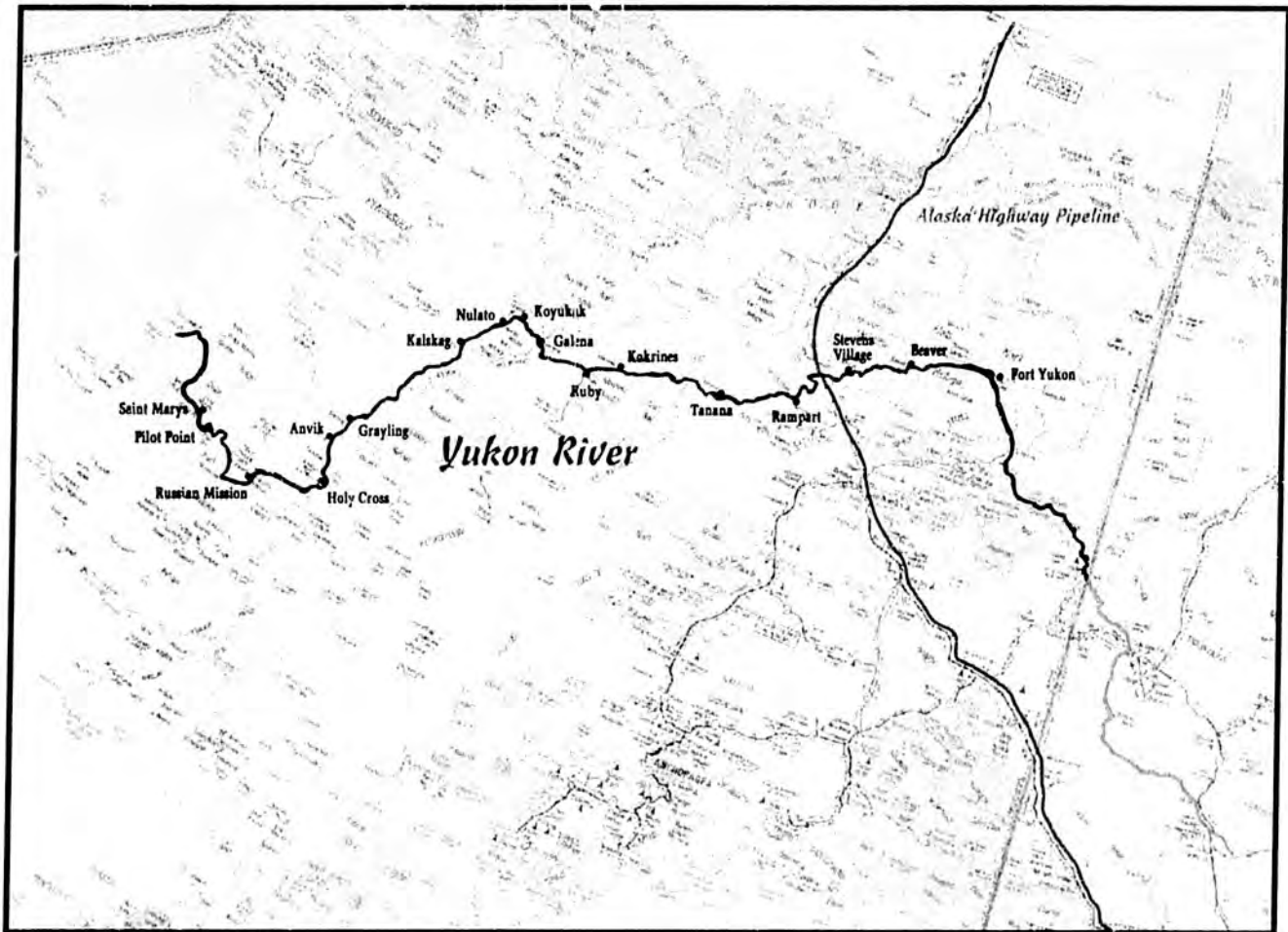


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ENERGY ALTERNATIVES FOR THE YUKON RIVER VALLEY



March 2001



Foothills Pipe Lines Ltd.

OVERVIEW

- △ This report concludes an internal study conducted by Foothills Pipe Lines Ltd.
for business development purposes.
- △ The intent of the report was to briefly review the potential for new energy
sources for communities along the Yukon River Valley as a result of the
pending construction of the Alaska Highway Pipeline.

ENERGY DEMAND IN THE YUKON RIVER VALLEY

- △ Yukon River Valley contains a series of small communities widely scattered along the river. The focus of this review is from Fort Yukon approximately 190 miles upstream of the Dalton Highway to Saint Marys approximately 760 miles downstream.
- △ It is understood that the energy requirements for these communities is currently provided by imported fuel. Diesel generators are typically used for the generation of electric power and heating oil is commonly used for heating homes and businesses.
- △ The Alaska Highway Pipeline, which is proposed to be constructed along the Dalton Highway in the area of the Yukon River, will transport up to 4.0 bcf of natural gas per day from the Alaskan North Slope to Alberta, Canada from where it will then be transported by other pipelines to the Lower 48.
- △ The Alaska Highway Pipeline will bring opportunities for alternative, and perhaps less expensive, electrical and heating energy for the residents of the Yukon Valley.

- ◆ Figure I - Identifies some of the communities along the river, their relative locations and their annual electrical and heating demand.
- ◆ Table I - Provides further elaboration on the communities, their size, location and annual energy consumption.
- ◆ The Base data and conversion factors were sourced from:
 - Feasibility of Natural Gas Distribution to Yukon River Valley or other rural areas, Ad-hoc Subcommittee of the Special Committee on Oil and Gas

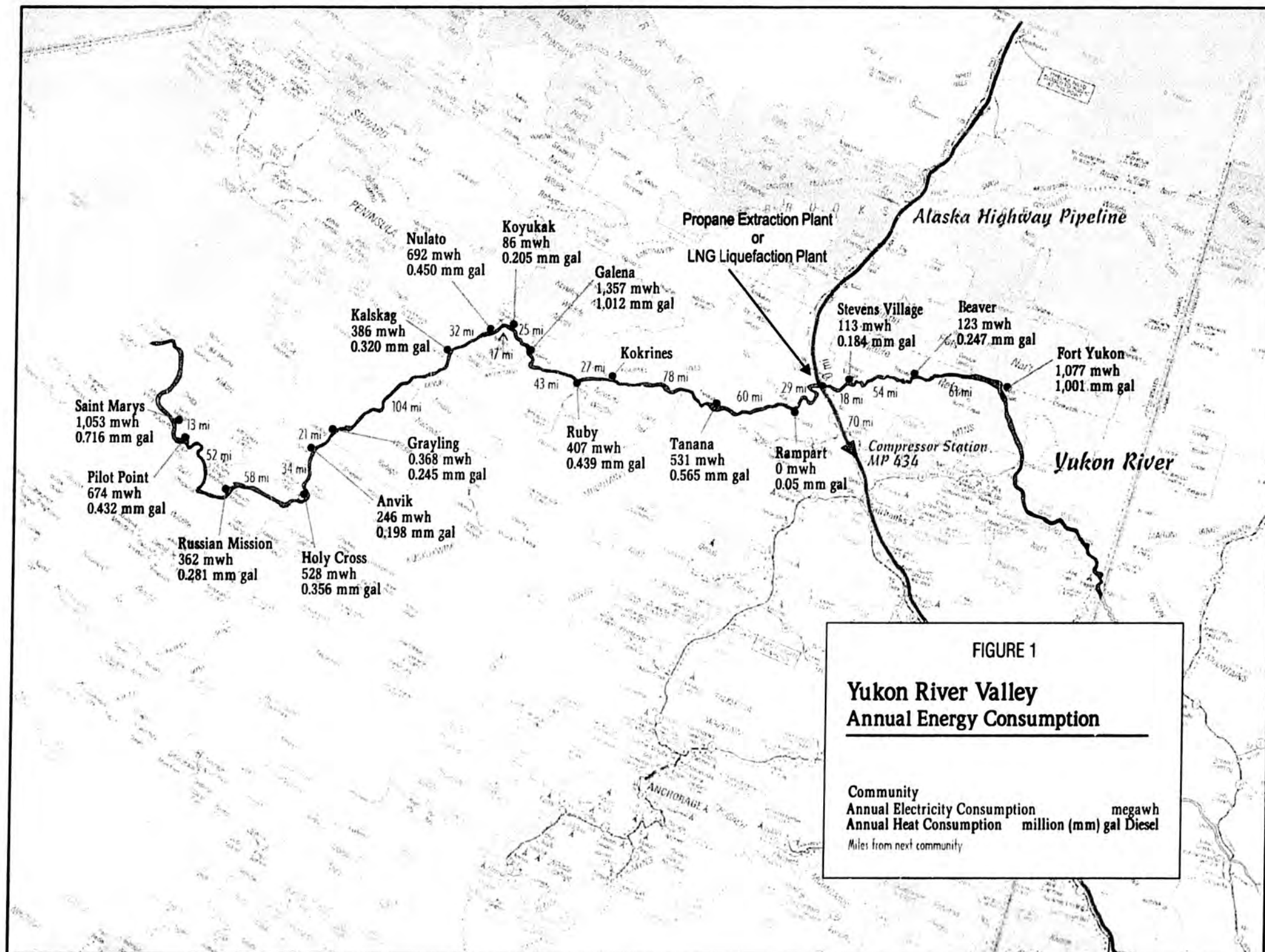


TABLE 1
YUKON RIVER VALLEY - ANNUAL ENERGY CONSUMPTION

			DISTANCE			ELECTRIC POWER		HEATING FUEL
COMMUNITY	POPULATION	NUMBER OF BUSINESSES & HOUSEHOLDS	TO	AS CROW FLIES Miles	WATER MILES Miles	CONSUMPTION kwh	GENERATOR FUEL #1 DIESEL US gallons	FUEL #1 DIESEL US gallons
UPSTREAM OF PIPELINE								
Fort Yukon	565	278	Beaver	61	70	1,077,480	189,562	1,000,800
Beaver	126	76	Stevens Village	54	91	122,962	27,030	273,600
Stevens Village	92	51	Pipeline	18	Scaled from map	113,265	30,454	183,600
Pipeline to Compressor Station				70				
Subtotal Upstream of Pipeline			Annual Consumption			1,313,707	247,046	1,458,000
DOWNSTREAM OF PIPELINE								
Compressor Station to Pipeline crossing of Yukon River				70				
Pipeline			Rampart	29	Scaled from map			
Rampart	66	14	Tanana	60	68			50,400
Tanana	300	157	Kokrines	78		530,875	123,074	565,200
Kokrines			Ruby	27	117			
Ruby	179	122	Galena	43	52	407,062	57,050	439,200
Galena	592	281	Koyukuk	25	32	1,356,914	657,720	1,011,600
Koyukuk	100	57	Nulato	17	17	86,365	22,233	205,200
Nulato	347	125	Kaltag	32	34	691,937	87,912	450,000
Kaltag	251	89	Grayling	104	100	386,332	59,884	320,400
Grayling	187	68	Anvik	21	18	367,802	47,150	244,800
Anvik	91	55	Holycross	34	38	246,346	37,616	198,000
Holycross	259	99	Russian Mission	58		527,921	60,615	356,400
Russian Mission	307	78	Pilot Station	52		361,640	62,540	280,800
Pilot Station	582	120	St Marys	13		673,725	95,908	432,000
Saint Mary's	482	199				1,052,727	152,311	716,400
Subtotal Downstream of Pipeline			Annual Consumption			6,689,646	1,464,013	5,270,400
Total Energy Annual Consumption						8,003,353	1,711,059	6,728,400

Data obtained from Feasibility of Natural Gas Distribution to Yukon River
To Yukon River Valley or Other rural areas
Ad-hoc Subcommittee of the
Special Committee of Oil and Natural Gas
Fate, Dyson, Joule

ENERGY OPTIONS

- △ The communities along the Yukon River require both electrical power and energy for heat.
- △ At present electric power is typically supplied by generators fueled by diesel located in each community. Number 1 diesel fuel is also used for home and business heating. The diesel fuel is barged to communities during the short summer season. It is understood that sufficient storage is provided at each community for a full year consumption.
- △ Several other options for providing this energy which will result from the construction of the Alaska Highway Pipeline include:
 - **Natural Gas**

Natural gas can be provided to the communities in one of several ways:

 - Pipelining of natural gas from the Alaska Highway Pipeline to the communities.
 - Liquefied Natural Gas (LNG) produced at the Alaska Highway Pipeline with barging to the communities where it would be stored, revaporized and distributed as required.
 - Compressed Natural Gas (CNG) compressed into pressure vessels on barges for transport to pressure vessels at each community where it would be stored and distributed as required.
 - **Propane**
 - Propane can be extracted from the natural gas in the Alaska Highway Pipeline and barged to each community where it would be stored and distributed as required.
 - **Electric Power**
 - Electric power can be generated at the Alaska Highway Pipeline by one of several processes using natural gas as a fuel. An additional process is waste heat recovery at the pipeline compressor stations on the Alaska Highway Pipeline.
 - The electricity would be transmitted by high voltage transmission lines to each community to provide the electric power requirements and possibly space heating.
- △ A brief discussion of each of these options is included in the following sections.

- ◆ Table 2 - Provides a rough conversion of the current diesel energy consumption into the equivalent requirement (quantities) of natural gas, LNG, propane and electricity.
- ◆ Figure 2 - Illustrates the relative energy densities of these various fuels.

Energy Density is indicative of the relative storage volumes required at the communities for each fuel. Natural gas by pipeline is the exception since the pipeline provides both the transportation medium and the storage container.

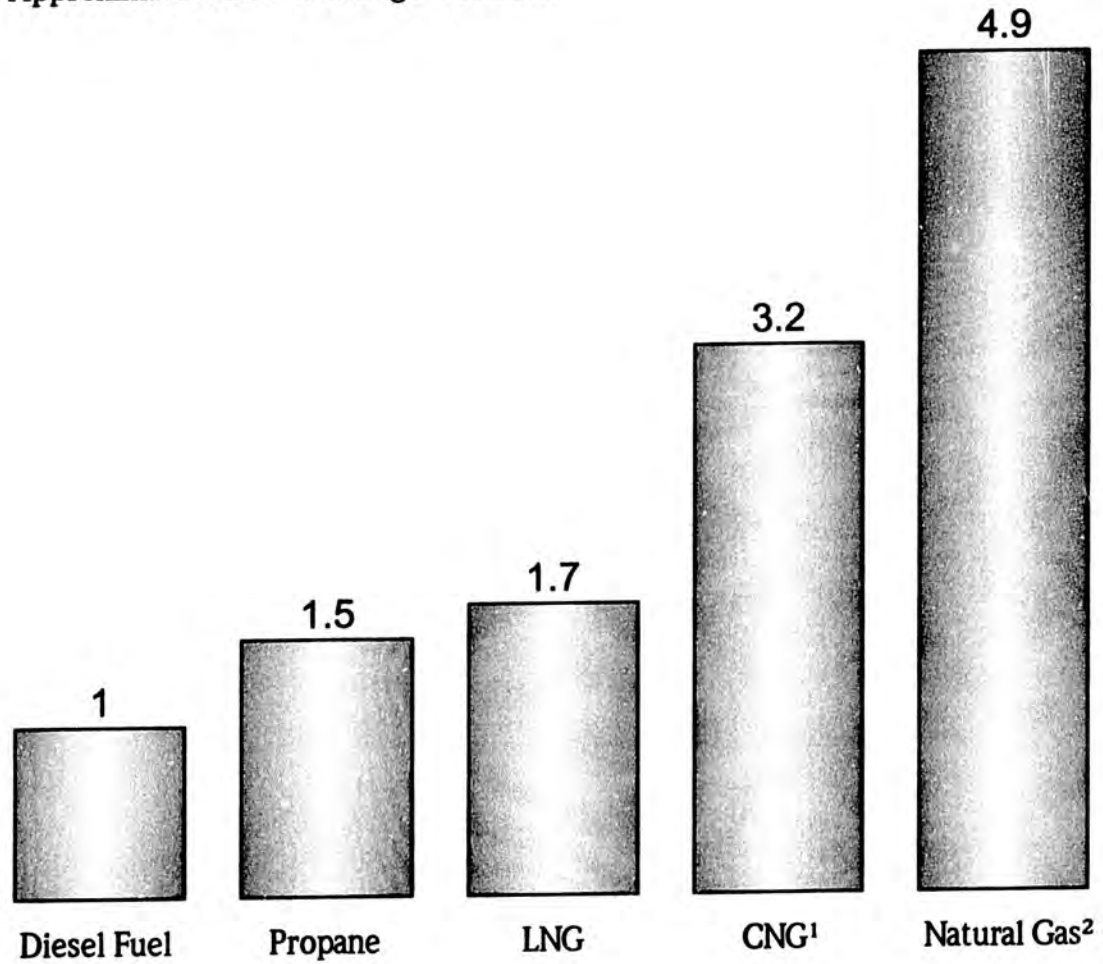
TABLE 2
YUKON RIVER VALLEY - ANNUAL ENERGY CONSUMPTION
EQUIVALENT ENERGY OF ALTERNATE FUELS

			ELECTRIC POWER - ANNUAL			HEATING - ANNUAL		TOTAL ENERGY EQUIVALENT				
COMMUNITY	POPULATION	NUMBER OF BUSINESSES & HOUSEHOLDS	CONSUMPTION kwh	GENERATOR FUEL #1 DIESEL US gallons	Equivalent Natural Gas scf	FUEL #1 DIESEL US gallons	Equivalent Natural Gas scf	NATURAL GAS EQUIVALENT scf	DIESEL STORAGE ¹ US gallons	LNG EQUIVALENT ¹ US gallons	PROPANE EQUIVALENT ¹ US gallons	ELECTRICITY EQUIVALENT kwh
UPSTREAM OF PIPELINE												
Fort Yukon	565	278	1,077,480	189,562	24,740,956	1,000,800	130,620,345	155,361,801	1,190,362	2,002,070	1,821,789	33,685,145
Beaver	126	76	122,962	27,030	3,527,859	273,600	35,709,296	39,237,155	300,630	505,630	460,099	9,037,288
Stevens Village	92	51	113,265	30,454	3,974,747	183,600	23,962,817	27,937,564	214,054	360,017	327,599	6,095,247
Subtotal Upstream of Pipeline			1,313,707	247,046	32,243,562	1,458,000	190,292,958	222,536,520	1,705,046	2,867,717	2,609,487	48,817,680
DOWNSTREAM OF PIPELINE												
Compressor Station to Pipeline crossing of Yukon River												
Pipeline												
Rampart	66	14				50,400	6,578,028	6,578,028	50,400	84,768	77,135	1,642,113
Tanana	300	157	530,875	123,074	16,063,179	565,200	73,767,887	89,831,067	688,274	1,157,608	1,053,368	18,945,995
Kokrines												
Ruby	179	122	407,062	57,050	7,445,962	439,200	57,322,817	64,768,779	496,250	834,643	759,485	14,716,901
Galena	592	281	1,356,914	657,720	85,843,268	1,011,600	132,030,423	217,873,690	1,669,320	2,807,629	2,554,810	34,316,461
Koyukuk	100	57	86,365	22,233	2,901,772	205,200	26,781,972	29,683,744	227,433	382,520	348,075	6,772,109
Nulato	347	125	691,937	87,912	11,473,961	450,000	58,732,394	70,206,355	537,912	904,714	823,247	15,353,657
Kaltag	251	89	386,332	59,884	7,815,846	320,400	41,817,465	49,633,311	380,284	639,600	582,005	10,825,477
Grayling	187	68	367,802	47,150	6,153,850	244,800	31,950,423	38,104,272	291,950	491,031	446,815	8,343,778
Anvik	91	55	246,346	37,616	4,909,506	198,000	25,842,254	30,751,760	235,616	396,283	360,598	6,697,503
Holycross	259	99	527,921	60,615	7,911,254	356,400	46,516,056	54,427,310	417,015	701,378	638,220	12,140,003
Russian Mission	307	78	361,640	62,540	8,162,498	280,800	36,649,014	44,811,512	343,340	577,464	525,464	9,510,553
Pilot Station	582	120	673,725	95,908	12,517,570	432,000	56,383,099	68,900,669	527,908	887,888	807,936	14,748,976
Saint Marys	482	199	1,052,727	152,311	19,879,088	716,400	93,501,972	113,381,060	868,711	1,461,085	1,329,518	24,394,185
Subtotal Downstream of Pipeline			6,689,646	1,464,013	191,077,753	5,270,400	687,873,803	878,951,556	6,734,413	11,326,609	10,306,678	178,407,711
Total Upstream and Downstream			8,003,353	1,711,059	223,321,315	6,728,400	878,166,761	1,101,488,076	8,439,459	14,194,326	12,916,164	227,225,390

¹ It is assumed that a full year storage must be provided in each community for propane, LNG and diesel. CNG would also require a full year storage. The storage volume is pressure dependent.

FIGURE 2
ENERGY DENSITY

Approximate Relative Storage Volumes



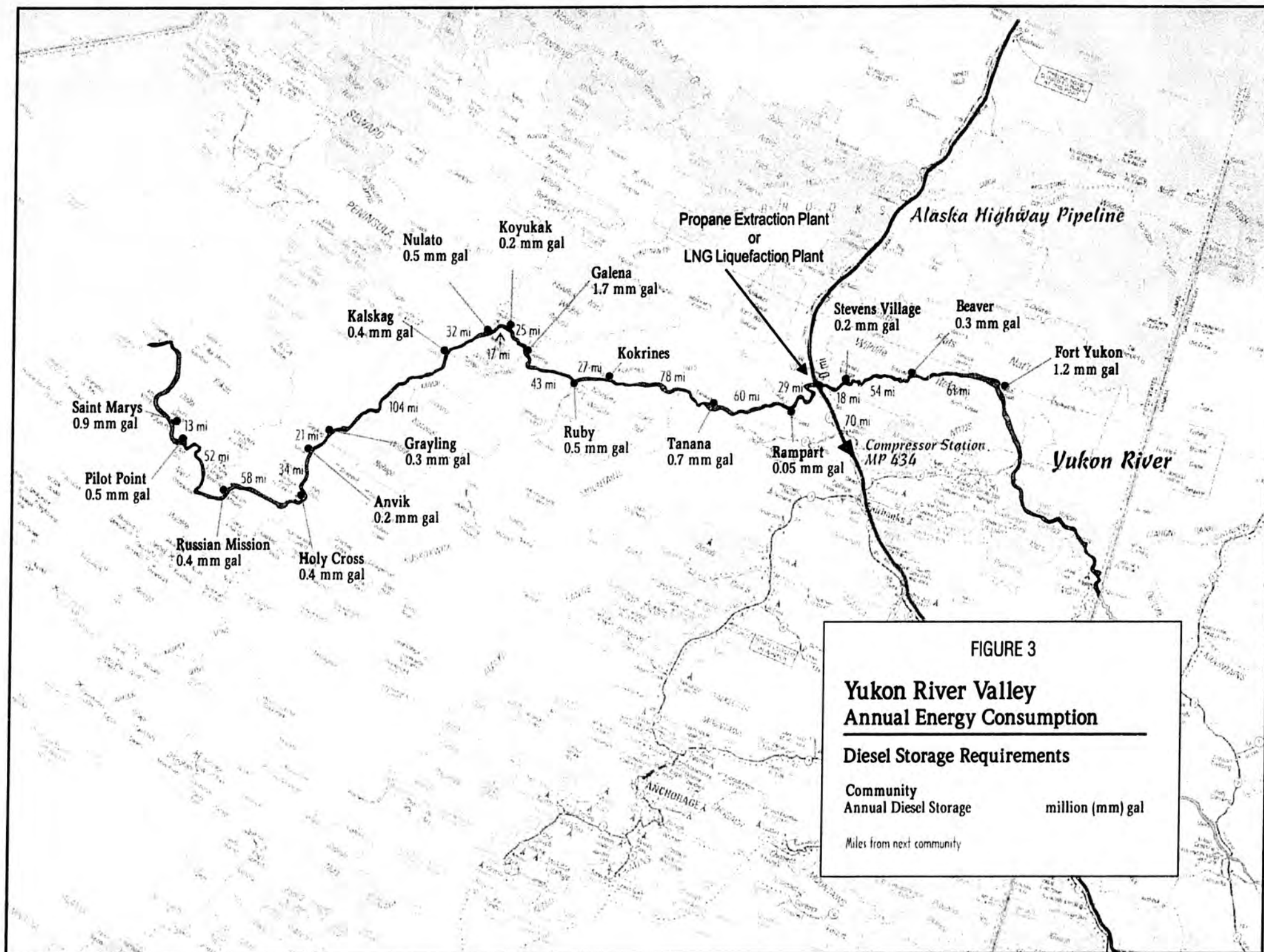
¹ At 3,600 psi storage pressure

² At 2,050 psi (assumed pipeline pressure)

DESCRIPTIONS OF ENERGY OPTIONS

Δ DIESEL FUEL BARGED TO COMMUNITIES

- Diesel fuel for electric generation and space heating is trucked along the Dalton Highway to a point where it is loaded onto barges for transport to the communities along the Yukon River where it is offloaded into storage.
- Typically sufficient storage is provided at each community for one full year of energy requirements.
- There are drawbacks to this alternative:
 - Shipments can only be made during the open water period on the Yukon River.
 - An entire years supply of fuel must be stored at each community during the summer.
 - Diesel fuel at approximately \$9.20/MMbtu (pre-delivery and storage) is significantly more expensive than natural gas.
- The advantages of the diesel fuel alternative are:
 - It is relatively insensitive to distance.
 - Diesel storage is relatively inexpensive as compared to other fuels.
 - Diesel fuel is relatively safe to handle and is familiar to most residents.



Δ NATURAL GAS

- Natural gas may become an economical alternative to diesel fuel as a result of the construction of the Alaska Highway Pipeline.
 - Natural gas can be provided to communities by several methods, including pipeline, Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG). Each method has its own advantages, disadvantages and limitations.
 - The use of natural gas for energy at the communities would eliminate the need to truck diesel fuel from Fairbanks to the Yukon River.
 - Natural gas at approximately \$1.20/MMBtu to \$3.20/MMBtu (pre-delivery and storage) is significantly less expensive than diesel fuel. Absent of any government intervention it is expected the price of natural gas will be market driven. Projections of the value the gas price in Chicago in the 2006 to 2007 time-frame are in the range of \$3.00 to \$5.00 per million Btu. By backing out the tolls from Chicago back to Fairbanks, the value of gas in Fairbanks would be in the \$1.20 to \$3.20 per million Btu range.
- ◆ Figure 4 - provides the Annual Energy Consumption of the named communities as a natural gas equivalent to the current diesel consumption.
- ◆ Figure 5 - Is a plot of Gas Futures from NYMEX at Henry Hub as provided by Gas Daily, Monday 12, 2001. Projections by others have placed (normal) gas prices in the \$2.50 to \$4.00 range by 2005 to 2010.

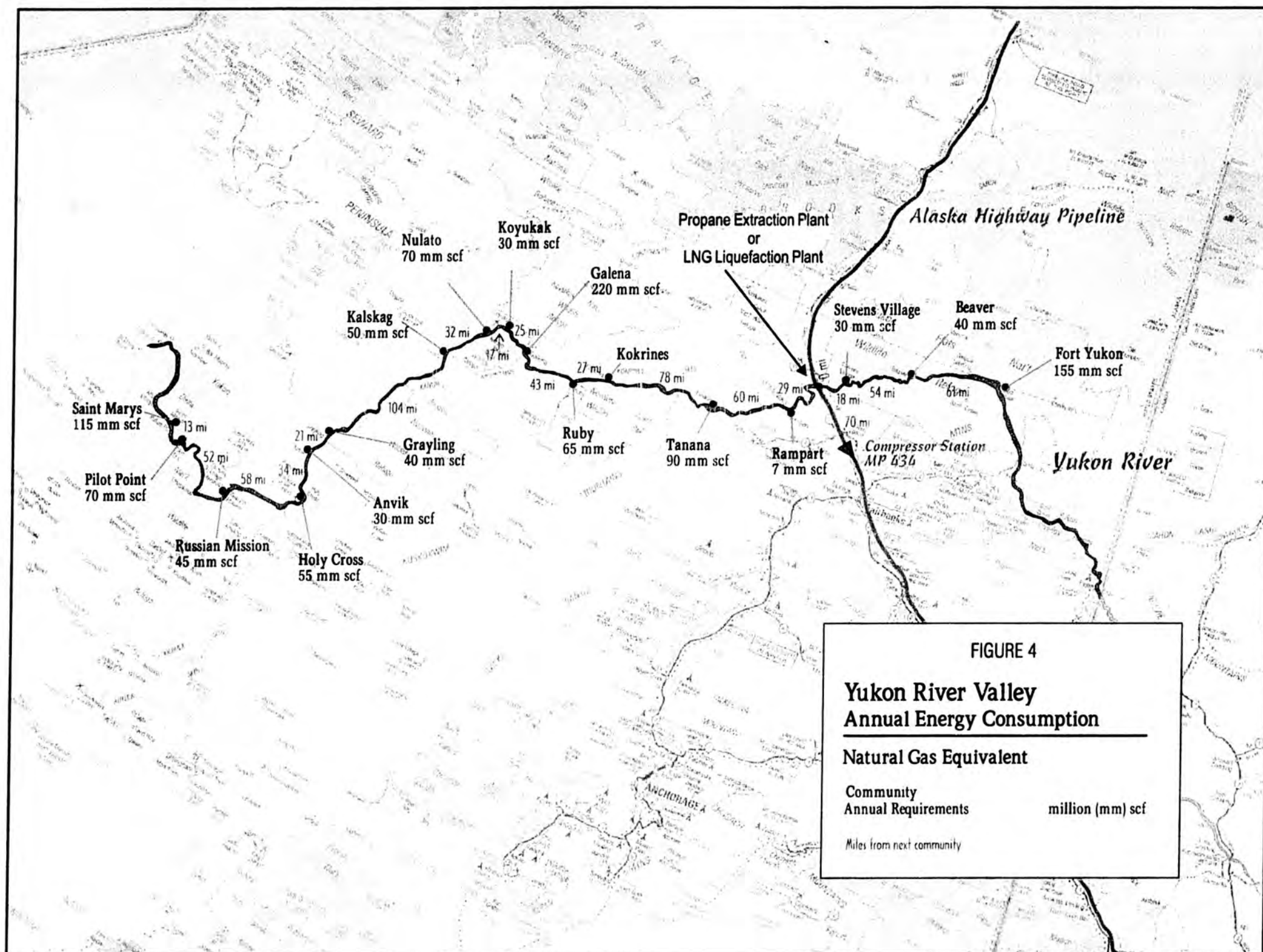
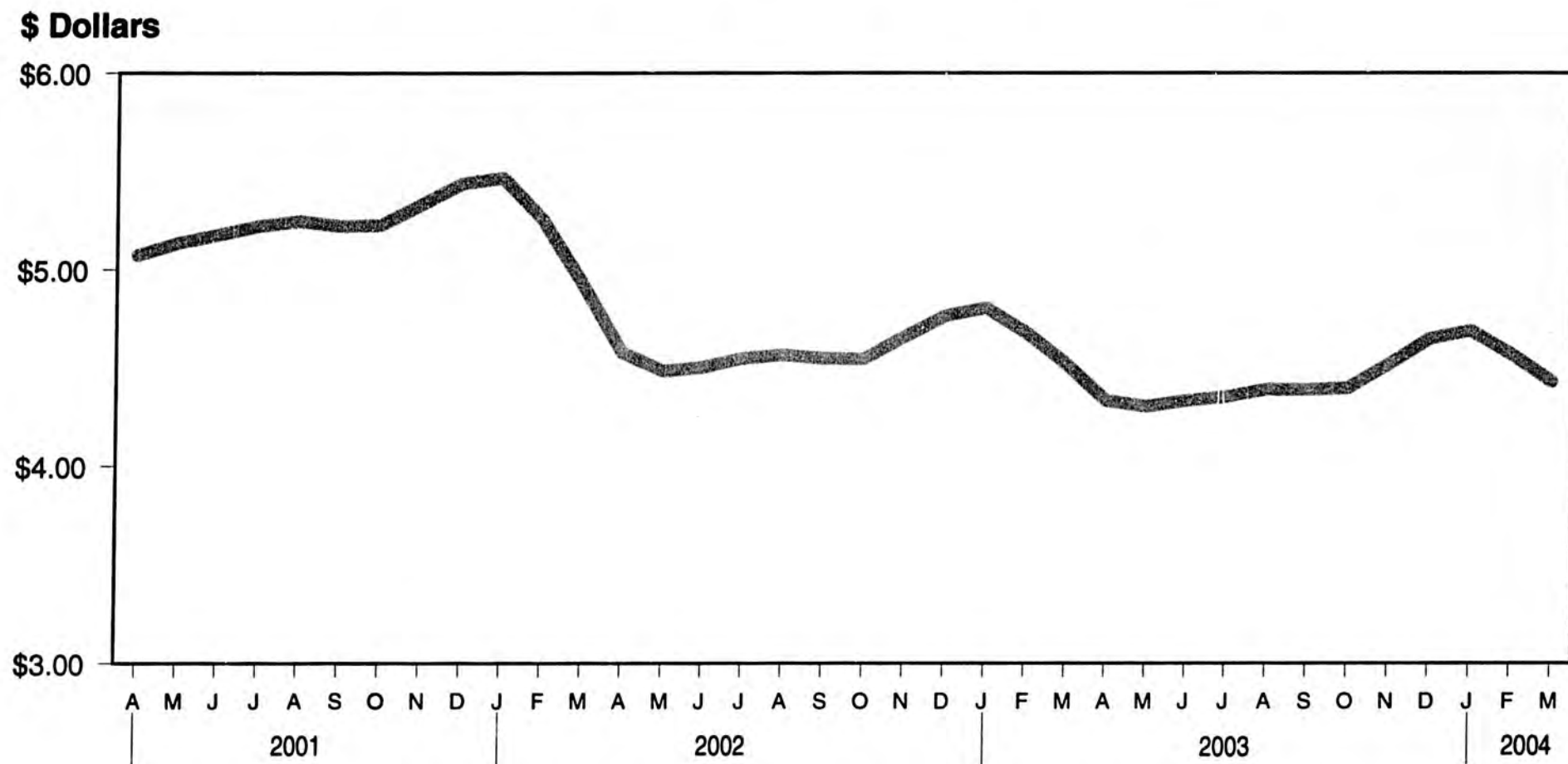


FIGURE 5
NATURAL GAS FUTURE PRICES



Source: Nymex Futures at Henry Hub Gas Daily, March 12, 2001

Natural gas pipeline to communities

- A pipeline to the communities would begin at a takeoff point at the Alaska Highway Pipeline in the vicinity of the pipeline crossing of the Yukon River. Metering and possibly pressure reduction facilities would be located here as well.
- A high pressure pipeline would then carry the natural gas to each of the communities. The pipeline would be sized to carry combined peak day demand of the connected communities for both electric power generation and space heating. Intermediate compression should not be required depending on the pipeline pressure and diameter.
- A regulator station and odorization facilities will be required at each community.
- Advantages of a natural gas pipeline include:
 - The pipeline is not subject to the river conditions (freeze-up, flooding, low water, etc.).
 - Other than a distribution system to the users, no major infrastructure is required in each community.
 - It is not weather dependent.
- A drawback to a natural gas pipeline is the high initial capital cost. As a result, the pipeline option may not be as economical as other alternatives for the more remote, low demand communities due to the distances involved.
- Other disadvantages include:
 - A natural gas distribution system would be required at each community served.
 - Each home, business and prime electric generator would need to be converted to natural gas as a fuel.
- Although the peak demand was not available for design purposes, it is estimated that an NPS 3 pipeline may be adequate for transporting the gas to Fort Yukon, Beaver and Stevens Village and a NPS 6 pipeline telescoping down to NPS 3 may be adequate for transporting the gas downstream to as far as Saint Marys.
- The cost of the pipeline would be in the vicinity range of \$75,000,000 in the Lower 48. Logistics and Alaskan construction cost adjustments will add to this cost.
- Pressure reduction and odorization facilities will be required at each community.
- Others have indicated that distribution within the communities may cost in the range of \$100,000 to \$150,000 per mile not including conversion.
- The Alaska Highway Pipeline may operate in a dense phase mode as opposed to carrying lean gas. In this case it would be necessary to remove the heavier products from the main gas stream prior to entering the transmission line to the communities. This would prevent drop out of these liquids as the pressure reduces in the transmission and distribution lines.

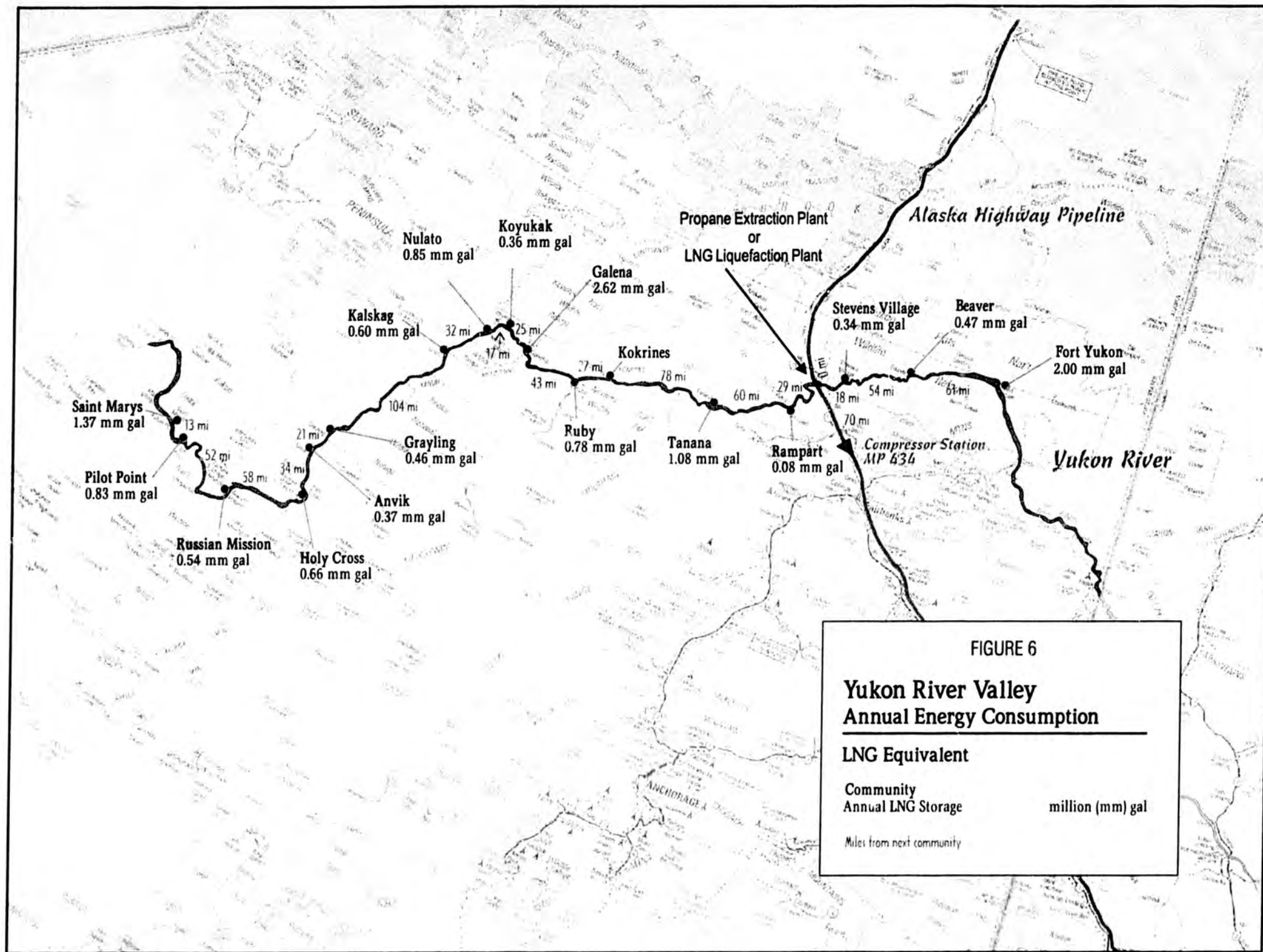
Propane is one of the components of the liquid which would be removed.

