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NEW PIPELINES, NEW OPPORTUNITIES

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ABSTRACT

The development of new pipeline systems through lands where the primary fuel source has been fuel oil or wood offers unique opportunities for the utilization of natural gas from the pipeline.

The use of gas in place of oil can improve local economies; reduce heating and energy cost and lower the emissions produced from energy sources.

A computer simulation has been built that can examine all the options for the use of gas from a pipeline system, considering direct replacement of fuel oil with a local gas pipeline system, the generation of electric power – locally or centralized at the pipeline, and the option of using cogeneration with the pipeline compressor stations.

The simulation provides both graphic and tabular presentation of the results to show payback and the influence of changes in key parameters.

The paper discusses this program and the possible applications to areas hitherto remote from the supply of natural gas for fuel.

INTRODUCTION

The prospect for new sources of gas supply and the construction of pipelines to convey that gas to market raises the possibility for the use of some of that gas to replace existing energy sources and to provide economic benefits to communities adjacent to the line.

This is a particularly attractive prospect for remote locations where present fuel supplies are costly and can be subject to interruptions in delivery.

A computer model has been developed to permit the economic evaluation of the impact of supplying natural gas to communities hitherto dependent on diesel oil and to examine the alternative ways of supplying energy.

This paper reviews the application of the model in the analysis of the economic options for the communities adjacent to the pipeline.

THE OPTIONS

Several options are available for the use of natural gas from the pipeline. These can be summarized as follows:

1. Supply of gas to the community for distribution to households and commercial users for space heating and to power plant for the generation of electricity.
2. Supply of gas to the community for space heating and the generation of electricity adjacent to the pipeline, a transmission line being used to carry the power to the community.
3. Generation of electricity adjacent to the pipeline and the construction of a power transmission line to the community for both power and heating.
4. Utilization of waste heat from compressor stations on the pipeline to generate electricity and the transmission of this power to the communities for both heating and light.

THE MODEL

The model comprises of three sections: the graphical summary of the alternatives, the community data input sheet, and the estimating backup sheets. For the purposes of this Paper and to keep the presentation of the model reasonably concise, it has been necessary to simplify the presentation. Several elements, such as gas quality, gas treatment, and site-specific details, have been taken out of the calculations and charts. Similarly, the prices of gas and diesel fuels have been generalized for the purpose of illustration and should not be taken as representing any particular case.

Graphical Summary

The graphical summary shows in both graphical and tabular format the five alternatives studied for each community. These are:

status quo, gas heating and gas power generation at the community, power generation at the pipeline and gas heating at the community, total power generation at the pipeline, and finally, total power cogeneration at the compressor station.

For convenience and clarity, each of these five alternatives has been color-coded. The summary gives the community name and population, its distance from the pipeline, the pipe size used, the cost of delivered fuel at the community, and the cost of gas at the pipeline.

The operating cost and the investment per capita is calculated for each of the five alternatives. No input is required for the sheet; one can see graphically where the four new alternatives intersect with the status quo; the status quo being the benchmark for measuring the other solutions. In some cases, the break-even point is reached within only a few years, indicating the viability of the conversion from fuel to gas.

Community Data Input Sheet

The community data input sheet is designed to give results even with absolute minimal input: community name, population, the distance of the community from the pipeline, the cost of delivered fuel, and the cost of gas at the pipeline.

All other variables are calculated using a statistical model based on the communities. These include household size, number of households, number of businesses, average home size, average business size, average yearly heating consumption per household and per business, average yearly power consumption per capita, and peak electrical load. Each of these theoretically calculated variables could be overwritten by entering the actual number when available.

Estimating Basis

The estimating sheet comprises of the status quo, lateral pipeline, community gas distribution, transmission line and substations, community conversion to gas, conversion to gas heating but power generation at pipeline, total power generation at pipeline, and cogeneration at the compressor station.

