 2,565,892
Valdez	5,011,354	1	5,000,000 Gal	$ 1,049,377	$ 92,437,400	$ -	$ 27,731,220	$ 12,016,862	$ 66,092,741	$ 132,185,482	$ 171,841,127	$ 6,609,274
Whale Pass	49,317	3	12,000 Gal	$ 12,960	$ 1,140,000	$ -	$ 342,000	$ 148,200	$ 815,100	$ 1,630,200	$ 2,119,260	$ 81,510
Wiseman	16,733	3	12,000 Gal	$ 37,440	$ 783,000	$ -	$ 234,900	$ 101,790	$ 559,845	$ 1,119,690	$ 1,455,597	$ 55,985
Womens Bay	659,819	28	12,000 Gal	$ 161,280	$ 12,099,400	$ -	$ 3,629,820	$ 1,572,922	$ 8,651,071	$ 17,302,142	$ 22,492,785	$ 865,107
Wrangell	3,314,709	139	12,000 Gal	$ 800,640	$ 51,293,400	$ -	$ 15,388,020	$ 6,668,142	$ 36,674,781	$ 73,349,562	$ 95,354,431	$ 3,667,478
Yakutat	686,666	30	12,000 Gal	$ 467,280	$ 12,166,000	$ 580,000	$ 3,823,800	$ 1,656,980	$ 9,113,390	$ 18,226,780	$ 23,694,814	$ 911,339

Attachment 2:

Detailed Transportation, Capital, and Operational Costs, Full Residential Energy Demand, CY 2017

COMMUNITY	DEMAND			LNG TANK QUANTITY			TRANSPORTATION COSTS							CAPITAL COSTS													OPERATING COST
Community	Number of Buildings	Heating & Electricity Consumption (MMBtu)	Gallons LNG	No. Tanks Based on Demand	Min. No. Tanks Based on Demand	Actual No. Tanks Req'd per Community	Transportation Method	LNG Source	Travel Distance (Miles)	Size of Tank	Weight of ISO Tanks and Fuel or Fuel (lbs)	Unit Transport Cost ($/lb-mi)	Annual Transport Cost	Tank Cost	Associated Balance of Plant	Supporting Infrastructure	Ground Conditioning	Distribution Piping	Total Genset Capacity (kW)	Dual Fuel Conversion Unit Cost	Capitol Costs Subtotal	30% Unknown Cost	Permitting and Engineering Cost	CAPEX -50%	CAPEX	Capex +30%	OPEX
Adak	44	10,955	132,556	12	13	7	Barge (Ice-Free)	Nikiski	800	12,000 Gal	936,000	0.00020	$ 149,760	$ 1,225,000	$ -	$ 191,000		$ 1,047,200	4,035	$ 504,000	$ 2,967,200	$ 890,160	$ 385,736	$ 2,121,548	$ 4,243,096	$ 5,516,025	$ 212,155
Akhiok	19	3,661	44,299	4	5	3	Barge (Ice-Free)	Nikiski	200	12,000 Gal	360,000	0.00020	$ 14,400	$ 525,000	$ -	$ 139,000		$ 452,200	360	$ 71,000	$ 1,187,200	$ 356,160	$ 154,336	$ 848,848	$ 1,697,696	$ 2,207,005	$ 84,885
Akutan	40	3,421	41,392	4	5	3	Barge (Ice-Free)	Nikiski	800	12,000 Gal	360,000	0.00020	$ 57,600	$ 525,000	$ -	$ 139,000		$ 952,000	407	$ 72,000	$ 1,688,000	$ 506,400	$ 219,440	$ 1,206,920	$ 2,413,840	$ 3,137,992	$ 120,692
Alcan Border	16	4,425	53,544	5	6	3	Road	Nikiski	580	12,000 Gal	432,000	0.00013	$ 32,573	$ 525,000	$ -	$ 139,000		$ 380,800			$ 1,044,800	$ 313,440	$ 135,824	$ 747,032	$ 1,494,064	$ 1,942,283	$ 74,703
Aleneva	9	1,734	20,984	2	5	3	Barge (Ice-Free)	Nikiski	200	12,000 Gal	360,000	0.00020	$ 14,400	$ 525,000	$ -	$ 139,000		$ 214,200			$ 878,200	$ 263,460	$ 114,166	$ 627,913	$ 1,255,826	$ 1,632,574	$ 62,791
Angoon	167	22,557	272,944	23	24	12	Barge (Ice-Free)	British Columbia	350	12,000 Gal	1,728,000	0.00020	$ 120,960	$ 2,100,000	$ -	$ 256,000		$ 3,974,600	1,585	$ 232,000	$ 6,562,600	$ 1,968,780	$ 853,138	$ 4,692,259	$ 9,384,518	$ 12,199,873	$ 469,226
Atka	24	1,802	21,801	2	5	3	Barge (Ice-Free)	Nikiski	800	12,000 Gal	360,000	0.00020	$ 57,600	$ 525,000	$ -	$ 139,000		$ 571,200	257	$ 60,000	$ 1,295,200	$ 388,560	$ 168,376	$ 926,068	$ 1,852,136	$ 2,407,777	$ 92,607
Bettles	9	2,489	30,119	3	5	3	Road	Nikiski	770	12,000 Gal	360,000	0.00013	$ 36,036	$ 525,000	$ -	$ 139,000		$ 214,200	600	$ 104,000	$ 982,200	$ 294,660	$ 127,686	$ 702,273	$ 1,404,546	$ 1,825,910	$ 70,227
Central	53	14,372	173,900	15	16	8	Road	Nikiski	650	12,000 Gal	1,152,000	0.00013	$ 97,344	$ 1,400,000	$ -	$ 204,000		$ 1,261,400	575	$ 100,000	$ 2,965,400	$ 889,620	$ 385,502	$ 2,120,261	$ 4,240,522	$ 5,512,679	$ 212,026