The availability of propane provides the opportunity to reduce the systems sensitivity to distance through pipelining gas to the nearer communities and servicing the more distant communities by the barging of propane.

LNG

- A second option for delivering natural gas to the communities is Liquefied Natural Gas (LNG).
- The LNG option would involve a liquefaction facility and storage at the Alaska Highway Pipeline in the vicinity of the pipeline crossing of the Yukon River.
- The LNG would be transferred from the storage at the liquefaction facility to barges for transportation to the communities. Either LNG trailers carried on barges or barges with permanently mounted LNG storage containers could be used.
- Storage, vaporization, odorization and distribution facilities would be provided at each community.
- The natural gas would be used to fuel the generators and to heat the homes and businesses.
- Others have indicated the LNG production, storage and loading facility could range from \$5,000,000 to in excess of \$15,000,000 and the offloading, storage and revaporization facility at the communities could cost in the range of \$3,000,000 to \$5,000,000 per community. The gas distribution system could range from \$100,000 to \$150,000 per mile.
- Each home or business must have its heating converted to natural gas and the prime electric generators must be converted to a natural gas fuel.
- Drawbacks to the use of LNG include:
 - As with the diesel alternative, shipments can only be made during the open water period on the Yukon River.
 - An entire year's LNG supply must be stored at each community during the summer.
 - The LNG storage containers are designed for cryogenic temperatures and as a result are very expensive.
 - A natural gas distribution system would be required at each community served.
 - Each user would need to be converted to natural gas as a fuel.
- The advantages of using LNG are:
 - It is less sensitive to distance than the pipeline.
 - The container sizes are much smaller than required for CNG.
- A hybrid to the LNG alternative may provide the opportunity for some optimization of the system.

The gas entering an LNG Liquefaction facility must be conditioned by the removal of most of the carbon dioxide and heavier hydrocarbon components. Propane is one of these components. Separating the propane from the heavier liquids provides the opportunity to reduce the system's sensitivity to distance by pipelining gas to the nearer communities and by barging propane to the more distant communities.



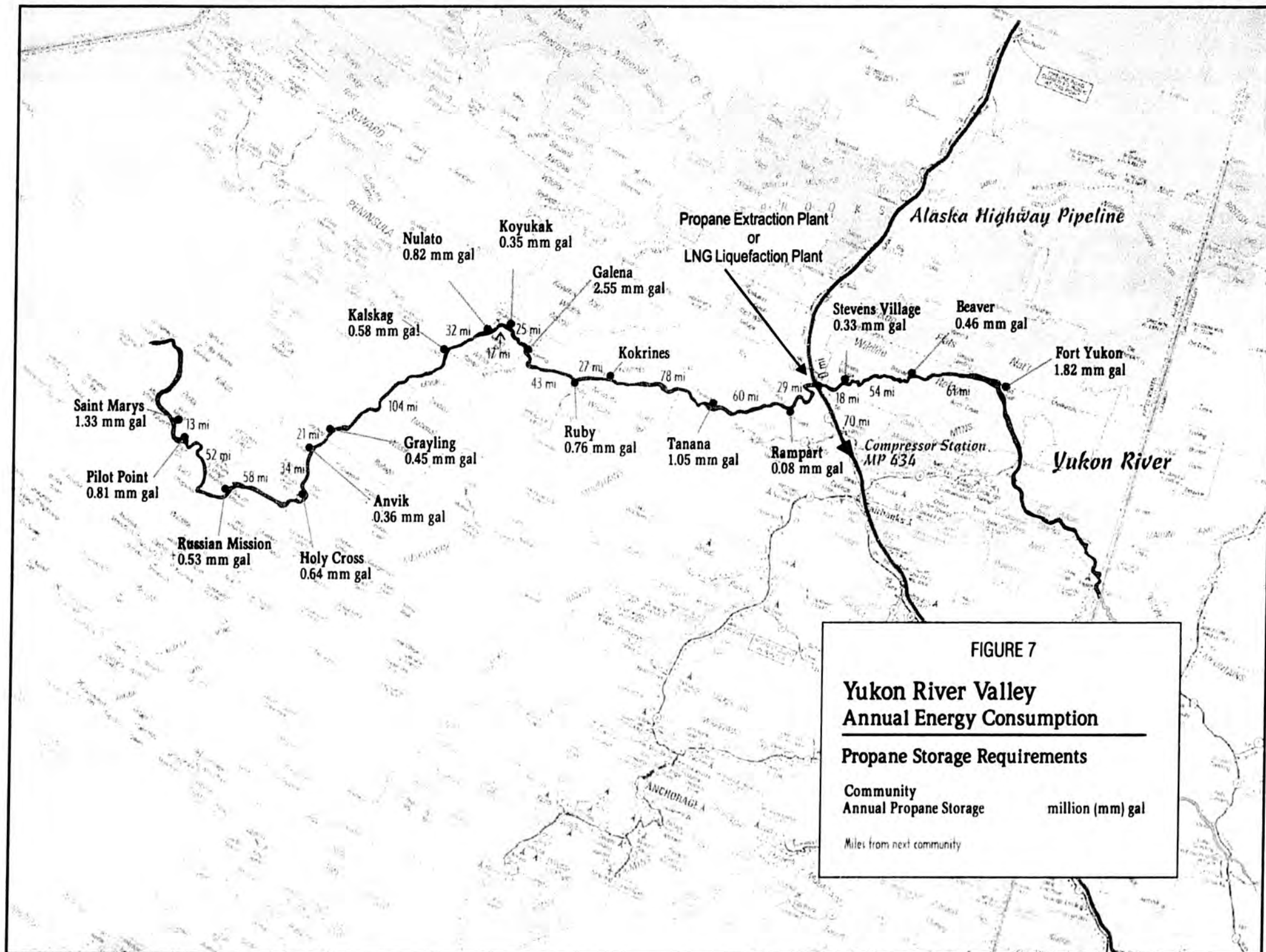
CNG

- Compressed Natural Gas (CNG) is another option for moving natural gas from the Alaska Highway Pipeline to the communities.
- The CNG option would involve a compressor facility at the Alaska Highway Pipeline in the vicinity of the pipeline crossing of the Yukon River.
- Pipeline gas would be compressed into storage vessels mounted on barges. The barges would deliver the CNG to the communities along the river where it would be offloaded into community storage facilities. The gas would then be distributed by a pipeline distribution system or in bulk to each user.
- The CNG would also be used as fuel for the generators.
- Disadvantages to this alternative are:
 - Shipments can only be made during the open water period on the Yukon River.
 - An entire years CNG supply must be stored at each community during the summer.
 - A natural gas distribution system would be required at each community served.
 - Each user would need to be converted to natural gas as a fuel.
 - The cost of the storage containers will be significant. Others have indicated that the storage required for each home would likely cost in excess of \$50,000 making this option uneconomical.
- An advantage is that the economics are less sensitive to distance than the pipeline option and the expensive LNG facilities would not be required.

▲ PROPANE

- The propane option would involve a stripping plant at the Alaska Highway Pipeline in the vicinity of the pipeline crossing of the Yukon River.
- Propane would be stored at this location until it could be transferred to barges for shipping to the communities.
- Each community would have a central storage facility sufficient for a full year's demand. The propane would be distributed to individual users (residences or businesses) from the central storage facility.
- Propane would be used as fuel for the prime electric generators and for heating homes and businesses.
- Some disadvantages to the use of propane include:
 - Shipments can only be made during the open water period on the Yukon River.
 - An entire years propane supply must be stored at each community.
 - Each user would need to be converted to propane as a fuel.
- Some advantages of using propane are:
 - The economics are less sensitive to distance than the pipeline option.
 - A gas distribution system is not required for each community however as with diesel fuel distribution by truck or other means would be required.
- A propane stripping plant of an adequate size to strip the annual propane requirements from the pipeline gas over an entire year would cost in the range of \$10 mm to \$15 mm.
- Propane storage facilities at the stripping plant may cost in the range of \$30 mm to \$40 mm.
- Storage costs at each community would depend on the community demand and may cost in the range of \$150,000 per 50,000 gallons.
- Propane storage will be required at each home or business and heating systems would need to be converted to propane.
- The above are Lower 48 costs. Logistics and Alaskan construction cost adjustments would need to be added.

- ◆ Figure 7 - Provides the propane storage requirements for each of the named communities
- ◆ Figure 8 - Provides a process flow schematic.



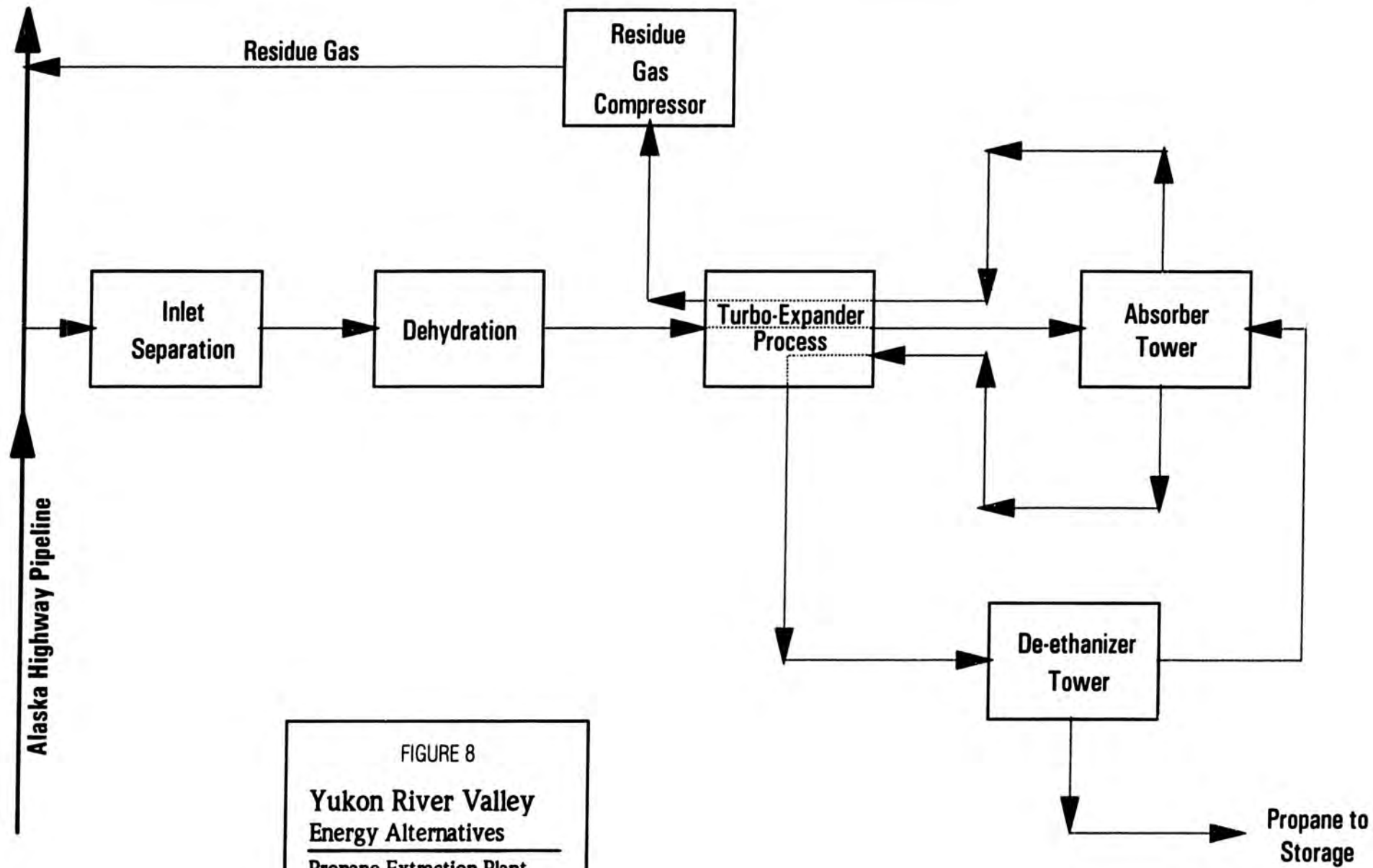


FIGURE 8
Yukon River Valley
Energy Alternatives
Propane Extraction Plant

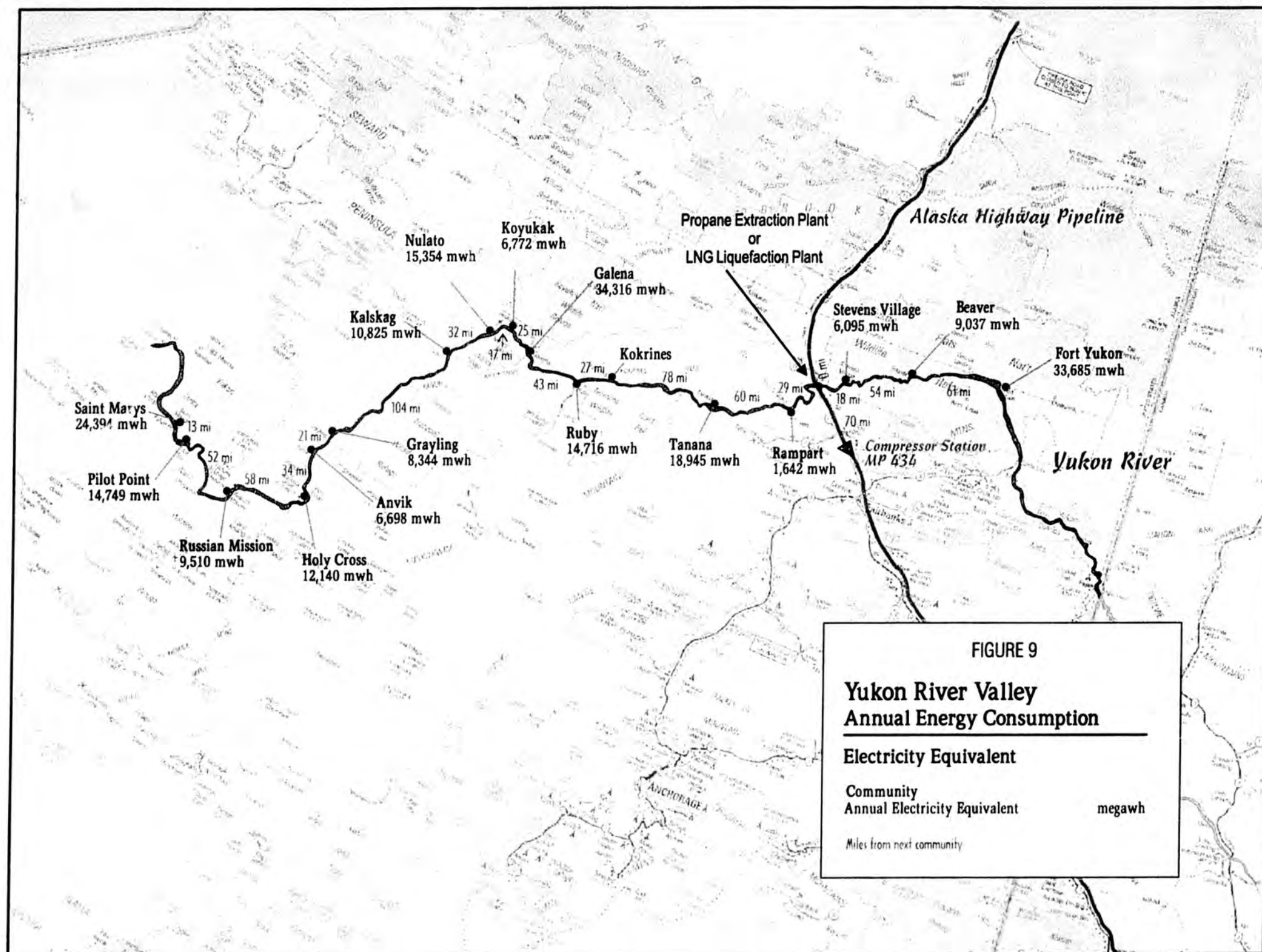
△ ELECTRIC POWER GENERATION AT THE PIPELINE

- The electric power alternative would involve generating electricity at the Alaska Highway Pipeline and distributing the electricity to the communities over high voltage transmission lines.
- The electricity would replace that generated by diesel generators in the communities and could be used as a source of light, power and heat for the community.
- Electricity could be generated using one of a number of processes such as gas fired steam electrical generation or various gas turbine cycles (simple cycle, combined cycle or combined cycle with co-generation).
- One additional option, co-generation, would use the waste heat from the pipeline compressor exhaust as the source of energy to generate electricity. The quantity of power available using waste heat recovery is limited by compressor station size and depending on the number of communities served and the peak demand, additional generating facilities may be required.
- A waste heat recovery facility attached to a 30 MW compressor may generate from 5 to 7 net MW of power at an installed cost of \$5,500,000 to \$8,500,000. Logistics costs and the Alaska construction cost adjustments would need to be added to these Lower 48 costs.
- Waste heat recovery:
 - Produces power with little environmental emissions.
 - Has high reliability and low operating and maintenance costs.
 - Is well suited to modular design.
 - The prime fuel is waste heat thus eliminating the need to burn high value fossil fuels.
- Some advantages of electric power generation at the pipeline are:
 - It is independent of river conditions (ie open water).
 - No barge storage or transportation is required.
 - No storage facilities are required at the communities.
 - No gas distribution system would be required in the communities.
 - An electrical distribution system in each community may not be required, if the present electrical distribution system is adequate for the heating load.
 - It can be very environmentally friendly depending on the generation system selected.
 - The waste heat recovery process requires no additional consumption of hydrocarbon fuel.
 - The present diesel fueled generators could be used as backup.

▲ ELECTRIC POWER GENERATION AT THE PIPELINE *Continued*

- Drawbacks to replacing diesel with electricity include:
 - The economics are sensitive to distance.
 - Each home would need to be converted to electric heat (baseboard heating or electric forced air furnaces).
 - A high voltage transmission line must be constructed.
- No effort has been made to cost the full electric system, these costs will be dependent on the peak demand which is unavailable at this time.

- ◆ Figure 9 - Provides the annual electric power requirements, equivalent to the current diesel consumption, for the named communities.
- ◆ Figure 10 - Is a simplified flow systematic for a waste heat recovery electrical power generator process.



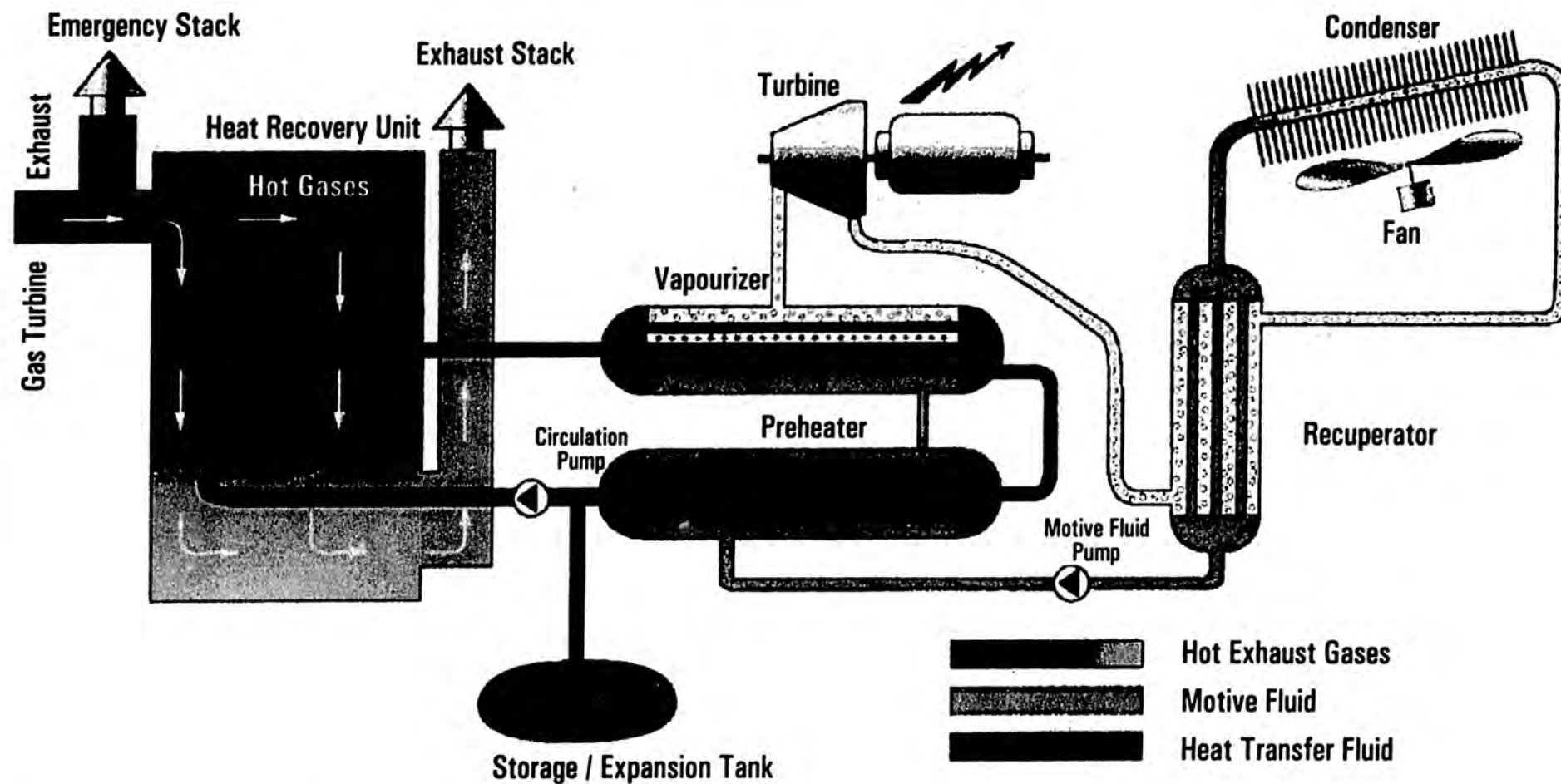


FIGURE 10

Yukon River Valley Energy Alternatives

Waste Heat Recovery
Electrical Power Generation Process

CONCLUSION

- ▲ The Alaska Highway Pipeline will provide a number of additional options for the supply of both electric power and heating fuel to the communities along the Yukon River Valley.
- ▲ The best option may be a combination of several alternatives, taking into consideration the distance to the communities, total energy demand and the energy demand of each community, peak requirements, risk, weather, capital and operating costs and Power Cost Equalization costs.
- ▲ Because of the potential for a significant benefit to the residents of the Yukon River Valley communities, further evaluation of the options and benefits should be considered.

◆ Table 3 - Provides a qualitative comparison of some of the advantages, disadvantages and limitations of each of the alternatives discussed.

TABLE 3
YUKON RIVER VALLEY - ALTERNATIVE FUELS

ENERGY OPTIONS	DIESEL	PIPELINE TO COMMUNITY	CNG	LNG	PROPANE	ELECTRIC POWER GENERATED AT PIPELINE
FACILITY REQUIREMENTS						
General	Trucking from Fairbanks Barging to community	Pipeline to communities	Compression of gas at Alaska Highway Pipeline Containment on barges	Liquefaction plant Storage at plant Containment on barges	Stripping plant at pipeline Storage at stripping plant Barge containment	Generation facilities Transmission line
At each community	Storage for full year - for generation - for community	Pressure regulation and odorization facility Distribution system to users Conversion of electric generators at community to gas fuel	High cost storage Distribution system to users Conversion of electric generators at community to gas fuel	Off-loading facilities Storage Vaporization and storage Distribution system to users Conversion of electric generators at community to gas fuel	Community Storage Conversion of electric generators at community to propane fuel	Transformer station Assume current electrical distribution is sufficient for electric heat load Current generators used for standby power
Per user	Storage tank	Conversion to gas furnace/heating	Conversion to gas furnace/heating	Conversion to gas furnace/heating	Conversion to propane furnace/heating Household Storage	Conversion to electric heat
ENERGY SOLUTION						
Heat	Diesel/fuel oil heat	Gas for heat	Gas for heat	Gas for heat	Propane for heat	Electricity for heat
Electricity	Diesel fueled generators in community	Use gas for fuel generation in community	Use gas for fuel generation in community	Use gas for fuel generation in community	Use propane for fuel generation in community	Electricity on grid
OPERATING COSTS						
	Trucking Barging Fuel distribution in communities	PL operations Gas distribution	Compression plant Barging Community storage	Liquefaction plant Barging Storage and vaporisation	Stripping plant Barging Storage	Generation facilities Cogeneration is relatively inexpensive Power line maintenance Transformer stations
	Electric generators	Electric generators	Gas distribution Electric generators	Gas distribution Electric generators	Distribution in community Electric generators	Electric distribution Reduced fuel usage
ADVANTAGES						
	Relatively insensitive to distance Storage costs are relatively inexpensive Safe to handle Familiar to most residents	Not subject to river conditions ie open water and flood Clean fuel Lower operating costs Low cost of fuel	Relatively insensitive to distance Storage costs are very expensive Clean fuel Low cost of fuel	Relatively insensitive to distance Expensive facilities Clean fuel Low cost of fuel	Relatively insensitive to distance	Reduced fuel usage No storage costs Clean fuel Not subject to river or weather conditions
DISADVANTAGES						
	Summer shipping only Requires full year of storage Sensitive to river conditions High cost of fuel	High capital cost	Summer shipping only Requires full year of storage Sensitive to river conditions	Summer shipping only Requires full year of storage Sensitive to river conditions More onerous regulatory requirements	Summer shipping only Requires full year of storage Sensitive to river conditions Distribution and user facilities more expensive than diesel	Risk of generator or power lines being down

Feasibility of Natural Gas Distribution to the Yukon River Valley and its Applicability to other Rural Areas.

**A Preliminary Report
Fate, Dyson, Joule**

The question posed by Representative's Ogan and Joule of the Special Committee on Oil and Gas was "Is it economically feasible to bring natural gas to the Yukon River drainage area if a natural gas pipeline should cross the Yukon River". We expanded on that question to apply any results to rural areas where transportation might be available such as roads or navigable waterways.

The table of contents is self-explanatory, with pages 14-15 and 22-23 blank due to requested information that has yet to arrive. Page two and three articulate the objectives and the questions.

Preliminary Summary

Although there are still several questions yet to be answered, and data as yet unseen, we can begin to see a somewhat clearer picture of the economics and problems of a gas distribution system in the Yukon River Valley.

At present, there are approximately a total of 8,439,459 gallons of diesel fuel used for both heating and transportation in 16 villages. In 1999 fuel averaged approximately \$1.65 per gallon. In this year of 2001, the price has gone up at least 10 cents per gallon. The total aggregate cost to the villages for fuel or diesel is \$14,769,053 per year.

The cost of LNG infrastructure and plant is approximately \$21.6 million including tankage at the three larger villages of Pilot Station, Galena and Fort Yukon. Eleven other villages re-gas and storage facilities would be \$8.8 million, the total coming to 30.4 million dollars. Adding the cost of capital at 6%, averaging approximately 1.2 million per year, brings the total to 31.2 million. If that were amortized over 20 years, the cost per year would be 1.56 million per year. Adding other transportation, personnel, and administration costs and a huge error factor of 20%, we could raise the yearly cost to 2.56 million per year for infrastructure.

The village distribution system is more complex and calculated somewhat differently. It may be prohibitive to pipe natural gas to each home or business. However, in most villages, an electrical infrastructure exists which could be added to at moderate cost. Therefore, electrical generation at the re-gassification plant seems to offer a better financial advantage.

Local pricing and industrial market pricing by the owner/pipeline operators will add to costs, but given the comparison of nearly \$14.8 million dollars for diesel fuel, the distribution and use appears feasible at this point in the investigation.

Compressed gas and propane were also evaluated. The cost of storage capacity for the amount needed and the infrastructure required makes this moderate, marginal, or even to cost prohibitive. For example, the storage capacity for each home would be approximately 60,000 scf per home or business. This equates to 160 million amortized over the same 20 years, or \$8 million plus approximately \$ 6.7 million of interest, on a total of \$18.7 million. This is mostly the same as diesel without figuring any other incidentals.

All the above computations were based on the prospect of long range storage with at least 7 months of unavailable barge transportation.

We found that if heavy transportation were available at a low tariff, there is no reason that this concept cannot be utilized in other rural areas of the state at the same or near economic level.

-Preliminary Report-
Feasibility of Natural Gas Distribution
To Yukon River Valley or other rural areas
Ad-hoc Subcommittee of the
Special Committee of Oil and Gas

Fate, Dyson, Joule

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- ii.-iv. LNG Fact Sheet
- v. Non-Traditional Sources and Uses of LNG by Jeff Beale, CH IV LNG Company
- vi. Calista Region Map

Research Project: Natural Gas Distribution to Rural Alaska

Objective: Exploring the feasibility of a gas distribution service to the Yukon River Valley or other rural areas if and when the gas pipeline should take the southern route.

Proposed Questions:

- 1) What are the Populations of Villages from St. Mary's all the way up to Fort Yukon?
- 2) What is the distance, in miles, between each village?
- 3) How much would a natural gas distribution complex cost and is it feasible to do in the Yukon Drainage area?
- 4) What is the estimate and feasibility of a plant that would produce either LNG or Gas that could be containerized and stored for transportation to the villages?
- 5) What kind of transportation facilities, including means of shipping, would be required at each village and on the Yukon River in the summer time?
- 6) What type of storage facilities would be needed to carry a supply of gas to the villages through those months when the rivers are frozen solid?
- 7) What size or type of plant/facility would be needed?
- 8) What type would be the least expensive: LNG, LPG, or Compressed?
- 9) Is Electrical Generation Utilizing Gas a possible solution?
- 10) What are the Power Cost Equalization Comparisons between fuel options?
- 11) What is the potential of shallow gas and coalfield methane usage as a future unexplored potential for rural Alaska?
- 12) What are other alternatives to provide power to the rural villages?

Data: See Attached information.

Alternatives:

Electricity Sources Being Explored:

LNG

1) Put a small LNG plant in each village. Then barge in LNG to run turbines that would provide electricity to villages. We encountered a wide variety of estimates on various operations.

The low was \$10 to \$12 million for a small LNG plant alone.

2) LPG and CNG

Other Sources

2) Mine Development

3) Shallow Gas & Coal Field Methane Potential

5) Fuel Cells and Planar solid oxide fuel cells

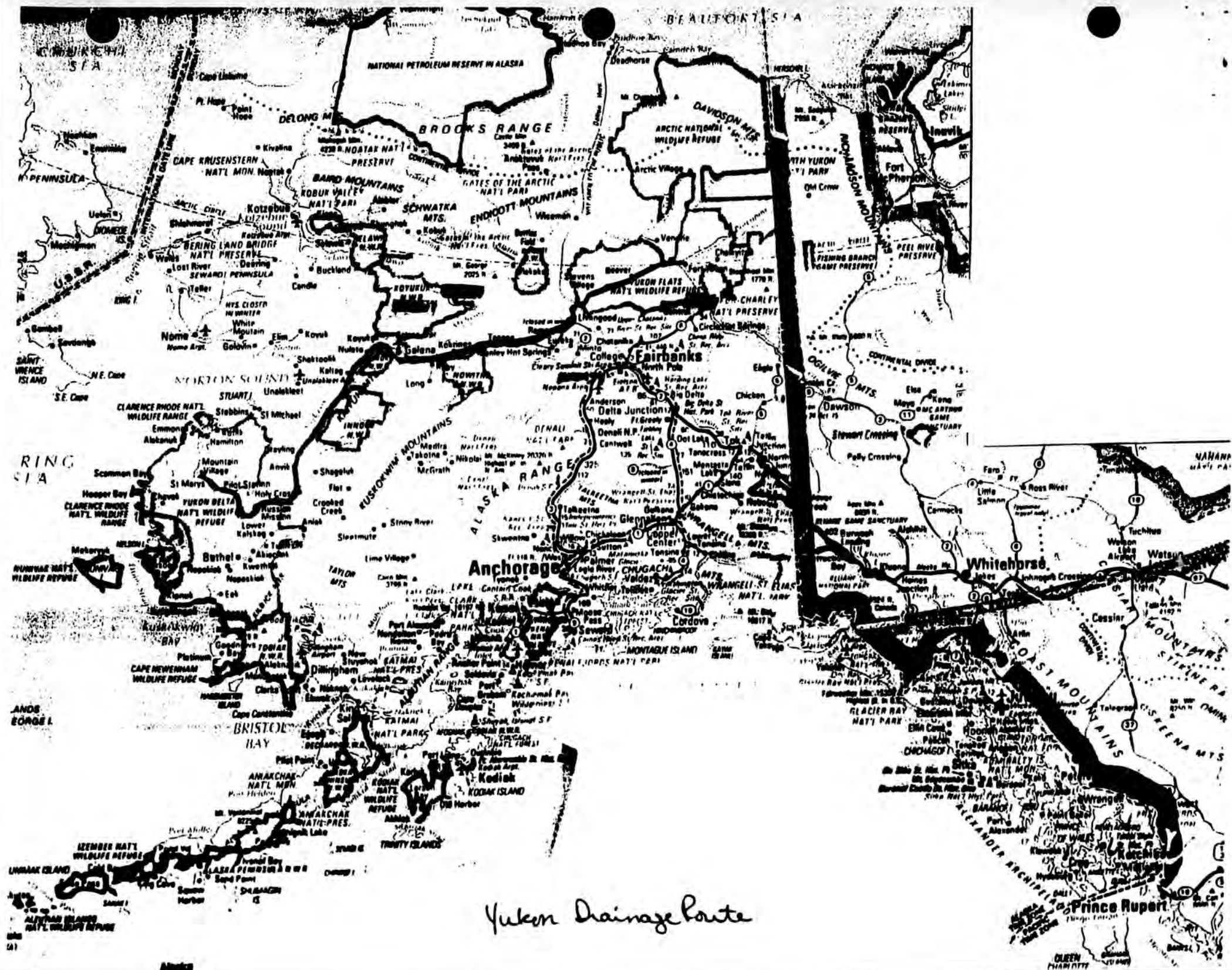
6) Wind Turbines

- 8) Photovoltaic device
- 9) Coal and railroad system
- 10) Biomass Fuels
- 11) Conservation
- 12) Clean Coal Technology

Sources of Capital Funds

Denali Commission
Private
Power Cost Equalization (PCE) - State of Alaska
Other Federal Dollars

Liquefied Natural Gas



Yukon Drainage Area Population and Distances

Village	Population	As Of
Fort Yukon	565	Dec. 2000 DCED
Beaver	126	1999 Dept. of Labor
Stevens Village	92	1999 Dept. of Labor
Rampart	66	1999 Dept. of Labor
Tanana	300	Dec. 2000 DCED
Kokrines		
Ruby	179	Dec. 2000 DCED
Galena	592	Dec. 2000 DCED
Koyukuk	100	Dec. 2000 DCED
Nulato	347	Dec. 2000 DCED
Kaltag	251	Dec. 2000 DCED
Grayling	187	Dec. 2000 DCED
Anvik	91	Dec. 2000 DCED
Holy Cross	259	Dec. 2000 DCED
Russian Mission	307	Dec. 2000 DCED
Pilot Station	582	Dec. 2000 DCED
St. Mary's	482	Dec. 2000 DCED
Total Number	4526	
Average	282.875	

		Ground Miles "as the crow flies" (approximate)	Water Miles 1973 Report statute miles
Fort Yukon	to Beaver	61	70
Beaver	to Stevens Village	54	91
Stevens Village	to Rampart	47	78
Rampart	to Tanana	60	68
Tanana	to Kokrines	78	tanana to ruby
Kokrines	to Ruby	27	117
Ruby	to Galena	43	52
Galena	to Koyukuk	25	32
Koyukuk	to Nulato	17	17
Nulato	to Kaltag	32	34
Kaltag	to Grayling	104	100
Grayling	to Anvik	21	18
Anvik	to Holy Cross	34	38
Holy Cross	to Russian Mission	58	
Russian Mission	to Pilot Station	52	
Pilot Station	to St. Mary's	13	

Distances provided by Kerry Kirkpatrick with DOT

Capt. Moore: Yutana Barge Lines: PO Box 220, Nenana 907-832-5505

MILEAGE AND TIME CHART BASED ON 5 MPH UPSTREAM

From	To	Miles	Runtime in hours
Emmonake	Mountain Village	67	13.4
Mountain Village	Saint Marys	20	3.4
Saint Marys	Pilot Station	25	5
Pilot Station	Marshal	45	9
Marshal	Russian Mission	57	11.4
Russian Mission	Holy Cross	75	15
Holy Cross	Anvik	38	7.6
Anvik	Grayling	20	4
Grayling	Blackburn	54	10.8
Blackburn	Kaltag	65	13
Kaltag	Nulato	36	7.25
Nulato	Koyukuk	15	3
Koyukuk	Galena	50	10
Galena	Ruby	54	10.7
Ruby	Tanana	120	24
Tanana	Nenana	192	38.4

MILEAGE AND TIME CHART BASED ON 10 MPH DOWN STREAM

Nenana	Tanana	192	19
Tanana	Ruby	120	12
Ruby	Galena	54	5.5
Galena	Koyukuk	50	5
Koyukuk	Nulato	15	3
Nulato	Kaltag	36	3.52
Kaltag	Blackburn	65	6.5
Blackburn	Grayling	55	5.5
Grayling	Anvik	20	2
Anvik	Holy Cross	38	3.8
Holy Cross	Russian Mission	75	7.5
Russian Mission	Marshal	57	5.7
Marshal	Pilot Station	45	4.5
Pilot Station	Saint Marys	25	2.5
Saint Marys	Mountain Village	20	2
Mountain Village	Emmonake	67	6.9

Notes: Times vary as much as one hour depending on different river conditions and availability of tide in lower river. To determine ETA's for different speeds, divide miles by speed. Multiply speed by time in decimal hours to figure miles. To determine speed divide miles by hours run. To change minutes into decimals, divide by 60. To change decimal minutes into minutes multiply by 60.

Barges, depending on large or small size, can carry 600-900 Tons. For larger items, such as tanks and housing, they may need to use a special barge.

**Would not or could not provide specific size.*

They go by Tanana ever 10 to 14 days on their way downstream. They stop at Tanana or 3 to 4 miles down from there.

They make trips upstream 3 times a year. Usually mid June, July, and the end of the season around August 21st.

