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Techno-economic assessment of pathways for electricity generation in northern remote communities in Canada using methanol and dimethyl ether to replace diesel

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ABSTRACT

There are many small remote northern communities in Canada that are not grid-connected and which rely entirely on diesel electricity generation to meet their electricity needs. Electricity prices in these isolated communities are much higher than in heavily populated regions due to the high operating costs of the diesel power plants and the high cost of supplying fuel to these communities. Diesel fuel also poses a risk of an environmental disaster caused by a marine fuel spill. This study investigates the feasibility of replacing diesel for electricity generation with clean bio-fuels. A techno-economic assessment compared the full cost of electricity generation for diesel (base case) with methanol and dimethyl ether. Case studies were developed for three remote northern communities in Nunavut.

From the cost models, full cost of diesel electricity generation including the bulk fuel purchase, delivery, and electricity generation at the three sites varied depending on the annual electricity demand; $0.66/kWh at 3300 MWh, $0.89/kWh at 1500 MWh, and $1.46/kWh at 1400 MWh, respectively. These costs compared well with actual customer rates at the two larger sites. Switching to methanol resulted in an increase of $0.046/kWh, $0.085/kWh, and $0.066/kWh, and dimethyl ether saw in an increase of $0.04/kWh, $0.11/kWh and $0.044/kWh, respectively, in the full cost of electricity. New bulk fuel storage projects increase the cost of electricity further between $0.05/kWh and $0.10/kWh. However, a $30/tonne CO_2 penalty adds $0.08/kWh for diesel electricity generation, whereas bio-based methanol and DME would be exempt. In light of the potential socio-economic benefits from switching to clean biofuels, as well as avoiding the enormous costs associated with the clean-up and economic losses due to a marine oil disaster, these clean fuel options seem reasonable as “transition technologies” toward renewable energy to replace diesel electricity generation in Canada's most remote northern communities.

1. Introduction

Currently, diesel fuel is the dominant source of energy for electricity and heat in many of Canada's northern and remote communities. The main reasons for this are the reliability of diesel–electric generation and the relatively low capital investment cost. However, communities in Canada's high arctic region are small and geographically isolated over a very large area. Operating costs for diesel power plants are high, and dominated by diesel fuel costs. These factors result in electricity prices that are much higher than in heavily populated southern regions of the country.

Because of their geographical isolation, with no local biomass resources, northern communities rely on annual bulk fuel resupply shipping vessels to deliver a full year's supply of diesel fuel during the short summer shipping season in order to meet their electricity needs. They must ensure that there is sufficient fuel in storage to last until the next seasonal bulk fuel delivery. Fig. 1 shows a map of Canada's northern territories and many of the remote ports of call for the annual fuel resupply vessels [1].

Because diesel is the most trusted and reliable source of electricity generation in Canada's far northern communities, we propose that clean biofuels which can integrate with existing diesel–electric power plants for producing electricity and heat, may be advantageous “transition technologies” in the near term toward renewable energy to replace diesel–electric generation. For the far northern regions, it seems more practical and economical to produce the renewable fuels where local biomass resources are available and to ship them to the North. However, in order to assess the overall feasibility of this approach, we need to have a solid understanding of the full cost of electricity production, including the annual resupply of fuel to northern and remote