Chenega Bay	31	8,827	106,803	9	10	5	Barge (Ice-Free)	Nikiski	250	12,000 Gal	720,000	0.00020	$ 36,000	$ 875,000	$ -	$ 165,000		$ 737,800	198	$ 60,000	$ 1,837,800	$ 551,340	$ 238,914	$ 1,314,027	$ 2,628,054	$ 3,416,470	$ 131,403
Chicken	5	1,383	16,733	2	5	3	Road	Nikiski	570	12,000 Gal	360,000	0.00013	$ 26,676	$ 525,000	$ -	$ 139,000		$ 119,000			$ 783,000	$ 234,900	$ 101,790	$ 559,845	$ 1,119,690	$ 1,455,597	$ 55,985
Chignik	97	13,902	168,214	15	16	8	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	1,152,000	0.00020	$ 276,480	$ 1,400,000	$ -	$ 204,000		$ 2,308,600	1,470	$ 267,000	$ 4,179,600	$ 1,253,880	$ 543,348	$ 2,988,414	$ 5,976,828	$ 7,769,876	$ 298,841
Chistochina	36	9,853	119,226	10	11	6	Road	Nikiski	400	12,000 Gal	792,000	0.00013	$ 41,184	$ 1,050,000	$ -	$ 178,000		$ 856,800	200	$ 40,000	$ 2,124,800	$ 637,440	$ 276,224	$ 1,519,232	$ 3,038,464	$ 3,950,003	$ 151,923
Chitina	52	14,434	174,651	15	16	8	Road	Nikiski	420	12,000 Gal	1,152,000	0.00013	$ 62,899	$ 1,400,000	$ -	$ 204,000		$ 1,237,600	301	$ 62,000	$ 2,903,600	$ 871,080	$ 377,468	$ 2,076,074	$ 4,152,148	$ 5,397,792	$ 207,607
Circle	40	10,166	123,007	11	12	6	Road	Nikiski	700	12,000 Gal	864,000	0.00013	$ 78,624	$ 1,050,000	$ -	$ 178,000		$ 952,000	188	$ 40,000	$ 2,220,000	$ 666,000	$ 288,600	$ 1,587,300	$ 3,174,600	$ 4,126,980	$ 158,730
Coffman Cove	89	18,165	219,799	19	20	10	Barge (Ice-Free)	British Columbia	150	12,000 Gal	1,440,000	0.00020	$ 43,200	$ 1,750,000	$ -	$ 230,000		$ 2,118,200	660	$ 107,000	$ 4,205,200	$ 1,261,560	$ 546,676	$ 3,006,718	$ 6,013,436	$ 7,817,467	$ 300,672
Cold Bay	46	7,087	85,750	8	9	5	Barge (Ice-Free)	Nikiski	800	12,000 Gal	648,000	0.00020	$ 103,680	$ 875,000	$ -	$ 165,000		$ 1,094,800	2,595	$ 321,000	$ 2,455,800	$ 736,740	$ 319,254	$ 1,755,897	$ 3,511,794	$ 4,565,332	$ 175,590
Coldfoot	6	1,659	20,079	2	5	3	Road	Nikiski	785	12,000 Gal	360,000	0.00013	$ 36,738	$ 525,000	$ -	$ 139,000		$ 142,800			$ 806,800	$ 242,040	$ 104,884	$ 576,862	$ 1,153,724	$ 1,499,841	$ 57,686
Copper Center	123	44,693	540,789	46	47	24	Road	Nikiski	365	12,000 Gal	3,384,000	0.00013	$ 160,571	$ 4,200,000	$ -	$ 412,000		$ 2,927,400			$ 7,539,400	$ 2,261,820	$ 980,122	$ 5,390,671	$ 10,781,342	$ 14,015,745	$ 539,067
Cordova	922	226,065	2,735,382	228	229	115	Barge (Ice-Free)	Nikiski	350	12,000 Gal	16,488,000	0.00020	$ 1,154,160	$ 20,125,000	$ -	$ 1,595,000		$ 21,943,600	10,853	$ 630,000	$ 44,293,600	$ 13,288,080	$ 5,758,168	$ 31,669,924	$ 63,339,848	$ 82,341,802	$ 3,166,992
Covenant Life	35	7,356	89,005	8	9	5	Barge (Ice-Free)	British Columbia	450	12,000 Gal	648,000	0.00020	$ 58,320	$ 875,000	$ -	$ 165,000		$ 833,000			$ 1,873,000	$ 561,900	$ 243,490	$ 1,339,195	$ 2,678,390	$ 3,481,907	$ 133,920
Craig	470	80,491	973,941	82	83	42	Barge (Ice-Free)	British Columbia	150	12,000 Gal	5,976,000	0.00020	$ 179,280	$ 7,350,000	$ -	$ 646,000		$ 11,186,000	4,515	$ 469,000	$ 19,651,000	$ 5,895,300	$ 2,554,630	$ 14,050,465	$ 28,100,930	$ 36,531,209	$ 1,405,047
Dillingham	855	173,011	2,093,439	175	176	88	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	12,672,000	0.00020	$ 3,041,280	$ 15,400,000	$ -	$ 1,244,000		$ 20,349,000			$ 36,993,000	$ 11,097,900	$ 4,809,090	$ 26,449,995	$ 52,899,990	$ 68,769,987	$ 2,645,000
Dot Lake	26	7,191	87,011	8	9	5	Road	Nikiski	550	12,000 Gal	648,000	0.00013	$ 46,332	$ 875,000	$ -	$ 165,000		$ 618,800			$ 1,658,800	$ 497,640	$ 215,644	$ 1,186,042	$ 2,372,084	$ 3,083,709	$ 118,604