Estimation of Current Average Village Power Cost Equalization (PCE)

Utility/Community	Total Fuel Used Gallons (#1 Diesel)	Total KWH KWH Produced Based on population	Cost #1 \$	PCE (%)	
Anvik	37,616	246,346	0.99	17	*This chart was the most current information available on the Power Cost Equalization Program. Dated: 6/30/99 From the statistical report of the Power Cost Equalization program. 12 th edition, May, 2000
Grayling	47,150	367,802	1.15	16.9	
Holy Cross	60,615	527,921	1.06	16	
Kaltag	59,884	386,332	1	17.1	
Koyukuk	22,233	86,365	1.36	15.8	
Nulato	87,912	691,937	1.04	17.3	
Pilot Station	95,908	673,725	1.06	17.7	
Galena	657,720	1,356,914	1.07	6.2	
Rampart					
Ruby	57,050	407,062	1.98	14.1	
Russian Mission	62,540	361,640	1.23	15.7	
Stevens Village	30,454	113,265	1.48	14	
Tanana	123,074	530,875	1.37	14.4	
Beaver	27,030	122,962	1.96	22.1	
Fort Yukon	189,562	1,077,480	1.3	11.8	
Saint Mary's	152,311	1,052,727	1.06	17.9	
Total	1,711,059	8,003,353	19.11	234	*Averages will be used in the cost equations.
Average	114,071	533,557	1.274	15.6	
Rounded			\$1.27	15.60%	
Current Estimates			\$1.65*	18.68%	
			per gallon	PCE	

*Badger Fuel, Alaska Petroleum, and Sourdough Fuel, retail delivery companies in Fairbanks, AK, where contacted in order to determine the average retail cost increase in #1 diesel fuel since 6/99. Fairbanks information was used because the North Pole refineries would be the most likely suppliers to the above communities. The average retail cost increase was 38 cents per diesel gallon. This means the approximate current retail price is \$1.65 per gallon.

According to the calculation, $(1.27/15.6) = .081$, there is an average increase to PCE of .081 per penny. By multiplying .081 by .38, we get an increase of 3.08% in PCE. This translates into a current estimated PCE of 18.68% $(15.6 + 3.08)$.

*The \$1.65 price appears low because it does not include state or federal road tax.

Estimation of Total Fuel Consumption for Businesses & Households

	# of Businesses and Households per Village	# of Approximate Gallons of #1 diesel fuel used for heating
Anvik	55	198,000
Grayling	68	244,800
Holy Cross	99	356,400
Kaltag	89	320,400
Koyukuk	57	205,200
Nulato	125	450,000
Pilot Station	120	432,000
Galena	281	1,011,600
Rampart	14	50,400
Ruby	122	439,200
Russian Mission	78	280,800
Stevens Village	51	183,600
Tanana	157	565,200
Beaver	76	273,600
Fort Yukon	278	1,000,800
Saint Mary's	199	716,400

Total	1,869	6,728,400	16 villages
-------	-------	-----------	-------------

- 1) Does not account for miscellaneous vehicles or public facilities that use diesel fuel.

- 2) The approximate number of # 1 diesel fuel is based on the equation:

An estimated average of 10 Gallons a day x number of households & businesses
x 30 days/month x 12 months/year.

3408 International Way, Fairbanks, AK 99701-7382
Phone (907) 452-7111 FAX (907) 457-8111
email: dbritton@fngas.com

**Northern Eclipse, LLC
Fairbanks Natural Gas, LLC**

Fax

To:	Randy Clem Daniels	From:	Don Britton
Company:	Office of Representative Fate	Pages:	2
Fax:	(907) 465-3883	Date:	January 23, 2001
Phone:	(907) 465-4530	Re:	LNG & CNG

☐ Urgent ☒ For Review ☐ Please Comment ☐ Please Reply ☐ Please Recycle

Randy,

As per your telephone request today, the following is some information regarding Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG), as it relates to its potential use as an energy source for heating and power generation for villages accessible by the Yukon River.

It is my understanding that you are evaluating the feasibility of barging CNG or LNG into villages along the Yukon River for use as a fuel for power generation and heating. You have indicated that each area will require approximately 7 months of energy to be stored on-site to serve an average community of approximately 500 people. This is due to the community's remoteness and winter access problems.

CNG - My initial reaction regarding CNG, is that due to the volumes of Gas required, the costs associated with the transportation and storage of the CNG would render the project uneconomical. For example a CNG unit capable of storing approximately 35,000 Standard Cubic Feet (SCF) of natural gas has an approximate cost of \$50,000.00. A capacity of 35,000 SCF is most likely not enough gas to serve 1 home for seven months, depending on it size.

LNG - If LNG is to be used as an energy alternative for these villages, the following infrastructure must be considered:

- An LNG production facility with enough capacity to serve the villages annual requirements. This facility will require enough storage to facilitate building inventories for the short delivery time frame. The capital cost of such facility may range from \$5 to \$15 million and may easily exceed \$15 million given capacity requirements and transport loading requirements.
- Transport equipment with enough capacity to transport large volumes in the short time frame. The most likely scenario is an LNG barge. I do not have access to estimated capital costs at

January 23, 2001

this time, as it is unfamiliar technology to me. The only water transportation of LNG that I am aware of is the ocean going tankers, which transport over 20 million gallons per haul to and from international deep-water ports.

- LNG offloading, storage and vaporization equipment at each village. Assuming a requirement for approximately 500,000 to 1,000,000 gallons of storage capacity, the estimated capital costs of storage and vaporization facilities would be in the range of \$3 to \$6 million per each location.
- Natural Gas distribution piping. The estimated capital costs for underground natural gas distribution piping from the storage tank to the end users is estimated \$100,000.00 to \$180,000.00 per mile.

As can be seen there are substantial capital investments required to build the infrastructure required to utilize natural gas in these villages. When compared to propane or diesel, the equipment used to produce, transport and store LNG is so expensive due to the fact that LNG is a cryogenic liquid and must be stored at temperature of negative 260 degrees F. Therefore special metals must be used which is not the case with propane or diesel. Also not discussed are the on going operation and maintenance requirements of these storage, vaporization and underground pipe distribution facilities.

I hope the above helps you to evaluate the potential use of natural gas for the areas being considered.

Note: The estimates given are rough numbers based on Fairbanks Natural Gas experience and may not reflect actual costs given varying site and project requirements.

Yours truly,



Daniel W. Britton
General Manager

MEMORANDUM
Yukon Pacific Corporation

TO: Randy, Brenda
FROM: Matt J. Gillis
DATE: February 2, 2001
SUBJECT: LNG Facilities Cost Estimate

Listed below by individual site is what amounts to some very preliminary cost numbers for LNG facilities to be used to serve rural Alaskan villages along the Yukon River. It was assumed that a LNG Liquefaction Plant would be built at a site where the gas pipeline will cross the Yukon River. The LNG Plant is sized at 200 million cubic feet of gas per year, which is the amount of energy that is currently used in the form of diesel fuel to generate electricity for the communities along the Yukon River. The LNG would be shipped to the communities by tractor trailers loaded onto barges. It will take 14 loads of 14 trailers to deliver all of the LNG. We have included two extra trailers for backup. Storage and regasification facilities would be built at each village sufficiently large enough to store one year's supply of LNG. \$2.0 million is included in the estimate for project design and management and a 20% contingency is included because of the preliminary nature of the numbers.

- LNG Liquefaction Plant with the ability to liquefy 2 million cubic feet per day = \$6 million. The plant will operate for 100 days per year.
- Storage facilities at the LNG Liquefaction Plant = three 50,000 gallon tanks = \$3.0 million.
- 16 insulated tractor trailers to transport the LNG = \$230,000 times 16 trailers = \$3.7 million.
- Dock facilities at the off-loading points = \$200,000.
- Storage and regasification facilities at Galena include two 50,000 gallon tanks = \$1.3 million.

- Storage and regasification facilities at Fort Yukon include one 50,000 gallon tank = \$1.0 million.
- Storage and regasification facilities at Pilot Station include one 30,000 gallon tank = \$0.8 million. This is the smallest size facility we would recommend since essentially no savings are gained by building a tank smaller than 30,000 gallons.
- Project design and management costs = \$2.0 million.
- 20% contingency = \$3.6 million.

The total cost for the items described above would be \$21.6 million. The costs for facilities at additional villages will need to be added in to this total to come up with a grand total.

I hope this will help. I will get some gas fired electric generation costs for you when I return from my trip next week.

Foothills Study Pending

LPG:

Two different Plants are used to process propane, the Expander Plant (gasline) and the Distillation Tower (pipeline). LPG can come out of a gas line or a crude line.

Assuming it comes from a crude line, a distillation tower is needed. Crude is taken out of the pipeline and heat is put to it. This boils off the methane, ethane, and propane. The propane is taken out and put in storage. The rest is put back into the line. The distillation tower needs a heat source (use part of the methane and ethane), a re-compressor (re-compress the methane, ethane, and anything else in the mix to put it back into the pipe), and a condenser (to reliquify propane). Small units are pretty cheap. \$1.5 to \$2.0 million dollars. For transportation one would buy tanks for Barges. A 60,000 gallon propane tank costs approximately \$50,000. It is put on the barge and off loaded to the village. This would be within the 1.5 to 2 million dollar cost. It is a real simple plant. Once the propane is boiled off (boil it off as a gas) it is condensed back into a liquid and then compressed and put it into storage. Once let out of tank pressure is released and it turns back into gas. Then it could be used in the capstone turbines. The opposite process is used for an expander plant with similar simplicity and price.

CNG:

CNG uses different parameters. Pressure from 2400lbs (pipeline) to 3000lbs. There is not much compression to get to CNG. \$1000 per horsepower of compression. The volume would be needed for calculations. Generally it would be very cheap. It would add less than 5 cents to the cost of gas. A compressor station and filling stations would be needed to fill tanks like propane or butane tanks that can be added on to barge.

Pan Handle Population & Distances

Southeast Area

	Population DCED Web Site
Valdez	4068
Cordova	2110
Yakutat	534
Haines	1238
Juneau	26751
Pelican	222
Gustavus	258
Hoonah	795
Elfin Cove	57
Kake	700
Angoon	638
Sitka	8588
Tenakee Springs	94
Point Baker	39
Port Alexander	119
Craig	1260
Klawock	722
Petersburg	3387
Wrangell	2479
Metlakatla	1464
Ketchikan	8263
Hydaburg	384
Total	64170
Average	2916.818182

From	To	Statute miles	Nautical Miles	Air Miles (straight line)
Angoon	Tenakee	34	29.58	31
Angoon	Hoonah	65	56.55	53
Angoon	False Is	27	23.49	
Angoon	Sergius	50	43.5	
Angoon	Sitka	75	65.25	42
Angoon	Kake	62	53.94	44
Angoon	Petersburg	115	100.05	77
Auke Bay	Tracy Arm	90	78.3	
Auke Bay	Haines	77	66.99	68
Auke Bay	Pelican	106	92.22	66
Auke Bay	Hoonah	53	46.11	35
Auke Bay	Sergius	125	108.75	
Auke Bay	Sitka	150	130.5	95
Auke Bay	Petersburg	138	120.06	116
Auke Bay	Gustavus	60	52.2	41
			0	
False Is	Angoon	27	23.49	
False Is	Sitka	48	41.76	
False Is	Sergius	23	20.01	
			0	
Haines	Skagway	17	14.79	18
Haines	Auke Bay	77	66.99	68
Haines	Juneau city	104	90.48	
			0	
Hollis	Ketchikan	45	39.15	40
Hollis	Metlakatla	57	49.59	50
Hollis	Wrangell	105	91.35	70
Hollis	Petersburg	135	117.45	94
Hollis	Kake	196	170.52	114
Hollis	Juneau City	251	218.37	213
			0	
Hoonah	Auke Bay	53	46.11	35
Hoonah	Juneau City	78	67.86	35
Hoonah	Pelican	69	60.03	32
Hoonah	Tenakee	55	47.85	24
Hoonah	Angoon	65	56.55	53
Hoonah	Kake	121	105.27	96
Hoonah	Sergius	108	93.96	
			0	
Juneau City	Haines	104	90.48	68
Juneau City	Hoonah	80	69.6	35
Juneau City	Petersburg	120	104.4	116
Juneau City	Ketchikan	240	208.8	234
Juneau City	Hollis	251	218.37	213
Juneau City	Tracy Arm	72	62.64	
Juneau City	Auke Bay	39	33.93	
			0	
Kake	Petersburg	64	55.68	40
Kake	Angoon	62	53.94	44
Kake	Sitka	127	110.49	53
Kake	Sergius	102	88.74	
Kake	Hoonah	121	105.27	96
			0	

Ketchikan	Metlakatla	18	15.66	16
Ketchikan	Prince Rupert	103	89.61	90
Ketchikan	Seattle	745	648.15	650
Ketchikan	Hollis	45	39.15	40
Ketchikan	Hyder	160	139.2	
Ketchikan	Wrangell	101	87.87	83
Ketchikan	Petersburg	134	116.58	113
Ketchikan	Punch Bowl	63	54.81	
Ketchikan	Bellingham	676	588.12	590
			0	
Petersburg	Wrangell	47	40.89	32
Petersburg	Sergius	152	132.24	
Petersburg	Sitka	177	153.99	94
Petersburg	Ketchikan	134	116.58	113
Petersburg	Hollis	135	117.45	94
Petersburg	Kake	64	55.68	40
Petersburg	Angoon	115	100.05	77
Petersburg	Juneau City	120	104.4	116
Petersburg	Auke Bay	138	120.06	116
			0	
Prince Rupert	Seattle	653	568.11	570
Prince Rupert	Ketchikan	103	89.61	90
Prince Rupert	Bellingham		0	500
			0	
Sergius	Sitka	25	21.75	

Other Energy Sources

Mine Site "Run Off" Power Alternatives

Mines use an immense amount of energy to operate. They may well bring lower cost power to the surrounding areas.

Calista Corporation: Donlin Creek Mine

Study to identify southwestern Calista regional least cost electrical power and energy requirements with and without the Donlin Creek Gold Mine Project and its feasibility and benefit options.

The study looked at several options that included rail-belt and new power plant construction. They recommended conducting a preliminary feasibility level analysis to further refine construction and operational costs of a new 80 mw coal fired plant in Bethel, Alaska with a 175 mile transmission line to the mine site in Donlin Creek. Fuel Cost of \$2.05 \$ per million BTU with the assumption of \$43.00/ ton coal delivered to Bethel and \$30.00/barrel bench mark price for Alaska North Slope Crude.

[Division of Geological and Geophysical Surveys (DGGs): Holitna Basin Project. Gas for Donlin Creek? Projected energy use for Donlin Creek Prospect is 66 MW peak demand with 27 million gallons of diesel fuel per year or 3.6 bcf gas (combustion turbine with 48% efficiency) Shallow gas and coalbed methane are potential sources. Analytical data has been partially received and a summary report should be out this spring.]

Cominco Alaska Incorporated: Red Dog Mine

- 1) Cominco is looking to replace diesel fuel with natural gas. This could improve air quality and could expand into an advantageous fuel source for local communities.
- 2) Shallow Gas Prospect: Cominco needs gas to replace diesel used to generate electricity. They have shallow gas leases and good prospects. Cominco will bear the cost of converting generators from diesel to gas, the access road, and pipeline to the mine facilities. (Mr. Jonathan Kelafant, Senior VP of Advanced Resources International, Inc. @ 703-528-8420 for more information on Red Dog shallow gas prospect)
- 3) Fuel Distribution: The DeLong Mountain Transportation System Port Site, which services Red Dog Mine, is strategically located for distribution diesel fuel to the local villages.

www.cominco.com

Cominco and NANA Development Corporation are evaluating the potential to develop shale-hosted natural gas reserves in areas adjoining the Red Dog mine as a means of reducing energy costs. Natural gas would be an ideal feed source for generating power at the Red Dog mine. The mine's current energy requirements are supplied by diesel-electric generators. Natural gas fired plants offer lower costs with fewer environmental emissions than those fuelled by diesel oil. If shale gas proves to be a viable option, it should provide a means of reducing power costs to the mine as well as to all the people in the region. Another option being considered is power generation from high-grade thermal coal deposits in the area.

Kennecott: Greens Creek Mining Company

5MW addition to Powerhouse-Clean burning combustion turbine.

Fairbanks Gold Mining Company: True North

True North has potential to reduced electrical rates for GVEA customers. Fort Knox purchases 25% of the total kilowatt-hours sold each year by GVEA. Without them residential rates would increase by 7% and commercial rates would increase by 10%

Usibelli Coal Mine, Inc.:

Healy Clean Coal Project - Waiting on answer to whether it is feasible or not.

Turbine Compressor

Capstone Turbine Compressor Distributors, an arm of Williams/Mapco are experts in the field of turbine compressors. They can make any size and then start stacking them for additional power.

The company is very interested in the prospect of providing electricity to rural Alaska, to be involved in the market, and use the experience as a basis in advertising around the world.

The turbines can burn all 3 fuels and cleaner. Diesel, propane, and LNG

Capstone would love to give us a break on the cost to get project going. The turbines are as cheap or cheaper than a comparable diesel machine. The real savings come as savings in fuel and emissions. There is a % savings on fuel from diesel to propane to LNG and a cleaner environment. Probably under \$1.50/ Btu (LNG). Capstone is doing an entire study, at their expense, based on the information we gave them on kWh usage and population in the Yukon Drainage area. They should have results in approximately 2 weeks. The study will cover, assuming a transfer to space heating, exact costs per area, savings in emissions, electricity and fuel costs.

Positive benefits of the turbines are:

With turbines we can start savings before LNG is available.

Villages already have diesel tanks available for use.

Propane tanks are cheaper than LNG tanks.

The North Pole Refinery could supply propane and diesel.

Turbines will be at the same or at a cheaper cost as the diesel machine and there would be cost savings in fuel and emissions.

Turbines don't break. They are practically maintenance free. They only need to be oiled. So, they last forever. They are like a jet engine but small package, compact but powerful. They only have one moving part (main shaft).

If there are any problems there is an 800 number to call where a technician would walk someone through the problem.

Reason so efficient in Alaska is that they work better in low elevation and the colder the air is the better. So, you get more horsepower. Gain about 10% efficiency.

Capstone Study Pending

This report should be complete, on a village by village basis, in approximately two weeks.

Preliminary Remarks:

The villages are now paying 50-60 cents per kilowatt-hour and the maintenance cost on a large diesel engine is about 40%. With the turbines, maintenance cost is reduced by about 90%, using the same fuel (diesel). The cost of electricity is reduced by 20-25%. And, even though the turbines are still burning diesel fuels we will get 95% fewer emissions than with the current diesel machines. Besides that we save on size. A 35,000 machine is the size of a refrigerator. Once the turbines are running on cheaper fuel, there will then be more savings.

Coalbed Methane

The Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys and the Los Alamos National Laboratory, GeoEngineering Group are proposing microhole technology for coalbed methane production on Native Alaskan lands with the goal of eventually replacing diesel with locally produced methane as the fuel for local heat and electric power generation. (Microhole Technology Development of Native Alaskan Coalbed Methane Resources, CBM Development in Remote Alaska) Contacts given in the report were Jim Albright, Los Alamos National Laboratory at 505-667-4318 and Jim Clough, Alaska Division of Geological & Geophysical Surveys at 907-451-5030.

Coalbed Methane Study

For further information contact: **Jim Clough**
Alaska Division of Geological & Geophysical Surveys
Ph: (907) 451-5030

Alaska's hypothetical coal resources exceed 5.5 trillion short tons and may contain up to 1,000 TCF (Trillion cubic feet) of gas. The coal resource varies in rank from bituminous to lignite, and formed in extensive Cretaceous to Tertiary aged basins throughout the state. Economically-producible coalbed methane is an attractive alternative to diesel fuel, which is the main energy source for home heating and electrical power generation throughout much of rural Alaska.

In 1994, the Division of Oil and Gas drilled the state's first coalbed methane test well near the town of Wasilla, located in the northern portion of Cook Inlet Basin. The well (AK-94CBM-1) was drilled to a total depth of 1,245 feet (380 m), continuously coring the Tertiary-age Tyonek Formation from 354 feet (108 m) to total depth. Eighteen seams of high-volatile C bituminous coal were encountered, with the thickest being 6.5 feet (2 m) and a net coal thickness of 41 feet (12.5 m). Thirteen of these seams were sampled for gas content. The core is available for viewing at the Alaska Geologic Materials Center in Eagle River, Alaska. Encouraged by the results of this well, the Division of Geological and Geophysical Surveys embarked on a multi-year study to determine whether coalbed methane could serve as a local energy source in rural Alaska. Three coal basin sites were selected using a coalbed methane producibility model developed by the Texas Bureau of Economic Geology: 1) western North Slope near Wainwright, 2) Yukon Flats at Fort Yukon and, 3) Alaska Peninsula near three Chignik Bay communities. Each site has the potential for thick beds of coal or lignite. These sites also present a cross section of the extreme climate and drill rig access problems that would face any coalbed methane development program in Alaska.

DGGS, in cooperation with the U.S. Geological Survey, is developing a drilling program that will assess the gas producibility for each of these sites. This program proposes drilling two exploratory wells at each site, conduct geologic and hydrologic testing of the wells, initiate water pumping to stimulate gas flow testing, and initiate a pilot test to determine the presence of gas resources.

There are on going projects by the Department of Energy about the recovery and utilization of Coal Mine Methane.

Project #1:

The objective of the project is to reduce methane emissions associated with underground coal mining operations by conducting a pilot-scale field demonstration of power generation and gas processing technologies developed for capturing, recovering, and utilizing coal mine methane emissions from coal mine operations. The estimated end date of the project is 9/30/03. [United States Department of Energy, Office of Fossil Energy, Project Fact Sheet and http://www.fe.doe.gov/oil_gasprocessing/coalmeth.shtml]

Project #2:

Convert coal mine methane from mines into liquified natural gas to fuel heavy trucks. The coal mine methane will be liquefied using a thermoacoustic refrigeration system. The system is called a TASHER and burns a side stream of Coal Mine methane to compress and expand helium contained within a specially designed reservoir. "During expansion, the helium reservoir and attached heat exchangers absorb heat from the main coal mine methane stream, cooling and liquifying it. The TASHAR has no moving parts, which means maintenance is low, and is constructed from low-cost materials." The system prevents coal mine methane from reaching the atmosphere and would eliminate 69,380 tons of greenhouse gases a year.

[http://www.fe.doe.gov/oil_gasprocessing/coalmeth.shtml]

Project #3:

A fuel cell power plant designed to capture and use coal mine methane emissions.

[http://www.fe.doe.gov/oil_gasprocessing/coalmeth.shtml]

DOE

Project ID DE-AC21-95MC32184

Project Title Coal Mine Methane Direct Utilization and in Situ Upgrading/ Storage

FE Program Gas/Oil - Gas Processing

Action #D36 of the Climate Change Action Plan will expand the RD & D efforts to broaden the range of cost-effective technologies and practices for recovering methane associated with mining. Methods could include lower cost, more complete methods for pre-mining recovery of methane from coal seams, using in-mine de-gasification streams, and demonstration of the use of fuel cells and other state-of-the-art technologies for waste methane utilization, transferring appropriate practices to the coal and utility industries.

Actual Completion Date: 12/10/1998





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Carbon Sequestration

Sequestration in Geologic Formations

Carbon dioxide sequestration in geologic formations includes oil and gas reservoirs, unmineable coal seams, and deep saline reservoirs.

Oil and Gas Reservoirs. In some cases, production from an oil or natural gas reservoir can be enhanced by pumping CO₂ gas into the reservoir to push out the product, which is called enhanced oil recovery. The United States is the world leader in enhanced oil recovery technology, using about 32 million tons of CO₂ per year for this purpose. From the perspective of the sequestration program, enhanced oil recovery represents an opportunity to sequester carbon at low net cost, due to the revenues from recovered oil/gas.

In an enhanced oil recovery application, the integrity of the CO₂ that remains in the reservoir is well-understood and very high, as long as the original pressure of the reservoir is not exceeded. The scope of this EOR application is currently economically limited to point sources of CO₂ emissions that are near an oil or natural gas reservoir.

FOCUS

Lawrence Berkeley Laboratory's Sally Benson heads a DOE effort to explore geologic sequestration.

[Read more \(leave site\)](#)

Coal Bed Methane. Coal beds typically contain large amounts of methane-rich gas that is adsorbed onto the surface of the coal. The current practice for recovering coal bed methane is to depressurize the bed, usually by pumping water out of the reservoir. An alternative approach is to inject carbon dioxide gas into the bed. Tests have shown that CO₂ is roughly twice as adsorbing on coal as methane, giving it the potential to efficiently displace methane and remain sequestered in the bed. CO₂ recovery of coal bed methane has been demonstrated in limited field tests, but much more work is necessary to understand and optimize the process.

Similar to the by-product value gained from enhanced oil recovery, the recovered methane provides a value-added revenue stream to the carbon sequestration process, creating a low net cost option. The U.S. coal resources are estimated at 6 trillion tons, and 90 percent of it is unmineable due to seam thickness, depth, and structural integrity. Another promising aspect of CO₂ sequestration in coal beds is that many of the large unmineable coal seams are near electricity generating facilities that are large point sources of CO₂ gas. Thus, limited pipeline transport of CO₂ gas would be required. Integration of coal bed methane with a coal-fired



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electricity generating system can provide an option for additional power generation with low emissions.

Saline Formations. Sequestration of CO₂ in deep saline formations does not produce value-added by-products, but it has other advantages. First, the estimated carbon storage capacity of saline formations in the United States is large, making them a viable long-term solution. It has been estimated that deep saline formations in the United States could potentially store up to 500 billion tonnes of CO₂.

Second, most existing large CO₂ point sources are within easy access to a saline formation injection point, and therefore sequestration in saline formations is compatible with a strategy of transforming large portions of the existing U.S. energy and industrial assets to near-zero carbon emissions via low-cost carbon sequestration retrofits.

Assuring the environmental acceptability and safety of CO₂ storage in saline formations is a key component of this program element. Determining that CO₂ will not escape from formations and either migrate up to the earth's surface or contaminate drinking water supplies is a key aspect of sequestration research. Although much work is needed to better understand and characterize sequestration of CO₂ in deep saline formations, a significant baseline of information and experience exists. For example, as part of enhanced oil recovery operations, the oil industry routinely injects brines from the recovered oil into saline reservoirs, and the U.S. Environmental Protection Agency (EPA) has permitted some hazardous waste disposal sites that inject liquid wastes into deep saline formations.

The Norwegian oil company, Statoil, is injecting approximately one million tonnes per year of recovered CO₂ into the Utsira Sand, a saline formation under the sea associated with the Sleipner West Heimdal gas reservoir. The amount being sequestered is equivalent to the output of a 150-megawatt coal-fired power plant. This is the only commercial CO₂ geological sequestration facility in the world.

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Fuel Cells

There is a lot of information out on fuel cells. They have many potential benefits including reduced pollution and fuel consumption, and efficient use of fuel. They are quiet and efficient, but far too expensive to be economical. A larger unit ~200 KW would cost around \$800K-900K. This is expensive compared to diesel electric generators or gas turbines in Anchorage but less expensive per KW than the Healy Clean Coal Power Plant. Small fuel cells suitable for individual homes are still not commercialized. (Ron Johnson, Project Director UAF Energy Center)

Representative Bill Hudson's Utility Restructuring Committee looked at fuel cell issues last session, 21st Legislature 2000.

When will it make sense?

UAF ENERGY CENTER - GOALS

- 1) Develop sustainable energy systems for use in Alaska.
- 2) Initial application focused on rural communities and off grid uses.
- 3) Provide third party testing/evaluation of such systems.
- 4) Develop ways to better link the electric with other utilities.
- 5) Establish long-term operator training program.
- 6) Provide technology for remote monitoring/operation.
- 7) Establish expertise to enable Alaskan value added component to be part of future systems.
- 8) Such systems could be used in communities as well as by industry worldwide especially in remote areas.
- 9) Ultimately, want to establish manufacturing base in Alaska for system fabrication and assembly.

UAF ENERGY CENTER: HELPING ALASKA TRANSITION TOWARD A SUSTAINABLE FUTURE

Observations: Average annual growth rate [worldwide]
Wind [26%], PV [17%], oil, coal, or nuclear [1%]

- True cost of wind-gen elec can be < 5 cents/kWh
- Cost of PV systems ww ~ \$6/Wp in '99
- Low S fuel excellent for cogeneration [stack heat rec]
- Storage and conservation key issues for use of renewables
- \$19B/yr saved in US via adoption of energy efficient refrigerators

The UAF Energy Center - Ron Johnson, Project Director,

Rural Alaskan communities have special challenges to supply dependable heat and electric power while preserving environmental quality. As one of a series of efforts toward this end, the University of Alaska Fairbanks, (UAF) with support from the U.S. Department of Energy (DOE), has established an Energy Center (EC) where new technologies relating to the production of heat and electric power can be evaluated in a northern setting. In its initial phase, the EC consists of a 74 m² (800 ft²) test chamber plus a 15 m² (160 ft²) auxiliary structure in which hydrogen is produced. These structures in turn are located inside an unheated 520 m² (5,600 ft²) warehouse. Initially, we have focused on the evaluation of fuel cells (FCs) and reformers, looking at both performance and reliability issues. Fuel cells produce electricity electrochemically and require a fuel (normally hydrogen) and oxidant (air). Reformers are sometimes added to the front end to convert a conventional fuel such as diesel to hydrogen. Later, we will study the integration of the electric and other utilities and focus on Arctic engineering issues.

While urban Alaskans enjoy the advantages of modern utility systems with energy costs and reliability similar to those in the Lower 48, those in rural Alaska do not. Two factors affect the cost and quality of energy in these villages: the high cost of transporting energy (most commonly in the form of liquid diesel fuel) and the lack of infrastructure. All utility systems, including electricity, water, sewer, and solid waste disposal, must be managed at the level of the community, resulting in higher costs due to the poor economies of scale. Severe arctic winters compound the problem, raising energy demands for both heating and electric power and causing complications for water and sewer systems.

Because of favorable economics, this power is now almost universally supplied by diesel-electric generators, a system with its own set of operational problems: leaky fuel storage tanks, low efficiencies, and short lifetimes caused by prolonged operation at low loads. It is time to look for viable alternatives to an almost total reliance on this technology. One obvious strategy is to consider the use of locally available renewable resources for generating electricity. However, the largest energy demand in the Arctic is for space heating, and recovery of waste heat from electrical generation is an obvious way of saving energy and must be considered as part of any new system.

The UAF Institute of Northern Engineering is embarking on a multiyear program to address these issues in a comprehensive fashion with the objective to create sustainable economies in each rural village. This implies the use of sustainable energy so that each village can begin to reduce its dependence on expensive and environmentally damaging imported fuel oil. Our vision involves the integration of the various utilities plus the use of trained local labor to operate the systems. One likely scenario involves the use of hydrogen as an energy storage medium that can be used both in a fuel cell to produce electricity and heat as well as in a combustion process to produce heat. Hydrogen has a very high energy storage density on a mass basis (38 kW-hr/kg, 1,000 times greater than electrochemical batteries). It is also a very clean fuel and produces no CO₂ when it is oxidized by air in a combustion process, although NO_x will be produced. In an electrochemical reaction in a fuel cell, neither will be produced. As capital costs of solar-electric technologies and hydrogen storage decrease, the day will come when hydrogen can economically be produced when the solar resource (wind, hydro, sunlight, etc.) is plentiful and stored until needed. In the meanwhile, hydrogen can be produced on site from conventional liquid or gaseous fossil fuels using reformation technologies.

Although the first steps involved the physical design and construction, our intermediate-term goal is to use the Energy Center as a platform to begin a systems approach to addressing problems relating to sustainable energy systems in rural Alaska and ultimately in other remote regions worldwide. In this context, we will add at least part of a model dwelling adjacent to the test chamber in the future so that potential users can see for themselves how the heat, produced water, and electricity can be productively used. We will design and test systems to extract heat and water and to protect the FCs from cold ambient temperatures.

We will also develop and begin to implement a training program to allow future users of the technology to gain hands-on experience and have an opportunity to be exposed to current efforts relating to deployment of sustainable energy systems worldwide. This training program will introduce maintenance personnel to the principles of operation of both the technologies for producing heat and electric power as well as how they interrelate to the water and waste disposal utilities. We will also discuss the central role of energy conservation and storage in effectively using renewable energy. These discussions will include examples of how to calculate system economics and payback periods. Conservation will include the use of compact fluorescent lights and other demand-side management strategies. Other discussion points will include resource recovery and environmental regulations. The latter are already playing key roles in rural Alaska with respect to bulk fuel oil storage.

Our systems analysis and development efforts will look at ways to integrate the various facets of community infrastructure, including heat, electric power, drinking water, waste disposal, indoor air quality, energy conservation, and preservation of environmental quality. This will include interconnecting the FCs with the rest of the local village grid and providing for offsite monitoring and control of the utility with appropriate telemetry. It will also include assurances that appropriate power quality is achieved. We will use recent developments in renewable technologies such as wind turbines, photovoltaics, and energy storage together with energy conservation and modern water treatment and waste disposal methods to help design and implement modern systems in rural Alaska. In remote areas worldwide, there is a heavy emphasis on reliability, even at the expense of higher initial costs, to minimize life cycle costs. Hence, we will not recommend deployment of any technology to rural Alaska until long-term tests have been conducted in a northern environment. The conducting of such tests is one major task of the Energy Center.

After the facility was completed in August of 1999, we have measured the performance of several fuel cells (FCs) and reformers. We have collected detailed energy balance data for five PEM FCs and a steam reformer and developed a control system for the latter. We have also performed thermodynamic analyses of the performances. Reformer operation was compared with equilibrium calculations using an FTIR for raffinate [H₂ depleted stream, which is then combusted with air to provide heat for the endothermic steam reforming and then becomes exhaust] gas analysis. Although the initial reformer tests were run using diesel fuel as the feedstock, we hope to look at other fuels in the future.

Concurrently, we are collecting data on energy use in Alaskan residences [both thermal and electrical] and developing a Simulink-based modeling capability to analyze energy systems including those employing FCs. In the future, we plan to become involved with other energy systems both fossil fuel based and renewable. The former will involve clean fuels and cogeneration. The latter will involve collaboration with user groups such as the KEA, which has made significant accomplishments introducing wind turbines to Alaska. We also want to prepare for setting up a training program for rural utility workers that incorporates conventional as well as alternative technology for the production of heat and power as well as integrating the electric power utility with those involved with water production and waste disposal.

Sustainable Energy Systems for Alaska

[part of this document submitted by Dr. Ron Johnson, ffraj@uaf.edu, UAF-Institute of Northern Engineering in 9/2000 as part of a federal initiatives process.]

To address affordable electricity in rural Alaska for both municipal and industrial applications, we will look at a host of energy technologies as well as energy conservation measures. During the first year, we will establish a 3-year plan to carry out a coordinated series of projects to benefit Alaska as well as other regions of the US and the world where remoteness is a critical issue.

Energy technologies can be categorized as (1) those needed to convert an energy source into electricity or heat, and (2) those used for storage of electrical energy or heat.

Under the first category, we will consider diesel-electric generators, wind turbines, photovoltaic devices, low-head hydro power, water turbines, thermoelectric and thermophotovoltaic generators, fuel cells, and hybrid systems combining two or more of the above technologies. Advantages can be taken of advances that may occur with respect to low sulfur [clean] fuels to improve the performance of several of these systems including improvements in the capture of waste heat [cogeneration].

Diesel-electric generators are the dominant source of electric power in rural Alaska today and are discussed in another part of this initiative. Fuel cells are electro-chemical devices that convert a fuel (normally hydrogen) directly into electricity. Billions of dollars are currently being spent by multi-national corporations and others to commercialize them for both stationary power and transportation. UAF has participated in this work for the past two years through the UAF Energy Center and will continue its efforts. This center has excellent staff and equipment for analyzing the performance of energy systems.

Wind turbines have produced electric power at many locations worldwide; in the lower 48, the current cost of electricity at modern plants is in the 5 to 10 cents/kW-hr range. Average growth rate of energy sources (percent) are wind (26), photovoltaics (17), oil, coal or nuclear (1) in 1998. The world wind capacity grew by one-third from 1998 to 1999 (to 10,000 MW). Most machines operated today consist of two- or three- bladed propellers mated to a generator with a gearbox. Currently, the Kotzebue Electric Association is operating several hundred kW worth of wind turbine capacity in Kotzebue, Alaska. Coastal Alaska possesses an abundant wind resource. As with other renewable systems, energy storage is a key issue.

Photovoltaic devices convert sunlight directly to electricity at efficiencies as high as 30%, although 10 - 15% is typical. With power densities around 125 W/m², a one square meter panel may produce a kW-hr each day. With costs of around \$6K per peak watt, electric power can be produced at a range of 25 to 50 cents/kW-hr. Obvious shortcomings in northern Alaskan applications are associated with the lack of solar input during those parts of the year when the demand for electrical power is the greatest. But the solar resource is still significant for two-thirds of the year in much of the state.

Hydropower currently accounts for 19% of electrical power production in Alaska; it is an ideal resource when flowing water is available at an elevation difference (with respect to the village elevation) of, for instance, at least 30 meters. This source of power is limited by the high costs of construction, and currently is used to power mostly the more densely populated areas of Alaska, such as Valdez. Tidal power has a niche market. For areas with little elevation difference, there is the possibility of water turbines. But such a technology is inefficient and subject to severe damage during breakup and other high flow conditions. Many villages in interior Alaska are not blessed with conditions suitable even for low head hydropower. Much of coastal Alaska is blessed with world-class wave energy. With prototype machines to harness wave power now being deployed in Europe and elsewhere, it is time to consider utilization of this technology in Alaska.

Biomass generators also use renewable resources. Waste heat from wood stoves can be converted directly into electricity through thermoelectric generators (TEGs). For the arctic, since the primary end use of energy for most of the year is thermal, it would be prudent to design cogeneration systems whose primary purpose is supplying heat, with electrical production as a by-product rather than the opposite, which is typically in most commonly used systems. One technology suited to this end involves mating a wood or oil stove to a thermoelectric generator (TEG). By incorporating this technology into the design of the stove at the front end, one should be able to maximize cogeneration efficiency and minimize life cycle costs. TEGs available today can easily supply a few tens of watts. Wood stoves have thermal outputs from 3 to 10 kW, so even a 3% efficient TEG could supply from 90 to 300 watts. This could supply a critical core of a household's electrical needs and minimize the O&M problems associated with DEGs. Capital costs are currently in the range of \$10-\$20/W due to small sizes and limited production. In much the same way, Thermophotovoltaic generators (TPVGs) can harness higher-grade heat via the photoelectric effect. **In designing storage systems** for electrical energy, we will consider batteries, hydrogen, hydro, and flywheels. Storage is a critical part of any technology where the energy resource is intermittent, such as wind and other solar energy.

Hydrogen, with a heating value of over 100,000 kJ/kg, offers the possibility of storing large amounts of energy per unit mass. For reasonably compact storage in pressure vessels, hydrogen can be compressed to several hundred atmospheres. Advances are occurring with respect to storage in metal hydride beds. It can be produced by the electrolysis of water via renewable energy sources or other technologies, then used as the fuel in a fuel cell. The efficiency of such a system [from PV array output to fuel cell output] may reach 40%. If the electricity used to produce the hydrogen costs, say, 35 cents per kW-hr, the cost of hydrogen will exceed \$100/M Btu (equivalent to \$14/gal heating oil). So, one may want to produce hydrogen with renewable energy only during periods of excess capacity (i.e., when the electricity is "free"). Hydrogen is the ultimate clean fuel, especially with respect to global warming.

