Wind - Hydrogen, a coupled energy alternative to diesel for Nunavut and other northern communities

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Summary

Nunavut faces energy challenges associated with extreme cold temperatures and vast distances between communities that are unique to Arctic and Subarctic Canada. While residents, largely Inuit, are concerned about climate change and its impacts on northern ecosystems, hunting and fishing, access to a reliable source of energy for electricity, heat and transportation is an acute priority. Hydrogen (H_2) has long been recognized for yielding high energy content per unit weight of fuel, and it can be produced using a range of methods and resources. Wind is an energy alternative for Nunavut because the average monthly wind speed and frequency of occurrence in a number of regions is adequate to power turbines. Variability in wind power can be overcome with energy storage technology. In a coupled system, wind power can be used to produce H_2 from water, which can be stored to stabilize the region's electrical grid during times of fluctuating electricity supply and demand. Most communities in Nunavut currently rely on diesel-generated power because they have reliable access to fuel and familiarity with equipment maintenance. This paper and presentation details how a coupled wind-H_2 system can reduce existing diesel infrastructure in the north, reducing both the levelized cost on electricity production and greenhouse gas emissions contributing to climate change.

Introduction

Communities in Nunavut rely on independent micro-grids for electricity generation that are powered exclusively by diesel-fired generators. Seasonal diesel delivery windows, via barge or airplane, result in higher electricity costs in Nunavut compared to the rest of Canada. The purpose of this study is to propose an affordable, sustainable, and safe energy option for Nunavut communities. Affordability is a product of the levelized cost of producing electricity, comprising fuel price, transportation and maintenance of power-generation infrastructure. Sustainability refers to reliable capacity to generate electricity in a safe manner.

Studies show that community-scale wind farms are feasible for communities like Rankin Inlet and Iqaluit, where average wind speed are 7.8 and 8.2 meters per second (m/s), respectively [1, 2, 3]. Energy storage solutions such as flywheels, batteries and hydrogen exist to overcome the challenge of low-wind periods which can extend for days or weeks at a time. While flywheels and batteries provide short-term energy storage, their cost increases relative to their storage capacity to accommodate longer low-wind periods of time (i.e., greater than two weeks).

Hydrogen can be derived from wind energy through water electrolysis with accessibility to a local water resource. A water electrolyzer uses wind energy to generate H_2 for storage in pressurized tanks which can discharge power over short (couple of hours) and long (days or weeks) periods of time.

Political Landscape

Energy in Nunavut is currently owned and managed by Qulliq Energy Corporation (QEC). No Independent Power Producer (IPP) policy exists allowing communities to produce their own electricity [4]. What this means is that the QEC has control over investment revenues, equipment maintenance contracts and training/employment opportunities, as opposed to community leaders. Development of an IPP policy would benefit residents by allowing for direct community investment and employment opportunities.

A Modelling Approach

The communities of Rankin Inlet, Iqaluit, Baker Lake, Whale Cove, and Sanikiluaq were selected for their proximity to water, wind speed and frequency potential, and their current electricity generation and consumption (Figure 1) [3]. A model was developed to determine the feasibility of a coupled wind-H_2 system to replace existing diesel infrastructure in these communities, economically and practically. Model inputs included: the amount of H_2 targeted; that is, to meet current daily energy consumption requirements, along with the amount of wind power required to generate said target. A grid-search approach was used as the optimizing algorithm to minimize the levelized cost of electricity (LCOE). Capacity parameters of: a wind farm, water electrolyzer and H_2 storage/fuel cell were applied and adjusted for optimization within the model. Benchmark data from literature [5, 6] was used to calculate LCOEs (using initial, operational and maintenance costs). A worst-case scenario was integrated into the model to recognize the high initial cost of implementation encountered by northern communities transporting equipment large distances from major urban centres in southern Canada. In addition, LCOEs were calculated by considering the future costs of wind-H_2 project that are expected to decline significantly by 2030 [7, 8].

Results & Discussion

The wind-H_2 LCOE for Iqaluit is almost equal that of the current diesel-generated rate for electricity (Figure 2). Iqaluit's wind speed/frequency is low and the community's energy demand is high relative to the others modelled. A significant difference was observed between the wind-H_2 LCOE and the current diesel rate for Rankin Inlet, Baker Lake, Whale Cove and Sanikiluaq (Figure 2). These communities are situated in locations with relatively high wind-H_2 potential, compared to Iqaluit, and currently pay high (diesel) electricity rates.

As the initial costs associated with the implementation of wind-H_2 decline as expected [7, 8], the differences shown in Figure 1 for these communities will increase. Similarly, communities like Iqaluit with low wind potential may see the LCOE for wind-H_2 fall lower than that of (diesel) electricity rates. With limited data currently available on installation costs and wind/weather, future modelling work is needed with more comprehensive field and economic datasets.

