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CANADA

POWERING NUNAVUT'S FUTURE WITH HABITAT-FRIENDLY RENEWABLE ENERGY

Reliable, affordable energy can help communities, the environment and the economy

Falling costs for renewable energy technology and battery storage are improving the economic case for investment in Nunavut. But better data and low-interest financing options are still needed to increase the attractiveness of renewable energy integration.

© Joshua Ostroff

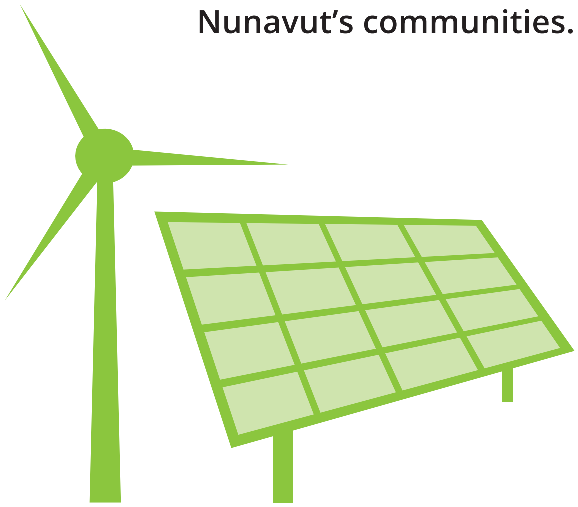
Canada's Arctic territory of Nunavut depends on fossil fuels for electricity and heat generation. This comes at a high environmental, financial and logistical cost to Nunavummiut. The extreme isolation of communities and limited year-round transportation access has meant that supply disruption and global price hikes pose significant risks to the region's energy security. Burning fossil fuels for heat and electricity also negatively impacts local air quality and contributes to black carbon, which speeds up snow and ice melt. As fuel is transported by ship, spills on land or sea also pose a significant environmental threat.

Since 2016, WWF-Canada's Arctic program has worked to demonstrate that low-impact renewable energy from wind and solar is possible and can contribute to sustainability in northern Canadian communities. Previous studies supported by WWF-Canada have predicted what the use of renewable energy in northern communities might look like and assessed how financing and fossil fuel subsidies impact the feasibility of renewable energy generation in the territory.

WWF-Canada continues to support a transition to habitat-friendly renewable energy in Nunavut by working in partnership with communities to develop energy co-operatives, offer training and educational opportunities, and provide renewable energy expertise.

NUNAVUT'S ROAD TO RENEWABLES

WWF-Canada engaged ITP Renewables to update and expand on a 2016 pre-feasibility study which projected what the use of renewable energy would look like for 13 of Nunavut's communities.



Using current publicly available data on community diesel fuel use for heating and electricity, energy pricing projections, and population and energy-use projections, the analysis lays out the most economical solution for all 25 communities to reach higher renewable energy contributions. Where possible solar and wind data was obtained from actual ground measurements — if not available, NASA satellite data was used and if data couldn't be found at all, estimates were made using known data from similar-size communities.

ITP Renewables applied a conservative 15-year project lifecycle to the financial analysis. Solar and wind assets typically last longer and future Independent Power Producer contracts are likely to span at least 20 years. The report also includes an economic analysis of three minimum renewable energy penetration scenarios (20 per cent, 40 per cent and 60 per cent) as well as the diesel-only base case with both an eight per cent and four per cent discount rate to test the impact of financing on project feasibility. (The "discount rate" is how much it costs to borrow money — it's affected by the base interest rate, access to grants, and how risky the bank thinks the project is.)

KEY FINDINGS

A lower cost for renewable solutions

Battery storage-supported wind or solar — but not both — is the most ideal renewable energy solution for most communities. Due to a reduction in battery technology costs in recent years, it is no longer critical to have different forms of renewable energy complementing each other due to a lack of adequate storage. As renewable energy technologies become cheaper and more efficient, the feasibility of a transition to renewables increases.

Don't cry over spilled electricity

Matching supply with demand can be a challenge — at times, renewable energy projects may deliver more electricity than is needed. By diverting this extra electricity into heating, diesel consumption can be further reduced, making renewable energy projects even more attractive. Baker Lake, for example, is identified as a community where any additional wind power-generated electricity could be used for heating, adding an extra $2 million to the value of the project. Heating fuel, unlike diesel used for electricity, is subject to the federal carbon tax so this compounds cost savings.

The devil is in the financing details

The viability of renewable energy projects can vary greatly depending on financial factors. Nearly half of the communities in Nunavut become more attractive for renewable energy project development should low interest access to capital be made available.

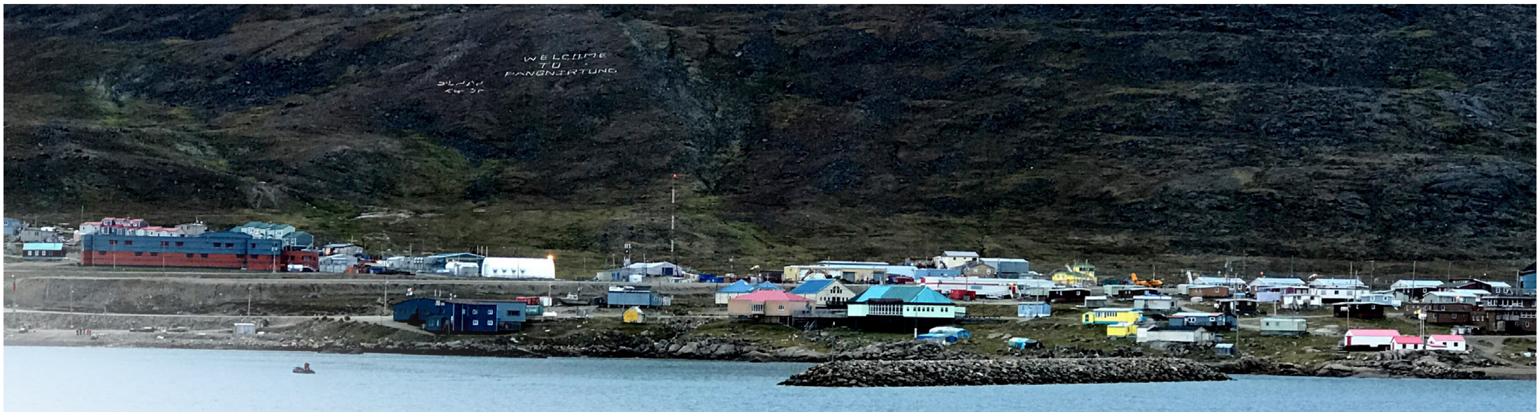
A sensitivity analysis to assess the impact of different financing costs was conducted for three communities: Rankin Inlet, Sanikiluaq and Baker Lake. While Rankin Inlet was attractive using standard financial assumptions — a project life of 15 years and an eight per cent discount rate — the smaller communities of Sanikiluaq and Baker Lake showed a remarkable dependency on project financing. A four per cent discount rate makes renewable energy penetrations up to 70 per cent attractive for Baker Lake while for Sanikiluaq a lower discount rate or an increase in the price of diesel would quickly make a project there worthwhile.

20% RENEWABLE ENERGY PENETRATION SCENARIO

COMMUNITY	8% DISCOUNT RATE	4% DISCOUNT RATE
Arctic Bay	Not immediately promising	Close – warrants further study
Arviat	Not immediately promising	Close – warrants further study
Baker Lake	Not immediately promising	Saves money!
Cambridge Bay	Not immediately promising	Not immediately promising
Cape Dorset	Not immediately promising	Close – warrants further study
Chesterfield Inlet	Close – warrants further study	Close – warrants further study
Clyde River	Not immediately promising	Not immediately promising
Coral Harbour	Close – warrants further study	Saves money!
Gjoa Haven	Not immediately promising	Not immediately promising
Grise Fiord	Close – warrants further study	Close – warrants further study
Hall Beach	Close – warrants further study	Close – warrants further study
Igloolik	Not immediately promising	Close – warrants further study
Iqaluit	Saves money!	Saves money!
Kimmirut	Close – warrants further study	Close – warrants further study
Kugaaruk	Not immediately promising	Close – warrants further study
Kugluktuk	Not immediately promising	Not immediately promising
Naujaat	Close – warrants further study	Close – warrants further study
Pangnirtung	Not immediately promising	Close – warrants further study
Pond Inlet	Not immediately promising	Not immediately promising
Qikiqtarjuaq	Not immediately promising	Close – warrants further study
Rankin Inlet	Saves money!	Saves money!
Resolute Bay	Not immediately promising	Close – warrants further study
Sanikiluaq	Close – warrants further study	Close – warrants further study
Taloyoak	Not immediately promising	Close – warrants further study
Whale Cove	Close – warrants further study	Close – warrants further study

This table uses the 20 per cent penetration scenario as an example to reveal the impact that low-interest project financing can have on project viability, comparing eight and four per cent discount-rate scenarios.

- Not immediately promising
- Close – warrants further study
- Saves money!



Top communities for cost-effective greenhouse gas reductions

Based on the lifecycle costs of renewable energy projects relative to the estimated amount of displaced diesel, and the strength of local solar and wind resources, six communities are identified as the most cost-effective candidates for reductions in greenhouse gas emissions: Rankin Inlet, Iqaluit, Baker Lake, Chesterfield Inlet, Coral Harbour and Sanikiluaq.