Batteries utilizing lead and sulfuric acid are widely used today and can return over 80% of the electricity stored. Unfortunately, they are expensive (\$100 - \$200/kW-hr), and they degrade with cycling. Other types of batteries include nickel-cadmium and zinc-air. Energy densities are much lower than those of hydrocarbon fuels by several orders of magnitude (normally a few tens of watt-hours per kg [zinc-air at 140, instead of over ten thousand]).

Flywheels are electromechanical batteries that can provide high power with limited storage. Today there are flywheels available in a 100 kW size with up to 3 kW-hr energy storage capacity. Their chief application is to respond quickly to changing loads so they can be of use in maintaining suitable power quality. They have long lifetimes and current costs are in the \$2K to \$10K/kW-hr.

Remote areas worldwide share common problems, two of which are (1) high transportation costs and (2) lack of infrastructure. These two and other factors place a premium on reliable technologies in minimizing life cycle costs. We must be able to stay abreast of developments in energy technology so that we can field test and then deploy suitable configurations. These configurations must include conservation measures as well as linkages to the other utilities (water and waste disposal).

UAF/INE will provide a focal point where several organizations can coordinate their studies, pooling their efforts and expertise. The success of this project requires input from all levels of technology research and development, including the private sector. UAF/INE would ask the private sector to participate by providing test technologies, and inviting suppliers to come to Alaska to share their expertise. UAF/INE will also work closely with entities such as the Alaska Division of Energy and the Regulatory Commission of Alaska in assessing appropriate village specific data, including village power and heating needs, and the willingness and ability of village participants to be effective partners in this work. Successful research and development in this area will result in a technology that meets the needs of community and industry that uses energy efficiently, and is applicable in a variety of situations. Each phase of this project will ensure that the next phase rests on a sound foundation of established basic engineering science, proven design, and reliable, established baselines.

Specific measures to be taken include (1) maintaining contact with those parts of the world facing similar issues, (2) periodic reviews of related activities in national laboratories, especially developments in fuel cell and hydrogen storage technology, (3) keeping abreast of R&D activities in those businesses engaged in the manufacturing and sales of renewable energy technologies. Of course, none of these above activities is as important as understanding what the needs, capabilities and wishes of the villagers are.

These technologies are not limited to those associated with the production of heat and electricity, as our goal is to have an integrated utility system that includes providing potable water as well as waste disposal and recycling.

Similarly, deployment of these technologies is not limited to Alaska, or even locations with cold climates. Rural sites in Alaska have many problems in common with remote sites worldwide, including those in Russia, Asia and Africa. Progress in this project will lead to technologies that can be exported to other regions of the world. We will work to further a long-term synergy among the US national labs, industry, foreign participants, local Alaska entities, and DOE -- all directed toward designing, developing, and deploying clean, renewable power production appropriate to the varied requirements of remote, off-grid locations.

Load leveling is a simple concept: power developed during periods of low demand is stored for later use at times of high demand. Using electrolysis to generate hydrogen could be used in this way: excess capacity could be stored for later use, while the DEG could be always run under optimal load. Two possible places where this could be used include diesel electric generator and wind turbine applications.

This strategy could also solve the major problem with wind turbines. Even in the windiest parts of Alaska, the winds are variable in intensity, and do not match the demand cycle of humans. Energy can be stored in battery banks, but these systems are very expensive per energy unit stored. In Kotzebue, where wind turbines have been installed, there still are DEGs for the times when the wind does not blow. Frequently, wind power only exacerbates the under loading problem of the DEG. However, if hydrogen can be generated and stored, the wind energy can be used when demand is high and the power is needed.

Improving the quality of life in any community must also consider issues associated with providing employment, providing clean water, and assuring sanitary handling of waste products. Even though many Alaskan villages are surrounded by water in the winter, it is in the frozen state, and melting ice to provide water for domestic consumption and use is expensive. Hence, in designing a utility to meet electrical and thermal demands, we must also consider water supply and waste disposal or by-product recovery issues. By integrating these needs into the front end, system efficiencies can be improved and life cycle costs minimized. For example, low-grade waste heat could be used to prevent water from freezing or for melting ice and snow. Plus, the electric loads associated with water and wastewater treatment equipment and the pumping of water need to be included on the demand side of the equation. Similarly energy recovery from the waste stream is an issue worthy of consideration.

Power quality is an important consideration, particularly when power electronic devices such as inverters are utilized in an electric utility system. Such switching devices may cause abnormal levels of voltage "spikes" or impulses and harmonics in the system. These impulses, if large enough, can damage consumer electronic equipment. Over- and under-voltages of a more long-term nature are also a potential problem for all types of electrical loads. If sufficiently high or low, they can seriously diminish the life expectancy of, for example, lighting products and electric motors.

A telemetry monitoring program will be established within UAF. to control these technologies at distance thereby providing a fail-safe 'tele-engineering' capability for these developing technologies.

One important focus of our initial operation of these units will be the operational aspects specific to northern engineering in Arctic and sub Arctic regions. This will include exposure to ambient temperatures for periods of time during the winter to better understand problems that may arise during start up following cold soak. The test units may be considered for placement at both in door and outdoor locations. Behavior of the materials out of which the units are constructed as well as efficacy of lubricants and icing in exhaust streams will be of particular interest. Of course, we expect the normal operational mode will be in a heated enclosure.

Other issues associated with northern engineering include: design of enclosures; capture of waste heat for space heating, sewage treatment, or co-generation; heat management to minimize permafrost melting; and operations in extreme wind conditions.

Indoor air quality (IAQ) issues and energy conservation should be part of any strategy employed to provide space heating. One of the world's major health issues is the poor IAQ associated with poorly ventilated combustion devices. This is true in both warm and cold climates. In the desire to reduce energy consumption while providing space heating and cooling needs, designers and builders have sometimes reduced air exchange rates to such low levels that IAQ has become unacceptable. This has caused problems especially in some Alaskan homes with elevated levels of radon. IAQ can be improved without much of an energy penalty by installing air-to-air heat exchangers, but operation of these devices presents special problems with very cold ambient air.

Training is a critical component and this is an activity that UAF will be heavily involved in. Since many villages may have only one or two individuals responsible for operating the wastewater, water, and power utility, we will provide training for all three of these at one site at UAF and elsewhere. At the UAF site, we will provide education and training focused on applications, maintenance, and customized systems design of small-scale power systems based on fuel cells and other clean, efficient, renewable energy technologies, as well as water and wastewater treatment. For the latter, we will corroborate with the Alaska Village Electric Co-operative, the Alaska Water Management Association and KEA. These groups are valuable both for their expertise in rural power and water issues, as well as being efficient networks for dispersing new information. Our hope is to use this training to produce videotape illustrating the interrelationships between the utilities.

Renewable energy will only be viable in the long term when coupled with energy conservation. As part of our training, we will focus on increasing awareness of energy conservation especially with respect to electrical appliances and space heating. We will provide examples, for instance, that illustrate lowering of life cycle costs when incandescent lights are replaced by compact fluorescent ones. Similarly, the use of air-to-air heat exchangers can lower space-heating costs while preserving indoor air quality (IAQ). The latter is a key health issue in northern remote communities, where poorly ventilated combustion equipment often contributes to unacceptable IAQ, sometimes even leading to death by asphyxiation. Moreover, the repair of fossil fuel-burning equipment such as snow machines indoors can lead to unsafe levels of Volatile Organic Compounds (VOCs) in homes. Similarly, the temporary storing indoors of honey bucket wastes can increase levels of pathogens.

The bottom line is that Alaska has both world-class fossil fuel and renewable energy resources. The latter include hydro, wave, and wind resources. We are heavily dependent on the former. It behooves us to now move toward efficient utilization of the latter to diversify our energy generation capability.

Ron Johnson UAF, 10/2000

Energy Efficiency Demonstration Projects

In 1997, the Alaska Energy Authority began providing assistance for one or two small energy efficiency demonstration projects in rural communities or schools each year. Typically, older T-12 fluorescent tubes and magnetic ballasts are replaced with high efficiency T-8 tubes and electronic ballasts. Motion sensors and high efficiency exit lights may also be added. Successful projects have been completed in Tanana, Aniak, and Chevak.

Lighting bills can be reduced by as much as one-third with a change to more efficient lighting products. Lighting retrofits in communities with high electrical rates (over \$.32 per kWh), can expect to pay back the cost of the retrofit out of savings in under three years. In communities with even higher electrical rates, the payback period may be as short as two years.

To find out more about this program, or if you think that your community may be a good Energy Efficiency Demonstration Project site, contact the Alaska Energy Authority.

Alaska Energy Authority/AIDEA
813 West Northern Lights Blvd.
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cleaning up **COAL**

The Cleanest Coal Technology — a Real Gas!

Don't think of coal as a solid black rock. Think of it as a mass of atoms. Most of the atoms are carbon. A few are hydrogen. And there are some others, like sulfur and nitrogen, mixed in. Chemists can take this mass of atoms, break it apart, and make new substances — like gas!

How do you break apart the atoms of coal? You may think it would take a sledgehammer, but actually all it takes is water and heat. Heat coal hot enough inside a big metal vessel, blast it with steam (the water), and it breaks apart. Into what?

The carbon atoms join with oxygen that is in the air (or pure oxygen can be injected into the vessel). The hydrogen atoms join with each other. The result is a mixture of carbon monoxide and hydrogen — a gas.



One of the most advanced - and cleanest - coal power plants in the world is the Píñon Pine plant near Reno, Nevada. Rather than burning coal, it turns coal into a gas that can be cleaned of almost all pollutants. (Click on photo for larger version.)

Now, what do you do with the gas?

You can burn it and use the hot combustion gases to spin a gas turbine to generate electricity. The exhaust gases coming out of the gas turbine are hot enough to boil water to make steam that can spin another type of turbine to generate even more electricity. But why go to all the trouble to turn the coal into gas if all you are going to do is burn it?

A major reason is that the impurities in coal — like sulfur, nitrogen and many other trace elements — can be almost entirely filtered out when coal is changed into a gas (a process called *gasification*). In fact, scientists have ways to remove 99.9% of the sulfur and small dirt particles from the coal gas. Gasifying coal is one of the best ways to clean pollutants out of coal.

Another reason is that the coal gases — carbon monoxide and hydrogen — don't have to be burned. They can also be used as valuable chemicals. Scientists have developed chemical reactions that turn carbon monoxide and hydrogen into everything from liquid fuels for cars and trucks to plastic toothbrushes!

Today, in Tampa, Florida, Terre Haute, Indiana, and Reno, Nevada, there are power plants generating electricity by gasifying coal, rather than burning it. At a plant in Kingsport, Tennessee, coal gas is being used to make plastic for photographic film and to make methanol (a fuel that can be burned in automobile engines).

Coal gasification could be one of the most promising ways to use coal in the future to generate electricity and other valuable products. Yet, it is only one of an entirely new family of energy processes called "Clean Coal Technologies" — technologies that can make fossil fuels future fuels.



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- vi. **Calista Region Map**

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Marty Moore
Captain

UAF Energy Center
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Ron Johnson
Project Director

Definitions:

BTU:

British thermal unit, a measure of the quantity of heat, defined since 1956 as approximately equal to 1,055 joules, or 252-gram calories. It was defined formerly as the amount of heat required to raise the temperature of one pound of water 1 degree F. The definition was changed because it was dependent on the initial temperature of the water. Gas utilities frequently use a larger unit, the therm, defined as 100,000 BTU, as a measure of gas consumption.*

LNG:

Liquefied natural gas, natural gas (primarily methane) that has been liquefied for ease of storing and transporting. LNG takes up about 1/600 the space that natural gas does in its gaseous form, and it can be easily shipped overseas. LNG is produced by cooling natural gas below its boiling point, -162 degrees C (-259 degrees F), and is stored in double-walled cryogenic containers at or slightly above atmospheric pressure. It can be converted back to its gaseous form by simply raising the temperature.*

LNG is more practical than liquefied petroleum gas or other liquid gases, particularly for use in large volumes, because it has the same chemical composition as natural gas. This fact and the growing demand for natural gas have stimulated LNG production. Moreover, LNG technology has made it possible to utilize natural gas from remote areas of the world where it previously had no commercial use and was flared (burned). Special tankers transport LNG from such countries as Algeria, Borneo, and Indonesia to markets in Europe, Japan, and the United States.*

*Source: Encyclopedia Britannica

Conversions:

1 gallon of diesel (1#)	=	139,000 BTU
7.5 gallons of heating oil #1	=	1 MCF or 1,000,000 BTU
12.1 gallons of LNG	=	1 MCF or 1,000,000 BTU
1,000,000 gallons of heating oil #1	=	1.6 M gallons of LNG in equivalent BTUs

1 gallon #1 diesel (heating oil) = 6.3 lbs
1 gallon #2 diesel = 6.7-6.9 lbs

LNG Fact Sheet

WHAT IS IT?

When natural gas is cooled to a temperature of approximately -260°F at atmospheric pressure it condenses to a liquid called liquefied natural gas (LNG). One volume of this liquid takes up about 1/600th the volume of natural gas at a stove burner tip. LNG weighs less than one-half that of water, actually about 45% as much. LNG is odorless, colorless, non-corrosive, and non-toxic. When vaporized it burns only in concentrations of 5% to 15% when mixed with air. Neither LNG, nor its vapor, can explode in an unconfined environment.

COMPOSITION

Natural gas is composed primarily of methane (typically, at least 90%), but may also contain ethane, propane and heavier hydrocarbons. Small quantities of nitrogen, oxygen, carbon dioxide, sulfur compounds, and water may also be found in "pipeline" natural gas. The liquefaction process removes the oxygen, carbon dioxide, sulfur compounds, and water. The process can also be designed to purify the LNG to almost 100% methane.

HOW IS IT STORED?

LNG tanks are always of double-wall construction with extremely efficient insulation between the walls. Large tanks are low aspect ratio (height to width) and cylindrical in design with a domed roof. Storage pressures in these tanks are very low, less than 5 psig. Smaller quantities, 70,000 gallons and less, are stored in horizontal or vertical, vacuum-jacketed, pressure vessels. These tanks may be at pressures anywhere from less than 5 psig to over 250 psig. LNG must be maintained cold (at least below -117°F) to remain a liquid, independent of pressure.

HOW IS IT KEPT COLD?

The insulation, as efficient as it is, will not keep the temperature of LNG cold by itself. LNG is stored as a "boiling cryogen," that is, it is a very cold liquid at its boiling point for the pressure it is being stored. Stored LNG is analogous to boiling water, only 470° colder. The temperature of boiling water (212°F) does not change, even with increased heat, as it is cooled by evaporation (steam generation). In much the same way, LNG will stay at near constant temperature if kept at constant pressure. This phenomenon is called "autorefrigeration". As long as the steam (LNG vapor boil off) is allowed to leave the tea kettle (tank), the temperature will remain constant.

If the vapor is not drawn off, then the pressure and temperature inside the vessel will rise. However, even at 100 psig, the LNG temperature will still be only about -200°F.

HAVE THERE BEEN ANY SERIOUS LNG ACCIDENTS?

[See also A Brief History of U.S. LNG Incidents.] First, one must remember that LNG is a form of energy and must be respected as such. Today LNG is transported and stored as safely as any other liquid fuel. Before the storage of cryogenic liquids was fully understood, however, there was a serious incident involving LNG in Cleveland, Ohio in 1944. This incident virtually stopped all development of the LNG industry for 20 years. The race to the Moon led to a much better understanding of cryogenics and cryogenic storage with the expanded use of liquid hydrogen (-423°F) and liquid oxygen (-296°F). LNG technology grew from NASA's advancement.

In addition to Cleveland, there have been two other U.S. incidents sometimes attributed to LNG. A construction accident on Staten Island in 1973 has been cited by some parties as an "LNG accident" because the construction crew was working inside an (empty, warm) LNG tank. In another case, the failure of an electrical seal on an LNG pump in 1979 permitted gas (not LNG) to enter an enclosed building. A spark of indeterminate origin caused the building to explode. As a result of this incident, the electrical code has been revised for the design of electrical seals used with all flammable fluids under pressure.

WHY IS IT BEING CONSIDERED FOR VEHICLE FUEL

- LNG, as fuel, is burned in the gaseous form. The benefits of burning natural gas are well documented when compared to gasoline or diesel.
- Natural gas produces significantly less of the emissions addressed in the 1990 Clean Air Act Amendments. Those emissions specifically being particulate matter (PM), carbon monoxide (CO), nitrogen compounds (NOx) and non-methane hydrocarbons (NMHC).
- LNG has a fairly high energy density when compared to the other clean burning alternative fuels. It still takes about 1.5 gallons of LNG per gallon of gasoline and 1.7 gallons per gallon of diesel to achieve the same range, however.
- LNG is (generally) less costly than gasoline or diesel on an equivalent energy basis.
- LNG fueling times are equivalent to the fuels it replaces.
- LNG can be trucked to fueling stations similar to the polluting liquid fuels.
- Although there are significant misconceptions about its safety, independent testing shows that the use of LNG as a vehicular fuel to be no more hazardous than gasoline and under many test conditions to be safer. Its ignition temperature is about 500°F higher than gasoline, ignition requires mixtures in the narrow %5 to 15% range, and it does not detonate in an open environment. Furthermore, spills will rapidly dissipate (rise) in the atmosphere as natural gas is buoyant at temperatures above -160°F.

WHAT IS CNG?

Compressed natural gas (CNG) is natural gas pressurized and stored in welding bottle-like tanks at pressures up to 3,600 psig. Typically, it is same composition of the local "pipeline" gas, with some of the water removed. CNG and LNG are both delivered to the engines as low pressure vapor (ounces to 300 psig). CNG is often misrepresented as the only form natural gas can be used as vehicle fuel. LNG can be used to make CNG. This process requires much less capital intensive equipment and about 15% of the operating and maintenance costs.

WHAT IS LPG?

Liquid petroleum gas (LPG, and sometimes called propane) is often confused with LNG and vice versa. They are not the same and the differences are significant. LPG is composed primarily of propane (upwards to 95%) and smaller quantities of butane. LPG can be stored as a liquid in tanks by applying pressure alone. LPG is the "bottled gas" often found under BBQ grills. LPG has been used as fuel in light duty vehicles for many years. Many petrol stations in Europe have LPG pumps as well.

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Liquefied Natural Gas - LNG - CNG - NGV - Alternative Fuels - Vehicles - LCNG - CCNG - Clean Air - Propane - Global Warming

~ Non-Traditional Sources and Uses of LNG ~

By Jeff Beale, CH-IV LNG Company

INTRODUCTION

When one thinks about LNG the immediate thought is generally about the large international export/import projects or the traditional gas company peak shaver. As implied in the title, this paper explores LNG from different perspectives, such as, how else might LNG be produced and what other commercial uses might there be. This paper attempts to stimulate thought about other ways of thinking about LNG.

Non-traditional sourcing of LNG includes a review of all of the aspects of the process from the gas production, transportation (both as gas and liquid), and, particularly, the liquefaction process. The primary goal of non-traditional LNG sourcing is non-traditional pricing, i.e., how to make small LNG project economics perform as much larger scaled programs.

Non-traditional uses include, of course, some discussion of LNG as a vehicle fuel, but the discussion also touches on some of the increasing interest world-wide in energy distribution (fuel and electricity) in rapidly developing countries.

NON-TRADITIONAL SOURCING OF LNG

Gas Source:

The purchase (commodity) cost of gas can vary over a great range. Some gas, because of its location, pressure, and/or composition may have a very low inherent marketability, hence, purchase cost. One of the beauties of LNG is that most of these deficiencies can be overcome in its production and distribution. There is some gas "sitting" in the ground today, not being marketed, or not marketable, for a variety of reasons. Accessing these sources can help deliver the economics necessary for small LNG projects. Some of these sources include:

Distressed and small remote gas fields that are not viable for the traditional production and collection can serve as the supply for small liquefiers. If there is a road servicing the wells then there is a way to get the gas to market.

Abandoned and sealed coal mines provide low cost supplies of high levels of methane. Many of these sources also provide Section 29 tax credits which can yield upwards to \$1/mmbtu to the mine owners.

Landfill gas at first blush offers a unique combination of highly desirable attributes - low cost, renewable, easily separable methane and carbon dioxide that is located close to large urban areas. That's the good news. The liquefaction process requires that all components that solidify at liquefaction temperatures must be removed prior to liquefaction. That may require a substantial capital investment. That's the bad news. Landfill gas exists at near atmospheric pressure requiring the gas to be pulled from the landfill under vacuum conditions. This permits the potential of air 'break through.' Liquefying methane in the presence of oxygen can result in spontaneous combustion. That's the ugly news. Attention to the bad and ugly news can result

in a low cost LNG supply very close to the desired market, however.

Gas Transportation:

Small LNG facilities offer a twist on the normal gas transportation thinking. It may be best to place the liquefaction plant near the gas source and/or remote from the LNG need and transport the LNG by truck (or maybe barge). Any feasibility study on a new plant should consider this option and variations on it.

Gas Pretreatment:

Simply stated, gas pretreatment relates to what needs to be "done" to the feed gas to make it liquefiable. This may include compression, filtering of solids, removal of liquids and gases that would solidify under liquefaction, and purification (removal of non-methane gases). Non-traditional gas sources may have much higher (45%) carbon dioxide content than normal pipeline gas ($\gg 1\%$). Landfill gas will need multiple stages of compression, this, interestingly enough, can be used in the gas clean up and purification process. It is easier to purify high nitrogen natural gases in the liquefaction stage, however. Pretreatment is where any oxygen present must be detected and removed.

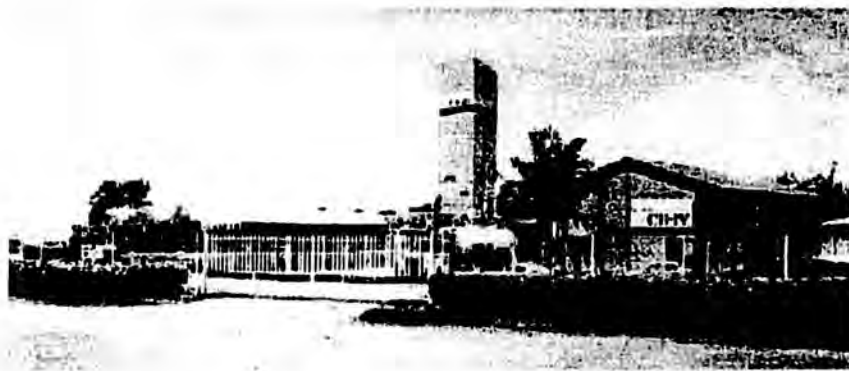
Gas Liquefaction:

Liquefying natural gas is easy . . . liquefying natural gas cost effectively is the challenge. Liquefaction requires energy. The source of that energy, along with installed capital costs, set the liquefaction cost. Low cost gas means low cost fuel which may mean low cost liquefaction. Low capital recovering may mean low cost LNG. Included in these potential low cost scenarios are:

"Piggy-Back" plants are those that overlay on existing cryogenic natural gas processing plants. Most favorable are those that liquefy large quantities of methane as part of normal operation. These would include nitrogen rejection units (see at right) and helium extraction plants. A small side stream of LNG can often be taken from these plants without upsetting the thermodynamic balance, particularly in the evening hours. These also require fairly small capital investments. Cryogenic hydrocarbon extraction and petro-chemical processes also pose opportunities, but one must be very careful when looking at these facilities to assure the process gas is liquefiable.



Stand-alone liquefaction plants (such as the one below) are relatively capital intensive when compared to the other options. There is a vast number of natural gas liquefaction "cycles" (combination of heat exchange and refrigeration) on which to base a design. The U.S. Patent Office is filled with different cycles and variations on themes. The gas being liquefied, however, pretty much takes the same liquefaction path independent of the refrigeration cycle. The dry, clean gas enters a heat exchanger and exits as LNG. Increasing the methane content is accomplished by incorporating a distillation tower and dividing the heat exchange into a series of heat exchanger cores. The design of the refrigeration cycle drives the capital and operating costs of the liquefaction plant. Three basic refrigeration techniques are discussed below: 1) gas compression-expansion, 2) turbo-expansion, and 3) Stirling cycle.



Modular LNG Production Facility

1. **Gas expansion-compression.** This is the basic cycle that cools the household refrigerator and air conditions your car. A refrigerant gas is compressed to high pressure and then cooled with air or water causing complete or partial condensation of the refrigerant. The refrigerant is then expanded across a restriction causing a substantial drop in pressure and in temperature. The cold refrigerant stream is ex-changed against the process stream liquefying the natural gas. The refrigerant (now a gas) is then returned to the compressor completing the cycle.
2. **Turbo-expansion.** Pressure let-down locations, such as city gate stations, offer a thermodynamic answer to low-cost liquefaction. Before discussing turbo-expanders a brief review of gas pipeline operations is in order. Gas is moved from the gas field to the gas utility in high pressure transmission pipelines (600 to 1,200 psig). Before the gas can be distributed its pressure must be reduced to typically less than 100 psig at so-called "city gates" or take station. The city gate is an ideal location to utilize a turbo-expander liquefaction cycle because it takes advantage of the wasted refrigeration associated with the pressure drop very efficiently.

A turbo-expander is essentially a centrifugal compressor running backwards. What does that mean? A centrifugal compressor is rotated by a motor (requiring energy). The gas entering the compressor is (relatively) low pressure and ambient temperature. The gas leaving the compressor is (relatively) high pressure and high temperature. What if the unit was run backwards, i.e., expanded, not compressed? High pressure gas (as from a gas transmission line) at ambient temperature enters the expander. As the high pressure gas moves through the expander two very significant things happen: the blades of the expander are forced to rotate because of the flow (generating power and dropping the pressure), and as the pressure drops so does the temperature. The end result is a low pressure, low temperature gas stream (refrigeration) and a rotating shaft (usable horse power). The refrigeration can be used to liquefy a side stream of the high pressure gas. The warmed-up, expanded, gas stream can now be sent into the gas distribution system. The rotating shaft is available to perform any other "work" necessary in the operation.

3. **Stirling Cycle.** The Stirling refrigeration cycle is not new to cryogenics, but it only recently has been getting attention relative to natural gas liquefaction. The Stirling Cycle could easily take a technical paper to describe its operation adequately. It, however, is being viewed by many as the cost-effective solution to small liquefaction plants, less than 10,000 gallons per day. A small Stirling machine would combine the refrigeration and the heat exchanger into a single unit. Stirling liquefiers, once commercialized, are expected to have low capital costs and maintenance costs due to the very few moving parts. The Stirling machine may fit a very important niche in making small quantities of LNG available in many areas of the country.

Local gas company (LDC) peakshavers are feeling the impact of the changing winds of the natural gas industry. What historically was inconceivable, may now be very doable. LDCs are beginning to realize that they are sitting on an underutilized asset. Typically the entire storage has been reserved for the gas company, but experience shows that rarely is more than 50% is needed. Furthermore, the plants were designed for 200 days a year liquefier operation, when in fact, many more days of operation are possible.

Update on NFPA 59A and DOT Part 193

NFPA 59A, "Standard for the Production, Storage and Handling of LNG," was originally developed in the mid-1960s. It has been routinely reviewed and kept current through the volunteer LNG Technical Committee, of which this author is a member. 59A has published revised editions 7 times in the 31 intervening years.

DOT 49 CFR Part 193, "Liquefied Natural Gas Facilities; Federal Safety Standards," was promulgated in early 1980. Part 193 undergoes a much less intensive review process. By the time of this presentation the first major modification to it may well have been approved. Part 193 is often the "standard of choice" of the Authority Having Jurisdiction.

For the first time since these standards have co-existed there is serious discussion pertaining to the DOT adopting NFPA 59A sections on siting, design, construction, equipment, and fire protection. If adopted, siting of shop-fabricated based LNG facilities would become considerably simpler. Part 193 would also be a more up to date document due to the rigorous and routine review by the LNG Technical Committee.

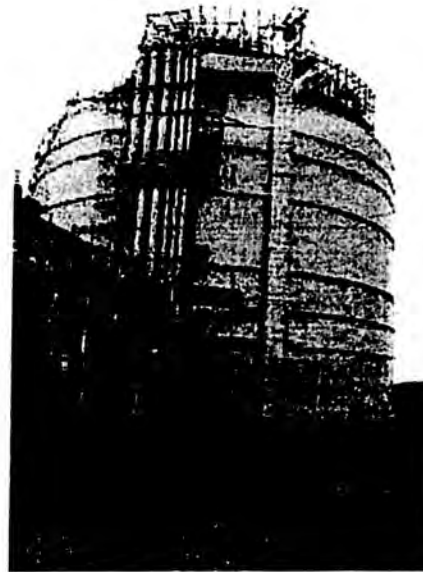
Reference: "A Progress Review of the NFPA Petition to the US DOT Regarding the Integration of NFPA 59A into 49CFR193," presented at the 1997 AGA Operations Conference, Nashville.

LNG Storage:

A major deviation in thinking in terms of design basis for "base-loaded" small LNG plants is in the storage. Instead of needing 200 days of storage, depending on the storage at the various end-use points, only 5 or 10 days of storage may be needed. This may result in the installation a few shop-fabricated LNG tanks (shown first below) instead of a large field-erected LNG tank (shown second below). Since many of these programs will be based on a certain growth over a certain period of time, the program managers can also manage the growth of their storage. It may not be necessary to have all of the storage installed at the beginning of the program.



Shop-Fabricated LNG tank



Field-Erected LNG Tank

LNG Distribution:

This dimension of the LNG program, at least, is fairly straight forward. How much is it going to cost to transport LNG from the source to the end-use? Typically 11,000 gallon trailers like the one below carry the LNG. A simple phone call to any of the LNG trucking operations yields a quick answer. The cost is determined by the distance covered and the gallons transported. A key factor in any program is load factor. In the case of LNG trucking, as the load factor on LNG trailer(s) increases the program would probably be best served by owning and operating the LNG trailers independent of commercial truckers. Larger scale programs may begin looking to rail and barge shipments of LNG.



LNG Transport Trailer Leaving LNG to CNG Fueling Station

NON-TRADITIONAL USES OF LNG

Hub & Spoke:

Imagine a developing country, state, territory seeking the ability to rapidly expand its electric grid into the "wilderness" just like rural electrification in the United States earlier in this century. The problem is, oil is expensive (and imported) and/or the closest refinery is extremely far away. Coal is out of the question for a variety of reasons. Hydro, wind, solar, geo-thermal power are impractical or uneconomical. Yet the country has substantial, indigenous natural gas reserves. That's the good news - the bad news is that gas pipeline infrastructure is non-existent, not economically viable, or environmentally destructive. What do you do?

This is the basis of the "Hub & Spoke" concept, where a new natural gas liquefaction plant is built (the hub), over-the-road LNG transportation is provided to support the (new) remote gas-fired power plants (the spokes). The program can be extended to vehicle fuel and satellite gas distribution with the same impact. However, satellite gas distribution with a low load factor can have a detrimental impact on the overall program economics.

Propane Replacement:

Propane replacement is exactly that, whether speaking about local gas distribution (see below) or industrial fuel. This is also a program that allows for fairly straight forward economical analysis. Not every propane program is ripe for LNG. Assuming the economics bear out, LNG programs are simpler to operate and more reliable, especially in the very cold winter climates.



Large Propane-Air Peakshaving Facility

Highly Dedicated, Captive End-User:

There are a variety of potential natural gas users that due to special circumstances could benefit from a small baseload supply of LNG.

- A *paper mill* that is experiencing boiler stack emission excursions from its heavy fuel oil during the middle of the day and must reduce output to stay below allowable emission levels. With the introduction of natural gas in a co-burn role the boiler can maintain 100% plant capacity. Unfortunately the closest gas pipeline is too far away to justify installation of a lateral. Enter LNG.
- A *synthetic woolen mill* burns about 1 mmbtu of gas per day to generate electricity. Historically the plant has been on a fully interruptible gas contract with propane back-up. A review of annual operating costs showed that trucking in LNG to provide year-round fuel was the best choice. The facility, owned by the LNG supplier, not the mill owner, now receives an average of over one LNG truck per day.
- *Mine haul trucks* offer one of the most exciting opportunities for LNG growth. These monster fuel users operate 24-hours per day, operate in a very fixed geography and pay no highway taxes. This is one market in need of new technology, however. As big as these rigs are, there is very little room to support non-conforming LNG tanks. Similarly, there are no 2,200 to 2,500 HP engines to power the rigs. This, too, shall change.

Vehicular Fuel:

Anyone that has heard me speak or read any of my other papers knows that I will not let a chance to talk about LNG as vehicle fuel pass. Having said that, this paper will focus only on "real" natural gas vehicle (NGV) programs. What is meant by "real"? Real as opposed to tests, pilots, demonstrations, etc., etc. A real program stands on its own economics; it does not require government incentives or environmental mandates to make it work. In other words, it means a lot of vehicles burning a lot of natural gas. What that means is we're not talking about fueling vehicles with compressors . . . we're talking about fueling them with pumps. So what are the "real" programs?

- *Dedicated long haul* is the term used when the same tractors run the same routes week after week. Many Class 8 tractors consume 80 gallons of diesel a day (or more). Quickly thinking about that at 5½ days per week that's about 23,000 gallons of diesel per year. How many cents per gallon saving are needed to justify running on an alternative fuel? This information has been published in a number of places; suffice to say, dedicated long haul can offer opportunities.
- *Centralized fleet fueling* is commonplace in many areas. Different vehicles from different fleets can use these fueling stations be it a "no frills" station like the first one below or like the next one below that is part of a mini-mart.



Card Access Fleet Fueling Station



Public Access LNG vehicle Fueling Station

- The **LNG Corridor** is an evolving concept where a network of LNG fueling stations is developed over specific high frequency routes such that over-the-road trucks can move with a high level of confidence that fuel will be available to them.
- **SuperCNG station** is the name CH-IV LNG Company has given to a new approach to fueling a large quantity of CNG continuously to either a high population of light duty vehicles (taxis and vans) or a large fleet of transit buses. Anyone who has tried to make a large CNG program operate with compressors is well aware of the difficulties realized with continuous capacity, energy consumption during peak hours and inability to fully fill CNG tanks due to the heat of compression. The SuperCNG station has eliminated all of these problems and more. The SuperCNG station is an optimum way of using LNG to produce CNG.

SUMMARY

There is more activity (at least discussion and conceptualizing) in small tank LNG projects than there has been since the early 1970s; just ask any tank manufacturer. As stated at the beginning, one purpose of this paper was to stimulate thought about other ways of thinking about LNG. A number of topics were touched upon in this paper and probably many inadvertently missed. When one takes into account the completely depreciated LNG peakshavers, Order 636, new utility thinking, new players, new markets, the partnering of gas companies and electric producers, and so on and so on . . . LNG could be a fun place to be over the

next decade.

CH-IV LNG Company can provide complete programs from LNG sourcing (or production), through distribution, to receiving and delivery facilities. This includes propane replacement; baseload and peakshaving satellite plants; and vehicle fueling stations (both LNG and CNG). The financial structure of such programs can be defined in the best interests of the end-user, including commodity and demand pricing for energy sales and lease/purchase for capital assets. We can also assist in financing and developing LNG projects. Consider a partnership with CH-IV LNG Company. You bring the market and we will bring the technology, the equipment and the capital.

- CH-IV Corporation which specializes in LNG and associated natural gas and cryogenic engineering and consulting
 - CH-IV Cryogenics which designs, fabricates and installs LNG-based fuel systems.
-

For more information email us at info@CH-IV.com.

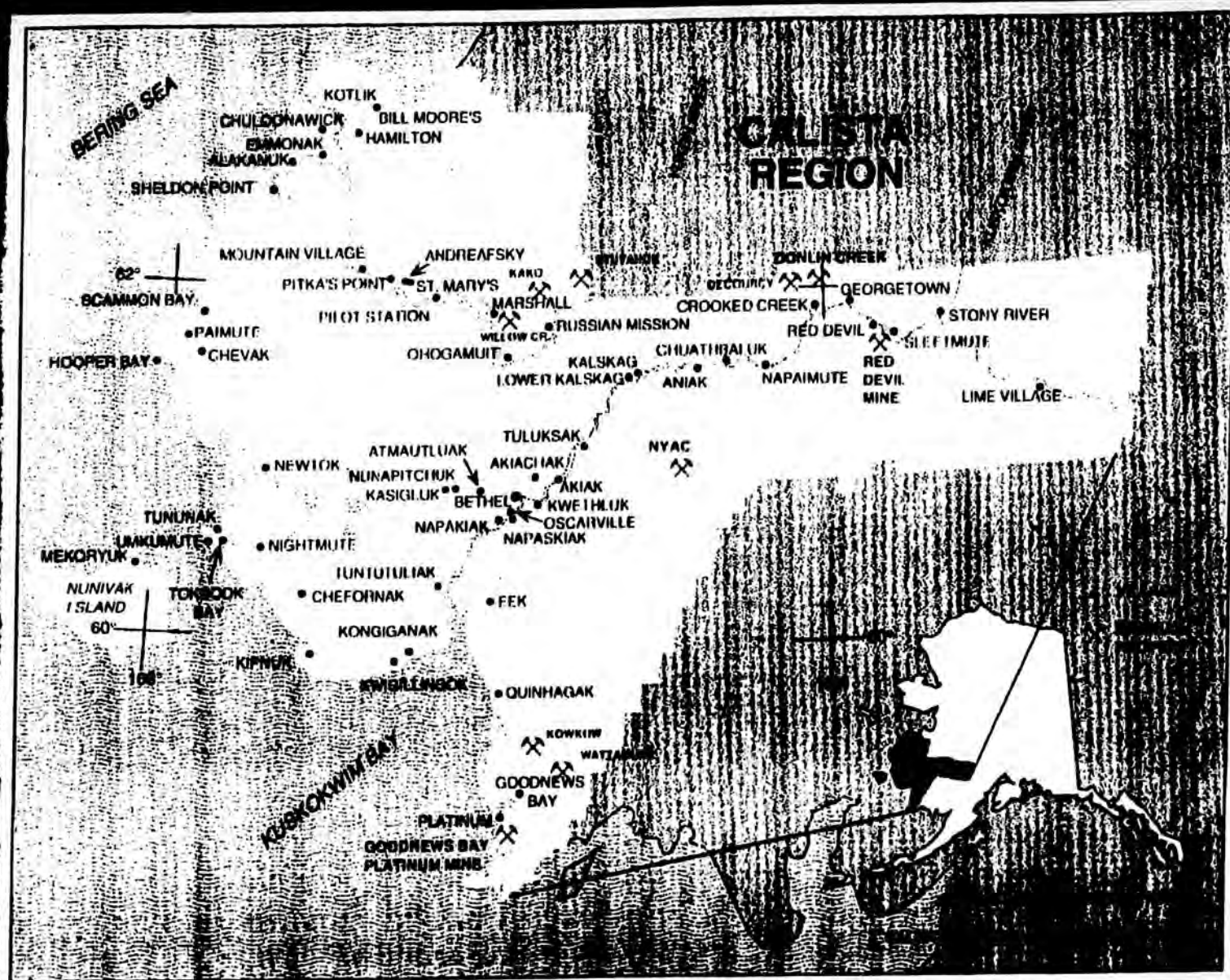
Or write, call or fax us at:

CH-IV LNG Company
Specialists in NGV Fueling
1120C Benfield Boulevard
Millersville, MD 21108
410-729-4255
Fax 410.729.4273

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Last Updated May 3, 2000



Contact: Herb Zepp @ 602-768-5589

Date: March 28, 2001

Re: Propane & Butane

Recommendation:

Propane and Butane are not ideal in this situation and that they would not be able to under price diesel. Propane and Butane are already extracted at the wells before it is put into the pipeline. So there is not much in the pipeline gas. You would need a spur pipeline, which is expensive, or you would need to re-liquefy the gas. Herb doesn't have any idea on costs on a refinery scale. He is familiar with the process after it leaves the refinery and goes to the job site.