Generally, no input is required on these sheets. Although, if one wants to overwrite the input quantity generated on the input sheet (in blue), or change the model's pricing figures, (in green), these could be overwritten for further sensitivity analysis. There are special buttons for both scenarios to enable one to revert to the theoretical values.

Additionally, the model allows for three global multipliers (in brown, at the top of the sheet) – currently set to one (1) – for labor, consumable materials, and subcontract columns. The model also allows, for each sheet (in yellow), the miscellaneous cost entries by the user if required for further sensitivity analysis.

Status Quo. The status quo sheet calculates the yearly operating costs for labor and consumable materials. It shows the fuel consumption for power generation, heating, operators' cost, operating spares, and third party maintenance per kilowatt.

Lateral Pipeline. The lateral pipeline sheet estimates the cost of the pipeline, based on the sizes determined on the input sheet. If

the size on the input sheet were less than 6" then we would recommend a minimum of 6", as the incremental cost between 2-6" is only in the cost of the pipe, a minor amount compared to the overall cost when considering right of way, installation at the remote communities, and river and creek crossings.

Gas Distribution. We have made an allowance of \$3000 per household to provide for a gas distribution system within the community. The load requirements are for housing and industries, and to design a distribution system for each community.

Transmission Line and Substations. This sheet covers the cost of the transmission line from either the pipeline or the compressor station to the community. The model allows 25 kV for distances up to 30 km, 46 kV for distances between 30-50 km, and 132 kV for distances greater than 50 km. Allowances have been made for step up and step down transformers in substations.

Community Conversion to Gas. In this sheet, we estimate the installed cost of the selected gas-driven generator and gas consumption at the community, the cost of the household conversion to gas, and the yearly maintenance and operating costs. Data from this sheet, together with the cost of the lateral gas line to the community, will form the first alternative of gas heating and community and gas power.

Conversion to Gas, Generation at Pipeline. This alternative assumes that the power will be generated at the pipeline and that we will provide community gas heating, requiring the building of the lateral pipeline.

Conversion to Electricity and Total Power Generation at Pipeline. In this case we assume that a lateral is not constructed and that the power generation for lighting and heating is generated at the pipeline and transmitted to the community via the transmission line. Thus, appliance conversion at each household will be to electric instead of to gas.

Conversion to Electricity, Generation at Compressor Station. This alternative assumes the generation of electricity at the pipeline compressor station(s) using a steam turbine or an organic Rankine cycle that gets its energy from the compressors' waste heat. We have assumed that the waste heat is free.

The assumption that waste heat is free does not account for the small loss of power and/or increase in fuel consumption due to increase in exhaust backpressure in the gas turbine. However, this is a second order effect in relation to the overall increase in cycle efficiency and reduction in fuel usage compared with independent power generation. This is again a site- and unit-specific factor, which the model can simulate in the practical case.

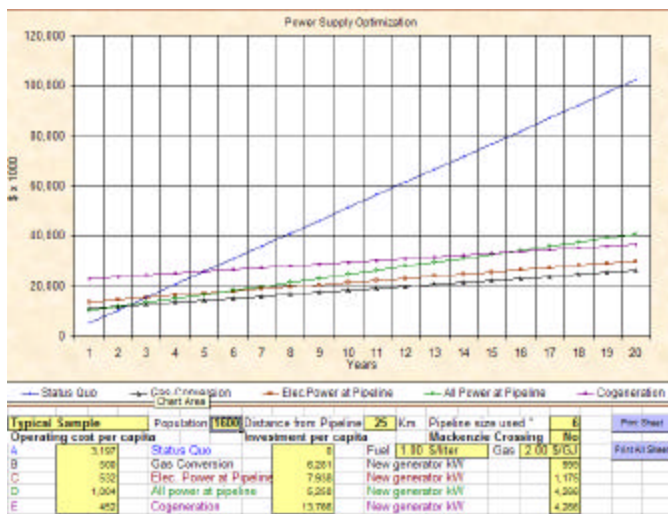
DISCUSSION OF RESULTS

To illustrate the applications of the model, an example has been used based on a hypothetical community adjacent to the proposed Mackenzie Valley pipeline. There will be four variations in the base case, used to demonstrate the sensitivity to significant parametric changes.