Dry Creek	29	8,021	97,049	9	10	5	Road	Nikiski	550	12,000 Gal	720,000	0.00013	$ 51,480	$ 875,000	$ -	$ 165,000		$ 690,200			$ 1,730,200	$ 519,060	$ 224,926	$ 1,237,093	$ 2,474,186	$ 3,216,442	$ 123,709
Eagle	72	19,562	236,700	20	21	11	Road	Nikiski	655	12,000 Gal	1,512,000	0.00013	$ 128,747	$ 1,925,000	$ -	$ 243,000		$ 1,713,600	450	$ 80,000	$ 3,961,600	$ 1,188,480	$ 515,008	$ 2,832,544	$ 5,665,088	$ 7,364,614	$ 283,254
Edna Bay	18	3,783	45,774	4	5	3	Barge (Ice-Free)	British Columbia	150	12,000 Gal	360,000	0.00020	$ 10,800	$ 525,000	$ -	$ 139,000		$ 428,400			$ 1,092,400	$ 327,720	$ 142,012	$ 781,066	$ 1,562,132	$ 2,030,772	$ 78,107
Elfin Cove	13	2,732	33,059	3	5	3	Barge (Ice-Free)	British Columbia	350	12,000 Gal	360,000	0.00020	$ 25,200	$ 525,000	$ -	$ 139,000		$ 309,400	347	$ 710,000	$ 1,683,400	$ 505,020	$ 218,842	$ 1,203,631	$ 2,407,262	$ 3,129,441	$ 120,363
Excursion Inlet	6	1,261	15,258	2	5	3	Barge (Ice-Free)	British Columbia	350	12,000 Gal	360,000	0.00020	$ 25,200	$ 525,000	$ -	$ 139,000		$ 142,800			$ 806,800	$ 242,040	$ 104,884	$ 576,862	$ 1,153,724	$ 1,499,841	$ 57,686
False Pass	15	2,321	28,085	3	5	3	Barge (Ice-Free)	Nikiski	800	12,000 Gal	360,000	0.00020	$ 57,600	$ 525,000	$ -	$ 139,000		$ 357,000	375	$ 73,000	$ 1,094,000	$ 328,200	$ 142,220	$ 782,210	$ 1,564,420	$ 2,033,746	$ 78,221
Gakona	86	19,114	231,277	20	21	11	Road	Nikiski	370	12,000 Gal	1,512,000	0.00013	$ 72,727	$ 1,925,000	$ -	$ 243,000		$ 2,046,800			$ 4,214,800	$ 1,264,440	$ 547,924	$ 3,013,582	$ 6,027,164	$ 7,835,313	$ 301,358
Game Creek	7	1,471	17,801	2	5	3	Barge (Ice-Free)	British Columbia	350	12,000 Gal	360,000	0.00020	$ 25,200	$ 525,000	$ -	$ 139,000		$ 166,600			$ 830,600	$ 249,180	$ 107,978	$ 593,879	$ 1,187,758	$ 1,544,085	$ 59,388
Glennallen	203	62,112	419,987	35	36	18	Road	Nikiski	200	12,000 Gal	2,592,000	0.00013	$ 67,392	$ 3,150,000	$ -	$ 334,000		$ 4,831,400			$ 8,315,400	$ 2,494,620	$ 1,081,002	$ 5,945,511	$ 11,891,022	$ 15,458,329	$ 594,551
Gulkana	36	9,166	110,911	10	11	6	Road	Nikiski	360	12,000 Gal	792,000	0.00013	$ 37,066	$ 1,050,000	$ -	$ 178,000		$ 856,800			$ 2,084,800	$ 625,440	$ 271,024	$ 1,490,632	$ 2,981,264	$ 3,875,643	$ 149,063
Gustavus	212	38,822	469,746	40	41	21	Barge (Ice-Free)	British Columbia	350	12,000 Gal	2,952,000	0.00020	$ 206,640	$ 3,675,000	$ -	$ 373,000		$ 5,045,600	842	$ 138,000	$ 9,231,600	$ 2,769,480	$ 1,200,108	$ 6,600,594	$ 13,201,188	$ 17,161,544	$ 660,059
Haines	782	228,214	2,761,389	231	232	116	Barge (Ice-Free)	British Columbia	450	12,000 Gal	16,704,000	0.00020	$ 1,503,360	$ 20,300,000	$ -	$ 1,608,000		$ 18,611,600			$ 40,519,600	$ 12,155,880	$ 5,267,548	$ 28,971,514	$ 57,943,028	$ 75,325,936	$ 2,897,151
Hobart Bay	1	210	2,543	1	5	3	Barge (Ice-Free)	British Columbia	320	12,000 Gal	360,000	0.00020	$ 23,040	$ 525,000	$ -	$ 139,000		$ 23,800			$ 687,800	$ 206,340	$ 89,414	$ 491,777	$ 983,554	$ 1,278,620	$ 49,178
Hollis	44	8,251	99,837	9	10	5	Barge (Ice-Free)	British Columbia	150	12,000 Gal	720,000	0.00020	$ 21,600	$ 875,000	$ -	$ 165,000		$ 1,047,200	450	$ 69,000	$ 2,156,200	$ 646,860	$ 280,306	$ 1,541,683	$ 3,083,366	$ 4,008,376	$ 154,168
Hoonah	305	64,367	778,840	65	66	33	Barge (Ice-Free)	British Columbia	350	12,000 Gal	4,752,000	0.00020	$ 332,640	$ 5,775,000	$ -	$ 529,000		$ 7,259,000			$ 13,563,000	$ 4,068,900	$ 1,763,190	$ 9,697,545	$ 19,395,090	$ 25,213,617	$ 969,755
Hydaburg	128	15,845	191,724	16	17	9	Barge (Ice-Free)	British Columbia	150	12,000 Gal	1,224,000	0.00020	$ 36,720	$ 1,575,000	$ -	$ 217,000		$ 3,046,400	4,325	$ 255,000	$ 5,093,400	$ 1,528,020	$ 662,142	$ 3,641,781	$ 7,283,562	$ 9,468,631	$ 364,178