Transportation by barge or truck.

Installed it is about \$2.00 a gallon for a 50,000 gal tank.

Vaporize it, pump it, and process it.

Neither does well in cold temperatures, in fact Butane is worse. Once vaporized at temps that cold (42 mi below) it would reliquify. Depends on pressure when it freezes. Condenses back out if not a vapor.

Storage is cheaper with diesel.

Product cost not significantly different.

Re-condensing issues.

Tap off gas-line.

Economically won't compete with diesel.

Benefits are strictly environmental.

"Gut feeling, no economic advantage"

Propane Boiling Pt -45°C
Butane Boiling Pt. 0°C

Yutana Barge**Cost per ton per mile**

Nenana to Galena (366 miles costs \$233.00 for one ton)	0.6366
Nenana to Ft. Yukon (530 miles costs \$293.00 for one ton)	0.5528

LP Gas Uses

The world consumption of LP Gas is currently around 180 million tonnes a year. By the year 2001, demand is expected to be approximately 200 million tonnes a year.

LP Gas stands for Liquefied Petroleum Gas and is a mixture of light hydrocarbons which are gaseous at atmospheric temperature and pressure. LP Gas occurs naturally in crude oil and natural gas production fields and is also produced in the oil refining process.

LP Gas's main components are Propane (C₃H₈) and Butane (C₄H₁₀) which interestingly have a different boiling point : -45°C for propane and 0°C for butane.

It is not difficult to pinpoint why LP Gas is a popular fuel. It can be readily liquefied for storage and transportation by a modest increase in pressure or by a reduction in temperature. It can thus be moved around like a liquid, but burned like a gas.

Liquefied LP Gas packs a lot of energy into a small space and its vaporisation and therefore, its combustion is efficient. Each kilogramme contains around 12000 kcal of energy.

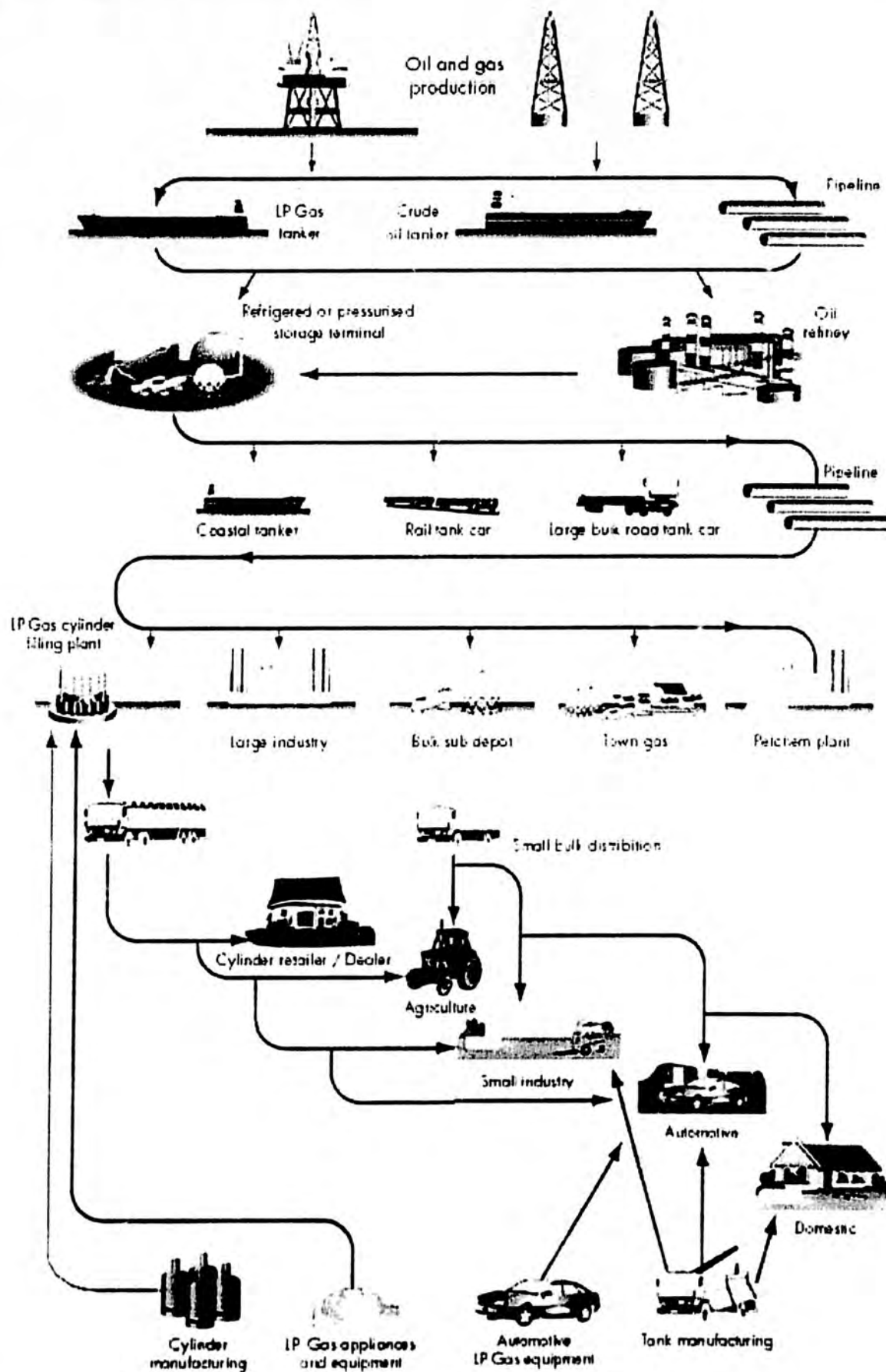
LP Gas is also today's fuel for a cleaner tomorrow. The absence of sulphur and the remarkably low production of NO_x, air toxics and particles during combustion make LP Gas one of the world's most environmentally friendly sources of energy.

LP Gas is the portable fuel. It can bring to users all the benefits of gas as a fuel without any costly infrastructure. Consumers in even the remotest areas can benefit as can mobile users. This 'go anywhere' image of propane and butane developed from the 1930's as bottled gas became increasingly available.

Last but not least, uses for LP Gas are legion. Basically, one can distinguish three main use categories for LP Gas :

- LP Gas as a fuel
- LP Gas as a motor fuel
- LP Gas as chemical feedstock.

Distribution Chain



Publications

LP GAS, A CLEAN & MULTI-PURPOSE ENERGY FOR ALL

- What is LP Gas?
 - Where Does LP Gas Come From?
 - LP Gas Operations
 - How Does the LP Gas Industry Work?
 - Major Uses of LP Gas
 - Major Benefits of LP Gas
 - The Future with LP Gas
-

LP GAS, A CLEAN & MULTI-PURPOSE ENERGY FOR ALL

LP Gas was discovered in the early 1900s. Throughout the years thousands applications have been developed to make use of this clean burning, all-purpose, readily available, and efficient fuel. Although the uses of LP Gas are widespread throughout the world, many are not as familiar with it as they are of the more familiar natural gas, electricity, gasoline (petrol), and diesel. Yet LP Gas provides the same benefits to consumers as these other energies safely, dependably, and efficiently to tens of millions of everyday users.

Consider this: Only this single fuel, LP Gas, can serve such a wide variety of uses as cooking fuel for the family in Brazil and the restaurant owner in India, refrigeration for the shop owner in Ireland, Autogas for taxis in Tokyo, heat for the family home in Canada, flame weeding for the rancher in Texas, heat to provide lift for the first solo non-stop round the world balloon trip, hair spray for the Hollywood starlet, and life saving fuel for Mt. Everest climbers. Even the Olympic torch is LP Gas powered. That's why it is sometimes referred to as the world's most multi-purpose fuel.

This publication is intended to provide information on the multiple uses and recent developments of this reliable source of energy.

What is LP Gas?

LP Gas (or LPG) stands for "Liquefied Petroleum Gas". It is the term widely used to describe a family of light hydrocarbons called "gas liquids". The most prominent members of this family are propane (C_3H_8) and butane (C_4H_{10}). Other members of the LP Gas family are ethane and pentane. These latter fuels have their own distinctive markets and are not further discussed here.

The term "liquefied gas" may seem a contradiction in terms since all things in nature are either a liquid, a solid or a gas. Yet, it is the unique character of LP Gas that makes it such a popular and widely used fuel. LP Gas at normal temperature and pressure is a gas. It changes to a liquid when subjected to modest pressure or cooling. In liquid form the pressure is about twice the pressure in a normal truck tire.

The reason LP Gas is liquefied is to make it easy and efficient to transport and store. One unit of liquid has the same energy content as 270 units of gas. If left as a gas the container to hold the fuel would be 270 times larger than what is required as a liquid. In other words, LP Gas has density (compactness) for storage and transportation, yet all the benefits of a clean vaporous fuel when used at the burner tip.

LP Gas usually consists of a mixture of propane and butane for standard heating and cooking purposes. Propane starts vaporising above $-45\text{ }^{\circ}\text{C}$, so it is the more versatile for general use. Butane starts vaporising above $-2\text{ }^{\circ}\text{C}$ and requires a propane/butane mixture in cold environments as it will not vaporise as readily as propane. LP Gas can also be used in specialised applications that require a

more rigorous specification. Such applications include food processing, aerosol propellants and automotive fuel.

Where Does LP Gas Come From?

LP Gas is a derivative of two large energy industries: natural gas processing and crude oil refining.

When natural gas is drawn from the earth, it is a mixture of several gases and liquids. Methane, which is sold by gas utilities as "natural gas" constitutes about 90 percent of this mixture. Of the remaining 10 percent, 5 percent is propane and 5 percent is other gases such as butane and ethane. Before natural gas can be transported or used, the LP Gases (which are slightly heavier than methane, the major component of natural gas) are separated out. Depending on the "wetness" of a producing gas field, gas liquids generally contain 1%-3% of the unprocessed gas stream. Some LP Gases are also trapped in crude oil. In order to stabilise the crude oil for pipeline or tanker distribution, these "associated" or "natural gases" are further processed into LP Gas. Worldwide, gas processing is a source of approximately 60% of LP Gas produced.

In crude oil refining the LP Gases are the first products produced on the way to making the heavier fuels such as diesel, jet fuel, fuel oil, and gasoline. Roughly 3% of a typical barrel of crude oil is refined into LP Gas although as much as 40% of a barrel could be converted into LP Gas. Worldwide, crude oil refining is the source of the other roughly 40% of LP Gas supplies although the ratio between gas processing and refining varies among regions.

LP Gas production from both these sources is a natural derivative. That means production of LP Gas is assured since the primary motive for gas processors and refiners is to produce fuels other than LP Gas but first the LP Gases are produced. Although tied to the production of natural gas and crude oil, LP Gas has its own distinct marketing advantages and can perform nearly every fuel function of the primary fuels from which it is derived.

LP Gas Operations

LP Gas Transportation and Distribution System

From natural gas and crude oil production facilities LP Gas moves by pipeline, rail car, barge, truck transport and local delivery truck to the ultimate user in specialised containers. Refrigerated ships deliver into equally refrigerated storage terminals marine transport. Worldwide movement of LP Gas cargoes is a sophisticated, well-developed industry spanning more than 40 years. In most cases LP Gas is transported and is stored as a liquid. The only time LP Gas reverts to its natural vaporous state is prior to its end use.

Storage Containers and Equipment

Customer storage can be as large as required or as small as practical. From simple decorative candles and butane lighters to huge underground caverns, storage requirements can be accommodated. Storage containers may be aboveground or underground depending on local codes and conditions. Worldwide, the most popular storage for small usage is 6-20 kilo cylinders or "bottles". Larger residential, commercial, agricultural and industrial users generally require tanks of 500 to 4,000 litres. Depots or terminals in the distribution chain use storage tanks as large as economically necessary to satisfy customer demand cost-effectively.

How Does the LP Gas Industry Work?

LP Gas exists as a gas at normal atmospheric pressure and temperature, only existing as a liquid at low temperatures or under modest pressure. Normally the gas is stored in liquid form under pressure in a container made either of steel or aluminium. Tanks are filled to no more than a recommended maximum liquid capacity allowing space for the LP Gas in liquid form to expand in response to changes in temperature. Therefore, the LP Gas within the tank is in both a liquid and gaseous state. As LP Gas in its gaseous form is drawn from the tank some of the pressure in the container is released. This causes some of the remaining liquid LP Gas to turn gaseous drawing heat from the tank.

Because the pressure of the LP Gas in the container varies with the surrounding temperature, and

because the pressure is much higher than is needed by the appliances that use it, a pressure regulator controls the flow to suit the appliance that is being fuelled. LP Gas draws heat from its surroundings in order to vaporise so it is important that the correct size of container is chosen which will satisfy the off-take all year round with varying temperatures.

LP Gas Codes and Standards

Production, storage, transportation, use and handling practices of the fuel and related equipment are subject to strict standards and regulations by many international, national and local authorities. Because of LP Gas' long history of use, codes and standards continue to evolve as new uses are found and new technologies are developed.

When properly handled and used LP Gas is a safe fuel. Characteristics of LP Gas include low flammability range, high ignition temperature, a fuel under pressure requiring sealed containers and fuel systems, immediate vaporisation upon exposure to the atmosphere, a foul-smelling, non-poisonous odour in case of a leak, and non-toxic. These inherent characteristics of the fuel itself help make it possible to experience all the benefits without incident.

From its earliest days founders of the industry recognized the unique properties of LP Gas and began developing standards and codes of practice even before 1920. As the industry grew and more uses developed constant attention has been spent on upgrading standards and regulations. Each new application and means of transport may require review so that codes and practices incorporate new technologies. Professional organisations and industry experts are constantly engaged to ensure safe practices for every possible application of LP Gas.

As with all forms of energy, LP Gas requires proper handling and use in order to avoid incidents. During its more than 80 years of providing heat, light and power, LP Gas can rightfully claim an excellent safety record. However, it is essential that those properly trained in safe practices handle LP Gas. Likewise customers should be aware of the basic characteristics of the fuel and how equipment operates. Of utmost importance is knowing what to do in case of an emergency. Education and awareness precludes incidences and their consequences. Those handling and using LP Gas should be properly trained.

LP Gas standards and codes embody the technical expertise of a mature industry that constantly seeks to improve its safety performance within all sectors of the industry. There are many such standards and codes referred to in the World LP Gas Association's joint publication with the United Nations Environment Programme entitled "***LP Gas Safety - Guidelines for Good Safety Practice in the LP Gas Industry.***" Consideration should be given to adopting standards and codes, which have achieved international recognition rather than undertake the laborious work of preparing new ones.

Major Uses of LP Gas

Choosing LP Gas as an energy source represents a valuable contribution to the ongoing fight to conserve energy and protect the environment. With a wealth of applications LP Gas offers numerous ways to provide energy and combat pollution at the same time.

LP Gas has literally thousands of uses around the home, on the farm, in commercial business, in industry and transportation. Wherever heat, light or power is required, LP Gas can be used.

The residential and commercial markets where it is used for cooking, heating, water heating, drying, and refrigeration consume some 50% of the world total LP Gas retail sales. When LP Gas provides heat, power, and light together, the combined system is a very cost effective total energy source.

Residential

Cooking
Space heating
Air-conditioning
Patio heaters
Boats
Swimming Pools

Central heating
Hot water
Gas barbecue
Camping
Gardening
Clothes drying

Commercial

Heating (offices/premises)
Sanitary hot water
Refrigeration
Clothes drying
Balanced flue heaters
Central heating

Portable warm air blowers
Fixed warm air heaters
Radiant heating
Swimming pools
Terrace heaters
Air-conditioning

Agriculture

Agriculture and horticulture industries around the world know that LP Gas is the "growing" fuel, not only the "green" fuel. Greenhouse heating, flame weeding, crop drying, waste incineration, and powering equipment are among the ways LP Gas works in agriculture.

Flame weeding
Greenhouses

Crop drying
Distilling

LP Gas as a Transportation Fuel

LP Gas is the preferred alternative automotive transportation fuel. Recognised early on in the search for viable alternative fuels, Autogas is today the most important and accepted alternative fuel in the automotive sector with more than 5.5 million vehicles operating in 38 countries. There are reasons why LP Gas is so popular. Driving range is equivalent to gasoline, engines last longer, refuelling infrastructure is affordable, and in many countries the fuel is less expensive. Above its technical and economic advantages, LP Gas is clean and helps combat urban air pollution. New hi-tech fuel systems work in consort with on-board emission control systems making it possible to meet even the most rigorous emission standards.

Industrial Applications

In industry, the metalworking, ceramic and glass producers, textile, paper, construction industries and many others use LP Gas. These industries value this fuel that provides controllable heat only where wanted and leaves no residue after combustion. Whether across the street or across the oceans, moving goods is widely dependent on LP Gas powered forklift-industrial trucks.

Ceramic manufacture
Glass manufacturing
Laundry
Drying (cement, bricks)
Pre-heating of material
Laboratory (crucibles)
Thawing
Paint removal (burning)
Clearing fog on airfields
Feedstock for production of chemicals

Glazing of pottery
Metal heating and processing
(drying and curing)
Cigarette lighter fuel
Aluminium die-casting
Remote emergency lighting
Pre-heating engines
Mobile & remote generators
Production of film

Leisure Industry

Even the leisure industry is greatly dependent on LP Gas. Outdoor grill users prefer LP Gas because there is no messy charcoal to deal with, temperature control is instantaneous, and no residual fire that may harm some one or property. Whether for home, restaurants, or party venues patio heaters are commonly dependent on LP Gas. Even outdoor pest control is possible using LP Gas equipment. Whether providing heat, light and power for the camper in a national park or for the climbers to the top of Mt. Everest, LP Gas is there.

Non-Fuel Uses

Aerosols

Refrigerants

Major Benefits of LP Gas

LP Gas is Available

LP Gas is available now. There is nothing exotic to invent or improve. The transportation system that moves it is in place, the tanks that store it are available today. Annually, more than 200 million tonnes are used worldwide. LP Gas is derived from gas processing and crude oil refining. As long as oil and gas are the primary fuels on which our lives and economies depend (a likely scenario for at least the next 75 years), LP Gas will be available.

LP Gas is Portable

Portable means it can be stored, transported, and used virtually any place on the globe. It has infinite "shelf life" which means that LP Gas does not deteriorate over time. Whether stored in large pressurised or refrigerated tanks, in cylinders for domestic and commercial use or in small butane cigarette lighters, its benefits are the same. It is the only fuel frequently used in remote locations principally because of its portability. The latter is also an advantage when considering capital costs. If end-use demand patterns change or cease, equipment can be easily moved to other sites.

LP Gas is sometimes referred to as a "pipeline on wheels" offering all the benefits of natural gas without infrastructure and capital cost constraints.

LP Gas is a Modern Energy

In developing and developed countries, LP Gas is an essential fuel. Access to modern fuels instead of relying on traditional fuels such as dung or charcoal becomes a social issue when consumers are denied access to modern fuels and a healthy home environment. LP Gas is the perfect solution: available now, low cost access, reliable, and clean.

A compact basic heating, cooking, and lighting system supplied from a portable bottle gives the low-income family access to many of the basic living essentials of more affluent societies. Later, as economies grow and standard of living increases, refrigeration and electric power generation can be added. Ultimately a central distribution LP Gas system can provide all the basic necessities and conveniences for an entire community. Community planners will find they need not wait for the natural gas or electric grid systems to be installed in order to give citizens modern energy. Facing large capital outlays investors are reluctant to spend the money until there is sufficient energy demand. LP Gas can build load incrementally until the demand merits the investment in these utility infrastructures.

LP Gas is Friendly to the Environment

LP Gas is clean burning. In a world heavily impacted by environmental concerns, LP Gas stands above most fuels and can compete with the cleanest. It is clean burning because of its simple chemical make-up. When properly mixed with air to form a combustible mixture it produces virtually no soot (particulate matter), low carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NOx), which are the basic precursors of ozone sometimes known as "smog". Because LP Gas is stored and transported under modest pressure, the transportation and storage system is closed to the atmosphere preventing any evaporative emissions. LP Gas impacts greenhouse (GHG) emissions less than any

other fossil fuel when measured through the total fuel cycle. LP Gas is colourless, odourless, tasteless and contains no additives. Small amounts of an odourant are added to create a foul smell to aid in detection of leaks. In the event of a leak, LP Gas will readily vaporise and dissipate into the atmosphere and will not contaminate aquifers or soil as do most liquid fuels.

LP Gas is a Partner with Other Energies

Some energies are friendlier to the environment than others. Non-fossil fuels such as solar and wind are particularly friendly but have reliability limitations. Solar works only when the sun shines, wind machines only when there is wind. Both depend on battery or thermal storage for non-functioning periods. Often this energy storage is unreliable or costly.

The flexibility of LP Gas makes it possible to partner with these other energy sources. When solar or wind are not producing energy, LP Gas can supplement the basic energy supply. Automatic switching equipment makes it possible to have LP Gas as a silent and reliable partner adding heat or power whenever needed. Both the environment and the customer benefit from this unique partnership.

LP Gas is a Partner in New Technologies

Technology for space travel now comes to earth in the form of fuel cells. Fuel cells create power and heat from fuels through a electrochemical process rather than burning. The cell converts the chemical energy of hydrogen and oxygen into electrical energy. The by-products of this process are water vapour and heat. Nitrogen oxides and sulphur emissions are negligible and greenhouse gases are less than half that of internal combustion engines. Because LP Gas (C_3H_8) contains hydrogen it is an excellent candidate for powering fuel cells.

Another advantage of fuel cells is the potential to achieve high-energy efficiency. That means extracting the maximum energy out of the fuel that feeds the cell. Generating electricity from the cell itself, then capturing the waste heat from the conversion process makes it possible to achieve an efficiency level of nearly 85%.

Various fuel cell technologies are under development and some demonstration units are now operating. Although the fuel cell is not yet cost effective for residential and commercial use, the LP Gas industry is committed to supporting this technology by aggressively participating in several developmental projects.

Another exciting technology is the micro-turbine. This LP Gas powered device provides electric power by driving a generator and the exhaust heat can be used for either heat or cooling. Advantages of the micro-turbine over the typical internal combustion engine are low maintenance, long life, and low emissions while providing either portable or stationary power. Meanwhile efforts continue to develop efficient gas air conditioning and heat pumps.

The Future with LP Gas

Whether energy needs are in developing or developed economies, LP Gas is a proven provider. No citizen should be without access to modern energy.

Governments can assist in our collective quest of making available a dependable, efficient, environmentally friendly fuel by formulating consistent policies that encourage development.

Suppliers, investors and the World LP Gas Association (WLPGA) stand ready and welcome the opportunity to build on the long history of the LP Gas industry to make the world's most multi-purpose fuel available to everyone.

This is a publication of the WLPGA, the international organisation that exists to unite the broad interests of the vast worldwide LP Gas industry.

The WLPGA's mission is to promote the use of LP Gas as a clean, all-purpose and efficient fuel.

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TYPICAL PROPERTIES OF COMMERCIAL LPG

	Commercial Butane	Commercial Propane
Relative density of liquid at 15 fC	0,57 to 0,58	0,50 to 0,51
Imperial gallons/ton at 15 fC	385 to 393	439 to 448
Litre/tonne at 15 fC	1 723 to 1 760	1 965 to 2 019
Relative density of gas compared with air at 15 fC and 1 013,25 mbar	1,90 to 2,10	1,40 to 1,55
Volume of gas (litres) per kg of liquid at 15 fC and 1 013,25 mbar	406 to 431	537 to 543
Volume of gas (ft ³) per lb of liquid at 60f F and 30 in Hg	6,5 to 6,9	8,5 to 8,7
Boiling point at atmospheric pressure fC approx.	-2	-45
Vapour pressure for products at their maximum specified vapour pressure (gauge):		
Temp. fC	Bar	Bar
-40	*	2,3
-18	0,9	4,5
0	1,93	6,9
15	4,83	14,5
38	5,86	17,6
45		
Latent heat of vaporisation (kJ/kg) at 15 fC	372,2	358,2
Latent heat of vaporisation (Btu/lb) at 60f F	160	154
Specific heat of liquid at 15 fC (kJ/kg fC)	2,386	2,512

Sulphur content per cent weight	Negligible 0,02	to Negligible 0,02
Limits of flammability (percentage by volume of gas in a gas-air mixture to form a combustible mixture)	Upper 9,0 Lower 1,8	Upper 10,0 Lower 2,2
Calorific Values:		
Gross:		
(MJ/m ³) dry	121,8	93,1
(Btu/ft ³) dry	3 270	2 500
(MJ/kg)	49,3	50,0
(Btu/lb)	21 200	21 500
Nett:		
(MJ/m ³) dry	112,9	86,1
(Btu/ft ³) dry	3 030	2 310
(MJ/kg)	45,8	46,3
(Btu/lb)	19 700	19 900
Air required for combustion (m ³ to burn 1 m ³ of gas)	30	24

* Minimum Commercial Butane vapour pressure at 18°C is minus 5224 mbar g.



What is LPG



Safe Handling of
LPG



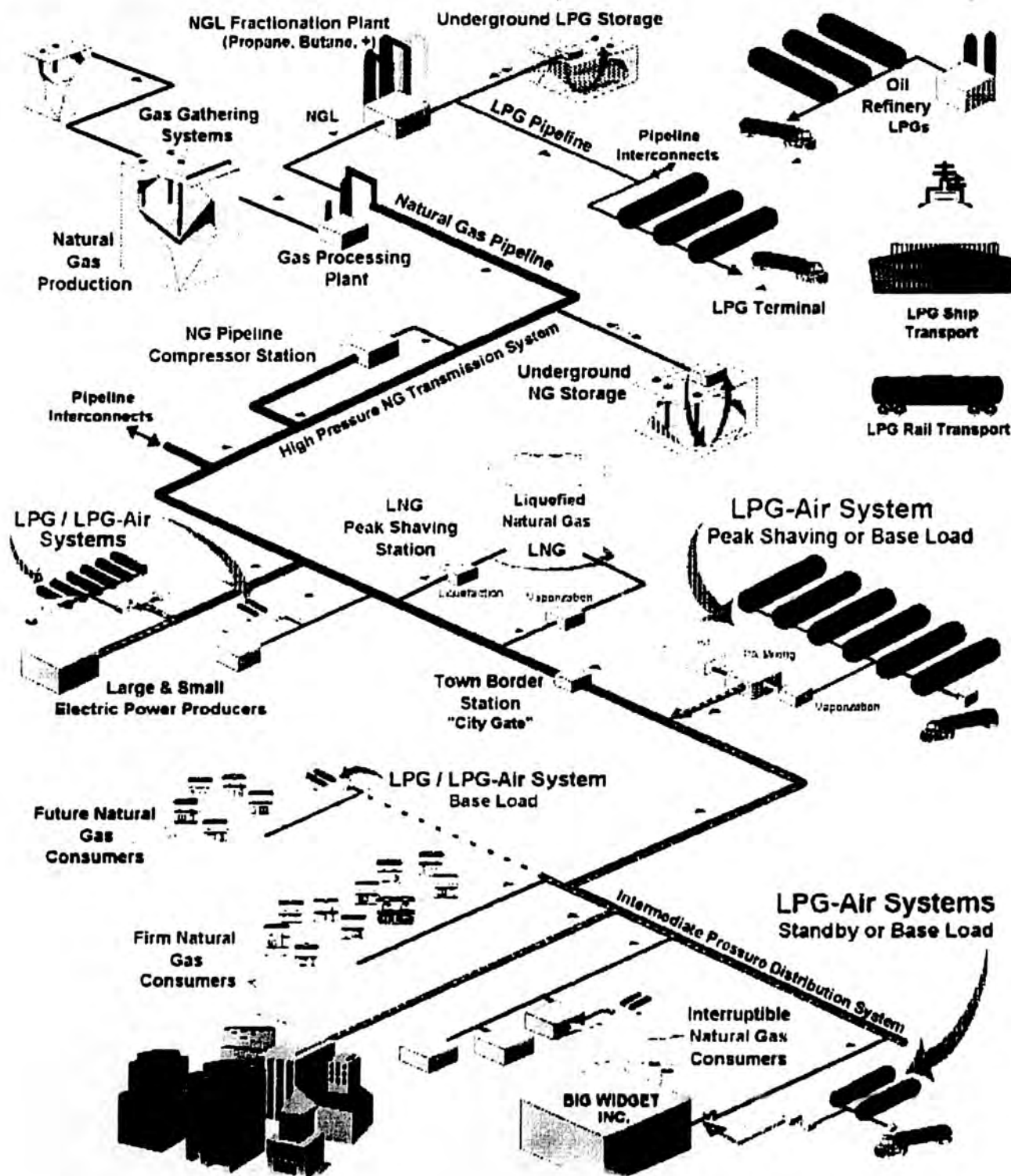
Brand Names

Introduction

Gas energy gets used...

Demand for clean-burning natural gas (composed primarily of *methane*) is growing around the world. And in North America, a dynamic gas-energy marketplace offers an array of competitive choices - and risks - from wellhead to burner tip. In the new *gas-energy* marketplace, propane **peak shaving** and **standby systems** provide supply security and flexibility for many gas utilities and consumers. Most of these plants produce "propane-air" for direct replacement of natural gas.

North American Gas Energy Grid



Glossary

LDC Local Distribution Company. LDCs operate natural gas distribution systems linking consumers & pipelines. LDCs may also provide gas storage & peaking services.

LNG Liquefied Natural Gas. When cooled to about -260 °F, methane becomes a liquid for storage or transport in insulated tanks, trucks and ships.

LPG Liquefied Petroleum Gas. LPG or LP-gas refers to several gas liquids, including propane and butane.

NG Natural Gas. NG is a mixture of methane and various other hydrocarbons and inert gases.

NGLs Natural Gas Liquids. NGLs are hydrocarbon components of natural gas other than methane, including ethane, propane and butane.

Propane is one of several LPGs derived during both natural gas production and crude oil refining.

Commercial propane, under the trade names LPG, LP-gas and HD-5 Propane, is widely used as peak shaving fuel. Stored as a liquid, a gallon of propane contains the energy in over 90 cubic feet of natural gas. 11 gallons of propane have about the same energy as 1 Mcf of natural gas, or about 1 million btu "MMBtu".

Propane Peak Shaving ...an overview offers a brief look at design considerations and equipment types common to utility-owned propane peak shaving systems. For further information, contact **Standby Systems, Inc.**

Phone: **612.721.4473** E-mail: info@standby.com

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Typical Properties
of LPG



What is LPG



Brand Names

SAFE HANDLING OF LPG

The two liquefied petroleum gases which are generally available in the UK are Commercial Butane and Commercial Propane as defined in BS 4250.

The combustion of LPG produces carbon dioxide (CO₂) and water vapour, but sufficient air must be available. Inadequate appliance flueing and / or ventilation, or poor air-gas mixing (for example due to lack of servicing) can result in the production of toxic carbon monoxide.

Everyone concerned with the storage and handling of LPG should be familiar with the following characteristics and potential hazards:

- (a) LPG is stored as a liquid under pressure. It is almost colourless and its weight is approximately half that of an equivalent volume of water.
 - (b) LPG vapour is denser than air: butane is about twice as heavy as air and propane about one and a half times as heavy as air. Consequently, the vapour may flow along the ground and into drains, sinking to the lowest level of the surroundings and be ignited at a considerable distance from the source of leakage. In still air vapour will disperse slowly.
 - (c) LPG can form a flammable mixture when mixed with air. The flammable range at ambient temperature and pressure extends between approximately 2 % of the vapour in air at its lower limit and approximately 10 % of the vapour in air at its upper limit. Within this range there is a risk of ignition. Outside this range any mixture is either too weak or too rich to propagate flame. However, over-rich mixtures can become hazardous when diluted with air and will also burn at the interface with air.
- At pressures greater than atmospheric, the upper limit of flammability is increased but this increase with pressure is not linear.
- (d) Escape of even small quantities of the liquefied gas can give rise to large volumes of vapour / air mixture and thus cause considerable hazard. A suitably calibrated explosimeter may be used for testing the concentration of LPG in air.

A NAKED FLAME SHOULD NEVER BE USED TO SEARCH FOR A LEAK

- (e) At very high concentrations in air, LPG vapour is anaesthetic and subsequently an asphyxiant by diluting or decreasing the available oxygen.
- (f) Commercial LPG is normally odorised before distribution by the addition of an odorant, such as

ethyl mercaptan or dimethyl sulphide, to enable detection by smell of the gas at concentrations down to one-fifth of the lower limit of flammability (i.e. approximately 0,4 % of the gas in air). However, in certain cases where the odorant may be detrimental to a process (for example in aerosol applications) the LPG is not odorised.

(g) Escape of LPG may be noticeable other than by smell. When the liquid evaporates, the cooling effect on the surrounding air causes condensation and even freezing of water vapour in the air. This effect may show itself as frost at the point of escape and thus make it easier to detect an escape of LPG. Because the refractive index of LPG differs from air, leaks can sometimes be seen as a 'shimmering'.

(h) Owing to its rapid vaporisation and consequent lowering of temperature, LPG, particularly liquid, can cause severe frost burns if brought into contact with the skin. Personal protective equipment (e.g. hand and eye protection) should be worn if this hazard is likely to occur.

A container which has held LPG and is 'empty' may still contain LPG in vapour form and is thus potentially dangerous. In this state the internal pressure is approximately atmospheric. If a valve is leaking or is left open, air can diffuse into the container forming a flammable mixture and creating a risk of explosion: alternatively, LPG can diffuse to the atmosphere.

Note: These properties are general characteristics of LPG, and items such as (h) should not occur in normal cylinder usage.



Typical
Properties of
LPG



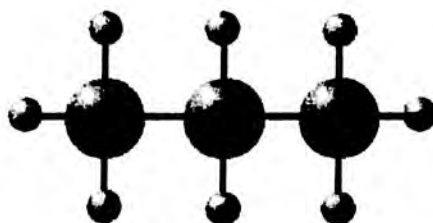
Safe Handling of
LPG



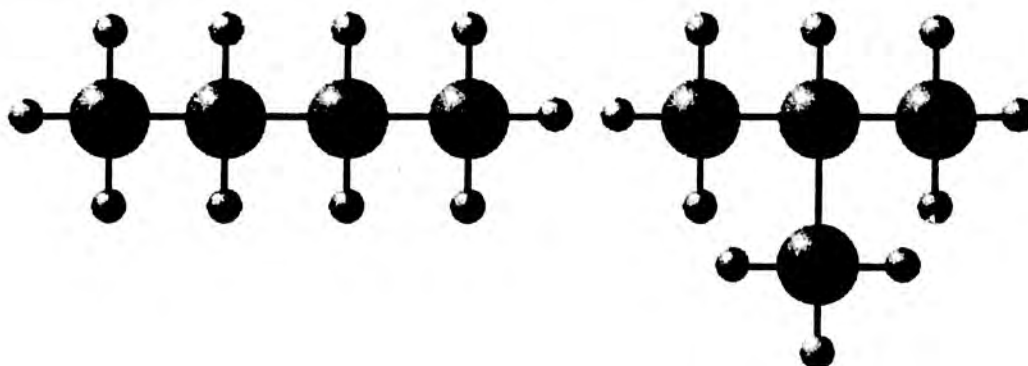
Brand Names

WHAT IS LPG?

LPG is the generic name for commercial propane and commercial butane. There are hydrocarbon products produced by the oil and gas industries. Commercial Propane predominantly consists of hydrocarbons containing three carbon atoms, mainly propane (C_3H_8).



Commercial Butane predominantly consists of hydrocarbons containing four carbon atoms, mainly n- and iso - butanes (C_4H_{10}).



They have the special property of becoming liquid at atmospheric temperature if moderately compressed and reverting to gases when the pressure is sufficiently reduced. Advantage is taken of this property to transport and store these products in the liquid state, in which they are roughly 250 times as dense as they are when gases.

Butane is usually supplied to customers in cylinders, propane can be supplied in cylinders or in bulk for storage in tanks at the customers premises.

IF A CYLINDER IS NO LONGER NEEDED IT SHOULD BE RETURNED TO A LOCAL DEALER.

"WHO OWNS WHO"

Acrobat .pdf downloadable **Guidance Table**

If that is not possible many Local Authority amenity sites have storage cages from which the gas supplier arranges pick up.

Updated: **23/05/2000**

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ApplicationsMini Bulk Suppliers

HOME HEATING WITH LP GAS

LP Gas is the most versatile of fuels for heating, hot water, cooking and a host of other uses. LP Gas is liquefied petroleum gas. It is used just like natural gas and can do everything natural gas can do - and more.

If you are not on the natural gas main, LP Gas is the obvious alternative - it is simply brought to you by road delivery. Although you will use it just like any other gas supply, we actually deliver it to you as a liquid. This is because of the curious property which allows us to turn it into liquid by quite moderate pressure which can then be transported in road tankers, or it can be put into transportable cylinders.

There are two grades of LP Gas, butane and propane. Butane is used mainly in cylinders for portable applications in mobile heaters in the home, and for leisure activities such as boats, caravans and barbecues. Butane cylinders are available from a vast network of retail brand stockists. There are over 16000 such outlets in the UK.

Propane is the LP Gas used for central heating, for hot-water, and gas-fires, convector heaters and, of course, for cooking. Gas is essential, if you want a living flame fire and LP Gas is ideal.

Remember, virtually all appliances offered for natural gas use can be provided for LP Gas use. You must however specify that it is required to operate on propane as details like gas jet sizes are different. There is a lot more heat energy in a cubic foot of propane, than there is in a cubic foot of natural gas.

BULK STORAGE SUPPLY

The usual method of providing the LP Gas system for home heating etc. is to provide a small storage vessel which the road tanker will deliver the liquid into. This is then connected to the house, often by a buried pipeline so that from here it is then much the same as other piped gas supplies.

The LP Gas supplier will provide a storage vessel on hire or rental terms which will cover its maintenance and regular inspection.

The position of the storage vessel is important and the LP Gas supplier will be able to advise you on the detail. For instance, the road tanker must be able to park in a safe position when making a delivery and the vessel needs to comply with Codes of Practice which specify the distance from the house and the property boundary. Consideration is also needed to the run of the road tanker delivery hose when making a delivery, so that it will not cause inconvenience while it is laid out from the hose reel.

Since the liquid in the vessel creates its own gas pressure, no pumps are needed. When the outlet valve on top of the vessel is open, gas will flow. In fact the pressure has to be reduced, usually in two stages, down to the standard 37mbar for domestic appliances and pressure regulators are incorporated in the system to achieve this. Other controls are also provided to ensure maximum safety of supplies. These and other technical details are set out in the Association Code of Practice 1 part 2, drawn up by member companies.

The pipework installation from the storage vessel should be carried out by a CORGI Registered gas installer and the LP Gas supplier will be able to provide advice on this.