The need for more and better data

Better data on the quality of wind and solar resources in each community and peak times for energy consumption is needed in order to provide a robust assessment of the financial viability of renewable energy projects for Nunavut communities.

Nunavut is on the verge of a major change to its energy systems. The introduction of a net metering program in 2018 and the impending Independent Power Producer policy facilitate new ways of generating electricity in Nunavut. The federal government's price on carbon, an interest in territory-wide community energy planning and a focus on federally-funded diesel reduction initiatives are helping push forward the transition to renewable energy for northern communities.

As this report demonstrates, habitat-friendly renewable energy is reliable and robust enough to power Nunavut's future.

SPOTLIGHT: RANKIN INLET

© Northern Energy Capital

Thanks to a strong wind resource and sizeable community of 3,000 people, the report found that there is an immediate financial case for renewable energy development in the Kivalliq hub of Rankin Inlet. A single 2.3-megawatt wind turbine, along with battery back-up, could achieve a nearly 50 per cent renewable energy contribution, saving 2.4 million litres of diesel and abating 6.2 kilotons of carbon emissions each year. Installing a second turbine could bring this contribution up to 74 per cent renewable and allow for excess energy generated to be used for heating to further offset diesel consumption.

FOR MORE INFORMATION

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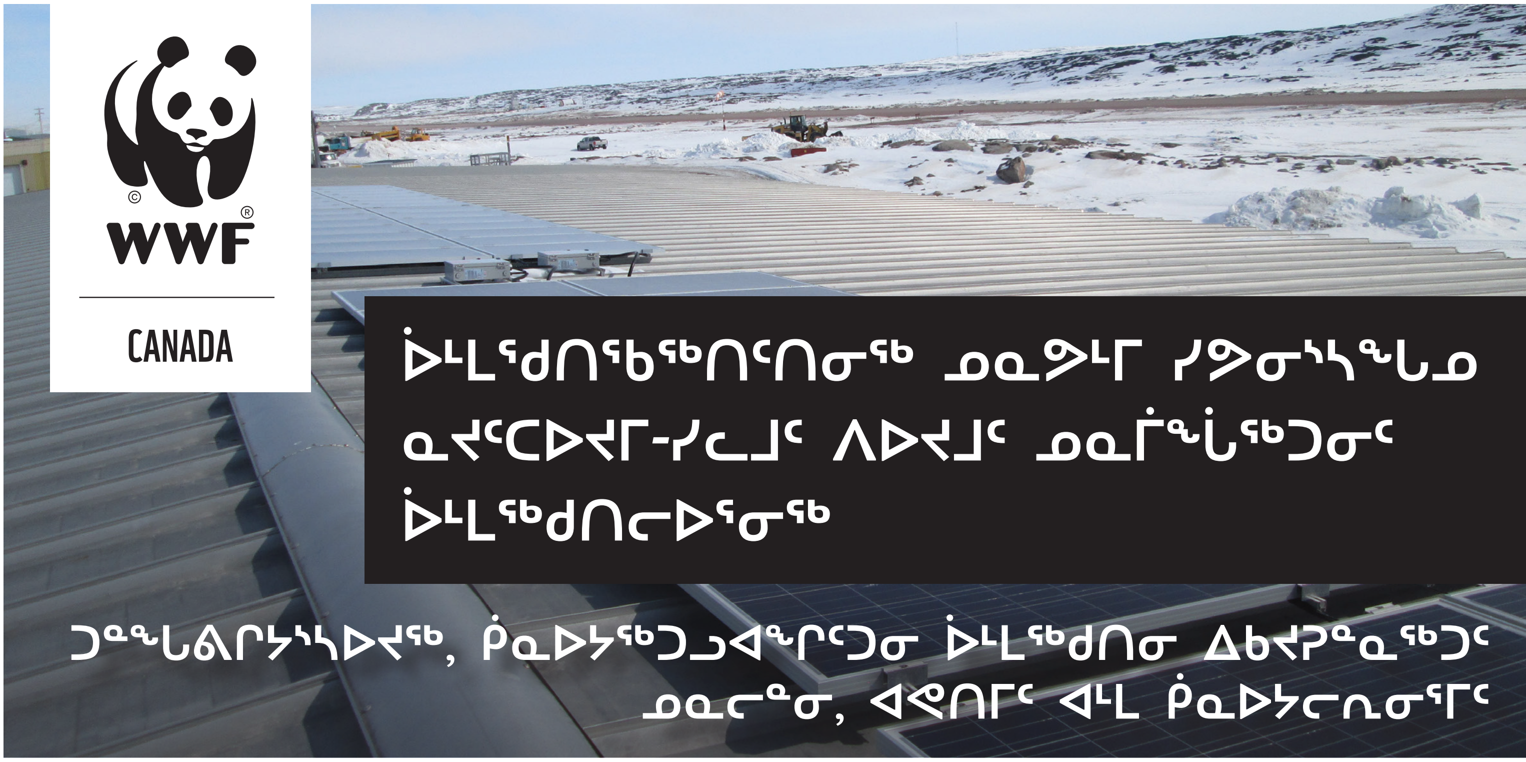


ᐆᒪᕐᑯᑎᖃᖅᑎᑦᑎᓂᖅ ᓄᓇᕗᒻᒥ ᓯᕗᓂᒃᓴᖓᓄ ᓇᔪᑦᑕᐅᔪᒥ-ᓯᓚᓘᑦ ᐱᐅᔪᓘᑦ ᓄᓇᒦᖑᓚᖅᑐᓂᑦ ᐆᒪᖅᑯᑎᓕᐅᕐᓂᖅ

ᑐᓐᖓᕕᒋᓯᔅᓴᐅᔪᖅ, ᑮᓇᐅᔭᖅᑐᓗᐊᖏᑦᑐᓂ ᐆᒪᖅᑯᑎᓂ ᐃᑲᔪᕈᓐᓇᖅᑐᑦ ᓄᓇᓕᓐᓂ, ᐊᕙᑎᒥᑦ ᐊᒻᒪ ᑮᓇᐅᔭᓕᕆᓂᕐᒥᑦ

ᐊᑎᑦᓕᕙᑦᓕᐊᔪᑦ ᐊᑭᖏᑦ ᓄᓇᒦᖑᓚᖅᑐᓂ ᐆᒪᖅᑯᑎᓕᐅᓂᕐᒧᑦ ᐊᒻᒪ ᐹᑕᓖ ᑐᖅᑯᖅᑕᐅᓂᖏᑦ ᐱᐅᓯᕙᑦᓕᐊᔪᑦ ᑮᓇᐅᔭᓕᕆᓂᑦᑎᒍᑦ ᐱᓕᕆᑎᑦᑎᓂᕐᒧᑦ ᓄᓇᕗᒻᒥ. ᑭᓯᐊᓂ ᐱᐅᓂᖅᓴᓂᑦ ᑐᑭᓯᒋᐊᕈᑎᓂᑦ ᐊᒻᒪ ᐱᔪᒪᓂᕐᑲᑎᐊᖏᓐᓂᖓ ᑮᓇᐅᔭᖃᖅᑎᑦᑎᓂᕐᒧᑦ ᓇᓖᕋᕐᕋᓴᓂᑦ ᓱᓕ ᐱᔭᐅᔭᕆᐊᖃᖅᑐᑦ ᕿᕙᕆᐊᕐᓗᒍ ᐱᔪᒥᓇᕐᓂᖓ ᓄᑕᐅᖖᑯᓐᓇᖅᑐᑦ ᐆᒪᖅᑯᑎᑦ ᐃᓚᓕᐅᕝᔭᐅᓂᖏᑦ.