Many remote communities in Nunavut and other Arctic and Subarctic regions rely on aging diesel infrastructure that is associated with increasing operational and maintenance costs and decreasing efficiencies. A consequence of these circumstances is an increase in electricity rates, for example: Rankin Inlet's rates increased by ~25% between 2005 and 2020 (Figure 3).

If northern communities meeting the criteria described in this paper for accessibility to wind potential and adequate water for H_2 electrolysis, were to adapt a coupled wind-H_2 system to reduce existing diesel infrastructure, they could reduce their electricity costs with or without the worst-case scenario modelled (Figure 3).

Development of an IPP policy allowing communities to produce their own electricity would enable communities to benefit from direct investment and employment in new energy-sector technologies.

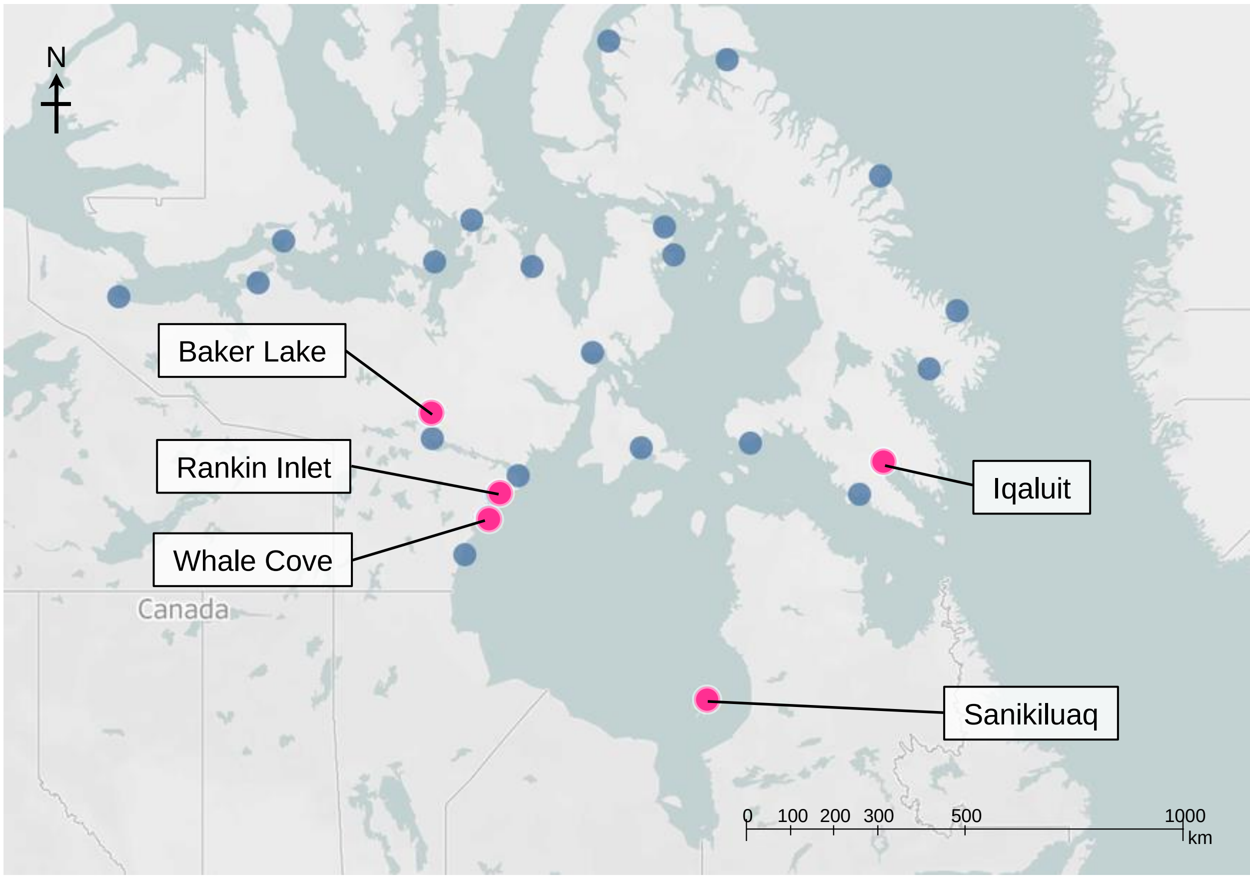

Figure 1. Map of Northeastern Canada. Location of communities in the Northwest Territories selected for this study are indicated by a pink dot. Blue dots show the location of other communities in the Northwest Territories.