In this analysis, the terminology used will be that adopted for the graphical presentation of the results, namely:

- Option A Status Quo (existing diesel generation of power and fuel oil for space heating)
- Option B Conversion of community to gas for space heating and gas supplied for local power generation.
- Option C Generation of electricity at the pipeline with a dedicated generator and supply of gas to the community via a lateral gas line for space heating.
- Option D Generation of power for heating and lighting at the pipeline with a dedicated generator and transmission of electricity to the community for both light and heat.
- Option E Capturing some of the waste heat from a pipeline compressor station to provide all the energy required by the community for light and heat, transmitting this power via a transmission line.

Base Case. The base case, where the community with a population of 800 is situated 25 km from the pipeline, shows that option B, which is the conversion of community gas for space and gas supply for local power generation, breaks even with status quo (existing diesel generation of power and fuel oil for space heating), in about three years. In the long-term, B is the least expensive option. Option C, which is the generation of electricity at the pipeline with a dedicated generator and supply of gas to the community via a lateral gas line for space heating, has a higher capital cost than option B and breaks even with status quo in about

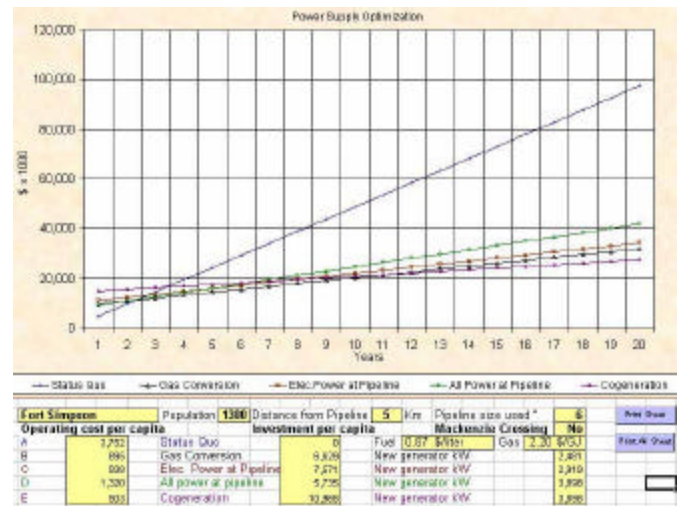


five years. Option D, which is the generation of power for heating and lighting at the pipeline with a dedicated generator and transmission of electricity to the community for both light and heat, breaks even in about four years and has a lower initial capital cost than the previous options. Option E, which is capturing some of the

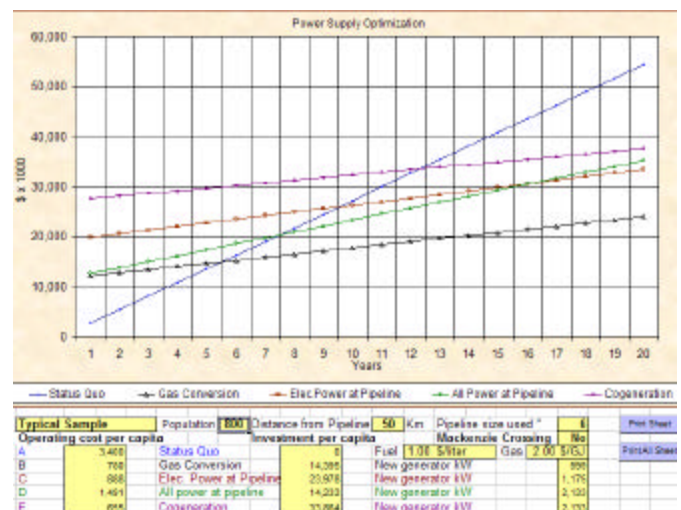
waste heat from a pipeline compressor station to provide all the energy required by the community for light and heat, transmitting this power via a transmission line, has the most expensive capital cost and breaks even in about eight years.