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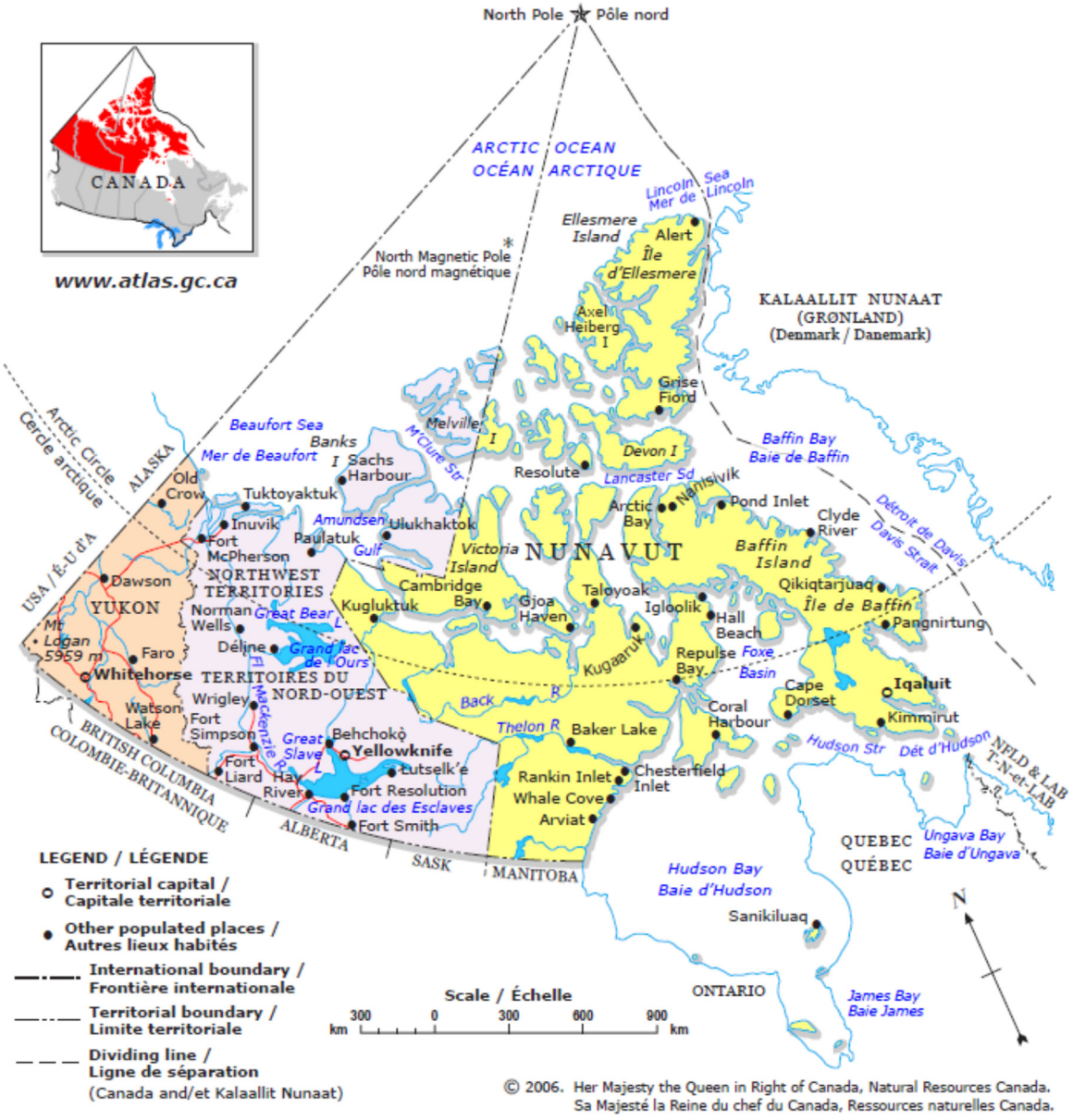

Fig. 1. Canada's northern Territories.
Source: Natural Resources Canada [1]

Fig. 2. Full cost model for diesel electricity production at a northern remote site.

communities, but these figures are not well-documented in the open literature. Reported costs for fuel and electricity can vary significantly and are often misleading. The wide range of reported costs may be due to various subsidies that are meant to offset the high price of fuel and electricity in the North.

This paper presents a comparative techno-economic assessment (TEA) of two biofuel pathways to replace diesel–electric generation in communities in Canada's arctic communities, in order to gauge the economic potential of biofuels for electricity generation, identify barriers as well as socio-economic or environmental benefits. Methanol and dimethyl ether (DME), which can be derived from biomass, are considered as potential renewable fuels to replace diesel.

2. Methodology

The general methodology for the TEA is to develop a full cost model for electricity production for a given pathway, using diesel as the base case for comparison. The base cases for diesel electricity generation were developed using data from engineering prefeasibility studies done at three Nunavut sites. The full generic cost model is shown graphically in Fig. 2. The block diagram in Fig. 2 represents a supply chain for electricity generation using diesel or an alternative fuel at a northern remote community. The full pathway takes into account the location and cost for the bulk fuel purchase, fuel delivery by a specific route to the Arctic community, as well as the necessary new onsite infrastructure investments (e.g., power plant and bulk fuel storage facility).