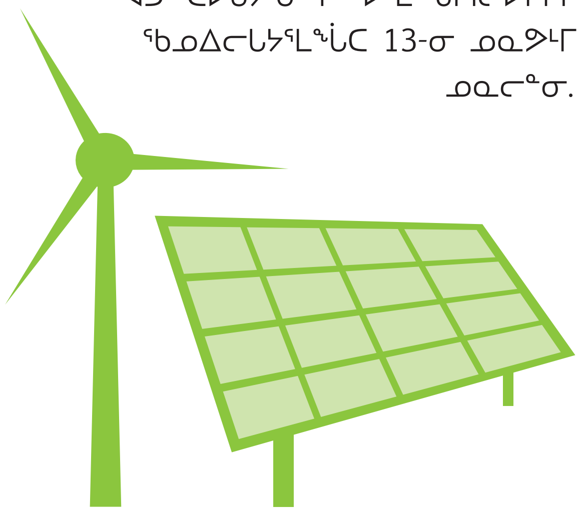
ᑲᓇᑕᒥ ᐅᑭᐅᑕᖅᑐᒥ ᓄᓇᕗᑦ ᑐᓐᖓᕕᖃᖅᑐᖅ ᐅᖅᓱᐊᓗᑦᑐᖅᑐᓄᑦ ᐆᒪᖅᑯᑎᓕᐅᓂᕐᒧᑦ ᐊᒻᒪ ᐆᓇᖅᑐᒥ ᐊᐅᓚᐅᑎᓂᑦ. ᑕᒪᓐᓇ ᓵᖅᑭᖅᑐᖅ ᕐᑯᕙᓯᑦᑐᓂᑦ ᐊᕙᑎᖓᓄ, ᑮᓇᐅᔭᓕᕆᓂᕐᒧᑦ ᐊᒻᒪ ᐃᖅᑲᓇᐃᔭᐅᑎᓄᑦ ᐊᑭᖏᓐᓂ ᓄᓇᕗᒻᒥᐅᓄᑦ. ᐅᖓᓯᓐᓂᖓᓃᑦᑐᑦ ᓄᓇᓖᑦ ᐊᒻᒪ ᐊᕐᕌᒍᓕᒫᒧᑦ ᐃᖏᕋᔾᔪᑎᒃᓴᖅᑎᐊᕋᓂ ᓲᓇᒃᑯᑕᑦ ᑭᖑᕙᖅᑳᑕᕐᓂᖏᑦ ᐊᒻᒪ ᓯᓚᕐᔪᐊᒥ ᐊᑭᖏᑦ ᕐᑯᕙᕆᐊᖅᑐᑦ ᐊᖏᔪᒥ ᐊᑦᑕᓇᕈᑎᖃᕈᓐᓇᖅᑐᑦ ᐊᕙᑦᑐᖅᓯᒪᔪᒧᑦ ᐆᒪᖅᑯᑎᓂ ᐊᑦᑕᓇᐃᖅᓯᒪᓂᕐᒧᑦ. ᐃᑯᐊᓚᑎᑦᑎᓂᖅ ᐅᖅᓱᐊᓗᓐᓂᑦ ᐅᖅᑰᓂᕐᒧᑦ ᐊᒻᒪ ᐆᒪᖅᑯᑎᓄᑦ ᐱᐅᖏᑦᑐᒥᑦ ᐊᑦᑐᐃᓂᖅᑲᖅᑎᑦᑎᔪᖅ ᐊᕙᑦᑐᖅᓯᒪᔪᒧᑦ ᓯᓚᖓᓂ ᐱᐅᓂᖓᓂ ᐊᒻᒪ ᕿᕐᓂᖅᑕᓂᑦ ᐳᔪᕐᓗᖅᑲᖅᑐᑎᑦ, ᓱᑲᑦᑎᑦᑎᕙᑦᓕᐊᔪ ᐊᐅᐸᑦᓕᐊᓂᖓᓂ ᐊᐳᑎ ᐊᒻᒪ ᓂᓚᖓᓂ. ᐅᖅᓱᐊᓗᒃ ᐅᒥᐊᕐᔪᐊᒃᑰᖅᑎᑕᐅᕙᒪᑦ, ᑯᕕᔪᑦ ᓄᓇᒥ ᐊᒻᒪ ᐃᒪᕐᒥ ᐊᖏᔪᒥ ᐊᑦᑕᓇᕈᑎᖃᕈᓐᓇᕐᒥᔪᑦ ᐊᕙᑎᖓᓄᑦ.

2016-ᒥᓂᑦ, WWF-ᑲᓇᑕᒥ ᐅᑭᐅᑕᖅᑐᒥ ᐱᓕᕆᐊᖅ ᐃᖅᑲᓇᐃᔭᖅᓯᒪᔪᑦ ᑕᑯᔅᓴᐅᑎᑦᑎᓗᑎ ᐊᑎᑦᑐᒥᑦ ᐊᑦᑐᐃᓂᖃᖅᑎᑦᑎᔪᑦ ᐊᐅᓚᔪᓐᓇᐅᑎᓂᑦ ᐊᓄᕆᒧᑦ ᐊᒻᒪ ᓯᕿᓂᕐᒧᑦ ᐊᒻᒪ ᐃᑲᔪᕐᓂᖃᕈᓐᓇᖅᑐᖅ ᒪᑭᒪᑎᑕᐅᓂᖏᓐᓄ ᐅᑭᐅᑕᖅᑐᒥ ᑲᓇᒥ ᓄᓇᓕᓐᓂᑦ. ᖃᐅᔨᓴᕐᓂᐅᖃᑦᑕᖅᓯᒪᔪᑦ ᐃᑲᔪᖅᑕᐅᔪᑦ WWF-ᑲᓇᑖᒃᑯᓐᓄᑦ ᒥᔅᓴᐅᓴᔅᓯᒪᔪᑦ ᐊᑐᖅᑕᐅᓂᖏᑦ ᐆᒪᖅᑯᑎᓕᐅᕈᑏᑦ ᐅᑭᐅᑕᖅᑐᒥ ᓄᓇᓕᓐᓂ ᖃᓄᐃᑦᑑᒐᔭᕐᒪᖔᖅ ᐊᒻᒪ ᖃᐅᔨᓵᖅᑐᖏᑦ ᖃᓄᖅ ᑮᓇᐅᔭᖃᖅᑎᑕᐅᓂᖓ ᐊᒻᒪ ᐅᖅᓱᐊᓗᑦᑐᖅᑐᓄᑦ ᐃᑲᔫᑎᓂᑦ ᐊᑐᐃᓐᓂᖃᕋᔭᕐᓂᖓᓄ ᓈᒪᓐᓂᖓᓄ ᖃᐅᔨᓴᓂᕐᒥᑦ ᐆᒪᖅᑯᑎᓕᐅᖅᑐᓂ ᐊᐅᓚᐅᑎᓂᑦ ᓄᓇᕗᒻᒥ.

WWF-ᑲᓇᑕ ᐃᑲᔪᖅᓱᕈᓐᓇᖅᑐᑦ ᐊᐅᓛᕐᓂᖓ ᓇᔪᖅᑕᐅᔪᒥ ᓯᓚᓗ ᐱᐅᔪᒥ ᐆᒪᖅᑯᑎᓕᐅᕐᓂᕐᒧᑦ ᓄᓇᕗᒻᒥ ᐃᖅᑲᓇᐃᔭᕐᑲᑎᕐᑲᖅᑐᑎᑦ ᐱᓕᕆᕐᑲᑎᕐᑲᓂᒃᑯᑦ ᓄᓇᓕᓐᓂᑦ ᓴᖅᑭᑎᑦᑎᓗᑎ ᐆᒪᖅᑯᑎᓕᐅᕐᓂᕐᒥᑦ ᐱᓕᕆᕐᑲᑏᑦᑐᓂᑦ, ᐃᓕᓐᓂᐊᑎᑦᑎᓗᑎ ᐊᒻᒪ ᐃᓕᓐᓂᐊᕐᓂᓕᕆᓂᐅᔪᑦ, ᐊᒻᒪ ᐱᑕᖅᑲᖅᑎᑦᑎᓗᑎ ᐆᒪᖅᑯᑎᓕᐅᕐᓂᕐᒧᑦ ᕿᐅᔾᒪᓂᐅᔪᓂᑦ.

ᓄᓇᕗᑦ ᐊᑐᕆᐊᖓ ᓄᑕᐅᓐᖑᕈᓐᓇᖅᑐᓄᑦ

WWF-ᑲᓇᑕ ᐱᖃᑕᐅᔪᑦ ITP ᓄᑕᐅᓐᖑᕈᓐᓇᖅᑐᑦ ᑐᑭᓯᒋᐊᖅᑎᑎᓪᓗᑎ ᐊᒻᒪ ᐊᖏᓪᓕᒋᐊᖅᑐᒍ 2016 ᓯᕗᓂᐊᒍ-ᓈᒻᒪᓐᓂᖓᓄ ᖃᐅᔨᓴᓂᕐᒥᑦ ᒥᎬᐅᓴᑦᑎᑦᑎᓚᐅᖅᑐᖅ ᖃᓄᐃᑦᑐᑦ ᐊᑐᖅᑕᐅᒐᔭᕐᓂᖏᑦ ᐆᒻᒪᖅᑯᑎᓕᐅᕈᑏᑦ ᖃᓄᐃᓕᒐᔭᕐᒪᖕᓚᑕ 13-ᓂ ᓄᓇᕗᒻᒥ ᓄᓇᓕᓐᓂ.



ᐊᑐᖅᑐᑎ ᐃᓄᓐᓄᑦ ᐊᑐᐃᓐᓇᐅᔪᓂᑦ ᑐᑭᓯᒋᐊᕈᑎᓂᑦ ᓄᓇᓕᒻᒥ ᐅᖅᓯᐊᓄ ᐊᑐᖅᑕᐅᓂᖏᓐᓄᑦ ᐆᓇᖅᑎᑦᑎᓂᕐᒧᑦ ᐊᒻᒪ ᐆᒪᖅᑯᑎᓕᐅᓂᕐᒧᑦ, ᐆᒻᒪᖅᑯᑎᓄᑦ ᐊᑭᖏᓐᓂ ᒥᎬᐅᓴᓐᓂᖅ, ᐊᒻᒪ ᐃᓄᒋᐊᓐᓂᖏᑦ ᐊᒻᒪ ᐆᒻᒪᖅᑯᑎᒧ ᐊᑐᖅᑕᐅᓂᖓ ᒥᎬᐅᓴᑦᑕᐅᔪᑦ, ᖃᐅᔨᓴᕐᓂᐅᔪᖅ ᑕᑯᒃᓴᐅᑎᑦᑎᔪᖅ ᑮᓇᐅᔭᖅᑐᖏᑖᓄᑦ ᐋᖅᑭᑌᐅᔪᑦ 25-ᓄ ᓄᓇᓕᓖᓄᑦ ᑎᑭᑦᑎᓗᑎ ᖁᑦᑎᓂᖅᓴᓂᑦ ᐆᒻᒪᖅᑯᑎᓂ ᑐᓂᓯᒥᔪᓂᑦ. ᑕᐃᒪᐃᒍᓐᓇᑎᓪᓗᒍ ᓯᕿᓂᕐᒧᑦ ᐊᒻᒪ ᐊᓄᕆᒧᑦ ᑐᑭᓯᒋᐊᕈᑏᑦ ᐱᔭᐅᓚᐅᖅᑐᑦ ᓄᓇᒥ ᖃᐅᔨᓴᖅᑕᐅᓯᒪᔪᓂᑦ s — ᐊᑐᐃᓐᓇᐅᕐᒋᒃᑎ, NASA ᖁᒻᒧᐊᑦᑎᑕᐅᓯᒪᔫᒃᑯᑦ ᑐᑭᓯᒋᐊᕈᑏᑦ ᐊᑐᖅᑕᐅᓚᐅᖅᑐᑦ, ᒥᎬᐅᓴᑦᑕᐅᔪᑦ ᐋᖅᑭᑦᑕᐅᓚᐅᖅᑐᑦ ᐊᑐᖅᑐᑎᑦ ᖃᐅᔨᒪᔭᐅᔪᓂᑦ ᐊᔾᔨᐸᓗᕐᒋᓐᓂ ᐊᕐᒋᓂᖅᑳᖅᑐᓂ ᓄᓇᓕᓐᓂ.