On the basis of these options, the optimum solution appears to be straightforward gas conversion.

Increase in Population. Assuming that the hypothetical community is still 25 km from the pipeline, but with doubling the population to 1600, the relative positions of the options remain unchanged. Still, the difference between investment options and cost per capita is reduced as a function of population size, and the break-even points for all cases is reduced in time.

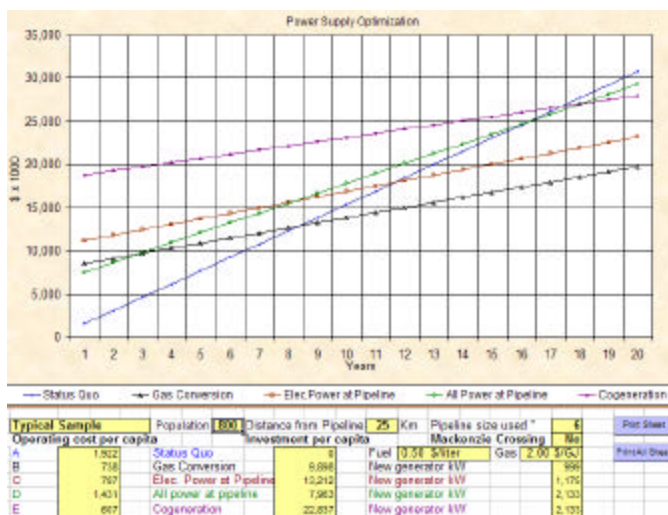


Distance from the Pipeline. If the distance of the base community (population 800) is increased from 25 km to 50 km from the pipeline, this has the opposite effect than that of increasing the population size. In other words, the difference between the options opens out, the investment cost per capita is significantly increased. This has the effect of spreading the curves apart and delaying the



break-even points. In this particular case, the shortest break-even time is with option B (in five years), while option D increases to eight years, C to nearly ten years, and for option E, to twelve years. This is a consequence of greatly increased investment cost per capita.

Cost of Diesel Fuel. Reverting to the base case community (population 800, situated 25 km from the pipeline), but changing the cost of fuel oil to \$.50/L (fifty cents per litre) rather than \$1/L (one dollar per litre), greatly reduces the benefits of conversion to gas. The curves are spread further apart compared with the base case and the break-even time for conversion to gas is delayed until the eighth year. Break-even dates for the other options correspondingly increase. Clearly, the benefits of conversion are sensitive to the ratio of gas cost to fuel cost.



Use of Gas Turbines for local power generation

The previous paragraph referred to the purchase of a gas fired reciprocating engine for power generation. Local power generation can also be provided by a gas turbine, although at power levels less than 1MW, the gas engine option is likely to be marginally less expensive in capital cost and more efficient.

The gas turbine, while less efficient than the reciprocating engine in the smaller sizes does, however, offer the benefit of an excess of waste heat in the exhaust gas. The abundance of waste heat can, if fully utilized, more than offset the lower efficiency of the simple cycle turbine. This option should therefore be seriously considered if the power plant could be situated in an industrial area where the exhaust heat can be used.

Comparison of overall efficiency will show the turbine with waste recovery in excess of 50% compared with a gas engine (no waste heat) of about 35%. For the purposes of the model, the database includes both gas turbines and reciprocating engines. However, the selection of the unit for local generation of power has been assumed to be a reciprocating engine at powers of less than 1MW and a gas turbine at powers of greater than 1MW. Details in both cases are extracted from the common database.

Where power is generated at the pipeline, the increase in load consequent upon the need for both electricity and space heating,

suggests the use of a gas turbine in all communities. The larger units needed for this option will have higher efficiency and, in some cases, offer the possibility of additional power generation from waste heat recovery, with an additional increment of efficiency. This possibility has not been included in the calculations but could be evaluated on a case-by-case basis.

The location of the community power plant and gas turbine close to a turbine powered compressor station will simplify maintenance and in fact may be part of a combined operation between the community and the pipeline company.