Hyder	48	10,088	122,064	11	12	6	Barge (Ice-Free)	British Columbia	200	12,000 Gal	864,000	0.00020	$ 34,560	$ 1,050,000	$ -	$ 178,000		$ 1,142,400			$ 2,370,400	$ 711,120	$ 308,152	$ 1,694,836	$ 3,389,672	$ 4,406,574	$ 169,484
Ivanof Bay	2	342	4,141	1	5	3	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	360,000	0.00020	$ 86,400	$ 525,000	$ -	$ 139,000		$ 47,600	224	$ 60,000	$ 771,600	$ 231,480	$ 100,308	$ 551,694	$ 1,103,388	$ 1,434,404	$ 55,169
Juneau	12187	2,592,353	31,367,469	1	1	1	Barge (Ice-Free)	British Columbia	350	5,000,000 Gal	109,472,465	0.00020	$ 7,663,073	$ 40,000,000	$ 10,000,000	$ -	$ 5,000,000	$ 290,050,600			$ 345,050,600	$ 103,515,180	$ 44,856,578	$ 246,711,179	$ 493,422,358	$ 641,449,065	$ 24,671,118
Kake	213	40,183	486,209	41	42	21	Barge (Ice-Free)	British Columbia	250	12,000 Gal	3,024,000	0.00020	$ 151,200	$ 3,675,000	$ -	$ 373,000		$ 5,069,400	2,431	$ 304,000	$ 9,421,400	$ 2,826,420	$ 1,224,782	$ 6,736,301	$ 13,472,602	$ 17,514,383	$ 673,630
Karluk	12	1,769	21,406	2	5	3	Barge (Ice-Free)	Nikiski	200	12,000 Gal	360,000	0.00020	$ 14,400	$ 525,000	$ -	$ 139,000		$ 285,600	140	$ 40,000	$ 989,600	$ 296,880	$ 128,648	$ 707,564	$ 1,415,128	$ 1,839,666	$ 70,756
Kasaan	23	1,567	18,964	2	5	3	Barge (Ice-Free)	British Columbia	150	12,000 Gal	360,000	0.00020	$ 10,800	$ 525,000	$ -	$ 139,000		$ 547,400	345	$ 62,000	$ 1,273,400	$ 382,020	$ 165,542	$ 910,481	$ 1,820,962	$ 2,367,251	$ 91,048
Kenny Lake	145	30,570	369,896	31	32	16	Road	Nikiski	400	12,000 Gal	2,304,000	0.00013	$ 119,808	$ 2,800,000	$ -	$ 308,000		$ 3,451,000			$ 6,559,000	$ 1,967,700	$ 852,670	$ 4,689,685	$ 9,379,370	$ 12,193,181	$ 468,969
Ketchikan	3259	637,969	7,719,425	1	1	1	Barge (Ice-Free)	British Columbia	150	5,000,000 Gal	26,940,793	0.00020	$ 808,224	$ 40,000,000	$ 10,000,000	$ -	$ 5,000,000	$ 77,564,200			$ 132,564,200	$ 39,769,260	$ 17,233,346	$ 94,783,403	$ 189,566,806	$ 246,436,848	$ 9,478,340
King Cove	181	29,463	356,506	30	31	16	Barge (Ice-Free)	Nikiski	800	12,000 Gal	2,232,000	0.00020	$ 357,120	$ 2,800,000	$ -	$ 308,000		$ 4,307,800	3,900	$ 543,000	$ 7,958,800	$ 2,387,640	$ 1,034,644	$ 5,690,542	$ 11,381,084	$ 14,795,409	$ 569,054
King Salmon	157	36,714	444,244	38	39	20	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	2,808,000	0.00020	$ 673,920	$ 3,500,000	$ -	$ 360,000		$ 3,736,600			$ 7,596,600	$ 2,278,980	$ 987,558	$ 5,431,569	$ 10,863,138	$ 14,122,079	$ 543,157
Klawock	297	42,439	513,513	43	44	22	Barge (Ice-Free)	British Columbia	150	12,000 Gal	3,168,000	0.00020	$ 95,040	$ 3,850,000	$ -	$ 386,000		$ 7,068,600			$ 11,304,600	$ 3,391,380	$ 1,469,598	$ 8,082,789	$ 16,165,578	$ 21,015,251	$ 808,279
Klukwan	41	8,617	104,263	9	10	5	Barge (Ice-Free)	British Columbia	450	12,000 Gal	720,000	0.00020	$ 64,800	$ 875,000	$ -	$ 165,000		$ 975,800			$ 2,015,800	$ 604,740	$ 262,054	$ 1,441,297	$ 2,882,594	$ 3,747,372	$ 144,130
Kodiak	2039	414,417	5,014,449	1	1	1	Barge (Ice-Free)	Nikiski	200	5,000,000 Gal	17,500,426	0.00020	$ 700,017	$ 40,000,000	$ 10,000,000	$ -	$ 5,000,000	$ 48,528,200			$ 103,528,200	$ 31,058,460	$ 13,458,666	$ 74,022,663	$ 148,045,326	$ 192,458,924	$ 7,402,266
Kupreanof	15	3,152	38,145	4	5	3	Barge (Ice-Free)	British Columbia	250	12,000 Gal	360,000	0.00020	$ 18,000	$ 525,000	$ -	$ 139,000		$ 357,000			$ 1,021,000	$ 306,300	$ 132,730	$ 730,015	$ 1,460,030	$ 1,898,039	$ 73,002
Larsen Bay	34	6,191	74,907	7	8	4	Barge (Ice-Free)	Nikiski	200	12,000 Gal	576,000	0.00020	$ 23,040	$ 700,000	$ -	$ 152,000		$ 809,200	393	$ 68,000	$ 1,729,200	$ 518,760	$ 224,796	$ 1,236,378	$ 2,472,756	$ 3,214,583	$ 123,638