ITP ᓄᓇᒥᓴᖅᑐᑦ ᓯᓚᒧᑦ ᐱᔪᓂᑦ ᐊᑐᖅᑕᐅᔪᑦ 15-ᓄᑦ ᐊᕐᕋᒍᓄᑦ ᐱᓕᕆᐊᖅ ᐊᑯᓂᐅᓂᖅᑲᖅᑐᖅ ᕿᓇᐅᔭᓕᕆᓂᖏᒧᑦ ᖃᐅᔨᓴᐃᓂᖏᒧ. ᓯᕿᓂᖏᒧᑦ ᐊᒻᒪ ᐊᓄᕆᒧᑦ ᐊᑯᓂᐅᓂᖅᓴᐅᓚᔪᓃᑦ ᐊᒻᒪ ᓯᕗᓂᔅᓯ ᐃᒻᒥᒃᑯᑦ ᐆᒪᖅᑯᑎᓕᐅᖅᑲᑦᑕᖅᑐᑦ ᑳᓐᑐᕌᑦ ᐊᑯᓂᐅᓂᖅᑲᓂᐊᖅᑐᑦ ᐊᕙᑎᓄᑦ ᐊᕐᕋᒍᓄᑦ. ᐅᓂᒃᑳᑦ ᐱᖃᓯᐅᔾᔩᒻᒥᔪᖅ ᕿᓇᐅᔭᓕᕆᓂᕐᒥᑦ ᖃᐅᔨᓴᓂᕐᒥᑦ ᐱᖓᓱᓂᑦ ᖃᑦᑏᓇᐅᔮᕆᔭᕐᒋᓐᓂ ᓄᓇᒥᓴᖅᑐᓂᑦ ᓯᓚᒧᑦ ᐱᐅᔪᓂᑦ ᐆᒪᖅᑯᑎᓕᐅᕆᓂᖏᒧᑦ ᖃᓄᐃᓐᓕᖓᓂᐅᔫᓐᓇᖅᑐᑦ (20 ᐳᓴᓐᑎ, 40 ᐳᓴᓐᑎ, ᐊᒻᒪ 60 ᐳᓴᓐᑎ) ᐊᒪᓗᑦᑕᐅᖅ ᐅᖅᓯᐊᓗᑦᑐᖅᑐᓂᑦ ᑕᒪᒃᑭᓐᓂ ᑎᓴᒪᐅᔫᖅᑐᓂᑦ ᐳᓴᓐᑎᓂᑦ ᐊᒻᒪ ᑎᓴᒪᓂᑦ ᐳᓴᓐᑎᓂᑦ ᐊᑭᑭᓪᓕᒋᐊᕐᓂᕐᒋᑦ ᖃᐅᔨᓴᕐᓗᒋᑦ ᐊᑦᑐᖅᑕᐅᔪᑦ ᖀᓇᐅᔭᖅᖃᐅᑎᑦᑎᓂᕐᒧᑦ ᓈᒻᒪᓂᖓᓄᑦ ᖃᐅᔨᓴᓂᕐᒧᑦ. (ᐅᓇ "ᐊᑭᑭᓪᓕᒋᐊᕐᓂᖓ" ᐊᑭᒋᔭᖓ ᐊᑐᖅᑐᐊᕐᓗᓂ ᖀᓇᐅᔭᓂᑦ -- ᐊᑦᑐᖅᑕᐅᔪᖅ ᕿᑐᓐᖏᕐᒋᐅᕈᑎᖏᓐᓄᑦ, ᐱᔭᕐᓴᐅᓂᖏᓐᓄᑦ ᑐᓂᔭᐅᔪᓂᑦ ᖀᓇᐅᔭᐃᑦ, ᐊᒻᒪ ᖃᓄᑎᒋ ᐊᑦᑕᓇᕈᑎᕐᑲᕈᓐᓇᕐᓂᖓᓄᑦ ᖀᓇᐅᔭᒃᑯᕕᒃ ᐃᓱᒪᒋᔭᖓᓄ ᐱᓕᕆᐊᒧᑦ.)

ᖃᐅᔮᔭᓪᓗᐊᑕᐅᔪᑦ

ᐊᑦᑎᓂᖅᓴᐃᑦ ᐊᑭᖏᑦ ᐆᒪᖅᑯᑎᓕᐅᓂᕐᒧᑦ ᓯᓚᒧᑦ ᐱᐅᔪᓄᑦ ᐋᖅᑭᑦᑐᑎᓂᑦ

ᐹᑦᑖᓄᑦ ᑐᖅᑯᖅᑕᐅᓯᒪᔪᓄᑦ ᐃᑲᔪᖅᑕᐅᔪᑦ ᐊᓄᓇᒧᑦ ᐅᑫᓘᓐᓅᑦ ᓯᕿᓂᕐᒧᑦ — ᑭᓯᐊᓂ ᑕᒪᒃᑭᐅᕐᒋᑦᑐᖅ — ᐱᔪᒥᓇᓛᖑᔪᖅ ᓄᓇᒥᓴᖅᑐᑦ ᓯᓚᒧᑦ ᐱᔪᓂᑦ ᐆᒪᖅᑯᑎᓕᐅᕐᕐᒧᑦ ᐋᖅᑭᒍᑏᑦ ᐊᒥᓲᓂᖅᓴᓄᑦ ᓄᓇᓕᓐᓄᑦ. ᐊᑦᑎᓪᓕᒋᐊᖅᓯᒪᓂᕐᒋᓐᓄᑦ ᐹᑦᑖ ᐊᑭᕐᒋᓐᓄᑦ ᐊᕐᕋᒎᓯᒪᓕᖅᑐᓂᑦ, ᐱᑕᖃᖅᑎᑎᓪᓚᕆᐊᖅᑲᕈᓐᓃᖅᑐᖅ ᐊᔾᔩᕐᒋᑦᑐᓂᑦ ᓄᓇᒥᓴᖅᑐᓂ ᐆᒪᖅᑯᑎᓕᐅᕆᓂᖏᒧᑦ ᐃᑲᔪᖃᑦᑕᐅᑎᓪᓗᑎ ᐹᑦᑖᓄᑦ ᑐᖅᑯᐃᕝᕆᖅᑎᐊᕐᒋᓐᓂᖓᓄᑦ. ᓄᓇᒥᓴᖅᑐᓂᑦ ᐆᒪᖅᑯᑏᑦ ᐊᑭᑭᓪᓚᑰᓪᓕᑎᓪᓗᑎᑦ ᐊᒻᒪ ᐊᐅᓚᓂᖅᑲᑦᑎᐊᓂᖅᓴᐃᓗᑎ, ᓈᒻᒪᓐᓂᖓᓄ ᖃᐅᔨᓴᕐᓂᖅ ᓄᓇᒥᓴᖅᑐᑦ ᖁᕝᕙᓇᐊᖅᑐᑦ.