At the house an emergency control valve will be provided, so that the internal gas system can be readily isolated if necessary.

LP Gas appliances like natural gas appliances are among the most efficient available, besides being among the most environmentally friendly forms of energy use. The latest developments include the new breed of "condensing" boilers which reduce considerably the fuel bill by extracting even more useful heat out of the LP Gas. For new or replacement boilers these are worth considering.

Once installed, the LP Gas supplier will fill the vessel and will agree with you the method of providing further supplies. The supplier can usually provide a top-up service which will ensure you always have gas on tap, or you could choose to telephone for a refill as necessary.

CYLINDER SUPPLIES

Sometimes it is not possible to fit an LP Gas storage vessel into a small garden. An alternative is to use LP Gas cylinders which are less restricted in terms of location. Although they come in many sizes the most appropriate for home heating are the propane 46 or 47 kg. size. Propane cylinders are always located outside of premises and the gas piped in. They can provide a similar service to the bulk vessel except for large off-takes.

For central heating installations it is usual to use four cylinders, two either side of an automatic change-over valve, often called a 'four-pack' system. The gas supply is fed from two cylinders at a time and when they begin to run out, the automatic device switches to the other two. Cylinders can be replaced then without interrupting the supply.

WHO TO CONTACT

There is a wide choice of supplier for LP Gas in the UK depending on where you are. Virtually all are members of the LP Gas Association who can be relied upon to comply with its Codes of Practice and UK Regulations. A list of current member companies can be obtained from the Association upon request. Any of these, if they deliver into your area, will provide you with advice on installation, prices of LP Gas and a host of other relevant information.

Propane Education & Research Council

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WHO WE ARE

The Propane Education & Research Council promotes the safe, efficient use of propane as a preferred energy source.

Propane fulfills energy needs by burning cleanly and efficiently, giving consumers more value for their energy dollar. It is a trusted and reliable energy source used by millions of Americans every day--for heating and cooling, cooking, drying clothes, lighting and even gas fireplaces.

Propane has many recreational, industrial, agriculture and commercial applications. It can be taken places no other fuel can reach. It is a leading alternative fuel for automobiles and trucks, and is widely used for forklifts and other special-duty vehicles and engines. Consumers can count on propane wherever and whenever they need it.

202-452-8975

Propane Education & Research Council

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Council**Fact Sheet****CONTACT US**
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HOME[Back](#)**Propane Facts****What Is Propane?**

Propane is a hydrocarbon (C₃H₈) and is sometimes referred to as liquefied petroleum gas, LP-gas or LPG. Propane is produced from both natural gas processing and crude oil refining. It is nontoxic, colorless and virtually odorless. As with natural gas, an identifying odor is added so the gas can be readily detected.

Propane is a Safe Fuel

The propane industry has developed numerous methods to make the transport and use of propane safe:

- Propane equipment and appliances are manufactured to rigorous safety standards.
- Propane has a narrow range of flammability when compared with other petroleum products. In order to ignite, the propane/air mix must contain from 2.2 to 9.6 percent propane vapor. If the mixture contains less than 2.2 percent gas, it is too lean to burn. If it contains more than 9.6 percent, it is too rich to burn.
- Propane won't ignite when combined with air unless the source of ignition reaches at least 940 degrees Fahrenheit. In contrast, gasoline will ignite when the source of ignition reaches only 430 to 500 degrees Fahrenheit.
- The odds of a person dying from a direct result of a propane transportation or storage accident involving loss of cargo are about the same as those of getting struck by an airplane falling from the sky.
- If liquid propane leaks, it vaporizes and dissipates into the air.
- Because it is released from a pressured container as a vapor, propane can't be ingested like gasoline or alcohol fuels.
- Because propane is virtually odorless and colorless in its natural state, a commercial odorant is added so propane can be detected if it leaks from its container.

Safety Starts with Education

The propane industry is also engaged in ongoing efforts to increase safety in the handling, use and maintenance of propane and propane equipment:

- The National Propane Gas Association (NPGA) offers an award-winning preventive maintenance program called GAS Check® (Gas Appliance System Check). Trained technicians inspect entire propane systems and appliances to ensure they are running safely and efficiently, so consumers can save money and enjoy a healthy environment. The program also educates homeowners on the proper maintenance of propane appliances and how to safely handle propane.
- The Certified Employee Training Program (CETP) is a nationally recognized training program for people involved in the handling of propane, equipment and appliances. The CETP is being used extensively throughout the country and is continually updated and expanded.
- Each year, thousands of industry employees and firefighters attend service and safety schools sponsored by the industry. The sessions provide important training in how to quickly control and safely handle a propane emergency.
- The NPGA, with funding from the Propane Education & Research Council, has developed a new comprehensive training program for America's public safety agencies and propane retailers. The educational package includes a 220-page textbook, *Propane Emergencies*, which has been sent free to every fire department in the country. The objectives of the emergency response program are to increase the level of responder safety, improve efficiency to mitigate emergencies and to encourage propane marketers and local emergency responders to develop working relations before an accident occurs.

Propane Is an Environmentally Friendly Fuel

- Propane is an approved, alternative clean fuel listed in the 1990 Clean Air Act as well as the National Energy Policy Act of 1992.
- Propane is one of the lightest, simplest hydrocarbons in existence, and, as a result, is one of the cleanest burning of all alternative fuels. New propane-fueled vehicles can meet the very tough Ultra-Low Emission Vehicle (ULEV) standards, and one model even meets the Super Ultra-Low Emission Vehicle (SULEV) standards.
- Burning coal to generate electricity releases carbon dioxide and other pollutants into the atmosphere. Per pound of fuel burned, coal emits more than twice the amount of carbon dioxide as does propane. By using propane gas instead of electricity, consumers can cut emissions and help preserve the environment.
- Propane gas is nontoxic, so it's not harmful to soil and water. Because propane does not endanger the environment, the placement of propane tanks either above or below ground is not regulated by the Environmental Protection Agency (EPA).
- According to the EPA, much of the sulfur dioxide in the atmosphere, which produces acid rain, is attributable to coal-fired, electricity-generating facilities. In contrast, neither the process by which propane is produced nor the combustion of propane gas produces significant acid rain contaminants.

Propane Is a Good Value

- According to the U.S. Department of Energy, it could cost consumers twice as much to operate their range, water heater, dryer or furnace with electricity than with propane gas.
- Overall propane costs for fleet vehicles typically range from 5 percent to 30 percent less than conventional or reformulated gasoline. Many states offer fuel tax incentives to encourage the use of clean fuels, thus further reducing operating costs.

Propane Is a Versatile Fuel

Propane is used by millions of people in many different environments-homes, industry, farming and more.

- More than 14 million families use propane to fuel their furnaces, water heaters, air conditioners, outdoor grills, fire places, dryers and range tops.
- Because propane produces minimal emissions, it is safe to use indoors. As a result, nearly 500,000 forklift trucks are powered by propane. Millions more choose this clean-burning alternative for bus, taxi, delivery and other fleets to minimize air pollution in metropolitan areas.
- Propane is used on 660,000 farms for irrigation pumps, grain dryers, standby generators and other farm equipment. It is an essential fuel for crop drying, flame cultivation, fruit ripening, space and water heating and food refrigeration.
- Propane is easy to transport and can be used in areas beyond the natural gas mains. Because it is 270 times more compact as a liquid than as a gas, it is economical to store and transport as a liquid.

Source: National Propane Gas Association/Propane Education & Research Council
2/1/00

Propane Education & Research Council

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[Back](#)**FAQs (Frequently Asked Questions) about Propane****Q. Is propane safe to use in my home?**

Propane is a safe fuel to use in your home and business. Propane has a narrow range of flammability and cannot be ingested like gasoline or alcohol fuels because it is released as a vapor from a pressured container. In addition, award-winning preventive maintenance programs like GAS Check® (Gas Appliance System Check) ensure that homeowners understand how to properly maintain their propane appliances and enjoy a healthy, safe environment.

Q. Why would I choose propane over electricity for my appliances and for heating my home?

According to the U.S. Department of Energy (Feb. 2000 projection), it could cost up to twice as much to operate your range, water heater, dryer or furnace with electricity than with propane gas. Propane gas furnaces and heaters provide more consistent warm air throughout your home at a lower cost than electric heat pumps and have a longer average life span of 20 years, compared with electric heat pumps' 12-year average life span.

Q. Is propane dangerous to the environment?

No. Propane is an approved, alternative clean fuel listed in the 1990 Clean Air Act and the National Energy Policy Act of 1992. Propane is one of the cleanest burning of all alternative fuels; new propane-fueled vehicles can meet the very tough Ultra-Low Emission Vehicle (ULEV) standards, and one model even meets the Super Ultra-Low Emission Vehicle (SULEV) standards. Propane is also nontoxic, so it's not harmful to soil or water.

Q. How can I be sure I'm handling the use of propane gas properly in my home?

The National Propane Gas Association (NPGA) has developed a comprehensive maintenance program called GAS Check® (Gas Appliance System Check), in which trained technicians inspect propane systems and appliances in homes to ensure they are running safely and efficiently. The program also educates homeowners on the proper maintenance of propane appliances and how to handle propane safely.

Propane Education & Research Council

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[HOME](#)[Back](#)**Propane: A Safe Fuel**

Propane vehicle tanks are constructed from carbon steel under a code developed by the American Society of Mechanical Engineers. A propane tank is 20 times more puncture resistant than a typical gasoline, methanol or ethanol tank.

New propane cylinders are manufactured with a device that shuts off the filling process when the tank reaches 80 percent of its liquid capacity. This allows for changes in fuel volume caused by temperature variations without any release of gas from the tank.

Propane engine fuel systems are fitted with safety devices and shut-off valves that function automatically if the fuel line ruptures.

Propane has the lowest flammability range of any alternative fuel.

Propane leaks are easily detected because an odorant with a scent similar to rotten eggs is added as a safety measure.

Propane is a nontoxic, nonpoisonous fuel that doesn't contaminate aquifers or soil.

Unlike gasoline and alcohol fuels, propane can't be ingested because it is stored in a closed container under pressure. It vaporizes internally when released from its container.

Propane with air won't ignite unless the source of ignition reaches at least 940 degrees Fahrenheit. In contrast, gasoline's source of ignition must reach only 430 to 500 degrees Fahrenheit before igniting.

If propane gas leaks, it doesn't puddle; it readily dissipates into the air.

The National Propane Gas Association (NPGA) offers an award-winning preventive maintenance program called GAS Check® (Gas Appliance System Check). Trained technicians inspect entire propane systems and appliances to ensure they are running safely and efficiently, so consumers can save money and enjoy a healthy environment. The program also educates homeowners on the proper maintenance of propane appliances and how to avoid potential health hazards.

The Certified Employee Training Program (CETP) is a nationally recognized training program for people involved in the handling of propane, equipment and appliances. The CETP is being used extensively throughout the country and is continually expanded and updated.

Source: National Propane Gas Association/Propane Education & Research Council
2/1/00

Propane Education & Research Council

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When used as a home energy source, propane gas fuels a variety of systems and products. It offers homeowners reliability, cleanliness, improved performance and, on average, costs half as much per BTU as electricity.

Warm and Cozy

Approximately 8.1 million households use propane gas to fuel their home-heating systems.

Furnaces

A propane furnace consistently supplies air at 120 degrees Fahrenheit. Electric heat pumps dispense 95-degree air, which is less than body temperature (98.6 degrees), so the air feels cool, not warm.

Propane gas furnaces last an average of 20 years, while electric heat pumps last an average of 12 years. The cost of repairing propane gas furnaces is also lower than the cost of repairing electric heaters.

Space Heaters

Vent-free propane-fueled space heaters are 99.9 percent efficient and include oxygen depletion sensors that automatically turn units off if oxygen levels drop below specified levels. They can also include thermostats and heat distribution blowers.

Propane-fueled space heaters produce fewer air pollutants and greenhouse gas emissions than those fueled by fuel oil and electricity. In fact, the energy used to power electric heaters produces emissions two to four times higher than the energy produced to power propane heaters.

Not Too Hot, Not Too Cold, Just Right

Propane gas water heaters cost approximately \$10 less per month to operate than comparable electric units. On average, propane water heaters are 42 percent less expensive than electric heaters.

Over an average life span, propane gas water heaters can save homeowners nearly \$2,000 more than an electric unit.

Propane gas water heaters heat more than twice as much water in an hour as a comparable electric model.

Relax by the Fireplace

Sales of gas-burning fireplace units are increasing. In fact, some propane marketers report that nearly one-third of their new customers are coming to them specifically for propane hearth products.

Propane gas fireplace systems cost between 30 and 60 percent less per hour of operation than wood burning fireplaces.

Propane gas fireplaces emit 40 times fewer emissions than wood-burning units and cost less to operate.

Propane gas fireplaces can be turned off easily with a switch, eliminating concern about remaining embers.

Now We're Cookin'

Propane-fueled cook tops offer instant heat and absolute temperature control.

Ninety-seven percent of professional chefs prefer cooking with gas.

Unlike electricity-powered appliances, propane appliances are not affected by power outages. Homeowners can continue to enjoy cooking meals in warm homes.

Tumblin' Dry

Propane-fueled dryers can complete drying tasks in approximately three-quarters of the time it takes an electric unit. Some models save up to 65 percent in costs over electric dryers.

Source: National Propane Gas Association/Propane Education & Research Council
2/1/00

PHOTOVOLTAICS IN ALASKA

A DOE-Sponsored Workshop: Meeting Alaska's Energy Needs

With fewer than 12,000 miles of paved road in the state, aviation is the major form of transportation in Alaska. Indeed, with hundreds of public use, land-based airports and perhaps as many as 3,000 remote landing strips, the 49th state is ripe for reliable remote power for aviation purposes. Solar electricity (photovoltaics, or PV) is a viable option for many of the state's energy needs.

This and other opportunities for solar electricity were discussed at a one-day workshop co-sponsored by the U.S. Department of Energy's Office of Solar Energy Technologies, the Alaska Energy Authority, and Sandia National Laboratories. *Photovoltaics in Alaska* focused on how PV converts sunlight into electricity, presented the practical applications for the technology, and featured several cold climate installations already in operation. Among the notable applications of PV for the State of Alaska (which operates all but one of the hundreds of airports) and the FAA (responsible for certifying them) are remote communications, instrument landing systems, VHF radio ranges, beacons, and weather stations, all essential components of small aircraft operation—the lifeblood of Rural Alaskan transportation.

The role photovoltaics play in the state's tourism economy was highlighted. Although numbers cannot be confirmed, there appear to be hundreds of small, off-grid uses of PV already in place at Alaska's hunting, fishing, and vacation lodges in the bush, according to industry spokespersons who participated in the workshop. Of the 600,000-plus people living in Alaska, perhaps 100,000 live away from its population centers, creating a burgeoning need for remote residential and village power systems. PV along or in conjunction with complementing technologies, such as wind, makes sound economical and environmental sense for these particular applications. These sentiments were endorsed not only by the chairman of Alaska's Million Solar Roofs Coalition, but by all of the PV industry members present. It is estimated that there

may be more than 1000 small, off-grid installations already providing power in Alaska.

The DOE was lauded for bringing credibility to the PV technology by sponsoring workshops of this nature, where potential customers for the clean, quiet energy source can hear accurate information on PV's benefits and diversity. Economic case studies and solar resource determinations were of particular interest to the group. The workshop was hosted, without fee on September 18, in conjunction with the 28th IEEE Photovoltaic Specialists Conference in Anchorage. The IEEE meets every 18 months throughout the country for a weeklong session attended by hundreds of PV specialists from the U.S. and elsewhere. Also holding its first meeting that week was Alaska's Million Solar Roofs coalition.

Participants at the workshop included members of Alaska's utilities (large and small), Native villages, telecommunications companies, the Alaska Railroad, governmental agencies, and the University of Alaska. Presenters were Roger Hill, Sandia, Paul Maycock of PV Energy Systems, and Jito Coleman of Northern Power Systems. Richard King of DOE's Office of Solar Energy Technologies organized the workshop.

See also the paper that was presented in support of the Alaska Million Solar Roofs Coalition efforts by Rich Seifert, at the 28th IEEE Photovoltaic Specialists Conference in Anchorage on September 19, 2000. "CONCEPTS FOR INTEGRATING PV INTO RURAL ALASKAN HOUSING AND UTILITIES". Web site: www.uaf.edu/coop-ext/faculty/seifert.

The Photovoltaic Systems Assistance Center has a website at www.sandia.gov/pv that is an excellent source for a new, updated list of photovoltaic and renewable energy publications. This is a new version since we published a faxable order form of this list in our Summer 2000 newsletter.

Alaska Million Solar Roofs Coalition Members:
—Alaska-Building Science Network, Anchorage—
David Mogar, Specialty Electric, Homer
Sub-Arctic Solar Alaska, Fairbanks
Greg Egan, Alaska Renewable Energy, Fairbanks
Kirk Garoutte, Susitna Energy Systems, Anchorage

latter situation seems to be the policy of the Alaska Department of Environmental Conservation.

Composting doesn't come cheap. The prices for compost toilet systems are generally pretty steep. A midsize Phoenix system which includes two toilets and a basement-style composting unit begins at about \$4,600 installed with vents and chutes, according to one designer. Additional information of all sorts can be found on one of the Fine Home Building Magazine websites: <http://www.taunton.com/fh/features/materials/toilets/2.htm>.

FUEL CELLS OFFER BRIGHT FUTURE FOR OFF-GRID BUILDERS

Home builders and developers who are struggling to find usable land for new projects will be interested to know that millions of beautiful new building sites are going to become available over the next 20 years. We're talking about sites that are away from the cities and towns, on mountain slopes and remote lakes, where there's no access to the electric grid.

There are currently just two ways to open such sites to development, and neither of them is ideal. The first would be to pay the electric utility to bring in power lines. But at \$10,000-\$50,000 a mile, you've got to be involved with a big-time development or have a billionaire client to make the economics work.

The second strategy would be to put together a stand-alone power system using some combination of photovoltaics (PVs), wind energy, and batteries, with a diesel generator for backup. But these types of systems are expensive — PVs, for example, cost \$4 per watt (at least) just for the panels and up to three times that much for the installed system. Moreover, stand-alone systems built with PVs or wind turbines are necessarily dependent on the weather and impose a limited energy budget on the owners (e.g., no electric cooking or water heating).

But there's an exciting third option looming on the horizon — fuel cells — which have the potential to

power an off-grid home, including all the modern appliances and gadgetry that Americans are accustomed to, without the owners having to keep an eye on the weather or the clock.

Several different types of fuel cells are under development, but all of them have three basic components:

1. A fuel processor to convert natural gas, methanol, or other hydrocarbons into hydrogen, which fuels the cell.
2. A stack that generates electricity (and heat) through electrochemical reactions
3. Power conditioning equipment to convert direct current into alternating current.

Builders, developers, and homeowners who use fuel cells in the future will appreciate the fact that they are very quiet and environmentally clean — so clean, in fact, that they aren't regulated by the US Environmental Protection Agency. And their efficiencies (electric only) are expected to be 40% or better.

Small fuel-cell systems, rated from 3-10 kilowatts (kW), are already being built as alpha and beta models by various manufacturers, with field testing under way. For example, the Bonneville Power Administration (BPA) is buying 1103-kW fuel cells from IdaTech (Bend, Oregon) to power remote homes in the Pacific Northwest (see figure). These off-the-grid beta units will be equipped with data loggers to assess their performance over the next couple of years with commercial models expected on the scene in 2003.

"More and more of our customers today are looking for reliable power in remote, difficult-to-serve locations," says Kevin Watkins, vice president of engineering for Pacific Northwest Generating Cooperative (PNGC). "IdaTech's [Proton Exchange Membrane] fuel-cell systems should provide an ideal solution once their testing phase is complete." PNGC is an association of electric utilities that is cooperating with BPA on the current field tests.



IdaTech's 3-kW fuel cell for off-grid homes measures 44 (H) × 49 (L) × 43 (W) inches (108 × 124 × 83 cm) and weighs 800 pounds (363 kg). The box contains the fuel processor, fuel-cell stack, and all balance-of-plant components, except the power electronics and inverter. The lid contains the electronic control system that automates the operation of the fuel-cell system. Visible in the near-right corner of the lower compartment is the top of the fuel-cell stack. The beta version includes several modifications, including a redesigned deionization cartridge to filter incoming water. (The filters on some of the alpha units clogged in areas with very hard water.)

One participating coop member is Lincoln Electric, based in Eureka, Montana. "The rocky terrain in Montana complicates underground power line installation, while lines installed above ground are limited by Forest Service fire hazard regulations," says Tim Engleson, a service representative with Lincoln. "We believe fuel cells will provide a solution to the dilemma of rural energy generation."

Electrical Engineer Craig Holmes, director of business development at IdaTech, says his company's fuel cell should be able to provide off-grid homes with electricity at about \$0.17 cents per kilowatt-hour (kWh). This number reflects operating costs only, which are dominated by fuel costs. Capital and maintenance costs for the fuel cell would add a few cents more. "If you factor in the thermal energy the fuel cell produces, which can be used for water heating or space heating, the cost per kWh goes down by about half," he notes.

The IdaTech fuel cells that are being installed through BPA will run on methanol, but the company's proprietary fuel processor can also convert propane or diesel fuel. Each system will generate 3 kW of continuous electrical power, enough to run a fully equipped 2,000-ft² house. Holmes says that some of the beta systems may be configured so their "waste" heat is used to preheat water. "Tests show that our fuel cell can keep water in a 60-gallon reheat storage tank at about 100°F," Holmes says.

Another company that has set its sights on the off-grid residential market is International Fuel Cells (IFC), a subsidiary of United Technologies based in South Windsor, Connecticut. IFC, which introduced a 200-kW fuel-cell system in 1992, probably has more operational experience with stationary fuel-cell power plants than any other company in the world. (Ed. Note: Large IFC Fuel Cells are the type installed at the Postal Service installation at the Anchorage Airport.)

Guy Hatch, IFC's director of Residential Systems, says the company is working on a 5-10 kW fuel cell aimed at the residential and light commercial markets. A beta model should be ready next year. "We see a real market for small stationary power systems for places where it's too expensive to bring in grid power," he says. "Right now, there are a lot of places where people would like to live, but can't, because of power limitations."

In addition to powering isolated single-family homes, fuel cells could also be used to power clusters of homes or even whole subdivisions off-grid. Exactly how such a mini-utility might be engineered remains to be seen. "For an off-grid subdivision, I think you would still want to put individual fuel cells in each house," Hatch says, "but interconnect them to balance the load and provide redundancy in case one or more of them went down."

Another approach would be to use two or more large fuel cells to power the whole development. For example, IFC's 200-kW fuel cell—the PC25—could power 75 homes or more. But if the fuel cell were centrally located who would pay the \$800,000 that such a system currently costs? The developer?

The homeowners? Or perhaps the manufacturer, who might own, operate, and maintain the fuel cell under some kind of contractual arrangement with the community? While these and other questions remain unanswered, we're strongly persuaded that fuel-cell prices are going to come down and that reliability is going to improve. In time that's going to open up millions of new building sites that have never been considered before.

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web site: www.cutter.com/energy/

SAVE MONEY...SAVE THE PLANET...USE LESS ENERGY

Is your television really turned off? Or is it using energy even when it is not on?

OK, here's a little known fact...some TVs and VCRs that don't meet energy efficiency standards consume energy even when they are turned off (but still plugged in). ENERGY STAR® TVs and VCRs don't. So your TV or VCR could be hogging energy and money even when you're not there!

Does your stereo or computer contribute to air pollution?

Every time you use inefficient appliances, you contribute to air pollution. This is because most of the energy consumed in our homes and offices is produced by power plants that use fossil fuels like coal, oil, and natural gas. When these fuels are burned, they release air pollutants and particles that contribute to smog, acid rain, respiratory disease and global warming.

What can you do?

When shopping for new consumer products—particularly lighting, electronics, and appliances—choose energy efficient ones with the ENERGY STAR® label to ensure that you are getting products that use less energy. If everybody buys ENERGY STAR® products instead of standard equipment over the next 15 years, we could cut global warming pollution equal to removing 17 million cars from the road for each of those years!

Is that all?

No, there's more savings. If everyone in the U.S. used energy efficient light fixtures or lamps in their kitchens or living rooms, we could save 70 billion kilowatt-hours of energy and prevent 100 billion pounds of carbon dioxide every year. That's the equivalent of removing 10 million cars from the road annually!

Shopping for a TV, VCR, computer, printer, a sound system, lighting products or even a large appliance (like a dishwasher, washer, dryer, refrigerator)?

Look for the ENERGY STAR® product. The ENERGY STAR® is awarded by the U.S. Environmental Protection Agency and the U.S. Department of Energy to products that meet or exceed federal energy efficiency standards.

Are you paying the bill?

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The seasonal variability in propane prices is considered a disadvantage by many potential auto propane users. However, the price gap between regular gasoline and auto propane has remained fairly constant on an annual basis as shown by the national price differential between regular gas and auto propane in Figure 25. For example, despite the price spike from late 1996 to early 1997, the average auto propane price was 59% and 56% that of regular gasoline in 1996 and 1997 respectively, compared to the 1991 - 1997 average of 55%. In 1998, the average auto propane price was 23.1 cents per litre, which was 56% that of regular gasoline.

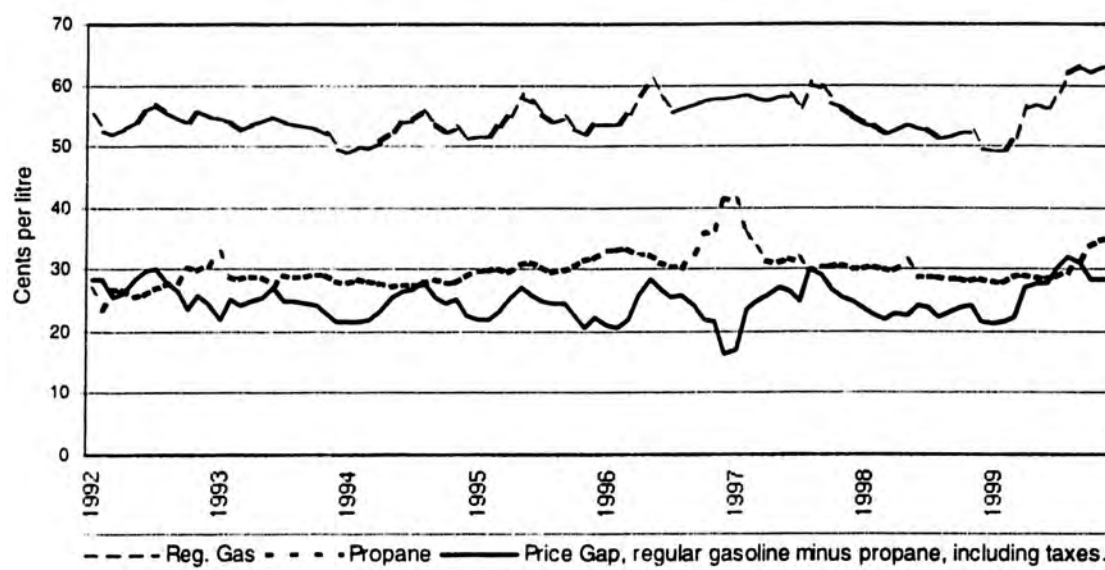
As an alternative transportation fuel, auto propane is compared to regular gasoline. However, since the majority of auto propane users are fleets and other heavy fuel consumers, it is more reasonable to compare auto propane to diesel fuel, its main competitor for the high mileage market.

Diesel fuel has a higher energy content than either gasoline or auto propane. It takes approximately 1.5 litres of propane to go the same distance as 1 litre of diesel fuel.

Table 6 compares average retail prices of both diesel fuel and auto propane. The average national price differential between diesel fuel and auto propane is 23.6 cents per litre, but on an energy equivalent basis, is only 8.3 cents per litre.

Table 7 compares federal and provincial fuel taxes. The federal government charges GST on auto propane but does not impose an excise tax. Provincial taxation of auto propane has not changed since 1997. However, the taxation of auto propane has seen a number of changes following the 1997 provincial budgets. Quebec removed its 8.2 cent per litre tax on auto propane effective March 26, 1997 in order to provide the same tax treatment to auto propane as afforded to natural gas. Quebec and British Columbia are the only provinces that exempt automotive propane from their provincial fuel taxes, although auto propane is subject to sales tax in both provinces. British Columbia announced a 7% sales tax on auto propane, effective June 1, 1997. The B.C. sales tax is roughly equivalent to a 2.2 cent per litre tax on auto propane. Most other provinces have lower taxes on propane than gasoline, which implies recognition of the lower energy content of propane and/or recognition of its cleaner fuel characteristics.

figure 25. Gasoline/Automotive Propane Price Differential



Source: MJ Ervin & Associates, Retail Fuel Prices Survey

Table 6. Comparison of 1999 Average Diesel and Auto Propane Prices (cents per litre)

Region	Diesel		Automotive Propane		Price Differential		Auto Propane equivalent to diesel price (including taxes)
	including taxes	excluding taxes	including taxes	excluding taxes	including taxes	excluding taxes	
Canada	54.0	31.6	30.4	23.4	23.6	8.2	45.7
Vancouver	53.1	30.2	31.6	25.8	21.5	4.4	47.5
Calgary	49.8	33.5	27.4	19.1	22.4	14.4	41.1
Regina	55.1	32.5	39.1	27.5	16.0	5.0	58.7
Winnipeg	51.3	33.1	33.2	25.4	18.1	7.7	49.9
Toronto	51.4	29.7	29.4	23.1	22.0	6.6	44.1
Montreal	58.4	30.6	41.0	35.6	17.4	-5.0	61.6
Saint John	60.5	34.9	49.0	35.9	11.5	-1.0	73.6

Source: MJ Ervin & Associates Retail Fuel Prices Survey

Feasibility of Natural Gas Distribution to the Yukon River Valley and its Applicability to other Rural Areas.

A Preliminary Report
Fate, Dyson, Joule

The question posed by Representative's Ogan and Joule of the Special Committee on Oil and Gas was "Is it economically feasible to bring natural gas to the Yukon River drainage area if a natural gas pipeline should cross the Yukon River". We expanded on that question to apply any results to rural areas where transportation might be available such as roads or navigable waterways.

The table of contents is self-explanatory, with pages 14-15 and 22-23 blank due to requested information that has yet to arrive. Page two and three articulate the objectives and the questions.

Preliminary Summary

Although there are still several questions yet to be answered, and data as yet unseen, we can begin to see a somewhat clearer picture of the economics and problems of a gas distribution system in the Yukon River Valley.

At present, there are approximately a total of 8,439,459 gallons of diesel fuel used for both heating and transportation in 16 villages. In 1999 fuel averaged approximately \$1.65 per gallon. In this year of 2001, the price has gone up at least 10 cents per gallon. The total aggregate cost to the villages for fuel or diesel is \$14,769,053 per year.

The cost of LNG infrastructure and plant is approximately \$21.6 million including tankage at the three larger villages of Pilot Station, Galena and Fort Yukon. At eleven other villages, re-gas and storage facilities would be \$8.8 million, the total coming to 30.4 million dollars. Adding the cost of capital at 6%, averaging approximately 1.2 million per year, brings the total to 31.2 million. If that were amortized over 20 years, the cost per year would be 1.56 million per year. Adding other transportation, personnel, and administration costs and a huge error factor of 20%, we could raise the yearly cost to 2.56 million per year for infrastructure.

The village distribution system is more complex and calculated somewhat differently. It may be prohibitive to pipe natural gas to each home or business. However, in most villages, an electrical infrastructure exists which could be added to at moderate cost. Therefore, electrical generation at the re-gassification plant seems to offer a better financial advantage.

Local pricing and industrial market pricing by the owner/pipeline operators will add to costs, but given the comparison of nearly \$14.8 million dollars for diesel fuel, the distribution and use appears feasible at this point in the investigation.

Compressed gas was also evaluated. The cost of storage capacity for the amount needed and the infrastructure required makes this marginal, or even cost prohibitive. For example, the storage capacity would be approximately 60,000 scf per home or business. This equates to 160 million amortized over the same 20 years, or \$8 million plus approximately \$ 6.7 million of interest, on a total of \$14.7 million. This is nearly the same as diesel without figuring any other incidentals.

All the above computations were based on the prospect of long range storage with at least 7 months of unavailable barge transportation.

We found that if heavy transportation were available at a low tariff, there is no reason that this concept cannot be utilized in other rural areas of the state at the same or near economic level.

-Preliminary Report-
Feasibility of Natural Gas Distribution
To Yukon River Valley or other rural areas
Ad-hoc Subcommittee of the
Special Committee of Oil and Gas

Fate, Dyson, Joule

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- ii.-iv. LNG Fact Sheet
- v. Non-Traditional Sources and Uses of LNG by Jeff Beale, CH IV LNG Company
- vi. Calista Region Map

Research Project: Natural Gas Distribution to Rural Alaska

Objective: Exploring the feasibility of a gas distribution service to the Yukon River Valley or other rural areas if and when the gas pipeline should take the southern route.

Proposed Questions:

- 1) What are the Populations of Villages from St. Mary's all the way up to Fort Yukon?
- 2) What is the distance, in miles, between each village?
- 3) How much would a natural gas distribution complex cost and is it feasible to do in the Yukon Drainage area?
- 4) What is the estimate and feasibility of a plant that would produce either LNG or Gas that could be containerized and stored for transportation to the villages?
- 5) What kind of transportation facilities, including means of shipping, would be required at each village and on the Yukon River in the summer time?
- 6) What type of storage facilities would be needed to carry a supply of gas to the villages through those months when the rivers are frozen solid?
- 7) What size or type of plant/facility would be needed?
- 8) What type would be the least expensive: LNG, LPG, or Compressed?
- 9) Is Electrical Generation Utilizing Gas a possible solution?
- 10) What are the Power Cost Equalization Comparisons between fuel options?
- 11) What is the potential of shallow gas and coalfield methane usage as a future unexplored potential for rural Alaska?
- 12) What are other alternatives to provide power to the rural villages?

Data: See Attached information.

Alternatives:

Electricity Sources Being Explored:

LNG

1) Put a small LNG plant in each village. Then barge in LNG to run turbines that would provide electricity to villages. We encountered a wide variety of estimates on various operations. The low was \$10 to \$12 million for a small LNG plant alone.

2) LPG and CNG

Other Sources

2) Mine Development

3) Shallow Gas & Coal Field Methane Potential

5) Fuel Cells and Planar solid oxide fuel cells

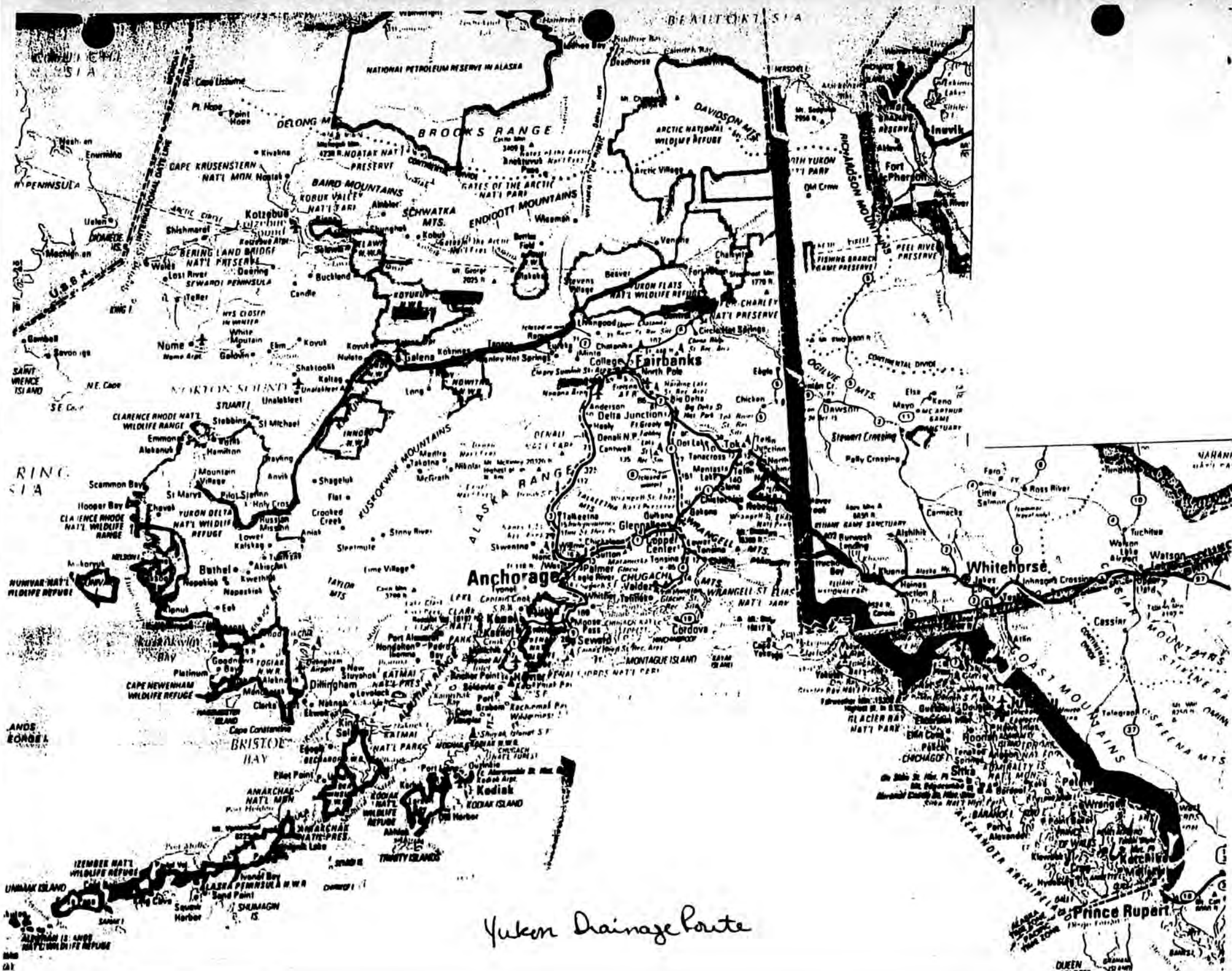
6) Wind Turbines

- 8) Photovoltaic device
- 9) Coal and railroad system
- 10) Biomass Fuels
- 11) Conservation
- 12) Clean Coal Technology

Sources of Capital Funds

Denali Commission
Private
Power Cost Equalization (PCE) - State of Alaska
Other Federal Dollars

Liquefied Natural Gas



Yukon Drainage Area Population and Distances

Village	Population	As Of
Fort Yukon	565	Dec. 2000 DCED
Beaver	126	1999 Dept. of Labor
Stevens Village	92	1999 Dept. of Labor
Rampart	66	1999 Dept. of Labor
Tanana	300	Dec. 2000 DCED
Kokrines		
Ruby	179	Dec. 2000 DCED
Galena	592	Dec. 2000 DCED
Koyukuk	100	Dec. 2000 DCED
Nulato	347	Dec. 2000 DCED
Kaltag	251	Dec. 2000 DCED
Grayling	187	Dec. 2000 DCED
Anvik	91	Dec. 2000 DCED
Holy Cross	259	Dec. 2000 DCED
Russian Mission	307	Dec. 2000 DCED
Pilot Station	582	Dec. 2000 DCED
St. Mary's	482	Dec. 2000 DCED
Total Number	4526	
Average	282.875	

		Ground Miles "as the crow flies" (approximate)	Water Miles 1973 Report statute miles
Fort Yukon	to Beaver	61	70
Beaver	to Stevens Village	54	91
Stevens Village	to Rampart	47	78
Rampart	to Tanana	60	68
Tanana	to Kokrines	78	tanana to ruby
Kokrines	to Ruby	27	117
Ruby	to Galena	43	52
Galena	to Koyukuk	25	32
Koyukuk	to Nulato	17	17
Nulato	to Kaltag	32	34
Kaltag	to Grayling	104	100
Grayling	to Anvik	21	18
Anvik	to Holy Cross	34	38
Holy Cross	to Russian Mission	58	
Russian Mission	to Pilot Station	52	
Pilot Station	to St. Mary's	13	

Distances provided by Kerry Kirkpatrick with DOT

Capt. Moore: Yutana Barge Lines: PO Box 220, Nenana 907-832-5505

MILEAGE AND TIME CHART BASED ON 5 MPH UPSTREAM

From	To	Miles	Runtime in hours
Emmonake	Mountain Village	67	13.4
Mountain Village	Saint Marys	20	3.4
Saint Marys	Pilot Station	25	5
Pilot Station	Marshal	45	9
Marshal	Russian Mission	57	11.4
Russian Mission	Holy Cross	75	15
Holy Cross	Anvik	38	7.6
Anvik	Grayling	20	4
Grayling	Blackburn	54	10.8
Blackburn	Kaltag	65	13
Kaltag	Nulato	36	7.25
Nulato	Koyukuk	15	3
Koyukuk	Galena	50	10
Galena	Ruby	54	10.7
Ruby	Tanana	120	24
Tanana	Nenana	192	38.4

MILEAGE AND TIME CHART BASED ON 10 MPH DOWN STREAM

Nenana	Tanana	192	19
Tanana	Ruby	120	12
Ruby	Galena	54	5.5
Galena	Koyukuk	50	5
Koyukuk	Nulato	15	3
Nulato	Kaltag	36	3.52
Kaltag	Blackburn	65	6.5
Blackburn	Grayling	55	5.5
Grayling	Anvik	20	2
Anvik	Holy Cross	38	3.8
Holy Cross	Russian Mission	75	7.5
Russian Mission	Marshal	57	5.7
Marshal	Pilot Station	45	4.5
Pilot Station	Saint Marys	25	2.5
Saint Marys	Mountain Village	20	2
Mountain Village	Emmonake	67	6.9

Notes: Times vary as much as one hour depending on different river conditions and availability of tide in lower river. To determine ETA's for different speeds, divide miles by speed. Multiply speed by time in decimal hours to figure miles. To determine speed divide miles by hours run. To change minutes into decimals, divide by 60. To change decimal minutes into minutes multiply by 60.