Livengood	7	1,936	23,426	2	5	3	Road	Nikiski	610	12,000 Gal	360,000	0.00013	$ 28,548	$ 525,000	$ -	$ 139,000		$ 166,600			$ 830,600	$ 249,180	$ 107,978	$ 593,879	$ 1,187,758	$ 1,544,085	$ 59,388
Lutak	25	5,254	63,575	6	7	4	Barge (Ice-Free)	British Columbia	450	12,000 Gal	504,000	0.00020	$ 45,360	$ 700,000	$ -	$ 152,000		$ 595,000			$ 1,447,000	$ 434,100	$ 188,110	$ 1,034,605	$ 2,069,210	$ 2,689,973	$ 103,461
McCarthy	20	5,496	66,496	6	7	4	Road	Nikiski	480	12,000 Gal	504,000	0.00013	$ 31,450	$ 700,000	$ -	$ 152,000		$ 476,000			$ 1,328,000	$ 398,400	$ 172,640	$ 949,520	$ 1,899,040	$ 2,468,752	$ 94,952
Mendeltna	19	5,410	65,460	6	7	4	Road	Nikiski	320	12,000 Gal	504,000	0.00013	$ 20,966	$ 700,000	$ -	$ 152,000		$ 452,200			$ 1,304,200	$ 391,260	$ 169,546	$ 932,503	$ 1,865,006	$ 2,424,508	$ 93,250
Mentasta Lake	46	14,432	174,622	15	16	8	Road	Nikiski	450	12,000 Gal	1,152,000	0.00013	$ 67,392	$ 1,400,000	$ -	$ 204,000		$ 1,094,800	0	$ -	$ 2,698,800	$ 809,640	$ 350,844	$ 1,929,642	$ 3,859,284	$ 5,017,069	$ 192,964
Metlakatla	493	54,483	659,240	55	56	28	Barge (Ice-Free)	British Columbia	100	12,000 Gal	4,032,000	0.00020	$ 80,640	$ 4,900,000	$ -	$ 464,000		$ 11,733,400			$ 17,097,400	$ 5,129,220	$ 2,222,662	$ 12,224,641	$ 24,449,282	$ 31,784,067	$ 1,222,464
Minto	65	13,856	167,661	14	15	8	Road	Nikiski	650	12,000 Gal	1,080,000	0.00013	$ 91,260	$ 1,400,000	$ -	$ 204,000		$ 1,547,000	708	$ 120,000	$ 3,271,000	$ 981,300	$ 425,230	$ 2,338,765	$ 4,677,530	$ 6,080,789	$ 233,877
Mosquito Lake	138	29,003	350,933	30	31	16	Barge (Ice-Free)	British Columbia	450	12,000 Gal	2,232,000	0.00020	$ 200,880	$ 2,800,000	$ -	$ 308,000		$ 3,284,400			$ 6,392,400	$ 1,917,720	$ 831,012	$ 4,570,566	$ 9,141,132	$ 11,883,472	$ 457,057
Mud Bay	104	21,857	264,471	23	24	12	Barge (Ice-Free)	British Columbia	450	12,000 Gal	1,728,000	0.00020	$ 155,520	$ 2,100,000	$ -	$ 256,000		$ 2,475,200			$ 4,831,200	$ 1,449,360	$ 628,056	$ 3,454,308	$ 6,908,616	$ 8,981,201	$ 345,431
Naknek	231	50,591	332,354	28	29	15	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	2,088,000	0.00020	$ 501,120	$ 2,625,000	$ -	$ 295,000		$ 5,497,800			$ 8,417,800	$ 2,525,340	$ 1,094,314	$ 6,018,727	$ 12,037,454	$ 15,648,690	$ 601,873
Naukati Bay	49	9,659	116,875	10	11	6	Barge (Ice-Free)	British Columbia	150	12,000 Gal	792,000	0.00020	$ 23,760	$ 1,050,000	$ -	$ 178,000		$ 1,166,200	488	$ 86,000	$ 2,480,200	$ 744,060	$ 322,426	$ 1,773,343	$ 3,546,686	$ 4,610,692	$ 177,334
Nelson Lagoon	22	2,399	14,120	2	5	3	Barge (Ice-Free)		800	12,000 Gal	360,000	0.00020	$ 57,600	$ 525,000	0	$ 139,000		$ 523,600	300	$ 67,000	$ 1,254,600	$ 376,380	$ 163,098	$ 897,039	$ 1,794,078	$ 2,332,301	$ 89,704
Newhalen	50	6,812	82,428	7	8	4	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	576,000	0.00020	$ 138,240	$ 700,000	$ -	$ 152,000		$ 1,190,000	1,560	$ 241,000	$ 2,283,000	$ 684,900	$ 296,790	$ 1,632,345	$ 3,264,690	$ 4,244,097	$ 163,235
Nikolski	13	1,074	12,994	2	5	3	Barge (Ice-Free)	Nikiski	800	12,000 Gal	360,000	0.00020	$ 57,600	$ 525,000	$ -	$ 139,000		$ 309,400	196	$ 60,000	$ 1,033,400	$ 310,020	$ 134,342	$ 738,881	$ 1,477,762	$ 1,921,091	$ 73,888
Nondalton	57	6,417	77,644	7	8	4	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	576,000	0.00020	$ 138,240	$ 700,000	$ -	$ 152,000		$ 1,356,600	0	$ -	$ 2,208,600	$ 662,580	$ 287,118	$ 1,579,149	$ 3,158,298	$ 4,105,787	$ 157,915