ᐊᓐᓂᕆᑦᑕᐃᓕᒃᑭᑦ ᑯᕕᔪᑦ ᐆᒪᖅᑯᑏᑦ

ᐊᔾᔨᒃᖃᑎᑦᑎᓂᖅ ᓱᓇᒃᑯᑖᓂᑦ ᐱᔭᐅᔪᒪᔪᓂᑦ ᐊᔾᓯᕈᓐᓇᕈᓐᓇᖅᑐᖅ — ᐃᑖᓐᓂᒃᑯᑦ, ᓄᓇᒥᓴᖅᑐᑦ ᐆᒪᖅᑯᑏᑦ ᐱᓕᕆᐊᑦ ᐆᒪᖅᑯᑎᒃᑎᑎᓂᖅᓴᐅᔪᓐᓇᖅᑐᑦ ᐱᔭᐅᔭᕆᐊᖅᑲᖅᑐᓂᑦ. ᓴᖑᑎᑦᑐᕆᑦ ᑖᓐᓇ ᐆᒪᖅᑯᑎᒃᓐᓂᐅᔪᖅ ᐆᓇᖅᑎᑦᑎᓂᖏᑦ, ᐅᖅᓯᐊᓗᑦᑐᕐᓂᖅ ᐊᑦᑎᓕᒋᐊᕈᓐᓇᕋᔭᖅᑐᖅ, ᓄᓇᒥᓴᖅᑐᑦ ᐆᒪᖅᑯᑎᓕᐅᕆᓂᖏᒧᑦ ᐱᔪᒥᓇᖅᓯᑎᑦᑎᒃᓐᓂᑎᑦᑎᔪᖅ. ᖃᒪᓂᑦᑐᐊᖅ, ᐆᑦᑑᑎᒋᓗᒍ, ᓇᓗᓇᐃᖅᑕᐅᓯᒪᔪᖅ ᓄᓇᓕᐅᔪᖅ ᐊᓄᕆᒧᑦ ᐆᒪᖅᑯᑎᒃᑲᓐᓂᐅᔪᑦ ᐊᑐᖅᑕᐅᔪᓐᓇᖅᑐᑦ ᐆᓇᖅᑎᑦᑎᓂᕐᒧᑦ, ᐃᓚᓯᒃᑲᓂᖅᑐᖅ $2 ᒥᓕᐊᓐᑲᓂᕐᓂᑦ ᖀᓇᐅᔭᑐᕐᓂᖓᓄ ᐱᓕᕆᐊᖅ. ᐅᖅᑰᑎᑦᑎᔾᔪᑎᖓ, ᓴᓂᐊᓂ ᐅᖅᓯᐊᓗᒻᒧᑦ ᐊᑐᖅᑕᐅᔪᓂ ᐆᒪᖅᑯᑎᓕᐅᕆᓂᒧᑦ, ᒐᕙᒪᑐᖅᑲᒃᑯᓐᓄᑦ ᐳᔪᕐᓗᓄᑦ ᑖᒃᓯᓕᖅᑕᐅᔪᓐᓇᖅᑐᖅ ᑖᓐᓇ ᖀᓇᐅᔭᖅᑐᓗᐊᕐᒋᑎᑦᑎᔪᖅ.

ᖃᓄᖅ ᐋᖅᑭᑦᓴᐅᓂᖓ ᐆᒪᖅᑯᑎᓄᑦ ᐊᑭᖓ

ᓈᒻᒪᓂᓇᔭᖓ ᓄᓇᒥᓴᖅᑐᓂ ᐆᒪᖅᑯᑎᓕᐅᕆᓂᖏᒧᑦ ᐱᓕᕆᐊᑦ ᐊᕐᒋᔪᒥᑦ ᐊᔾᔨᕐᒋᓂᖅᑲᕈᓐᓇᖅᑐᑦ ᑐᓐᖓᓂᖅᑲᖅᑐᑦ ᖀᓇᐅᔭᓕᕆᓂᖏᒧᑦ ᐱᔾᔪᑕᐅᔪᑦ. ᓇᐸᑦᑐᐊᐸᓗᕐᒋᑦ ᓄᓇᓖᑦ ᓄᓇᕗᒻᒥ ᐱᔪᒥᓇᓂᖅᓴᓕᖅᑐᑎᑦ ᓄᓇᒥᓴᖅᑐᓂ ᐆᒪᖅᑯᑎᓕᐅᕆᓂᖏᒧᑦ ᐱᓕᖓᓇᐊᒥ ᐱᕙᓪᓕᐊᑎᑦᑎᓂᖏᒧᑦ ᕿᑐᓐᖏᕐᒋᐅᕈᑎᑭᒃᓴᓇᐊᓕᒃ ᐱᔾᔪᑎᔪᓐᓇᕐᓱᑎ ᐊᑭᑐᔪᓄᑦ ᐊᑐᐃᓐᓇᐅᑎᑕᐅᓗᑎ.

ᐊᑦᑐᖅᑕᐅᓴᕋᐃᓐᓂᕐᒋᓐᓄᑦ ᖃᐅᔨᓴᕐᓗᒋᑦ ᐊᑦᑐᖅᑕᐅᔪᑦ ᐊᔾᔩᕐᒋᑦᑐᓄᑦ ᖀᓇᐅᔭᓕᕆᓂᖏᒧᑦ ᐊᑭᕐᒋᓐᓄᑦ ᖃᐅᔨᓴᕐᓂᖅᑲᓚᐅᖅᑐᑦ ᐱᖓᓱᓂᑦ ᓄᓇᓕᓐᓂᑦ: ᑲᖏᖅᖠᓂᖅ, ᓴᓂᕿᓗᐊᖅ ᐊᒻᒪ ᖃᒪᓂᑦᑐᐊᒥ. ᑲᖏᖅᖠᓂᖅ ᐱᒧᒥᓇᓚᐅᖅᑐᓂ ᐊᑐᕐᓗᓂ ᐊᑐᖅᑕᐅᒐᔪᑦᑐᓂ ᖀᓇᐅᔭᓕᕆᓂᖏᒧᑦ ᐃᓱᒪᒋᔭᐅᔪᓂᑦ -- ᐱᓕᕆᐊᖅ ᐊᑯᓂᐅᓂᖅᑲᖅᑐᖅ 15-ᓂᓄᑦ ᐊᕐᕋᒍᓄᑦ ᐊᒻᒪ ᑎᓴᒪᐅᔫᖅᑐᓂᑦ ᐳᓴᓐᑎᓂ ᐊᑭᑭᓪᓕᒋᐊᕐᓂᖓ ᖁᑦᑕᕆᓐᓂᖓ -- ᒥᑭᓂᖅᓴᐅᔪᑦ ᓄᓇᓖᑦ ᓴᓂᕿᓗᐊᖅ ᐊᒻᒪ ᖃᒪᓂᑦᑐᐊᖅ ᑕᑯᔅᓴᐅᑎᑦᑎᓚᐅᖅᑐᑦ ᐊᕐᒋᔪᒥᑦ ᑐᓐᖓᕕᖃᕐᓂᕐᒧᑦ ᐱᓕᕆᐊᒧᑦ ᖀᓇᐅᔭᖅᑲᖅᑎᑦᑎᓂᕐᒧᑦ. ᑎᓴᒪᓂᑦ ᐳᓴᓐᑎᓂ ᐊᑭᑭᓪᓕᒋᐊᕐᓂᖓ ᖁᑦᑕᕆᓐᓂᖓ ᓄᓇᒥᓴᖅᑐᓂ ᐆᒪᖅᑯᑎᓕᐅᕆᓂᖅ ᑎᑭᓯᒪᔪᒧ 70 ᐳᓴᓐᑎ ᐱᔪᒥᓇᕐᓂᖓ ᖃᒪᓂᑦᑐᐊᒧᑦ ᓴᓂᕿᓗᐊᕐᒧᓪᓗ ᐊᑦᑎᓂᖅᓴᖅ ᐊᑭᑭᓪᓕᒋᐊᕐᓂᖓ ᖁᑦᑕᕆᓐᓂᖓ ᐊᑭᖓᓂ ᐅᖅᓯᐊᓗᒃ ᕿᓚᒥᐅᔪᒥᑦ ᐱᓕᕆᐊᖑᒍᓐᓇᕋᔭᖅᑐᖅ.

20% ᓄᓇᒦᙵᖅᑐᓂᑦ ᐆᒻᒪᖅᑯᑎᓕᐅᕐᓂᖅ ᖃᓄᐃᓕᖓᓂᐅᔪᓐᓇᖅᑐᑦ

ᓄᓇᓕᐅᔪᖅ	8% ᐊᑭᑭᓪᓕᒋᐊᕐᓂᖓᓄᑦ ᖁᕝᕙᓯᓐᓂᖓ	4% ᐊᑭᑭᓪᓕᒋᐊᕐᓂᖓᓄᑦ ᖁᕝᕙᓯᓐᓂᖓ
ᐃᑉᐱᐊᕐᔪᒃ	[grey]	[orange]
ᐊᕐᕕᐊᑦ	[grey]	[orange]
ᖃᒪᓂᑦᑐᐊᖅ	[grey]	[green]
ᐃᖃᓗᒃᑑᑦᑎᐊᖅ	[grey]	[grey]
ᑭᙵᐃᑦ	[grey]	[orange]
ᐃᒡᓗᓕᒑᕐᔪᒃ	[orange]	[orange]
ᑲᖏᖅᑐᒐᐱᒃ	[grey]	[grey]
ᓴᓪᓖᑦ	[orange]	[green]
ᐅᖅᓱᖅᑑᖅ	[grey]	[grey]
ᐊᐅᔨᑦᑐᖅ	[orange]	[orange]
ᓴᓂᕋᔭᒃ	[orange]	[orange]
ᐃᒡᓗᓕᒃ	[grey]	[orange]
ᐃᖃᓗᐃᑦ	[green]	[green]
ᑭᒻᒥᕈᑦ	[orange]	[orange]
ᑰᒑᕐᔪᒃ	[grey]	[orange]
ᖁᕐᓗᖅᑑᖅ	[grey]	[grey]
ᓇᐅᔮᑦ	[orange]	[orange]
ᐸᓐᓂᖅᑑᖅ	[grey]	[orange]
ᒥᑦᑎᒪᑕᓕᒃ	[grey]	[grey]
ᕿᑭᖅᑕᖅᔪᐊᖅ	[grey]	[orange]
ᑲᖏᖅᖠᓂᖅ	[green]	[green]
ᖃᐅᔨᑦᑐᖅ	[grey]	[orange]
ᓴᓂᑭᓗᐊᖅ	[orange]	[orange]
ᑕᓗᖅᔪᐊᖅ	[grey]	[orange]
ᑎᑭᕋᖅᔪᐊᖅ	[orange]	[orange]

ᑎᑎᕋᖅᓯᒪᔪᑦ ᐊᑖᓂ ᐊᑐᖅᑐᑦ 20 ᐳᓴᓐᑎᒥ ᖃᓄᐃᓕᖓᓂᐅᔪᓐᓇᖅᑐᖅ ᐆᑦᑑᑎᒋᓪᓗᒍ ᓴᖅᑭᑎᓪᓗᒍ ᐊᑦᑐᖅᑕᐅᓂᖓ ᐅᑦᑎᑦᑐᑦ ᕿᑐᙵᕆᐅᕈᑎᖏᑦ ᐱᓕᕆᐊᖅ ᑮᓇᐅᔭᖃᖅᑎᑕᐅᓂᖓ ᐱᓕᕆᐊᒧᑦ ᓈᒪᓂᖃᕈᓐᓇᖅᑐᖅ, ᐊᔾᔨᒋᙱᖦᖢᐊᖅᑐᒋᑦ 8 ᐊᒻᒪ 4 ᐳᓴᓐᑎᓂ ᐊᑭᑭᓪᓕᒋᐊᕐᓂᖓ ᖁᕝᕙᓯᓐᓂᖓ ᖃᓄᐃᓕᖓᓂᕆᔭᐅᓇᖅᑕᖏᓐᓄᑦ.