Barges, depending on large or small size, can carry 600-900 Tons. For larger items, such as tanks and housing, they may need to use a special barge.

**Would not or could not provide specific size.*

They go by Tanana ever 10 to 14 days on their way downstream. They stop at Tanana or 3 to 4 miles down from there.

They make trips upstream 3 times a year. Usually mid June, July, and the end of the season around August 21st.

Estimation of Current Average Village Power Cost Equalization (PCE)

Utility/Community	Total Fuel Used Gallons (#1 Diesel)	Total KWH KWH Produced Based on population	Cost #1 \$	PCE (%)	
Anvik	37,616	246,346	0.99	17	*This chart was the most current information available on the Power Cost Equalization Program. Dated: 6/30/99 From the statistical report of the Power Cost Equalization program. 12 th edition, May, 2000
Grayling	47,150	367,802	1.15	16.9	
Holy Cross	60,615	527,921	1.06	16	
Kaltag	59,884	386,332	1	17.1	
Koyukuk	22,233	86,365	1.36	15.8	
Nulato	87,912	691,937	1.04	17.3	
Pilot Station	95,908	673,725	1.06	17.7	
Galena	657,720	1,356,914	1.07	6.2	
Rampart					
Ruby	57,050	407,062	1.98	14.1	
Russian Mission	62,540	361,640	1.23	15.7	
Stevens Village	30,454	113,265	1.48	14	
Tanana	123,074	530,875	1.37	14.4	
Beaver	27,030	122,962	1.96	22.1	
Fort Yukon	189,562	1,077,480	1.3	11.8	
Saint Mary's	152,311	1,052,727	1.06	17.9	
Total	1,711,059	8,003,353	19.11	234	*Averages will be used in the cost equations.
Average	114,071	533,557	1.274	15.6	
Rounded			\$1.27	15.60%	
Current Estimates			\$1.65*	18.68%	
			per gallon	PCE	

*Badger Fuel, Alaska Petroleum, and Sourdough Fuel, retail delivery companies in Fairbanks, AK, where contacted in order to determine the average retail cost increase in #1 diesel fuel since 6/99. Fairbanks information was used because the North Pole refineries would be the most likely suppliers to the above communities. The average retail cost increase was 38 cents per diesel gallon. This means the approximate current retail price is \$1.65 per gallon.

According to the calculation, $(1.27/15.6) = .081$, there is an average increase to PCE of .081 per penny. By multiplying .081 by .38, we get an increase of 3.08% in PCE. This translates into a current estimated PCE of 18.68% (15.6 + 3.08).

*The \$1.65 price appears low because it does not include state or federal road tax.

Estimation of Total Fuel Consumption for Businesses & Households

	# of Businesses and Households per Village	# of Approximate Gallons of #1 diesel fuel used for heating
Anvik	55	198,000
Grayling	68	244,800
Holy Cross	99	356,400
Kaltag	89	320,400
Koyukuk	57	205,200
Nulato	125	450,000
Pilot Station	120	432,000
Galena	281	1,011,600
Rampart	14	50,400
Ruby	122	439,200
Russian Mission	78	280,800
Stevens Village	51	183,600
Tanana	157	565,200
Beaver	76	273,600
Fort Yukon	278	1,000,800
Saint Mary's	199	716,400

Total 1,869 6,728,400 16 villages

1) Does not account for miscellaneous vehicles or public facilities that use diesel fuel.

2) The approximate number of # 1 diesel fuel is based on the equation:

An estimated average of 10 Gallons a day x number of households & businesses
x 30 days/month x 12 months/year.

3408 International Way, Fairbanks, AK 99701-7382
Phone (907) 452-7111 FAX (907) 457-8111
email: dbritton@fngas.com

**Northern Eclipse, LLC
Fairbanks Natural Gas, LLC**

Fax

To:	Randy Clem Daniels	From:	Dan Britton
Company:	Office of Representative Fate	Pages:	2
Fax:	(907) 465-3883	Date:	January 23, 2001
Phone:	(907) 465-4530	Re:	LNG & CNG

☐ Urgent ☒ For Review ☐ Please Comment ☐ Please Reply ☐ Please Recycle

Randy,

As per your telephone request today, the following is some information regarding Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG), as it relates to its potential use as an energy source for heating and power generation for villages accessible by the Yukon River.

It is my understanding that you are evaluating the feasibility of barging CNG or LNG into villages along the Yukon River for use as a fuel for power generation and heating. You have indicated that each area will require approximately 7 months of energy to be stored on-site to serve an average community of approximately 500 people. This is due to the community's remoteness and winter access problems.

CNG - My initial reaction regarding CNG, is that due to the volumes of Gas required, the costs associated with the transportation and storage of the CNG would render the project uneconomical. For example a CNG unit capable of storing approximately 35,000 Standard Cubic Feet (SCF) of natural gas has an approximate cost of \$50,000.00. A capacity of 35,000 SCF is most likely not enough gas to serve 1 home for seven months, depending on it size.

LNG - If LNG is to be used as an energy alternative for these villages, the following infrastructure must be considered:

- An LNG production facility with enough capacity to serve the villages annual requirements. This facility will require enough storage to facilitate building inventories for the short delivery time frame. The capital cost of such facility may range from \$5 to \$15 million and may easily exceed \$15 million given capacity requirements and transport loading requirements.
- Transport equipment with enough capacity to transport large volumes in the short time frame. The most likely scenario is an LNG barge. I do not have access to estimated capital costs at

January 23, 2001

this time, as it is unfamiliar technology to me. The only water transportation of LNG that I am aware of is the ocean going tankers, which transport over 20 million gallons per haul to and from international deep-water ports.

- LNG offloading, storage and vaporization equipment at each village. Assuming a requirement for approximately 500,000 to 1,000,000 gallons of storage capacity, the estimated capital costs of storage and vaporization facilities would be in the range of \$3 to \$6 million per each location.
- Natural Gas distribution piping. The estimated capital costs for underground natural gas distribution piping from the storage tank to the end users is estimated \$100,000.00 to \$150,000.00 per mile.

As can be seen there are substantial capital investments required to build the infrastructure required to utilize natural gas in these villages. When compared to propane or diesel, the equipment used to produce, transport and store LNG is so expensive due to the fact that LNG is a cryogenic liquid and must be stored at temperature of negative 260 degrees F. Therefore special metals must be used which is not the case with propane or diesel. Also not discussed are the on going operation and maintenance requirements of these storage, vaporization and underground pipe distribution facilities.

I hope the above helps you to evaluate the potential use of natural gas for the areas being considered.

Note: The estimates given are rough numbers based on Fairbanks Natural Gas experience and may not reflect actual costs given varying site and project requirements.

Yours truly,



Daniel W. Britton
General Manager

MEMORANDUM
Yukon Pacific Corporation

TO: Randy, Brenda
FROM: Matt J. Gillis
DATE: February 2, 2001
SUBJECT: LNG Facilities Cost Estimate

Listed below by individual site is what amounts to some very preliminary cost numbers for LNG facilities to be used to serve rural Alaskan villages along the Yukon River. It was assumed that a LNG Liquefaction Plant would be built at a site where the gas pipeline will cross the Yukon River. The LNG Plant is sized at 200 million cubic feet of gas per year, which is the amount of energy that is currently used in the form of diesel fuel to generate electricity for the communities along the Yukon River. The LNG would be shipped to the communities by tractor trailers loaded onto barges. It will take 14 loads of 14 trailers to deliver all of the LNG. We have included two extra trailers for backup. Storage and regasification facilities would be built at each village sufficiently large enough to store one year's supply of LNG. \$2.0 million is included in the estimate for project design and management and a 20% contingency is included because of the preliminary nature of the numbers.

- LNG Liquefaction Plant with the ability to liquefy 2 million cubic feet per day = \$6 million. The plant will operate for 100 days per year.
- Storage facilities at the LNG Liquefaction Plant = three 50,000 gallon tanks = \$3.0 million.
- 16 insulated tractor trailers to transport the LNG = \$230,000 times 16 trailers = \$3.7 million.
- Dock facilities at the off-loading points = \$200,000.
- Storage and regasification facilities at Galena include two 50,000 gallon tanks = \$1.3 million.

- Storage and regasification facilities at Fort Yukon include one 50,000 gallon tank = \$1.0 million.
- Storage and regasification facilities at Pilot Station include one 30,000 gallon tank = \$0.8 million. This is the smallest size facility we would recommend since essentially no savings are gained by building a tank smaller than 30,000 gallons.
- Project design and management costs = \$2.0 million.
- 20% contingency = \$3.6 million.

The total cost for the items described above would be \$21.6 million. The costs for facilities at additional villages will need to be added in to this total to come up with a grand total.

I hope this will help. I will get some gas fired electric generation costs for you when I return from my trip next week.

Foothills Study Pending

PROPANE PRICES: What Consumers Should Know

What Is Propane?

Most people know propane as the fuel in a white container attached to a barbecue grill. But propane has long proven its versatility for heating homes, heating water, cooking, drying clothes, fueling gas fireplaces, and as an alternative fuel for vehicles. However, more propane is used to make petrochemicals which are the building blocks for plastics, alcohols, fibers, and cosmetics, to name just a few.

Propane naturally occurs as a gas at atmospheric pressure but can be liquefied if subjected to moderately increased pressure. It is stored and transported in its compressed liquid form, but by opening a valve to release propane from a pressurized storage container, it is vaporized into a gas for use. Simply stated, propane is always a liquid until it is used. Although propane is non-toxic and odorless, an identifying odor is added so the gas can be readily detected.

Where Does Propane Come From?

A unique feature of propane is that it is not produced for its own sake, but is a by-product of two other processes, natural gas processing and petroleum refining. Figure 1 shows a diagram of where propane comes from and how it gets to the consumer.

Natural gas plant production of propane primarily involves extracting materials such as propane and butane from natural gas to prevent these liquids from condensing and causing operational problems in natural gas pipelines. Similarly, when oil refineries make major products such as motor gasoline and heating oil, some propane is produced as a by-product of those processes. It is important to understand that the by-product nature of propane production means that the volume made available from natural gas processing and oil refining cannot be adjusted when prices and/or demand for propane fluctuate.

In addition to these two processes, demand is met by imports of propane and by using stored inventories. Although imports provide the smallest (about 10 percent) component of U.S. propane supply, they are vital when consumption exceeds available domestic supplies of propane. Propane is imported by land (via pipeline and rail car from Canada) and by sea (in tankers from such countries as Algeria, Saudi Arabia, Venezuela, Norway, and the United Kingdom).

Figure 1. Propane Production and Distribution System

HUGH

LPG:

Two different Plants are used to process propane, the Expander Plant (gasline) and the Distillation Tower (pipeline). LPG can come out of a gas line or a crude line.

Assuming it comes from a crude line, a distillation tower is needed. Crude is taken out of the pipeline and heat is put to it. This boils off the methane, ethane, and propane. The propane is taken out and put in storage. The rest is put back into the line. The distillation tower needs a heat source (use part of the methane and ethane), a re-compressor (re-compress the methane, ethane, and anything else in the mix to put it back into the pipe), and a condenser (to reliquify propane). Small units are pretty cheap. \$1.5 to \$2.0 million dollars. For transportation one would buy tanks for Barges. A 60,000 gallon propane tank costs approximately \$50,000. It is put on the barge and off loaded to the village. This would be within the 1.5 to 2 million dollar cost. It is a real simple plant. Once the propane is boiled off (boil it off as a gas) it is condensed back into a liquid and then compressed and put it into storage. Once let out of tank pressure is released and it turns back into gas. Then it could be used in the capstone turbines. The opposite process is used for an expander plant with similar simplicity and price.

CNG:

CNG uses different parameters. Pressure from 2400lbs (pipeline) to 3000lbs. There is not much compression to get to CNG. \$1000 per horsepower of compression. The volume would be needed for calculations. Generally it would be very cheap. It would add less than 5 cents to the cost of gas. A compressor station and filling stations would be needed to fill tanks like propane or butane tanks that can be added on to barge.

*Will have more information
on LPG + Butane*

Herb Zepp.

Smith & Norington

AIG : Alaska Intrastate Gas Co.

Pan Handle Population & Distances

Southeast Area

	Population DCED Web Site
Valdez	4068
Cordova	2110
Yakutat	534
Haines	1238
Juneau	26751
Pelican	222
Gustavus	258
Hoonah	795
Elfin Cove	57
Kake	700
Angeon	638
Sitka	8588
Tenakee Springs	94
Point Baker	39
Port Alexander	119
Craig	1260
Klawock	722
Petersburg	3387
Wrangell	2479
Metlakatla	1464
Ketchikan	8263
Hydaburg	384
Total	64170
Average	2916.818182

From	To	Statute miles	Nautical Miles	Air Miles (straight line)
Angoon	Tenakee	34	29.58	31
Angoon	Hoonah	65	56.55	53
Angoon	False Is	27	23.49	
Angoon	Sergius	50	43.5	
Angoon	Sitka	75	65.25	42
Angoon	Kake	62	53.94	44
Angoon	Petersburg	115	100.05	77
Auke Bay	Tracy Arm	90	78.3	
Auke Bay	Haines	77	66.99	68
Auke Bay	Pelican	106	92.22	66
Auke Bay	Hoonah	53	46.11	35
Auke Bay	Sergius	125	108.75	
Auke Bay	Sitka	150	130.5	95
Auke Bay	Petersburg	138	120.06	116
Auke Bay	Gustavus	60	52.2	41
False Is	Angoon	27	23.49	
False Is	Sitka	48	41.76	
False Is	Sergius	23	20.01	
Haines	Skagway	17	14.79	18
Haines	Auke Bay	77	66.99	68
Haines	Juneau city	104	90.48	
Hollis	Ketchikan	45	39.15	40
Hollis	Metlakatla	57	49.59	50
Hollis	Wrangell	105	91.35	70
Hollis	Petersburg	135	117.45	94
Hollis	Kake	196	170.52	114
Hollis	Juneau City	251	218.37	213
Hoonah	Auke Bay	53	46.11	35
Hoonah	Juneau City	78	67.86	35
Hoonah	Pelican	69	60.03	32
Hoonah	Tenakee	55	47.85	24
Hoonah	Angoon	65	56.55	53
Hoonah	Kake	121	105.27	96
Hoonah	Sergius	108	93.96	
Juneau City	Haines	104	90.48	68
Juneau City	Hoonah	80	69.6	35
Juneau City	Petersburg	120	104.4	116
Juneau City	Ketchikan	240	208.8	234
Juneau City	Hollis	251	218.37	213
Juneau City	Tracy Arm	72	62.64	
Juneau City	Auke Bay	39	33.93	
Kake	Petersburg	64	55.68	40
Kake	Angoon	62	53.94	44
Kake	Sitka	127	110.49	53
Kake	Sergius	102	88.74	
Kake	Hoonah	121	105.27	96

Ketchikan	Metlakatla	18	15.66	16
Ketchikan	Prince Rupert	103	89.61	90
Ketchikan	Seattle	745	648.15	650
Ketchikan	Hollis	45	39.15	40
Ketchikan	Hyder	160	139.2	
Ketchikan	Wrangell	101	87.87	83
Ketchikan	Petersburg	134	116.58	113
Ketchikan	Punch Bowl	63	54.81	
Ketchikan	Bellingham	676	588.12	590
			0	
Petersburg	Wrangell	47	40.89	32
Petersburg	Sergius	152	132.24	
Petersburg	Sitka	177	153.99	94
Petersburg	Ketchikan	134	116.58	113
Petersburg	Hollis	135	117.45	94
Petersburg	Kake	64	55.68	40
Petersburg	Angoon	115	100.05	77
Petersburg	Juneau City	120	104.4	116
Petersburg	Auke Bay	138	120.06	116
			0	
Prince Rupert	Seattle	653	568.11	570
Prince Rupert	Ketchikan	103	89.61	90
Prince Rupert	Bellingham		0	500
			0	
Sergius	Sitka	25	21.75	

Other Energy Sources

Mine Site "Run Off" Power Alternatives

Mines use an immense amount of energy to operate. They may well bring lower cost power to the surrounding areas.

Calista Corporation: Donlin Creek Mine

Study to identify southwestern Calista regional least cost electrical power and energy requirements with and without the Donlin Creek Gold Mine Project and its feasibility and benefit options.

The study looked at several options that included rail-belt and new power plant construction. They recommended conducting a preliminary feasibility level analysis to further refine construction and operational costs of a new 80 mw coal fired plant in Bethel, Alaska with a 175 mile transmission line to the mine site in Donlin Creek. Fuel Cost of \$2.05 \$ per million BTU with the assumption of \$43.00/ ton coal delivered to Bethel and \$30.00/barrel bench mark price for Alaska North Slope Crude.

[Division of Geological and Geophysical Surveys (DGGS): Holitna Basin Project. Gas for Donlin Creek? Projected energy use for Donlin Creek Prospect is 66 MW peak demand with 27 million gallons of diesel fuel per year or 3.6 bcf gas (combustion turbine with 48% efficiency) Shallow gas and coalbed methane are potential sources. Analytical date has been partially received and a summary report should be out this spring.]

Cominco Alaska Incorporated: Red Dog Mine

- 1) Cominco is looking to replace diesel fuel with natural gas. This could improve air quality and could expand into an advantageous fuel source for local communities.
- 2) Shallow Gas Prospect: Cominco needs gas to replace diesel used to generate electricity. They have shallow gas leases and good prospects. Cominco will bear the cost of converting generators from diesel to gas, the access road, and pipeline to the mine facilities. (Mr. Jonathan Kelafant, Senior VP of Advanced Resources International, Inc. @ 703-528-8420 for more information on Red Dog shallow gas prospect)
- 3) Fuel Distribution: The DeLong Mountain Transportation System Port Site, which services Red Dog Mine, is strategically located for distribution diesel fuel to the local villages.

www.cominco.com

Cominco and NANA Development Corporation are evaluating the potential to develop shale-hosted natural gas reserves in areas adjoining the Red Dog mine as a means of reducing energy costs. Natural gas would be an ideal feed source for generating power at the Red Dog mine. The mine's current energy requirements are supplied by diesel-electric generators. Natural gas fired plants offer lower costs with fewer environmental emissions than those fuelled by diesel oil. If shale gas proves to be a viable option, it should provide a means of reducing power costs to the mine as well as to all the people in the region. Another option being considered is power generation from high-grade thermal coal deposits in the area.

Kennecott: Greens Creek Mining Company

5MW addition to Powerhouse-Clean burning combustion turbine.

Fairbanks Gold Mining Company: True North

True North has potential to reduced electrical rates for GVEA customers. Fort Knox purchases 25% of the total kilowatt-hours sold each year by GVEA. Without them residential rates would increase by 7% and commercial rates would increase by 10%

Usibelli Coal Mine, Inc.:

Healy Clean Coal Project - Waiting on answer to whether it is feasible or not.

Turbine Compressor

Capstone Turbine Compressor Distributors, an arm of Williams/Mapco are experts in the field of turbine compressors. They can make any size and then start stacking them for additional power. The company is very interested in the prospect of providing electricity to rural Alaska, to be involved in the market, and use the experience as a basis in advertising around the world.

The turbines can burn all 3 fuels and cleaner. Diesel, propane, and LNG. Capstone would love to give us a break on the cost to get project going. The turbines are as cheap or cheaper than a comparable diesel machine. The real savings come as savings in fuel and emissions. There is a % savings on fuel from diesel to propane to LNG and a cleaner environment. Probably under \$1.50/ Btu (LNG). Capstone is doing an entire study, at their expense, based on the information we gave them on kWh usage and population in the Yukon Drainage area. They should have results in approximately 2 weeks. The study will cover, assuming a transfer to space heating, exact costs per area, savings in emissions, electricity and fuel costs.

Positive benefits of the turbines are:

With turbines we can start savings before LNG is available.

Villages already have diesel tanks available for use.

Propane tanks are cheaper than LNG tanks.

The North Pole Refinery could supply propane and diesel.

Turbines will be at the same or at a cheaper cost as the diesel machine and there would be cost savings in fuel and emissions.

Turbines don't break. They are practically maintenance free. They only need to be oiled. So, they last forever. They are like a jet engine but small package, compact but powerful. They only have one moving part (main shaft).

If there are any problems there is an 800 number to call where a technician would walk someone through the problem.

Reason so efficient in Alaska is that they work better in low elevation and the colder the air is the better. So, you get more horsepower. Gain about 10% efficiency.

Capstone Study Pending

This report should be complete, on a village by village basis, in approximately two weeks.

Preliminary Remarks:

The villages are now paying 50-60 cents per kilowatt-hour and the maintenance cost on a large diesel engine is about 40%. With the turbines, maintenance cost is reduced by about 90%, using the same fuel (diesel). The cost of electricity is reduced by 20-25%. And, even though the turbines are still burning diesel fuels we will get 95% fewer emissions than with the current diesel machines. Besides that we save on size. A 35,000 machine is the size of a refrigerator. Once the turbines are running on cheaper fuel, there will then be more savings.

Coalbed Methane

The Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys and the Los Alamos National Laboratory, GeoEngineering Group are proposing microhole technology for coalbed methane production on Native Alaskan lands with the goal of eventually replacing diesel with locally produced methane as the fuel for local heat and electric power generation. (Microhole Technology Development of Native Alaskan Coalbed Methane Resources, CBM Development in Remote Alaska) Contacts given in the report were Jim Albright, Los Alamos National Laboratory at 505-667-4318 and Jim Clough, Alaska Division of Geological & Geophysical Surveys at 907-451-5030.

Coalbed Methane Study

For further information contact: Jim Clough
Alaska Division of Geological & Geophysical Surveys
Ph: (907) 451-5030

Alaska's hypothetical coal resources exceed 5.5 trillion short tons and may contain up to 1,000 TCF (Trillion cubic feet) of gas. The coal resource varies in rank from bituminous to lignite, and formed in extensive Cretaceous to Tertiary aged basins throughout the state. Economically-producible coalbed methane is an attractive alternative to diesel fuel, which is the main energy source for home heating and electrical power generation throughout much of rural Alaska.

In 1994, the Division of Oil and Gas drilled the state's first coalbed methane test well near the town of Wasilla, located in the northern portion of Cook Inlet Basin. The well (AK-94CBM-1) was drilled to a total depth of 1,245 feet (380 m), continuously coring the Tertiary-age Tyonek Formation from 354 feet (108 m) to total depth. Eighteen seams of high-volatile C bituminous coal were encountered, with the thickest being 6.5 feet (2 m) and a net coal thickness of 41 feet (12.5 m). Thirteen of these seams were sampled for gas content. The core is available for viewing at the Alaska Geologic Materials Center in Eagle River, Alaska. Encouraged by the results of this well, the Division of Geological and Geophysical Surveys embarked on a multi-year study to determine whether coalbed methane could serve as a local energy source in rural Alaska. Three coal basin sites were selected using a coalbed methane producibility model developed by the Texas Bureau of Economic Geology: 1) western North Slope near Wainwright, 2) Yukon Flats at Fort Yukon and, 3) Alaska Peninsula near three Chignik Bay communities. Each site has the potential for thick beds of coal or lignite. These sites also present a cross section of the extreme climate and drill rig access problems that would face any coalbed methane development program in Alaska.

DGGS, in cooperation with the U.S. Geological Survey, is developing a drilling program that will assess the gas producibility for each of these sites. This program proposes drilling two exploratory wells at each site, conduct geologic and hydrologic testing of the wells, initiate water pumping to stimulate gas flow testing, and initiate a pilot test to determine the presence of gas resources.

There are on going projects by the Department of Energy about the recovery and utilization of Coal Mine Methane.

Project #1:

The objective of the project is to reduce methane emissions associated with underground coal mining operations by conducting a pilot-scale field demonstration of power generation and gas processing technologies developed for capturing, recovering, and utilizing coal mine methane emissions from coal mine operations. The estimated end date of the project is 9/30/03. [United States Department of Energy, Office of Fossil Energy, Project Fact Sheet and http://www.fe.doe.gov/oil_gasprocessing/coalmeth.shtml]

Project #2:

Convert coal mine methane from mines into liquified natural gas to fuel heavy trucks. The coal mine methane will be liquefied using a thermoacoustic refrigeration system. The system is called a TASHER and burns a side stream of Coal Mine methane to compress and expand helium contained within a specially designed reservoir. "During expansion, the helium reservoir and attached heat exchangers absorb heat from the main coal mine methane stream, cooling and liquifying it. The TASHAR has no moving parts, which means maintenance is low, and is constructed from low-cost materials." The system prevents coal mine methane from reaching the atmosphere and would eliminate 69,380 tons of greenhouse gases a year. [http://www.fe.doe.gov/oil_gasprocessing/coalmeth.shtml]

Project #3:

A fuel cell power plant designed to capture and use coal mine methane emissions. [http://www.fe.doe.gov/oil_gasprocessing/coalmeth.shtml]

DOE

Project ID DE-AC21-95MC32184

Project Title Coal Mine Methane Direct Utilization and in Situ Upgrading/ Storage

FE Program Gas/Oil - Gas Processing

Action #D36 of the Climate Change Action Plan will expand the RD & D efforts to broaden the range of cost-effective technologies and practices for recovering methane associated with mining. Methods could include lower cost, more complete methods for pre-mining recovery of methane from coal seams, using in-mine de-gasification streams, and demonstration of the use of fuel cells and other state-of-the-art technologies for waste methane utilization, transferring appropriate practices to the coal and utility industries.

Actual Completion Date: 12/10/1998





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Carbon Sequestration

Sequestration in Geologic Formations

Carbon dioxide sequestration in geologic formations includes oil and gas reservoirs, unmineable coal seams, and deep saline reservoirs.

Oil and Gas Reservoirs. In some cases, production from an oil or natural gas reservoir can be enhanced by pumping CO₂ gas into the reservoir to push out the product, which is called enhanced oil recovery. The United States is the world leader in enhanced oil recovery technology, using about 32 million tons of CO₂ per year for this purpose. From the perspective of the sequestration program, enhanced oil recovery represents an opportunity to sequester carbon at low net cost, due to the revenues from recovered oil/gas.

In an enhanced oil recovery application, the integrity of the CO₂ that remains in the reservoir is well-understood and very high, as long as the original pressure of the reservoir is not exceeded. The scope of this EOR application is currently economically limited to point sources of CO₂ emissions that are near an oil or natural gas reservoir.



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Lawrence Berkeley Laboratory's Sally Benson heads a DOE effort to explore geologic sequestration.

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Coal Bed Methane. Coal beds typically contain large amounts of methane-rich gas that is adsorbed onto the surface of the coal. The current practice for recovering coal bed methane is to depressurize the bed, usually by pumping water out of the reservoir. An alternative approach is to inject carbon dioxide gas into the bed. Tests have shown that CO₂ is roughly twice as adsorbing on coal as methane, giving it the potential to efficiently displace methane and remain sequestered in the bed. CO₂ recovery of coal bed methane has been demonstrated in limited field tests, but much more work is necessary to understand and optimize the process.

Similar to the by-product value gained from enhanced oil recovery, the recovered methane provides a value-added revenue stream to the carbon sequestration process, creating a low net cost option. The U.S. coal resources are estimated at 6 trillion tons, and 90 percent of it is unmineable due to seam thickness, depth, and structural integrity. Another promising aspect of CO₂ sequestration in coal beds is that many of the large unmineable coal seams are near electricity generating facilities that are large point sources of CO₂ gas. Thus, limited pipeline transport of CO₂ gas would be required. Integration of coal bed methane with a coal-fired

electricity generating system can provide an option for additional power generation with low emissions.

Saline Formations. Sequestration of CO₂ in deep saline formations does not produce value-added by-products, but it has other advantages. First, the estimated carbon storage capacity of saline formations in the United States is large, making them a viable long-term solution. It has been estimated that deep saline formations in the United States could potentially store up to 500 billion tonnes of CO₂.

Second, most existing large CO₂ point sources are within easy access to a saline formation injection point, and therefore sequestration in saline formations is compatible with a strategy of transforming large portions of the existing U.S. energy and industrial assets to near-zero carbon emissions via low-cost carbon sequestration retrofits.

Assuring the environmental acceptability and safety of CO₂ storage in saline formations is a key component of this program element. Determining that CO₂ will not escape from formations and either migrate up to the earth's surface or contaminate drinking water supplies is a key aspect of sequestration research. Although much work is needed to better understand and characterize sequestration of CO₂ in deep saline formations, a significant baseline of information and experience exists. For example, as part of enhanced oil recovery operations, the oil industry routinely injects brines from the recovered oil into saline reservoirs, and the U.S. Environmental Protection Agency (EPA) has permitted some hazardous waste disposal sites that inject liquid wastes into deep saline formations.

The Norwegian oil company, Statoil, is injecting approximately one million tonnes per year of recovered CO₂ into the Utsira Sand, a saline formation under the sea associated with the Sleipner West Heimdal gas reservoir. The amount being sequestered is equivalent to the output of a 150-megawatt coal-fired power plant. This is the only commercial CO₂ geological sequestration facility in the world.

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Fuel Cells

There is a lot of information out on fuel cells. They have many potential benefits including reduced pollution and fuel consumption, and efficient use of fuel. They are quiet and efficient, but far too expensive to be economical. A larger unit ~200 KW would cost around \$800K-900K. This is expensive compared to diesel electric generators or gas turbines in Anchorage but less expensive per KW than the Healy Clean Coal Power Plant. Small fuel cells suitable for individual homes are still not commercialized. (Ron Johnson, Project Director UAF Energy Center)

Representative Bill Hudson's Utility Restructuring Committee looked at fuel cell issues last session, 21st Legislature 2000.

When will it make sense?

UAF ENERGY CENTER - GOALS

- 1) Develop sustainable energy systems for use in Alaska.
- 2) Initial application focused on rural communities and off grid uses.
- 3) Provide third party testing/evaluation of such systems.
- 4) Develop ways to better link the electric with other utilities.
- 5) Establish long-term operator training program.
- 6) Provide technology for remote monitoring/operation.
- 7) Establish expertise to enable Alaskan value added component to be part of future systems.
- 8) Such systems could be used in communities as well as by industry worldwide especially in remote areas.
- 9) Ultimately, want to establish manufacturing base in Alaska for system fabrication and assembly.

UAF ENERGY CENTER: HELPING ALASKA TRANSITION TOWARD A SUSTAINABLE FUTURE

Observations: Average annual growth rate [worldwide]
Wind [26%], PV [17%], oil, coal, or nuclear [1%]

- True cost of wind-gen elec can be < 5 cents/kWh
- Cost of PV systems ww ~ \$6/Wp in '99
- Low S fuel excellent for cogeneration [stack heat rec]
- Storage and conservation key issues for use of renewables
- \$19B/yr saved in US via adoption of energy efficient refrigerators

The UAF Energy Center - Ron Johnson, Project Director,

Rural Alaskan communities have special challenges to supply dependable heat and electric power while preserving environmental quality. As one of a series of efforts toward this end, the University of Alaska Fairbanks, (UAF) with support from the U.S. Department of Energy (DOE), has established an Energy Center (EC) where new technologies relating to the production of heat and electric power can be evaluated in a northern setting. In its initial phase, the EC consists of a 74 m² (800 ft²) test chamber plus a 15 m² (160 ft²) auxiliary structure in which hydrogen is produced. These structures in turn are located inside an unheated 520 m² (5,600 ft²) warehouse. Initially, we have focused on the evaluation of fuel cells (FCs) and reformers, looking at both performance and reliability issues. Fuel cells produce electricity electrochemically and require a fuel (normally hydrogen) and oxidant (air). Reformers are sometimes added to the front end to convert a conventional fuel such as diesel to hydrogen. Later, we will study the integration of the electric and other utilities and focus on Arctic engineering issues.

While urban Alaskans enjoy the advantages of modern utility systems with energy costs and reliability similar to those in the Lower 48, those in rural Alaska do not. Two factors affect the cost and quality of energy in these villages: the high cost of transporting energy (most commonly in the form of liquid diesel fuel) and the lack of infrastructure. All utility systems, including electricity, water, sewer, and solid waste disposal, must be managed at the level of the community, resulting in higher costs due to the poor economies of scale. Severe arctic winters compound the problem, raising energy demands for both heating and electric power and causing complications for water and sewer systems.

Because of favorable economics, this power is now almost universally supplied by diesel-electric generators, a system with its own set of operational problems: leaky fuel storage tanks, low efficiencies, and short lifetimes caused by prolonged operation at low loads. It is time to look for viable alternatives to an almost total reliance on this technology. One obvious strategy is to consider the use of locally available renewable resources for generating electricity. However, the largest energy demand in the Arctic is for space heating, and recovery of waste heat from electrical generation is an obvious way of saving energy and should be considered as part of any new system.

The UAF Institute of Northern Engineering is embarking on a multiyear program to address these issues in a comprehensive fashion with the objective to create sustainable economies in each rural village. This implies the use of sustainable energy so that each village can begin to reduce its dependence on expensive and environmentally damaging imported fuel oil. Our vision involves the integration of the various utilities plus the use of trained local labor to operate the systems. One likely scenario involves the use of hydrogen as an energy storage medium that can be used both in a fuel cell to produce electricity and heat as well as in a combustion process to produce heat. Hydrogen has a very high energy storage density on a mass basis (38 kW-hr/kg, 1,000 times greater than electrochemical batteries). It is also a very clean fuel and produces no CO₂ when it is oxidized by air in a combustion process, although NO_x will be produced. In an electrochemical reaction in a fuel cell, neither will be produced. As capital costs of solar-electric technologies and hydrogen storage decrease, the day will come when hydrogen can economically be produced when the solar resource (wind, hydro, sunlight, etc.) is plentiful and stored until needed. In the meanwhile, hydrogen can be produced on site from conventional liquid or gaseous fossil fuels using reformation technologies.

Although the first steps involved the physical design and construction, our intermediate-term goal is to use the Energy Center as a platform to begin a systems approach to addressing problems relating to sustainable energy systems in rural Alaska and ultimately in other remote regions worldwide. In this context, we will add at least part of a model dwelling adjacent to the test chamber in the future so that potential users can see for themselves how the heat, produced water, and electricity can be productively used. We will design and test systems to extract heat and water and to protect the FCs from cold ambient temperatures.

We will also develop and begin to implement a training program to allow future users of the technology to gain hands-on experience and have an opportunity to be exposed to current efforts relating to deployment of sustainable energy systems worldwide. This training program will introduce maintenance personnel to the principles of operation of both the technologies for producing heat and electric power as well as how they interrelate to the water and waste disposal utilities. We will also discuss the central role of energy conservation and storage in effectively using renewable energy. These discussions will include examples of how to calculate system economics and payback periods. Conservation will include the use of compact fluorescent lights and other demand-side management strategies. Other discussion points will include resource recovery and environmental regulations. The latter are already playing key roles in rural Alaska with respect to bulk fuel oil storage.

Our systems analysis and development efforts will look at ways to integrate the various facets of community infrastructure, including heat, electric power, drinking water, waste disposal, indoor air quality, energy conservation, and preservation of environmental quality. This will include interconnecting the FCs with the rest of the local village grid and providing for offsite monitoring and control of the utility with appropriate telemetry. It will also include assurances that appropriate power quality is achieved. We will use recent developments in renewable technologies such as wind turbines, photovoltaics, and energy storage together with energy conservation and modern water treatment and waste disposal methods to help design and implement modern systems in rural Alaska. In remote areas worldwide, there is a heavy emphasis on reliability, even at the expense of higher initial costs, to minimize life cycle costs. Hence, we will not recommend deployment of any technology to rural Alaska until long-term tests have been conducted in a northern environment. The conducting of such tests is one major task of the Energy Center.

After the facility was completed in August of 1999, we have measured the performance of several fuel cells (FCs) and reformers. We have collected detailed energy balance data for five PEM FCs and a steam reformer and developed a control system for the latter. We have also performed thermodynamic analyses of the performances. Reformer operation was compared with equilibrium calculations using an FTIR for raffinate [H₂ depleted stream, which is then combusted with air to provide heat for the endothermic steam reforming and then becomes exhaust] gas analysis. Although the initial reformer tests were run using diesel fuel as the feedstock, we hope to look at other fuels in the future.

Concurrently, we are collecting data on energy use in Alaskan residences [both thermal and electrical] and developing a Simulink-based modeling capability to analyze energy systems including those employing FCs. In the future, we plan to become involved with other energy systems both fossil fuel based and renewable. The former will involve clean fuels and cogeneration. The latter will involve collaboration with user groups such as the KEA, which has made significant accomplishments introducing wind turbines to Alaska. We also want to prepare for setting up a training program for rural utility workers that incorporates conventional as well as alternative technology for the production of heat and power as well as integrating the electric power utility with those involved with water production and waste disposal.