Northway	47	18,505	223,911	19	20	10	Road	Nikiski	550	12,000 Gal	1,440,000	0.00013	$ 102,960	$ 1,750,000	$ -	$ 230,000		$ 1,118,600	1,030	$ 165,000	$ 3,263,600	$ 979,080	$ 424,268	$ 2,333,474	$ 4,666,948	$ 6,067,032	$ 233,347
Old Harbor	84	14,495	175,391	15	16	8	Barge (Ice-Free)	Nikiski	200	12,000 Gal	1,152,000	0.00020	$ 46,080	$ 1,400,000	$ -	$ 204,000		$ 1,999,200	703	$ 118,000	$ 3,721,200	$ 1,116,360	$ 483,756	$ 2,660,658	$ 5,321,316	$ 6,917,711	$ 266,066
Ouzinkie	56	10,155	122,876	11	12	6	Barge (Ice-Free)	Nikiski	200	12,000 Gal	864,000	0.00020	$ 34,560	$ 1,050,000	$ -	$ 178,000		$ 1,332,800	336	$ 73,000	$ 2,633,800	$ 790,140	$ 342,394	$ 1,883,167	$ 3,766,334	$ 4,896,234	$ 188,317
Paxson	22	6,162	74,562	7	8	4	Road	Nikiski	425	12,000 Gal	576,000	0.00013	$ 31,824	$ 700,000	$ -	$ 152,000		$ 523,600			$ 1,375,600	$ 412,680	$ 178,828	$ 983,554	$ 1,967,108	$ 2,557,240	$ 98,355
Pelican	41	10,819	130,914	11	12	6	Barge (Ice-Free)	British Columbia	350	12,000 Gal	864,000	0.00020	$ 60,480	$ 1,050,000	$ -	$ 178,000		$ 975,800	921	$ 149,000	$ 2,352,800	$ 705,840	$ 305,864	$ 1,682,252	$ 3,364,504	$ 4,373,855	$ 168,225
Perryville	38	5,641	68,257	6	7	4	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	504,000	0.00020	$ 120,960	$ 700,000	$ -	$ 152,000		$ 904,400	473	$ 83,000	$ 1,839,400	$ 551,820	$ 239,122	$ 1,315,171	$ 2,630,342	$ 3,419,445	$ 131,517
Petersburg	1252	240,303	2,907,661	243	244	122	Barge (Ice-Free)	British Columbia	250	12,000 Gal	17,568,000	0.00020	$ 878,400	$ 21,350,000	$ -	$ 1,686,000		$ 29,797,600			$ 52,833,600	$ 15,850,080	$ 6,868,368	$ 37,776,024	$ 75,552,048	$ 98,217,662	$ 3,777,602
Point Baker	8	3,115	37,697	4	5	3	Barge (Ice-Free)	British Columbia	150	12,000 Gal	360,000	0.00020	$ 10,800	$ 525,000	$ -	$ 139,000		$ 190,400			$ 854,400	$ 256,320	$ 111,072	$ 610,896	$ 1,221,792	$ 1,588,330	$ 61,090

COMMUNITY	DEMAND			LNG TANK QUANTITY			TRANSPORTATION COSTS							CAPITAL COSTS													OPERATING COST
Community	Number of Buildings	Heating & Electricity Consumption (MMBtu)	Gallons LNG	No. Tanks Based on Demand	Min. No. Tanks Based on Demand	Actual No. Tanks Req'd per Community	Transportation Method	LNG Source	Travel Distance (Miles)	Size of Tank	Weight of ISO Tanks and Fuel or Fuel (lbs)	Unit Transport Cost ($/lb-mi)	Annual Transport Cost	Tank Cost	Associated Balance of Plant	Supporting Infrastructure	Ground Conditioning	Distribution Piping	Total Genset Capacity (kW)	Dual Fuel Conversion Unit Cost	Capitol Costs Subtotal	30% Unknown Cost	Permitting and Engineering Cost	CAPEX -50%	CAPEX	Capex +30%	OPEX
Pope-Vannoy Landing	3	513	6,212	1	5	3	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	360,000	0.00020	$ 86,400	$ 525,000	$ -	$ 139,000		$ 71,400			$ 735,400	$ 220,620	$ 95,602	$ 525,811	$ 1,051,622	$ 1,367,109	$ 52,581
Port Alexander	22	3,891	47,079	4	5	3	Barge (Ice-Free)	British Columbia	150	12,000 Gal	360,000	0.00020	$ 10,800	$ 525,000	$ -	$ 139,000		$ 523,600			$ 1,187,600	$ 356,280	$ 154,388	$ 849,134	$ 1,698,268	$ 2,207,748	$ 84,913
Port Alsworth	44	7,542	91,258	8	9	5	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	648,000	0.00020	$ 155,520	$ 875,000	$ -	$ 165,000		$ 1,047,200	466	$ 82,000	$ 2,169,200	$ 650,760	$ 281,996	$ 1,550,978	$ 3,101,956	$ 4,032,543	$ 155,098
Port Lions	77	14,121	170,863	15	16	8	Barge (Ice-Free)	Nikiski	200	12,000 Gal	1,152,000	0.00020	$ 46,080	$ 1,400,000	$ -	$ 204,000		$ 1,832,600			$ 3,436,600	$ 1,030,980	$ 446,758	$ 2,457,169	$ 4,914,338	$ 6,388,639	$ 245,717
Port Protection	26	5,101	61,724	6	7	4	Barge (Ice-Free)	British Columbia	150	12,000 Gal	504,000	0.00020	$ 15,120	$ 700,000	$ -	$ 152,000		$ 618,800			$ 1,470,800	$ 441,240	$ 191,204	$ 1,051,622	$ 2,103,244	$ 2,734,217	$ 105,162