ᒫᓇᑦᑕᐅᑎᒋ ᑕᐃᒪᐃᓐᓂᖃᓂᐊᖅᑑᔾᔨᕐᒋᑦᑐᖅ

ᖃᓂᒋᔾᔭ – ᖃᐅᔾᔭᖅᑕᐅᑲᓂᓇᐊᓕᒃ

ᑮᓇᐅᔭᓂᑦ ᐱᐅᖅᓱᐊᕐᓗᑎᕐ!

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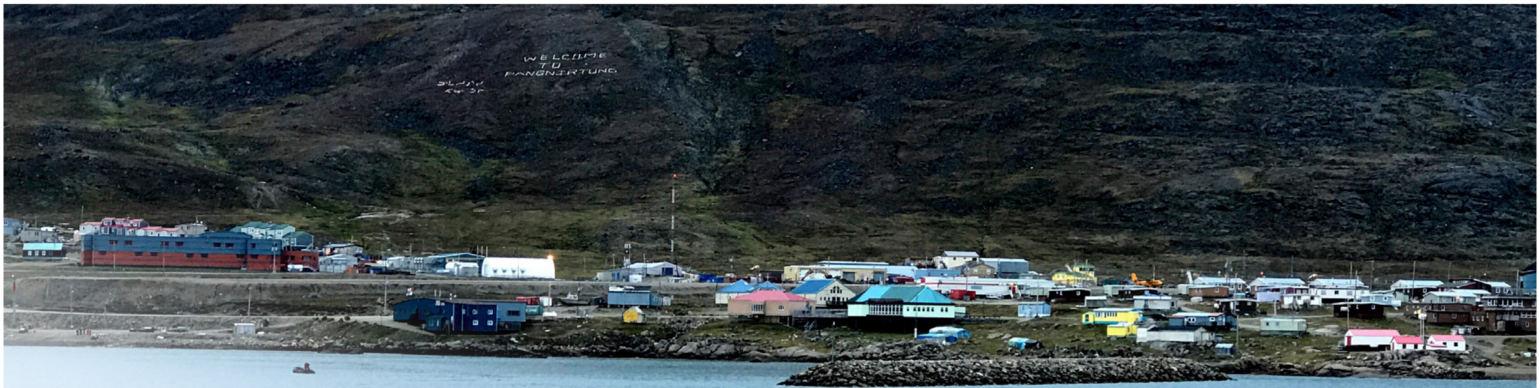

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ᖁᑦᑎᓛᖑᔪᑦ ᓄᓇᓖᑦ ᑮᓇᐅᔭᒃᑐᓗᐊᖏᑦᑐᓂᑦ ᐊᑦᑎᖓᓕᒋᐊᒃᑎᑦᑎᓂᕐᒧᑦ ᐳᔪᕐᓗᓂ ᓯᓚᒨᒃᑲᐃᓂᕐᒧᑦ

ᑐᓐᖓᕕᒋᓪᓗᒋᑦ ᐊᑯᓂᐅᓂᖏᓐᓄᑦ ᐊᑭᖏᑦ ᓄᓇᒥᖒᒃᑐᓂᑦ ᐆᒪᒃᑯᑎᓕᐅᓂᕐᒧᑦ ᐱᓕᕆᐊᑦ ᐊᔾᔨᐸᓗᒋᔭᖓ ᒥᔅᓴᐅᓴᑦᑕᐅᓯᒪᔪᓄᑦ ᐊᖏᓂᖓ ᑕᒪᐅᖓᑐᐃᓐᓈᒃᑐᒃ ᐅᒃᓯᐊᓗᒃ, ᐊᒻᒪ ᓴᖏᓂᖓ ᓄᓇᓕᒻᒥ ᓯᕿᓂᕐᒧᑦ ᐊᒻᒪ ᐊᓄᓇᒧᑦ, ᐊᕝᕕᓃᑦ ᓄᓇᓖᑦ ᓇᓗᓇᐃᒃᑕᐅᓯᒪᔪᑦ ᑮᓇᐅᔭᒃᑐᖏᓛᖑᔪᓐᓇᒃᑐᑎᑦ ᐊᑦᑎᖓᓕᒋᐊᒃᑎᑦᑎᓂᕐᒧᑦ ᐳᔪᕐᓗᓂ ᓯᓚᒨᒃᑲᐃᓂᕐᒧᑦ: ᑲᖏᕐᖠᓂᖅ, ᐃᖃᓗᐃᑦ, ᖃᒪᓂᑦᑐᐊᖅ, ᐃᒡᓗᓕᒫᕐᔪᒃ, ᓴᓪᓖᑦ ᐊᒻᒪ ᓴᓂᑭᓗᐊᖅ.

ᐱᑕᖃᓇᐊᖃᒃᑲᓂᕐᓂᖓ ᐊᒻᒪ ᐱᐅᓂᖅᓴᓂᑦ ᖃᐅᓴᕈᑎᒥᓂᕐᓂᑦ ᑎᑎᕋᖅᓯᒪᔪᓂᑦ

ᐱᐅᓂᖅᓴᓂᑦ ᖃᐅᓴᕈᑎᒥᓂᕐᓂᑦ ᑎᑎᕋᖅᓯᒪᔪᓂᑦ ᐱᐅᓂᖓᓄᑦ ᐊᓄᓇᒧᑦ ᐊᒻᒪ ᓯᕿᓂᕐᒧᑦ ᐊᑐᓂ ᓄᓇᓕᓐᓂ ᐊᒻᒪ ᖁᖎᕙᓯᓐᓂᓇᕙᑦᑕᖏᑦ ᐊᑐᖅᑕᐅᓂᖓᓄᑦ ᐆᒪᒃᑯᑏᑦ ᐱᑕᖃᓇᐊᖃᒃᑐᑦ ᓱᑲᑦᑐᒥᑦ ᖃᐅᔾᔅᐃᓂᖃᓂᐊᕐᓗᓂ ᑮᓇᐅᔭᑎᒍᑦ ᓈᒻᒪᓂᖓᓄᑦ ᓄᓇᒥᖒᒃᑐᓂ ᐆᒪᒃᑯᑎᓕᐅᓂᕐᒧᑦ ᐱᓕᕆᐊᓄᑦ ᓄᓇᕗᒻᒥ ᓄᓇᓕᖏᓐᓄᑦ.

ᓄᓇᕗᑦ ᐊᖏᔪᒥᑦ ᐊᓯᔾᔨᓕᖅᑐᖅ ᐆᒪᒃᑯᑎᓄᑦ ᐊᑐᕐᓂᖏᓐᓄᑦ. ᓴᖅᑭᖅᑎᑕᐅᓂᖓ ᑲᑎᑦᑐᒋᑦ ᖃᐅᔨᓴᐅᑦ ᐱᓕᕆᐊᖅ 2018-ᒥ ᐊᒻᒪ ᐱᒋᐊᖅᑎᑕᐅᓂᐅᓴᔪᖅ ᐃᒻᒥᒃᑯᑦ ᐆᒪᒃᑯᑎᓕᐅᖅᑎᐅᓂᖏᑦ ᐊᑕᐊᓚᖅ ᐊᑐᓇᐊᖃᖅᑎᑦᑎᔪᖅ ᓄᑖᓂᑦ ᐆᒪᒃᑯᑎᓕᐅᓂᖏᑦ ᓄᓇᕗᒻᒥ. ᓚᕙᒪᑐᖃᒃᑯᑦ ᐊᑭᖏᑦ ᐳᔪᕐᓗᓐᓄᑦ, ᐱᔪᒪᓂᕆᔭᐅᔪᖅ ᓄᓇᕗᓕᒫᒥ ᓄᓇᓕᓐᓂ ᐆᒪᒃᑯᑎᓕᐅᓂᖏᑦ ᐸᕐᓇᐃᓂᕐᒥᑦ ᐊᒻᒪ ᐱᓕᕆᐊᖃᓗᐊᕐᓗᓂ ᓚᕙᒪᑐᖃᒃᑯᓐᓄᑦ ᑮᓇᐅᔭᖃᖅᑎᑕᐅᔪᓂᑦ ᐅᖅᓱᐊᓗᑦᑐᓂᕐᒧᑦ ᐊᑦᑎᓕᒋᐊᒃᑎᑦᑎᓂᕐᒥᑦ ᐱᓕᕆᐊᓂᑦ ᐃᑲᔫᕐᓂᖃᒃᑐᑦ ᐊᔭᐅᖅᓯᒋᐊᒃᑐᑎᑦ ᐊᐅᓛᕐᓂᖓ ᓄᓇᒥᖒᒃᑐᓂ ᐆᒪᒃᑯᑎᓕᐅᓂᕐᒧᑦ ᐅᑭᐅᑕᒃᑐᒥ ᓄᓇᓕᓐᓄᑦ.