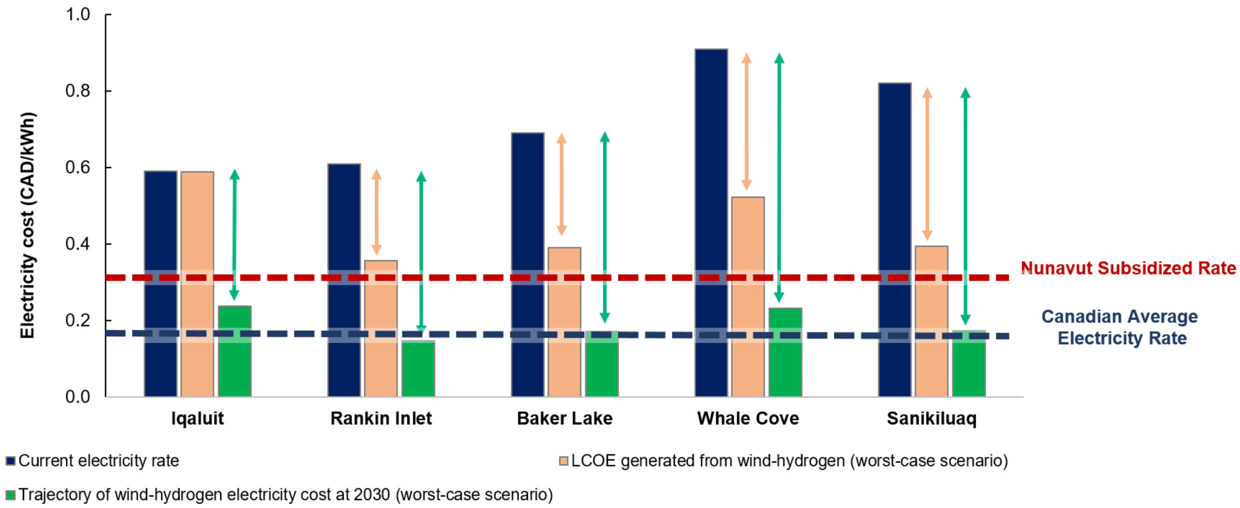

Figure 2. Model of five candidate communities for proposed wind-hydrogen coupled energy costs compared with existing diesel-generated electricity rates. Model inputs include the current diesel-only electricity rate (■), the wind-hydrogen levelized cost of electricity (■) and the projected wind-hydrogen cost in 2030 (■). Data sources: [9].

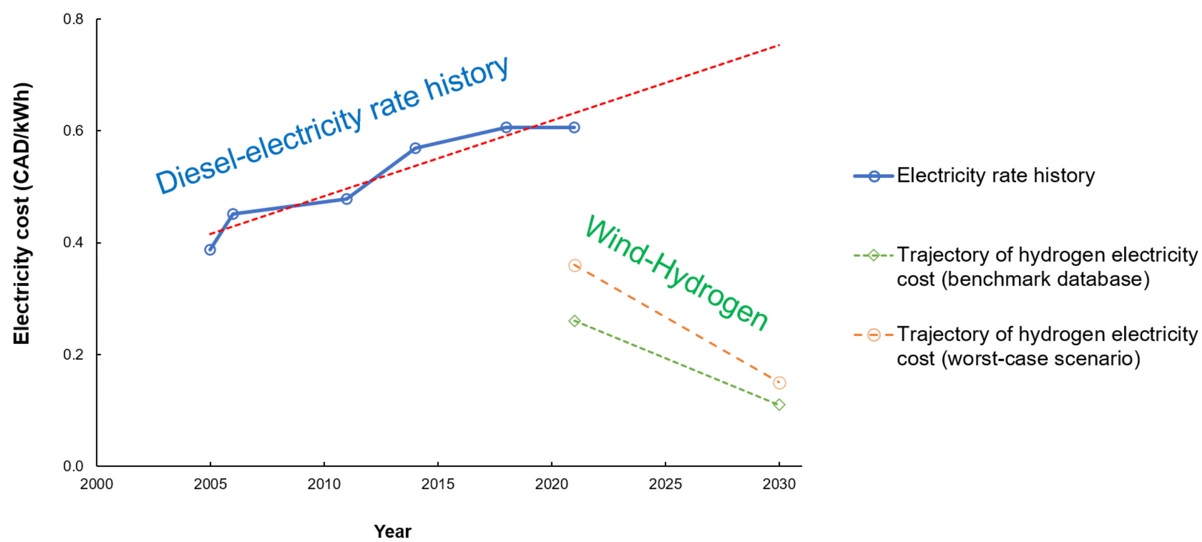

Figure 3. Comparison of historical electricity rates generated from diesel with the future modelled cost of electricity generated from hydrogen, using Rankin Inlet as an example. Data source: [10].

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