Sustainable Energy Systems for Alaska

[part of this document submitted by Dr. Ron Johnson, rfrj@uaf.edu, UAF-Institute of Northern Engineering in 9/2000 as part of a federal initiatives process.]

To address affordable electricity in rural Alaska for both municipal and industrial applications, we will look at a host of energy technologies as well as energy conservation measures. During the first year, we will establish a 3-year plan to carry out a coordinated series of projects to benefit Alaska as well as other regions of the US and the world where remoteness is a critical issue.

Energy technologies can be categorized as (1) those needed to convert an energy source into electricity or heat, and (2) those used for storage of electrical energy or heat.

Under the first category, we will consider diesel-electric generators, wind turbines, photovoltaic devices, low-head hydro power, water turbines, thermoelectric and thermophotovoltaic generators, fuel cells, and hybrid systems combining two or more of the above technologies. Advantages can be taken of advances that may occur with respect to low sulfur [clean] fuels to improve the performance of several of these systems including improvements in the capture of waste heat [cogeneration].

Diesel-electric generators are the dominant source of electric power in rural Alaska today and are discussed in another part of this initiative. Fuel cells are electro-chemical devices that convert a fuel (normally hydrogen) directly into electricity. Billions of dollars are currently being spent by multi-national corporations and others to commercialize them for both stationary power and transportation. UAF has participated in this work for the past two years through the UAF Energy Center and will continue its efforts. This center has excellent staff and equipment for analyzing the performance of energy systems.

Wind turbines have produced electric power at many locations worldwide; in the lower 48, the current cost of electricity at modern plants is in the 5 to 10 cents/kW-hr range. Average growth rate of energy sources (percent) are wind (26), photovoltaics (17), oil, coal or nuclear (1) in 1998. The world wind capacity grew by one-third from 1998 to 1999 (to 10,000 MW). Most machines operated today consist of two- or three- bladed propellers mated to a generator with a gearbox. Currently, the Kotzebue Electric Association is operating several hundred kW worth of wind turbine capacity in Kotzebue, Alaska. Coastal Alaska possesses an abundant wind resource. As with other renewable systems, energy storage is a key issue.

Photovoltaic devices convert sunlight directly to electricity at efficiencies as high as 30%, although 10 - 15% is typical. With power densities around 125 W/m², a one square meter panel may produce a kW-hr each day. With costs of around \$6K per peak watt, electric power can be produced at a range of 25 to 50 cents/kW-hr. Obvious shortcomings in northern Alaskan applications are associated with the lack of solar input during those parts of the year when the demand for electrical power is the greatest. But the solar resource is still significant for two-thirds of the year in much of the state.

Hydropower currently accounts for 19% of electrical power production in Alaska; it is an ideal resource when flowing water is available at an elevation difference (with respect to the village elevation) of, for instance, at least 30 meters. This source of power is limited by the high costs of construction, and currently is used to power mostly the more densely populated areas of Alaska, such as Valdez. Tidal power has a niche market. For areas with little elevation difference, there is the possibility of water turbines. But such a technology is inefficient and subject to severe damage during breakup and other high flow conditions. Many villages in interior Alaska are not blessed with conditions suitable even for low head hydropower. Much of coastal Alaska is blessed with world-class wave energy. With prototype machines to harness wave power now being deployed in Europe and elsewhere, it is time to consider utilization of this technology in Alaska.

Biomass generators also use renewable resources. Waste heat from wood stoves can be converted directly into electricity through thermoelectric generators (TEGs). For the arctic, since the primary end use of energy for most of the year is thermal, it would be prudent to design cogeneration systems whose primary purpose is supplying heat, with electrical production as a by-product rather than the opposite, which is typically in most commonly used systems. One technology suited to this end involves mating a wood or oil stove to a thermoelectric generator (TEG). By incorporating this technology into the design of the stove at the front end, one should be able to maximize cogeneration efficiency and minimize life cycle costs. TEGs available today can easily supply a few tens of watts. Wood stoves have thermal outputs from 3 to 10 kW, so even a 3% efficient TEG could supply from 90 to 300 watts. This could supply a critical core of a household's electrical needs and minimize the O&M problems associated with DEGs. Capital costs are currently in the range of \$10-\$20/W due to small sizes and limited production. In much the same way, Thermophotovoltaic generators (TPVGs) can harness higher-grade heat via the photoelectric effect.

In designing storage systems for electrical energy, we will consider batteries, hydrogen, hydro, and flywheels. Storage is a critical part of any technology where the energy resource is intermittent, such as wind and other solar energy.

Hydrogen, with a heating value of over 100,000 kJ/kg, offers the possibility of storing large amounts of energy per unit mass. For reasonably compact storage in pressure vessels, hydrogen can be compressed to several hundred atmospheres. Advances are occurring with respect to storage in metal hydride beds. It can be produced by the electrolysis of water via renewable energy sources or other technologies, then used as the fuel in a fuel cell. The efficiency of such a system [from PV array output to fuel cell output] may reach 40%. If the electricity used to produce the hydrogen costs, say, 35 cents per kW-hr, the cost of hydrogen will exceed \$100/M Btu (equivalent to \$14/gal heating oil). So, one may want to produce hydrogen with renewable energy only during periods of excess capacity (i.e., when the electricity is "free"). Hydrogen is the ultimate clean fuel, especially with respect to global warming.

Batteries utilizing lead and sulfuric acid are widely used today and can return over 80% of the electricity stored. Unfortunately, they are expensive (\$100 - \$200/kW-hr), and they degrade with cycling. Other types of batteries include nickel-cadmium and zinc-air. Energy densities are much lower than those of hydrocarbon fuels by several orders of magnitude (normally a few tens of watt-hours per kg [zinc-air at 140, instead of over ten thousand]).

Flywheels are electromechanical batteries that can provide high power with limited storage. Today there are flywheels available in a 100 kW size with up to 3 kW-hr energy storage capacity. Their chief application is to respond quickly to changing loads so they can be of use in maintaining suitable power quality. They have long lifetimes and current costs are in the \$2K to \$10K/kW-hr.

Remote areas worldwide share common problems, two of which are (1) high transportation costs and (2) lack of infrastructure. These two and other factors place a premium on reliable technologies in minimizing life cycle costs. We must be able to stay abreast of developments in energy technology so that we can field test and then deploy suitable configurations. These configurations must include conservation measures as well as linkages to the other utilities (water and waste disposal).

UAF/INE will provide a focal point where several organizations can coordinate their studies, pooling their efforts and expertise. The success of this project requires input from all levels of technology research and development, including the private sector. UAF/INE would ask the private sector to participate by providing test technologies, and inviting suppliers to come to Alaska to share their expertise. UAF/INE will also work closely with entities such as the Alaska Division of Energy and the Regulatory Commission of Alaska in assessing appropriate village specific data, including village power and heating needs, and the willingness and ability of village participants to be effective partners in this work. Successful research and development in this area will result in a technology that meets the needs of community and industry that uses energy efficiently, and is applicable in a variety of situations. Each phase of this project will ensure that the next phase rests on a sound foundation of established basic engineering science, proven design, and reliable, established baselines.

Specific measures to be taken include (1) maintaining contact with those parts of the world facing similar issues, (2) periodic reviews of related activities in national laboratories, especially developments in fuel cell and hydrogen storage technology, (3) keeping abreast of R&D activities in those businesses engaged in the manufacturing and sales of renewable energy technologies. Of course, none of these above activities is as important as understanding what the needs, capabilities and wishes of the villagers are.

These technologies are not limited to those associated with the production of heat and electricity, as our goal is to have an integrated utility system that includes providing potable water as well as waste disposal and recycling.

Similarly, deployment of these technologies is not limited to Alaska, or even locations with cold climates. Rural sites in Alaska have many problems in common with remote sites worldwide, including those in Russia, Asia and Africa. Progress in this project will lead to technologies that can be exported to other regions of the world. We will work to further a long-term synergy among the US national labs, industry, foreign participants, local Alaska entities, and DOE -- all directed toward designing, developing, and deploying clean, renewable power production appropriate to the varied requirements of remote, off-grid locations.

Load leveling is a simple concept: power developed during periods of low demand is stored for later use at times of high demand. Using electrolysis to generate hydrogen could be used in this way: excess capacity could be stored for later use, while the DEG could be always run under optimal load. Two possible places where this could be used include diesel electric generator and wind turbine applications.

This strategy could also solve the major problem with wind turbines. Even in the windiest parts of Alaska, the winds are variable in intensity, and do not match the demand cycle of humans. Energy can be stored in battery banks, but these systems are very expensive per energy unit stored. In Kotzebue, where wind turbines have been installed, there still are DEGs for the times when the wind does not blow. Frequently, wind power only exacerbates the under loading problem of the DEG. However, if hydrogen can be generated and stored, the wind energy can be used when demand is high and the power is needed.

Improving the quality of life in any community must also consider issues associated with providing employment, providing clean water, and assuring sanitary handling of waste products. Even though many Alaskan villages are surrounded by water in the winter, it is in the frozen state, and melting ice to provide water for domestic consumption and use is expensive. Hence, in designing a utility to meet electrical and thermal demands, we must also consider water supply and waste disposal or by-product recovery issues. By integrating these needs into the front end, system efficiencies can be improved and life cycle costs minimized. For example, low-grade waste heat could be used to prevent water from freezing or for melting ice and snow. Plus, the electric loads associated with water and wastewater treatment equipment and the pumping of water need to be included on the demand side of the equation. Similarly energy recovery from the waste stream is an issue worthy of consideration.

Power quality is an important consideration, particularly when power electronic devices such as inverters are utilized in an electric utility system. Such switching devices may cause abnormal levels of voltage "spikes" or impulses and harmonics in the system. These impulses, if large enough, can damage consumer electronic equipment. Over- and under-voltages of a more long-term nature are also a potential problem for all types of electrical loads. If sufficiently high or low, they can seriously diminish the life expectancy of, for example, lighting products and electric motors.

A telemetry monitoring program will be established within UAF, to control these technologies at distance thereby providing a fail-safe 'tele-engineering' capability for these developing technologies.

One important focus of our initial operation of these units will be the operational aspects specific to northern engineering in Arctic and sub Arctic regions. This will include exposure to ambient temperatures for periods of time during the winter to better understand problems that may arise during start up following cold soak. The test units may be considered for placement at both in door and outdoor locations. Behavior of the materials out of which the units are constructed as well as efficacy of lubricants and icing in exhaust streams will be of particular interest. Of course, we expect the normal operational mode will be in a heated enclosure.

Other issues associated with northern engineering include: design of enclosures; capture of waste heat for space heating, sewage treatment, or co-generation; heat management to minimize permafrost melting; and operations in extreme wind conditions.

Indoor air quality (IAQ) issues and energy conservation should be part of any strategy employed to provide space heating. One of the world's major health issues is the poor IAQ associated with poorly ventilated combustion devices. This is true in both warm and cold climates. In the desire to reduce energy consumption while providing space heating and cooling needs, designers and builders have sometimes reduced air exchange rates to such low levels that IAQ has become unacceptable. This has caused problems especially in some Alaskan homes with elevated levels of radon. IAQ can be improved without much of an energy penalty by installing air-to-air heat exchangers, but operation of these devices presents special problems with very cold ambient air.

Training is a critical component and this is an activity that UAF will be heavily involved in. Since many villages may have only one or two individuals responsible for operating the wastewater, water, and power utility, we will provide training for all three of these at one site at UAF and elsewhere. At the UAF site, we will provide education and training focused on applications, maintenance, and customized systems design of small-scale power systems based on fuel cells and other clean, efficient, renewable energy technologies, as well as water and wastewater treatment. For the latter, we will corroborate with the Alaska Village Electric Co-operative, the Alaska Water Management Association and KEA. These groups are valuable both for their expertise in rural power and water issues, as well as being efficient networks for dispersing new information. Our hope is to use this training to produce videotape illustrating the interrelationships between the utilities.

Renewable energy will only be viable in the long term when coupled with energy conservation. As part of our training, we will focus on increasing awareness of energy conservation especially with respect to electrical appliances and space heating. We will provide examples, for instance, that illustrate lowering of life cycle costs when incandescent lights are replaced by compact fluorescent ones. Similarly, the use of air-to-air heat exchangers can lower space-heating costs while preserving indoor air quality (IAQ). The latter is a key health issue in northern remote communities, where poorly ventilated combustion equipment often contributes to unacceptable IAQ, sometimes even leading to death by asphyxiation. Moreover, the repair of fossil fuel-burning equipment such as snow machines indoors can lead to unsafe levels of Volatile Organic Compounds (VOCs) in homes. Similarly, the temporary storing indoors of honey bucket wastes can increase levels of pathogens.

The bottom line is that Alaska has both world-class fossil fuel and renewable energy resources. The latter include hydro, wave, and wind resources. We are heavily dependent on the former. It behooves us to now move toward efficient utilization of the latter to diversify our energy generation capability.

Ron Johnson UAF, 10/2000

Energy Efficiency Demonstration Projects

In 1997, the Alaska Energy Authority began providing assistance for one or two small energy efficiency demonstration projects in rural communities or schools each year. Typically, older T-12 fluorescent tubes and magnetic ballasts are replaced with high efficiency T-8 tubes and electronic ballasts. Motion sensors and high efficiency exit lights may also be added. Successful projects have been completed in Tanana, Aniak, and Chevak.

Lighting bills can be reduced by as much as one-third with a change to more efficient lighting products. Lighting retrofits in communities with high electrical rates (over \$.32 per kWh), can expect to pay back the cost of the retrofit out of savings in under three years. In communities with even higher electrical rates, the payback period may be as short as two years.

To find out more about this program, or if you think that your community may be a good Energy Efficiency Demonstration Project site, contact the Alaska Energy Authority.

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cleaning up **COAL**

The Cleanest Coal Technology — a Real Gas!

Don't think of coal as a solid black rock. Think of it as a mass of atoms. Most of the atoms are carbon. A few are hydrogen. And there are some others, like sulfur and nitrogen, mixed in. Chemists can take this mass of atoms, break it apart, and make new substances — like gas!

How do you break apart the atoms of coal? You may think it would take a sledgehammer, but actually all it takes is water and heat. Heat coal hot enough inside a big metal vessel, blast it with steam (the water), and it breaks apart. Into what?

The carbon atoms join with oxygen that is in the air (or pure oxygen can be injected into the vessel). The hydrogen atoms join with each other. The result is a mixture of carbon monoxide and hydrogen — a gas.



One of the most advanced - and cleanest - coal power plants in the world is the Pifon Pine plant near Reno, Nevada. Rather than burning coal, it turns coal into a gas that can be cleaned of almost all pollutants. (Click on photo for larger version.)

Now, what do you do with the gas?

You can burn it and use the hot combustion gases to spin a gas turbine to generate electricity. The exhaust gases coming out of the gas turbine are hot enough to boil water to make steam that can spin another type of turbine to generate even more electricity. But why go to all the trouble to turn the coal into gas if all you are going to do is burn it?

A major reason is that the impurities in coal — like sulfur, nitrogen and many other trace elements — can be almost entirely filtered out when coal is changed into a gas (a process called *gasification*). In fact, scientists have ways to remove 99.9% of the sulfur and small dirt particles from the coal gas. Gasifying coal is one of the best ways to clean pollutants out of coal.

Another reason is that the coal gases — carbon monoxide and hydrogen — don't have to be burned. They can also be used as valuable chemicals. Scientists have developed chemical reactions that turn carbon monoxide and hydrogen into everything from liquid fuels for cars and trucks to plastic toothbrushes!

Today, in Tampa, Florida, Terre Haute, Indiana, and Reno, Nevada, there are power plants generating electricity by gasifying coal, rather than burning it. At a plant in Kingsport, Tennessee, coal gas is being used to make plastic for photographic film and to make methanol (a fuel that can be burned in automobile engines).

Coal gasification could be one of the most promising ways to use coal in the future to generate electricity and other valuable products. Yet, it is only one of an entirely new family of energy processes called "Clean Coal Technologies" — technologies that can make fossil fuels future fuels.



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- vi. **Calista Region Map**

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Marty Moore
Captain

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Ron Johnson
Project Director

Definitions:

BTU:

British thermal unit, a measure of the quantity of heat, defined since 1956 as approximately equal to 1,055 joules, or 252-gram calories. It was defined formerly as the amount of heat required to raise the temperature of one pound of water 1 degree F. The definition was changed because it was dependent on the initial temperature of the water. Gas utilities frequently use a larger unit, the therm, defined as 100,000 BTU, as a measure of gas consumption.*

LNG:

Liquefied natural gas, natural gas (primarily methane) that has been liquefied for ease of storing and transporting. LNG takes up about 1/600 the space that natural gas does in its gaseous form, and it can be easily shipped overseas. LNG is produced by cooling natural gas below its boiling point, -162 degrees C (-259 degrees F), and is stored in double-walled cryogenic containers at or slightly above atmospheric pressure. It can be converted back to its gaseous form by simply raising the temperature.*

LNG is more practical than liquefied petroleum gas or other liquid gases, particularly for use in large volumes, because it has the same chemical composition as natural gas. This fact and the growing demand for natural gas have stimulated LNG production. Moreover, LNG technology has made it possible to utilize natural gas from remote areas of the world where it previously had no commercial use and was flared (burned). Special tankers transport LNG from such countries as Algeria, Borneo, and Indonesia to markets in Europe, Japan, and the United States.*

*Source: Encyclopedia Britannica

Conversions:

1 gallon of diesel (1#)	=	139,000 BTU
7.5 gallons of heating oil #1	=	1 MCF or 1,000,000 BTU
12.1 gallons of LNG	=	1 MCF or 1,000,000 BTU
1,000,000 gallons of heating oil #1	=	1.6 M gallons of LNG in equivalent BTUs

1 gallon #1 diesel (heating oil) = 6.3 lbs
1 gallon #2 diesel = 6.7-6.9 lbs

LNG Fact Sheet

WHAT IS IT?

When natural gas is cooled to a temperature of approximately -260°F at atmospheric pressure it condenses to a liquid called liquefied natural gas (LNG). One volume of this liquid takes up about 1/600th the volume of natural gas at a stove burner tip. LNG weighs less than one-half that of water, actually about 45% as much. LNG is odorless, colorless, non-corrosive, and non-toxic. When vaporized it burns only in concentrations of 5% to 15% when mixed with air. Neither LNG, nor its vapor, can explode in an unconfined environment.

COMPOSITION

Natural gas is composed primarily of methane (typically, at least 90%), but may also contain ethane, propane and heavier hydrocarbons. Small quantities of nitrogen, oxygen, carbon dioxide, sulfur compounds, and water may also be found in "pipeline" natural gas. The liquefaction process removes the oxygen, carbon dioxide, sulfur compounds, and water. The process can also be designed to purify the LNG to almost 100% methane.

HOW IS IT STORED?

LNG tanks are always of double-wall construction with extremely efficient insulation between the walls. Large tanks are low aspect ratio (height to width) and cylindrical in design with a domed roof. Storage pressures in these tanks are very low, less than 5 psig. Smaller quantities, 70,000 gallons and less, are stored in horizontal or vertical, vacuum-jacketed, pressure vessels. These tanks may be at pressures anywhere from less than 5 psig to over 250 psig. LNG must be maintained cold (at least below -117°F) to remain a liquid, independent of pressure.

HOW IS IT KEPT COLD?

The insulation, as efficient as it is, will not keep the temperature of LNG cold by itself. LNG is stored as a "boiling cryogen," that is, it is a very cold liquid at its boiling point for the pressure it is being stored. Stored LNG is analogous to boiling water, only 470° colder. The temperature of boiling water (212°F) does not change, even with increased heat, as it is cooled by evaporation (steam generation). In much the same way, LNG will stay at near constant temperature if kept at constant pressure. This phenomenon is called "autorefrigeration". As long as the steam (LNG vapor boil off) is allowed to leave the tea kettle (tank), the temperature will remain constant.

If the vapor is not drawn off, then the pressure and temperature inside the vessel will rise. However, even at 100 psig, the LNG temperature will still be only about -200°F.

HAVE THERE BEEN ANY SERIOUS LNG ACCIDENTS?

[See also A Brief History of U.S. LNG Incidents.] First, one must remember that LNG is a form of energy and must be respected as such. Today LNG is transported and stored as safely as any other liquid fuel. Before the storage of cryogenic liquids was fully understood, however, there was a serious incident involving LNG in Cleveland, Ohio in 1944. This incident virtually stopped all development of the LNG industry for 20 years. The race to the Moon led to a much better understanding of cryogenics and cryogenic storage with the expanded use of liquid hydrogen (-423°F) and liquid oxygen (-296°F). LNG technology grew from NASA's advancement.

In addition to Cleveland, there have been two other U.S. incidents sometimes attributed to LNG. A construction accident on Staten Island in 1973 has been cited by some parties as an "LNG accident" because the construction crew was working inside an (empty, warm) LNG tank. In another case, the failure of an electrical seal on an LNG pump in 1979 permitted gas (not LNG) to enter an enclosed building. A spark of indeterminate origin caused the building to explode. As a result of this incident, the electrical code has been revised for the design of electrical seals used with all flammable fluids under pressure.

WHY IS IT BEING CONSIDERED FOR VEHICLE FUEL

- LNG, as fuel, is burned in the gaseous form. The benefits of burning natural gas are well documented when compared to gasoline or diesel.
- Natural gas produces significantly less of the emissions addressed in the 1990 Clean Air Act Amendments. Those emissions specifically being particulate matter (PM), carbon monoxide (CO), nitrogen compounds (NOx) and non-methane hydrocarbons (NMHC).
- LNG has a fairly high energy density when compared to the other clean burning alternative fuels. It still takes about 1.5 gallons of LNG per gallon of gasoline and 1.7 gallons per gallon of diesel to achieve the same range, however.
- LNG is (generally) less costly than gasoline or diesel on an equivalent energy basis.
- LNG fueling times are equivalent to the fuels it replaces.
- LNG can be trucked to fueling stations similar to the polluting liquid fuels.
- Although there are significant misconceptions about its safety, independent testing shows that the use of LNG as a vehicular fuel to be no more hazardous than gasoline and under many test conditions to be safer. Its ignition temperature is about 500°F higher than gasoline, ignition requires mixtures in the narrow 5% to 15% range, and it does not detonate in an open environment. Furthermore, spills will rapidly dissipate (rise) in the atmosphere as natural gas is buoyant at temperatures above -160°F.

WHAT IS CNG?

Compressed natural gas (CNG) is natural gas pressurized and stored in welding bottle-like tanks at pressures up to 3,600 psig. Typically, it is same composition of the local "pipeline" gas, with some of the water removed. CNG and LNG are both delivered to the engines as low pressure vapor (ounces to 300 psig). CNG is often misrepresented as the only form natural gas can be used as vehicle fuel. LNG can be used to make CNG. This process requires much less capital intensive equipment and about 15% of the operating and maintenance costs.

WHAT IS LPG?

Liquid petroleum gas (LPG, and sometimes called propane) is often confused with LNG and vice versa. They are not the same and the differences are significant. LPG is composed primarily of propane (upwards to 95%) and smaller quantities of butane. LPG can be stored as a liquid in tanks by applying pressure alone. LPG is the "bottled gas" often found under BBQ grills. LPG has been used as fuel in light duty vehicles for many years. Many petrol stations in Europe have LPG pumps as well.

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~ Non-Traditional Sources and Uses of LNG ~

By Jeff Beale, CH-IV LNG Company

INTRODUCTION

When one thinks about LNG the immediate thought is generally about the large international export/import projects or the traditional gas company peak shaver. As implied in the title, this paper explores LNG from different perspectives, such as, how else might LNG be produced and what other commercial uses might there be. This paper attempts to stimulate thought about other ways of thinking about LNG.

Non-traditional sourcing of LNG includes a review of all of the aspects of the process from the gas production, transportation (both as gas and liquid), and, particularly, the liquefaction process. The primary goal of non-traditional LNG sourcing is non-traditional pricing, i.e., how to make small LNG project economics perform as much larger scaled programs.

Non-traditional uses include, of course, some discussion of LNG as a vehicle fuel, but the discussion also touches on some of the increasing interest world-wide in energy distribution (fuel and electricity) in rapidly developing countries.

NON-TRADITIONAL SOURCING OF LNG

Gas Source:

The purchase (commodity) cost of gas can vary over a great range. Some gas, because of its location, pressure, and/or composition may have a very low inherent marketability, hence, purchase cost. One of the beauties of LNG is that most of these deficiencies can be overcome in its production and distribution. There is some gas "sitting" in the ground today, not being marketed, or not marketable, for a variety of reasons. Accessing these sources can help deliver the economics necessary for small LNG projects. Some of these sources include:

Distressed and small remote gas fields that are not viable for the traditional production and collection can serve as the supply for small liquefiers. If there is a road servicing the wells then there is a way to get the gas to market.

Abandoned and sealed coal mines provide low cost supplies of high levels of methane. Many of these sources also provide Section 29 tax credits which can yield upwards to \$1/mmbtu to the mine owners.

Landfill gas at first blush offers a unique combination of highly desirable attributes - low cost, renewable, easily separable methane and carbon dioxide that is located close to large urban areas. That's the good news. The liquefaction process requires that all components that solidify at liquefaction temperatures must be removed prior to liquefaction. That may require a substantial capital investment. That's the bad news. Landfill gas exists at near atmospheric pressure requiring the gas to be pulled from the landfill under vacuum conditions. This permits the potential of air 'break through.' Liquefying methane in the presence of oxygen can result in spontaneous combustion. That's the ugly news. Attention to the bad and ugly news can result

in a low cost LNG supply very close to the desired market, however.

Gas Transportation:

Small LNG facilities offer a twist on the normal gas transportation thinking. It may be best to place the liquefaction plant near the gas source and/or remote from the LNG need and transport the LNG by truck (or maybe barge). Any feasibility study on a new plant should consider this option and variations on it.

Gas Pretreatment:

Simply stated, gas pretreatment relates to what needs to be "done" to the feed gas to make it liquefiable. This may include compression, filtering of solids, removal of liquids and gases that would solidify under liquefaction, and purification (removal of non-methane gases). Non-traditional gas sources may have much higher (45%) carbon dioxide content than normal pipeline gas ($\gg 1\%$). Landfill gas will need multiple stages of compression, this, interestingly enough, can be used in the gas clean up and purification process. It is easier to purify high nitrogen natural gases in the liquefaction stage, however. Pretreatment is where any oxygen present must be detected and removed.

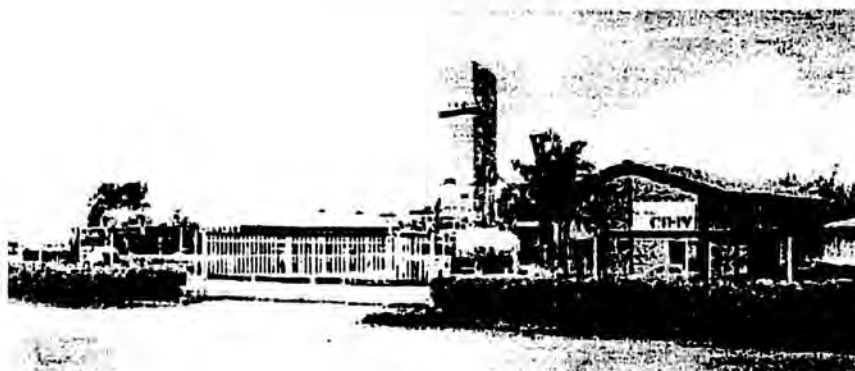
Gas Liquefaction:

Liquefying natural gas is easy . . . liquefying natural gas cost effectively is the challenge. Liquefaction requires energy. The source of that energy, along with installed capital costs, set the liquefaction cost. Low cost gas means low cost fuel which may mean low cost liquefaction. Low capital recovering may mean low cost LNG. Included in these potential low cost scenarios are:

"Piggy-Back" plants are those that overlay on existing cryogenic natural gas processing plants. Most favorable are those that liquefy large quantities of methane as part of normal operation. These would include nitrogen rejection units (see at right) and helium extraction plants. A small side stream of LNG can often be taken from these plants without upsetting the thermodynamic balance, particularly in the evening hours. These also require fairly small capital investments. Cryogenic hydrocarbon extraction and petro-chemical processes also pose opportunities, but one must be very careful when looking at these facilities to assure the process gas is liquefiable.



Stand-alone liquefaction plants (such as the one below) are relatively capital intensive when compared to the other options. There is a vast number of natural gas liquefaction "cycles" (combination of heat exchange and refrigeration) on which to base a design. The U.S. Patent Office is filled with different cycles and variations on themes. The gas being liquefied, however, pretty much takes the same liquefaction path independent of the refrigeration cycle. The dry, clean gas enters a heat exchanger and exits as LNG. Increasing the methane content is accomplished by incorporating a distillation tower and dividing the heat exchange into a series of heat exchanger cores. The design of the refrigeration cycle drives the capital and operating costs of the liquefaction plant. Three basic refrigeration techniques are discussed below: 1) gas compression-expansion, 2) turbo-expansion, and 3) Stirling cycle.



Modular LNG Production Facility

1. **Gas expansion-compression.** This is the basic cycle that cools the household refrigerator and air conditions your car. A refrigerant gas is compressed to high pressure and then cooled with air or water causing complete or partial condensation of the refrigerant. The refrigerant is then expanded across a restriction causing a substantial drop in pressure and in temperature. The cold refrigerant stream is ex-changed against the process stream liquefying the natural gas. The refrigerant (now a gas) is then returned to the compressor completing the cycle.
2. **Turbo-expansion.** Pressure let-down locations, such as city gate stations, offer a thermodynamic answer to low-cost liquefaction. Before discussing turbo-expanders a brief review of gas pipeline operations is in order. Gas is moved from the gas field to the gas utility in high pressure transmission pipelines (600 to 1,200 psig). Before the gas can be distributed its pressure must be reduced to typically less than 100 psig at so-called "city gates" or take station. The city gate is an ideal location to utilize a turbo-expander liquefaction cycle because it takes advantage of the wasted refrigeration associated with the pressure drop very efficiently.

A turbo-expander is essentially a centrifugal compressor running backwards. What does that mean? A centrifugal compressor is rotated by a motor (requiring energy). The gas entering the compressor is (relatively) low pressure and ambient temperature. The gas leaving the compressor is (relatively) high pressure and high temperature. What if the unit was run backwards, i.e., expanded, not compressed? High pressure gas (as from a gas transmission line) at ambient temperature enters the expander. As the high pressure gas moves through the expander two very significant things happen: the blades of the expander are forced to rotate because of the flow (generating power and dropping the pressure), and as the pressure drops so does the temperature. The end result is a low pressure, low temperature gas stream (refrigeration) and a rotating shaft (usable horse power). The refrigeration can be used to liquefy a side stream of the high pressure gas. The warmed-up, expanded, gas stream can now be sent into the gas distribution system. The rotating shaft is available to perform any other "work" necessary in the operation.

3. **Stirling Cycle.** The Stirling refrigeration cycle is not new to cryogenics, but it only recently has been getting attention relative to natural gas liquefaction. The Stirling Cycle could easily take a technical paper to describe its operation adequately. It, however, is being viewed by many as the cost-effective solution to small liquefaction plants, less than 10,000 gallons per day. A small Stirling machine would combine the refrigeration and the heat exchanger into a single unit. Stirling liquefiers, once commercialized, are expected to have low capital costs and maintenance costs due to the very few moving parts. The Stirling machine may fit a very important niche in making small quantities of LNG available in many areas of the country.

Local gas company (LDC) peakshavers are feeling the impact of the changing winds of the natural gas industry. What historically was inconceivable, may now be very doable. LDCs are beginning to realize that they are sitting on an underutilized asset. Typically the entire storage has been reserved for the gas company, but experience shows that rarely is more than 50% is needed. Furthermore, the plants were designed for 200 days a year liquefier operation, when in fact, many more days of operation are possible.

Update on NFPA 59A and DOT Part 193

NFPA 59A, "Standard for the Production, Storage and Handling of LNG," was originally developed in the mid-1960s. It has been routinely reviewed and kept current through the volunteer LNG Technical Committee, of which this author is a member. 59A has published revised editions 7 times in the 31 intervening years.

DOT 49 CFR Part 193, "Liquefied Natural Gas Facilities; Federal Safety Standards," was promulgated in early 1980. Part 193 undergoes a much less intensive review process. By the time of this presentation the first major modification to it may well have been approved. Part 193 is often the "standard of choice" of the Authority Having Jurisdiction.

For the first time since these standards have co-existed there is serious discussion pertaining to the DOT adopting NFPA 59A sections on siting, design, construction, equipment, and fire protection. If adopted, siting of shop-fabricated based LNG facilities would become considerably simpler. Part 193 would also be a more up to date document due to the rigorous and routine review by the LNG Technical Committee.

Reference: "A Progress Review of the NFPA Petition to the US DOT Regarding the Integration of NFPA 59A into 49CFR193," presented at the 1997 AGA Operations Conference, Nashville.

LNG Storage:

A major deviation in thinking in terms of design basis for "base-loaded" small LNG plants is in the storage. Instead of needing 200 days of storage, depending on the storage at the various end-use points, only 5 or 10 days of storage may be needed. This may result in the installation a few shop-fabricated LNG tanks (shown first below) instead of a large field-erected LNG tank (shown second below). Since many of these programs will be based on a certain growth over a certain period of time, the program managers can also manage the growth of their storage. It may not be necessary to have all of the storage installed at the beginning of the program.



Shop-Fabricated LNG tank



Field-Erected LNG Tank

LNG Distribution:

This dimension of the LNG program, at least, is fairly straightforward. How much is it going to cost to transport LNG from the source to the end-use? Typically 11,000 gallon trailers like the one below carry the LNG. A simple phone call to any of the LNG trucking operations yields a quick answer. The cost is determined by the distance covered and the gallons transported. A key factor in any program is load factor. In the case of LNG trucking, as the load factor on LNG trailer(s) increases the program would probably be best served by owning and operating the LNG trailers independent of commercial truckers. Larger scale programs may begin looking to rail and barge shipments of LNG.



LNG Transport Trailer Leaving LNG to CNG Fueling Station

NON-TRADITIONAL USES OF LNG

Hub & Spoke:

Imagine a developing country, state, territory seeking the ability to rapidly expand its electric grid into the "wilderness" just like rural electrification in the United States earlier in this century. The problem is, oil is expensive (and imported) and/or the closest refinery is extremely far away. Coal is out of the question for a variety of reasons. Hydro, wind, solar, geo-thermal power are impractical or uneconomical. Yet the country has substantial, indigenous natural gas reserves. That's the good news - the bad news is that gas pipeline infrastructure is non-existent, not economically viable, or environmentally destructive. What do you do?

This is the basis of the "Hub & Spoke" concept, where a new natural gas liquefaction plant is built (the hub), over-the-road LNG transportation is provided to support the (new) remote gas-fired power plants (the spokes). The program can be extended to vehicle fuel and satellite gas distribution with the same impact. However, satellite gas distribution with a low load factor can have a detrimental impact on the overall program economics.

Propane Replacement:

Propane replacement is exactly that, whether speaking about local gas distribution (see below) or industrial fuel. This is also a program that allows for fairly straight forward economical analysis. Not every propane program is ripe for LNG. Assuming the economics bear out, LNG programs are simpler to operate and more reliable, especially in the very cold winter climates.



Large Propane-Air Peakshaving Facility

Highly Dedicated, Captive End-User:

There are a variety of potential natural gas users that due to special circumstances could benefit from a small baseload supply of LNG.

- A *paper mill* that is experiencing boiler stack emission excursions from its heavy fuel oil during the middle of the day and must reduce output to stay below allowable emission levels. With the introduction of natural gas in a co-burn role the boiler can maintain 100% plant capacity. Unfortunately the closest gas pipeline is too far away to justify installation of a lateral. Enter LNG.
- A *synthetic woolen mill* burns about 1 mmbtu of gas per day to generate electricity. Historically the plant has been on a fully interruptible gas contract with propane back-up. A review of annual operating costs showed that trucking in LNG to provide year-round fuel was the best choice. The facility, owned by the LNG supplier, not the mill owner, now receives an average of over one LNG truck per day.
- *Mine haul trucks* offer one of the most exciting opportunities for LNG growth. These monster fuel users operate 24-hours per day, operate in a very fixed geography and pay no highway taxes. This is one market in need of new technology, however. As big as these rigs are, there is very little room to support non-conforming LNG tanks. Similarly, there are no 2,200 to 2,500 HP engines to power the rigs. This, too, shall change.

Vehicular Fuel:

Anyone that has heard me speak or read any of my other papers knows that I will not let a chance to talk about LNG as vehicle fuel pass. Having said that, this paper will focus only on "real" natural gas vehicle (NGV) programs. What is meant by "real"? Real as opposed to tests, pilots, demonstrations, etc., etc. A real program stands on its own economics; it does not require government incentives or environmental mandates to make it work. In other words, it means a lot of vehicles burning a lot of natural gas. What that means is we're not talking about fueling vehicles with compressors . . . we're talking about fueling them with pumps. So what are the "real" programs?

- *Dedicated long haul* is the term used when the same tractors run the same routes week after week. Many Class 8 tractors consume 80 gallons of diesel a day (or more). Quickly thinking about that at 5½ days per week that's about 23,000 gallons of diesel per year. How many cents per gallon saving are needed to justify running on an alternative fuel? This information has been published in a number of places; suffice to say, dedicated long haul can offer opportunities.
- *Centralized fleet fueling* is commonplace in many areas. Different vehicles from different fleets can use these fueling stations be it a "no frills" station like the first one below or like the next one below that is part of a mini-mart.



Card Access Fleet Fueling Station



Public Access LNG vehicle Fueling Station

- The *LNG Corridor* is an evolving concept where a network of LNG fueling stations is developed over specific high frequency routes such that over-the-road trucks can move with a high level of confidence that fuel will be available to them.
- *SuperCNG station* is the name CH-IV LNG Company has given to a new approach to fueling a large quantity of CNG continuously to either a high population of light duty vehicles (taxis and vans) or a large fleet of transit buses. Anyone who has tried to make a large CNG program operate with compressors is well aware of the difficulties realized with continuous capacity, energy consumption during peak hours and inability to fully fill CNG tanks due to the heat of compression. The SuperCNG station has eliminated all of these problems and more. The SuperCNG station is an optimum way of using LNG to produce CNG.

SUMMARY

There is more activity (at least discussion and conceptualizing) in small tank LNG projects than there has been since the early 1970s; just ask any tank manufacturer. As stated at the beginning, one purpose of this paper was to stimulate thought about other ways of thinking about LNG. A number of topics were touched upon in this paper and probably many inadvertently missed. When one takes into account the completely depreciated LNG peakshavers, Order 636, new utility thinking, new players, new markets, the partnering of gas companies and electric producers, and so on and so on . . . LNG could be a fun place to be over the

next decade.

CH-IV LNG Company can provide complete programs from LNG sourcing (or production), through distribution, to receiving and delivery facilities. This includes propane replacement; baseload and peakshaving satellite plants; and vehicle fueling stations (both LNG and CNG). The financial structure of such programs can be defined in the best interests of the end-user, including commodity and demand pricing for energy sales and lease/purchase for capital assets. We can also assist in financing and developing LNG projects. Consider a partnership with CH-IV LNG Company. You bring the market and we will bring the technology, the equipment and the capital.

- CH-IV Corporation which specializes in LNG and associated natural gas and cryogenic engineering and consulting
 - CH-IV Cryogenics which designs, fabricates and installs LNG-based fuel systems.
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