ᐅᑯᐊ ᐅᓂᒃᑳᑦ ᑕᑯᔅᓴᐅᑎᑦᑎᔪᑦ, ᓇᔪᒃᑕᐅᔪᒥ-ᓯᓚᒧᑦ ᐱᐅᔪᑦ ᓄᓇᒥᖒᒃᑐᑦ ᐆᒪᒃᑯᑎᓕᐅᕈᑎᑦ ᑐᓐᖓᑯᑎᔅᓴᐅᔪᑦ ᐊᒻᒪ ᓈᒻᒪᓂᖅᑲᒃᑐᓂ ᐆᒪᒃᑯᑎᖃᒃᑎᑦᑎᓂᕐᒧᑦ ᓄᓇᕗᒻᒥ ᓯᕗᓂᔅᓴᖓᓄᑦ.

ᑕᑯᔅᓴᐅᓂᖓ: ᑲᖏᕐᖠᓂᖅ


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ᐊᓄᓇᑦᑎᐊᖃᑦᑕᕐᓂᖓᓄᑦ ᐊᒻᒪ ᐊᖏᔪᒐᓚᐅᓪᓗᓂ ᓄᓇᓕᐅᔪᖅ 3,000-ᓂ ᐃᓄᓕᒃ, ᐅᓂᒃᑳᑦ ᖃᐅᔾᔨᒪᔪᑦ ᒫᓐᓇᑦᑕᐅᑎᒋ ᑮᓇᐅᔭᓕᓇᓂᕐᒧᑦ ᓄᓇᒥᖒᒃᑐᓂ ᐆᒪᒃᑯᑎᓕᐅᓂᕐᒧᑦ ᐱᕚᓕᐊᑎᑦᑎᓂᕐᒧᑦ ᑭᕚᓕᕐᒥ ᑲᖏᕐᖠᓂᕐᒥᑦ. ᐊᑕᐅᓯᖅ 2.3-megawatt ᐊᓄᓇᒧᑦ ᐆᒪᒃᑯᑎᓕᐅᕈᑦ, ᐹᑕᓖᒧᑦ ᓇᓕᐅᒃᑯᒫᖃᒃᑐᓂ, ᑎᑭᑦᑎᔪᓐᓇᒃᑐᖅ ᖃᓂᒋᔭᐸᓗᐊᓂ 50 ᐳᓴᓐᑎᓂ ᓄᓇᒥᖒᒃᑐᓂ ᐆᒪᒃᑯᑎᓂᕐ, ᐱᐅᒃᓱᐊᒃᑐᑦ 2.4 ᒥᓕᐊᓂ ᐃᒥᐅᕌᑦ ᐊᒻᒪ ᐊᑐᖏᑎᑦᑎᔪᑦ 6.2 kilotons ᐳᔪᕐᓗᓂ ᓯᓚᒨᒃᑲᒃᑐᓂ ᐊᕐᕕᒍᑕᓛᕐ. ᐋᖅᑭᔅᓯᓂᖅ ᐊᑕᐅᓯᒃᑲᓂᕐᒥᑦ ᐊᓄᓇᒧᑦ ᐆᒪᒃᑯᑎᓕᐅᕈᓪᒥᑦ ᑐᓂᓯᓂᖓ ᑎᑭᒍᓐᓇᕋᔭᒃᑐᖅ 74 ᐳᓴᓐᑎᓂ ᓄᓇᒥᖒᒃᑐᓂ ᐊᒻᒪ ᐆᒪᒃᑯᑎᓕᐅᕈᑎᐅᓗᐊᒃᑐᑦ ᐊᑐᒃᑕᐅᔪᓐᓇᕐᓗᑎ ᐆᓇᖅᑎᑦᑎᓂᕐᒧᑦ ᐊᑐᖏᓂᖅᓴᖃᓂᐊᕐᓗᒍ ᐅᖅᓱᐊᓗᒃ.

ᑐᑭᓯᒋᐊᒃᑲᓐᓂᕈᒪᒍᕕᑦ:
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ᖁᔭᓐᓇᒦᒃᑐᒋᑦ ᐅᖅᓱᐊᓗᓕᕆᔨᒃᑯᑦ ᓄᓇᕗᑦ ᒐᕙᒪᒃᑯᓐᓂᑦ, ᖁᓪᓕᖅ ᐆᒪᒃᑯᑎᓕᕆᔨᒃᑯᑦ ᑯᐊᐳᕇᓴᓐ, ᕿᑭᖅᑖᓗᒃ ᓇᒻᒥᓂᓕᓐᓄᑦ ᐱᕙᓪᓕᐊᑎᑦᑎᓂᕐᒧᑦ ᑯᐊᐳᕇᓴᓐ, ᐊᒻᒪ Northern Energy Capital ᑐᓂᓯᓂᖏᓐᓄᑦ ᑐᑭᓯᒋᐊᕈᑎᖏᓐᓂᑦ

RENEWABLE ENERGY IN NUNAVUT SCOPING ANALYSIS

Final Report

September 2019

About IT Power

The IT Power Group, formed in 1981, is a specialist renewable energy, energy efficiency and carbon markets consulting company. The group has offices and projects throughout the world.

IT Power (Australia) was established in 2003 and has undertaken a wide range of projects, including designing grid-connected renewable power systems, providing advice for government policy, feasibility studies for large, off-grid power systems, developing micro-finance models for community-owned power systems in developing countries and modelling large-scale power systems for industrial use.

The staff at IT Power (Australia) have backgrounds in renewable energy and energy efficiency, research, development and implementation, managing and reviewing government incentive programs, high level policy analysis and research, including carbon markets, engineering design and project management.

About this report

This report summarises a pre-feasibility study conducted for renewable energy integration in 25 communities in Nunavut, Canada. The study was conducted using the techno-economic power system modelling tool HOMER PRO.

This report was commissioned by World Wildlife Fund (WWF) Canada.

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EXECUTIVE SUMMARY

Canada's Arctic territory of Nunavut depends on fossil fuels for the entirety of its electricity and heat generation. As well as facing high prices and environmental risk from fossil fuel use and transportation through the territory, the extreme isolation and limited access year-round has meant that supply disruption and global price hikes pose a significant risk to the region's energy security. The consequence of this risk has been highlighted when regular shipments have been disrupted and vital fuel has instead been flown in via small aircraft to maintain services [1]. Previous studies have shown the potential to integrate renewable energy (RE) generation and storage as a pathway to reduce costs, and improve energy security and community resilience.

ITP Renewables was engaged by WWF Canada to undertake an expanded and updated RE pre-feasibility study encompassing all 25 communities serviced by the territory's utility, Qulliq Energy Corporation. This report is the updated pre-feasibility study, and includes assessment of the renewable energy resources, technical pre-feasibility, and economic analysis of three minimum RE scenarios (20%, 40% and 60% annual RE contribution) and the diesel-only base case.

The investigation finds that with an analysis period of 15 years, a discount rate of 8% (nominal), and relatively low diesel prices compared to historical volatility, two communities (Rankin Inlet and Iqaluit) appear to have an immediate case to move to higher RE contributions, while nine other communities have RE cases within $2m of breakeven. This suggests that, where grant funding is available to these communities, RE may be attractive and further study would be warranted.

At a 4% discount rate, Baker Lake and Coral Harbour join Rankin Inlet and Iqaluit as having an immediate case for RE integration. This suggests that, where concessional debt financing is available to these communities, and/or investment risk can be lowered, RE may be attractive and further study would be warranted.

At Rankin Inlet, it was found that the installation of a single 2.3MW wind turbine coupled with 1.6MW/3.36MWh battery pack gave an Internal Rate of Return (IRR) of 9.2% and a simple payback of 9.6 years. This could achieve around 49% RE, saving 2.4 ML of diesel fuel per year, 6.2 Mt of CO_2e emissions, and potentially up to 21 kL of avoided heating oil consumption by using excess renewable electricity for heating.

At Iqaluit, the integration of 5MW of PV (no storage) was found to have an IRR of 8.9% and simple payback of 9.4 years. This system would achieve an annual RE contribution of 10%.

In general, RE was more attractive where the wind resource data available showed higher and more consistent wind speeds, and where the community's electricity demand was larger (as this allowed for larger RE plant and the associated economies-of-scale). RE was also more attractive when the lower discount rate was assumed, as the discount rate is a proxy for the cost of capital, and RE investments are generally capital-intensive.

Sensitivity analysis was undertaken for three communities to investigate the influence that discount rate and diesel price has on the optimal RE capacity and return on investment. The analyses show that sensitivity to these variables is highly dependent on the community, with some communities being close to economic feasibility and others remaining a long way off.

Based on the lifecycle costs of RE scenarios relative to the diesel-only base case, the apparent strength of local wind resources, and the potential for cost-effective reductions in GHG emissions, Rankin Inlet, Iqaluit, Baker Lake, Coral Harbour, Chesterfield Inlet and Sanikuaq are suggested as priorities for further study.