Saint George	42	5,180	62,673	6	7	4	Barge (Ice-Free)	Nikiski	800	12,000 Gal	504,000	0.00020	$ 80,640	$ 700,000	$ -	$ 152,000		$ 999,600	980	$ 164,000	$ 2,015,600	$ 604,680	$ 262,028	$ 1,441,154	$ 2,882,308	$ 3,747,000	$ 144,115
Saint Paul	162	27,891	337,484	29	30	15	Barge (Ice-Free)	Nikiski	800	12,000 Gal	2,160,000	0.00020	$ 345,600	$ 2,625,000	$ -	$ 295,000		$ 3,855,600	2,920	$ 395,000	$ 7,170,600	$ 2,151,180	$ 932,178	$ 5,126,979	$ 10,253,958	$ 13,330,145	$ 512,698
Sand Point	246	35,201	425,934	36	37	19	Barge (Ice-Free)	Nikiski	800	12,000 Gal	2,664,000	0.00020	$ 426,240	$ 3,325,000	$ -	$ 347,000		$ 5,854,800	2,880	$ 376,000	$ 9,902,800	$ 2,970,840	$ 1,287,364	$ 7,080,502	$ 14,161,004	$ 18,409,305	$ 708,050
Saxman	120	18,802	227,505	19	20	10	Barge (Ice-Free)	British Columbia	150	12,000 Gal	1,440,000	0.00020	$ 43,200	$ 1,750,000	$ -	$ 230,000		$ 2,856,000			$ 4,836,000	$ 1,450,800	$ 628,680	$ 3,457,740	$ 6,915,480	$ 8,990,124	$ 345,774
Silver Springs	44	12,528	151,592	13	14	7	Road	Nikiski	350	12,000 Gal	1,008,000	0.00013	$ 45,864	$ 1,225,000	$ -	$ 191,000		$ 1,047,200			$ 2,463,200	$ 738,960	$ 320,216	$ 1,761,188	$ 3,522,376	$ 4,579,089	$ 176,119
Sitka	3545	638,593	7,726,970	1	1	1	Barge (Ice-Free)	British Columbia	300	5,000,000 Gal	26,967,124	0.00020	$ 1,618,027	$ 40,000,000	$ 10,000,000	$ -	$ 5,000,000	$ 84,371,000			$ 139,371,000	$ 41,811,300	$ 18,118,230	$ 99,650,265	$ 199,300,530	$ 259,090,689	$ 9,965,027
Skagway	436	103,110	1,247,627	104	105	53	Barge (Ice-Free)	British Columbia	450	12,000 Gal	7,560,000	0.00020	$ 680,400	$ 9,275,000	$ -	$ 789,000		$ 10,376,800			$ 20,440,800	$ 6,132,240	$ 2,657,304	$ 14,615,172	$ 29,230,344	$ 37,999,447	$ 1,461,517
Slana	77	21,620	261,607	22	23	12	Road	Nikiski	425	12,000 Gal	1,656,000	0.00013	$ 91,494	$ 2,100,000	$ -	$ 256,000		$ 1,832,600	730	$ 123,000	$ 4,311,600	$ 1,293,480	$ 560,508	$ 3,082,794	$ 6,165,588	$ 8,015,264	$ 308,279
Tanacross	53	10,324	124,918	11	12	6	Road	Nikiski	500	12,000 Gal	864,000	0.00013	$ 56,160	$ 1,050,000	$ -	$ 178,000		$ 1,261,400			$ 2,489,400	$ 746,820	$ 323,622	$ 1,779,921	$ 3,559,842	$ 4,627,795	$ 177,992
Tatitlek	36	9,760	118,096	10	11	6	Barge (Ice-Free)	Nikiski	350	12,000 Gal	792,000	0.00020	$ 55,440	$ 1,050,000	$ -	$ 178,000		$ 856,800	315	$ 62,000	$ 2,146,800	$ 644,040	$ 279,084	$ 1,534,962	$ 3,069,924	$ 3,990,901	$ 153,496
Tazlina	111	30,667	371,068	31	32	16	Road	Nikiski	355	12,000 Gal	2,304,000	0.00013	$ 106,330	$ 2,800,000	$ -	$ 308,000		$ 2,641,800			$ 5,749,800	$ 1,724,940	$ 747,474	$ 4,111,107	$ 8,222,214	$ 10,688,878	$ 411,111
Tenakee Springs	72	15,045	182,044	16	17	9	Barge (Ice-Free)	British Columbia	350	12,000 Gal	1,224,000	0.00020	$ 85,680	$ 1,575,000	$ -	$ 217,000		$ 1,713,600			$ 3,505,600	$ 1,051,680	$ 455,728	$ 2,506,504	$ 5,013,008	$ 6,516,910	$ 250,650
Tetlin	43	7,917	95,794	8	9	5	Road	Nikiski	500	12,000 Gal	648,000	0.00013	$ 42,120	$ 875,000	$ -	$ 165,000		$ 1,023,400			$ 2,063,400	$ 619,020	$ 268,242	$ 1,475,331	$ 2,950,662	$ 3,835,861	$ 147,533
Thorne Bay	214	42,989	520,162	44	45	23	Barge (Ice-Free)	British Columbia	150	12,000 Gal	3,240,000	0.00020	$ 97,200	$ 4,025,000	$ -	$ 399,000		$ 5,093,200	1,075	$ 155,000	$ 9,672,200	$ 2,901,660	$ 1,257,386	$ 6,915,623	$ 13,831,246	$ 17,980,620	$ 691,562
Tok	532	194,472	2,353,108	197	198	99	Road	Nikiski	500	12,000 Gal	14,256,000	0.00013	$ 926,640	$ 17,325,000	$ -	$ 1,387,000		$ 12,661,600	7,010	$ 702,000	$ 32,075,600	$ 9,622,680	$ 4,169,828	$ 22,934,054	$ 45,868,108	$ 59,628,540	$ 2,293,405