Waste heat recovery

Reference is made to the possibility of increasing the efficiency of gas turbines with waste heat recovery. The efficiency of a simple cycle gas turbine varies from 25% up to 38%, small turbines of 1MW or more will be at the high end of the efficiency range. The exhaust from a turbine carries away a substantial fraction of the energy produced in the combustion of fuel. In combined cycle turbines a part of the exhaust (waste) heat can be recovered in a boiler and put to use in a steam turbine to drive a generator and additional power may be produced.

Where adequate supplies of water may not be available or very costly, or where operation with steam is not practical, an organic Rankine cycle using another working fluid can be employed. This system has been successfully applied to compressor stations in Alberta.

The cost of a waste heat recovery system varies with size, at the low end a cost of \$2,000/kW for 250kW output is estimated, at the high end of 5.0MW and more the cost falls to about \$850/kw. Typically, up to 25% of the gas turbine power can be recovered in the exhaust heat recovery system. This has the effect of reducing the specific fuel consumption from 8,500 BTU/kW/hr to 6,500 BTU/kW/hr or less.

For smaller gas turbines, the additional capital cost of an organic Rankine cycle or steam turbine recovery system is not generally economic and this has not been considered as a practical option for power generation at the smaller communities.

An alternative way to use the waste heat is through direct application to a process that requires heat. Such uses can be as varied as kiln dryers and greenhouses. To maximize the benefits from this option, the power plant should be installed alongside the premises of the users of the waste heat. Plants in association with industrial estates are particularly appropriate.

Power from the pipeline

Assuming that there will be a number of large gas turbine powered stations on the pipeline, accessibility to these stations from any community should not be difficult. These stations will be carrying a significant amount of energy into the atmosphere through this exhaust system.

Adding a power recovery system, such as the Ormat unit, to the exhaust of a 30MW gas turbine, there will be up to 5 or 6MW of electrical power, part or all of which could be made available for community power. This arrangement would not only provide each community with a source of energy at minimum operating cost, it would also provide this power without any pollution or

environmental impact. This is truly “green power” and the community would no longer be contributing any CO₂, NOX or SOX to the atmosphere.

Environmental Benefits

The use of natural gas as a fuel will lower the CO₂ content of the gasses ejected into the atmosphere without a corresponding increase in other pollutants. Fuel oil, whether used in a diesel engine or a furnace, tends to produce particulates and smoke. Low emission versions of gas-fired engines will reduce these nuisances. Gas turbines can further help the environment with reduction in emission levels, especially if the exhaust heat is put to good use.

The maximum benefit for the environment is obtained from the waste heat recovery system at the compressor stations. This virtually eliminates the pollution for the community and places no additional burden on the environment at the pipeline.

While continuing the discussion on the environment and pollution, it should not be forgotten that where gas turbines are used to generate electric power for the community and heat has been used for process in industrial plants, there may well be some low grade heat remaining that can be utilized for district heating and hot water supply to adjacent dwellings and commercial premises.

CONCLUSIONS

The benefits for the communities adjacent to the pipeline resulting from access to gas supplies from the pipeline could be considerable based on the samples reviewed. This study has examined a number of different ways in which the gas may be brought from the pipeline to the communities and how the new source of fuel may be used.

The options include direct supply of gas from the pipeline to provide power and heat, generation of electricity close to the pipeline accompanied by a lateral to supply gas for heat, a total electric solution to generate power at the pipeline for both light and heat and, finally, the recovery of energy from the compressor station exhaust to provide both light and heat to the communities.

The examination of the results for the hypothetical communities considered and sensitivities examined shows consistency in the disposition of the various options.

This model can be very useful in determining the viabilities and evaluating the economics of different conversion options of changing diesel fuel to gas fuel.

It should be emphasized that the determination of the optimum solution in a specific case is entirely dependent upon factors such as community size, distance and accessibility to the pipeline, local conditions and the relative costs of diesel or other fuels and gas.