Tolsona	18	5,125	62,015	6	7	4	Road	Nikiski	350	12,000 Gal	504,000	0.00013	$ 22,932	$ 700,000	$ -	$ 152,000		$ 428,400			$ 1,280,400	$ 384,120	$ 166,452	$ 915,486	$ 1,830,972	$ 2,380,264	$ 91,549
Tonsina	39	11,173	135,196	12	13	7	Road	Nikiski	400	12,000 Gal	936,000	0.00013	$ 48,672	$ 1,225,000	$ -	$ 191,000		$ 928,200			$ 2,344,200	$ 703,260	$ 304,746	$ 1,676,103	$ 3,352,206	$ 4,357,868	$ 167,610
Ugashik	7	1,198	14,495	2	5	3	Barge (Ice-Free)	Nikiski	1200	12,000 Gal	360,000	0.00020	$ 86,400	$ 525,000	$ -	$ 139,000		$ 166,600			$ 830,600	$ 249,180	$ 107,978	$ 593,879	$ 1,187,758	$ 1,544,085	$ 59,388
Unalaska	927	141,980	1,717,964	144	145	73	Barge (Ice-Free)	Nikiski	800	12,000 Gal	10,440,000	0.00020	$ 1,670,400	$ 12,775,000	$ -	$ 1,049,000		$ 22,062,600			$ 35,886,600	$ 10,765,980	$ 4,665,258	$ 25,658,919	$ 51,317,838	$ 66,713,189	$ 2,565,892
Valdez	1573	414,161	5,011,354	1	1	1	Barge (Ice-Free)	Nikiski	300	5,000,000 Gal	17,489,624	0.00020	$ 1,049,377	$ 40,000,000	$ 10,000,000	$ -	$ 5,000,000	$ 37,437,400			$ 92,437,400	$ 27,731,220	$ 12,016,862	$ 66,092,741	$ 132,185,482	$ 171,841,127	$ 6,609,274
Whale Pass	20	4,076	49,317	5	6	3	Barge (Ice-Free)	British Columbia	150	12,000 Gal	432,000	0.00020	$ 12,960	$ 525,000	$ -	$ 139,000		$ 476,000			$ 1,140,000	$ 342,000	$ 148,200	$ 815,100	$ 1,630,200	$ 2,119,260	$ 81,510
Wiseman	5	1,383	16,733	2	5	3	Road	Nikiski	800	12,000 Gal	360,000	0.00013	$ 37,440	$ 525,000	$ -	$ 139,000		$ 119,000			$ 783,000	$ 234,900	$ 101,790	$ 559,845	$ 1,119,690	$ 1,455,597	$ 55,985
Womens Bay	283	54,530	659,819	55	56	28	Barge (Ice-Free)	Nikiski	200	12,000 Gal	4,032,000	0.00020	$ 161,280	$ 4,900,000	$ -	$ 464,000		$ 6,735,400			$ 12,099,400	$ 3,629,820	$ 1,572,922	$ 8,651,071	$ 17,302,142	$ 22,492,785	$ 865,107
Wrangell	1053	273,943	3,314,709	277	278	139	Barge (Ice-Free)	British Columbia	200	12,000 Gal	20,016,000	0.00020	$ 800,640	$ 24,325,000	$ -	$ 1,907,000		$ 25,061,400			$ 51,293,400	$ 15,388,020	$ 6,668,142	$ 36,674,781	$ 73,349,562	$ 95,354,431	$ 3,667,478
Yakutat	270	56,749	686,666	58	59	30	Barge (Ice-Free)	British Columbia	550	12,000 Gal	4,248,000	0.00020	$ 467,280	$ 5,250,000	$ -	$ 490,000		$ 6,426,000	5,300	$ 580,000	$ 12,746,000	$ 3,823,800	$ 1,656,980	$ 9,113,390	$ 18,226,780	$ 23,694,814	$ 911,339
Yakutat	270	56,749	686,666	58	59	30	Barge (Ice-Free)	Nikiski	550	12,000 Gal	4,248,000	0.00020	$ 467,280	$ 5,250,000	$ -	$ 490,000		$ 6,426,000	5,300	$ 580,000	$ 12,746,000	$ 3,823,800	$ 1,656,980	$ 9,113,390	$ 18,226,780	$ 23,694,814	$ 911,339

Erratum

Notes of clarification for Northern Economics LNG study based on feedback from Regulatory Commission of Alaska.

Cost of Power Adjustment cannot be used to recover capital costs of a qualifying facility (p. 7) nor the purchase of LNG dual fuel system (p. 8). Per 3 AAC 52.502(a), COPA allows utility to recover, outside a general rate case, costs that are 1) subject to change at a rate that would cause financial harm to the utility if recovered outside a general rate case, 2) beyond the control the utility, and 3) easily verifiable. It is unlikely that LNG dual fuel system would satisfy these conditions.

In the memo from 12-18-2015, the study states “capital costs of [qualifying facility] would be recovered through an addition to the rate base.” The memo appears to assume RCA rate regulation, but many qualifying facilities would not be rate regulated by statute or RCA precedent.

[*Added by Alaska Energy Authority, February 2017*]