In all cases, falling renewable energy and storage costs will improve the financial case for renewable energy investment in the medium term, and similarly for increasing diesel prices and/or a price on carbon.

LIST OF ABBREVIATIONS

BESS	Battery Energy Storage System
CAD	Canadian Dollars
CO2-e	Carbon Dioxide Equivalent, a unit of GHG emission
GHG	Greenhouse Gas
HOMER	Hybrid Optimisation of Multiple Energy Resources
IPP	Independent Power Producer
IRR	Internal Rate of Return
ITP	IT Power (Australia) Pty Ltd
kW	Kilowatt, unit of power
kWh	Kilowatt-hour, unit of energy (1 kW generated/used for 1 hour)
kWp	Kilowatt-peak, unit of power for PV panels tested at STC
NPC	Net Present Cost
PP2	Tesla Powerpack 2hr (charge/discharge rate allows full charge or discharge in 2 hours)
PP4	Tesla Powerpack 4hr (charge/discharge rate allows full charge or discharge in 4 hours)
PPD	Petroleum Products Division
PV	Photovoltaic
QEC	Qulliq Energy Corporation
RE	Renewable Energy
STC	Standard Test Conditions for PV panels (1,000 W/m^2 irradiance, 25 °C cell temperature, Atmospheric Mass 1.5)
WISE	Waterloo Institute for Sustainable Energy
WWF	World Wildlife Fund Canada
AUD	Australian Dollar
ITP	IT Power (Australia) Pty Ltd
kW	Kilowatt, unit of power
kWh	Kilowatt-hour, unit of energy (1 kW generated/used for 1 hour)
kWp	Kilowatt-peak, unit of power for PV panels tested at STC
PV	Photovoltaic
STC	Standard Test Conditions for PV panels (1,000 W/m^2 irradiance, 25 °C cell temperature, Atmospheric Mass 1.5)

CONTENTS

1. INTRODUCTION

1.1. Background

The northern Arctic territory of Nunavut has the highest cost of electricity in Canada, primarily due to a low population density and a dependence on imported fossil fuels for generation. Using diesel fuel for electricity generation contributes to climate change through the emission of greenhouse gases, and its transportation and use across the territory presents spill risk in Nunavut's unique natural environment. Pressingly, dependency on a single energy source presents risks to energy security, due to supply interruption and future price exposures, as was recently the case in the Northwest Territories when fuel and supplies had to be airlifted into Paulatuk [1]. These factors have led to the identification of local renewable energy resources, such as wind and solar, as important assets to make these remote communities more independent, sustainable and reduce electricity costs.

Qulliq Energy Corporation (QEC) is the generator and distributor of electrical energy for retail supply in Nunavut and has approximately 15,000 electrical customers across the territory. The Corporation generates and distributes electricity to Nunavummiut through the operation of stand-alone diesel plants in 25 communities meeting community peak demands ranging from approximately 200 kW at Grise Fiord to 10 MW at Iqaluit [2]. For the 2018/19 financial year, electricity generation is forecast to require 51,355,000 L of fuel at a cost of CAD $48 million.

Previous studies have investigated the potential integration of renewable energy and storage systems, and found systems with renewable energy could provide an attractive alternative to reduce fuel use for QEC. Both wind and solar have continued to become increasingly cost effective, as has battery storage technology [3], which historically has been a limiting factor in achieving higher renewable energy penetrations.

1.2. Objectives

The objective of the investigation is to perform a pre-feasibility study for integration of PV and wind for the 25 communities serviced by QEC. A number of scenarios are to be explored. Firstly, the baseline case which represents business as usual with diesel only, then three further increasing renewable energy contributions - 20%, 40% and 60%.

For each community, the study describes:

- the solar and wind resource based on best available data
- the existing diesel infrastructure
- current diesel consumption for both electricity and heating

- the decrease in diesel use and CO_2-e emissions as well as savings to energy generation and maintenance costs.

The report expands on earlier analysis [4] which considered a subset of 13 communities and provides updated analysis, including cost and technology changes (e.g. lithium-ion batteries are now preferable to lead-acid batteries due to significant cost reductions in the past three years) and quantification of surplus electrical energy that could be utilised by thermal loads in each community.

1.3. Previous Studies

1.3.1. Renewable Energy Deployment in Canadian Arctic - Phase 1: Pre-Feasibility Studies and Community Engagement for Nunavut 2016 [4]

The Waterloo Institute for Sustainable Energy (WISE) analysed the potential for solar PV and wind energy integration into the 25 Nunavut communities receiving power from QEC. The investigation conducted a two-step selection process to identify the communities for which renewable energy would prove most feasible. The initial 25 communities were passed through and assessed on the basis of their renewable energy resources, the transportation costs, the community size, greenhouse gas (GHG) emissions and the electricity rate. Taking the top results from each region, 13 communities were selected for further analysis. HOMER models were developed for each of these communities and used to assess the feasibility of renewable energy deployment based on 2015 load data. Ranking of the results was performed based on a number of criteria, including potential O&M savings (Sanikiluaq), lowest Cost of Electricity (COE) in a hypothetical no diesel case (Sanikiluaq), and offset generator capacity (Rankin Inlet), among others. The report then identifies the five communities recommended for more detailed feasibility studies: Sanikiluaq, Iqaluit, Rankin Inlet, Baker Lake and Arviat.

1.3.2. Rankin Inlet Energy Assessment Report – March 2018 [5]

The Alaska Centre for Energy and Power (ACEP) and WWF conducted extensive consultations with the community of Rankin Inlet in 2017 as a request from the community to identify solutions to reduce energy costs and improve resilience. The report explores in detail the potential for wind energy in the community and potential siting, and finds Rankin Inlet to be a highly promising site. The report identifies eight roadmap options for the community to consider over the short and long term. The detailed wind resource information provided by this report is included in our updated investigation.

1.3.3. Potential for Wind Energy in Nunavut Communities 2016 [6]

JP Pinard Consulting was engaged by QEC to the assess the wind resource in 25 communities, determine which of the sites have the potential for economic wind operation and identify next steps. Using RETScreen to conduct the analysis in the first instance and then HOMER to subsequently model operational aspects, the study found the top five communities to be the same as the above WISE report. The authors note that QEC is justified in moving forward in considering wind energy developments with both large and small turbines. The cost assumptions provided in the 2016 report, while noting their own considerable uncertainties, were considered to be suitable for our study as a pre-feasibility estimate and used in the proceeding analysis to develop cost curves for small- and large-scale wind.

1.4. Communities & Diesel Usage

Data on the consumption of diesel fuel for both heating and electricity generation for the communities ranked by population is summarised in Figure 1. Appendix A includes a table of this information for the 25 communities.

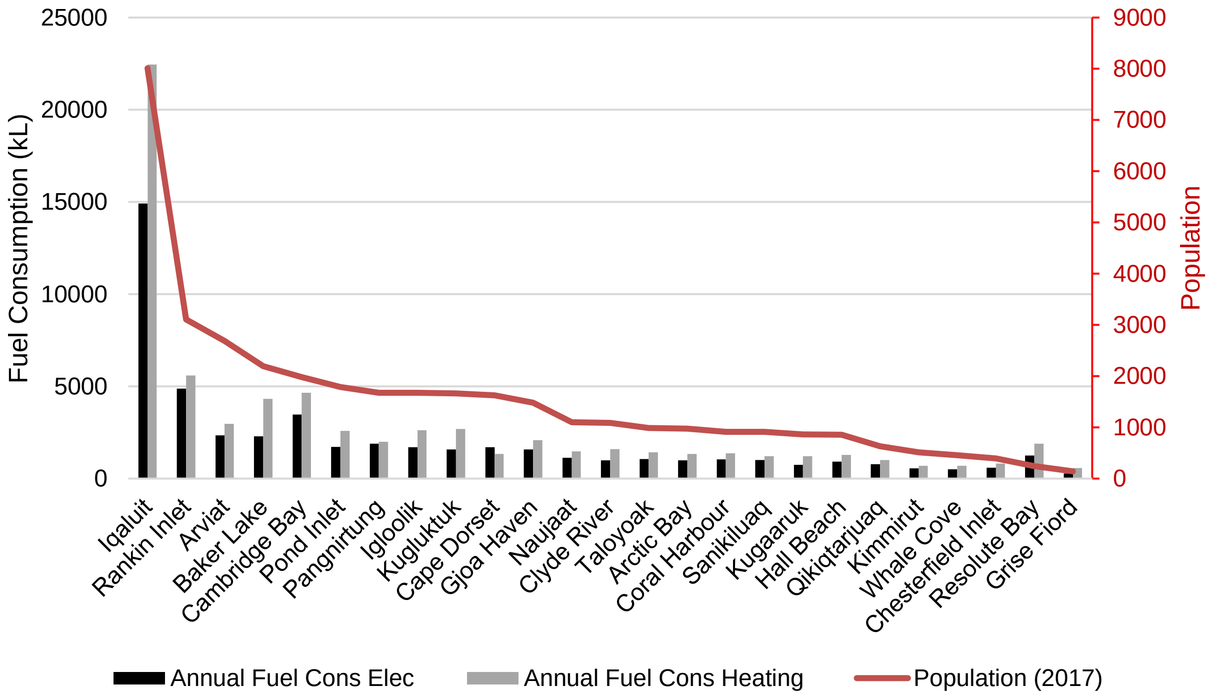

Figure 1 Population and fuel consumption for each community [12]

The location of each community is shown in Figure 2.

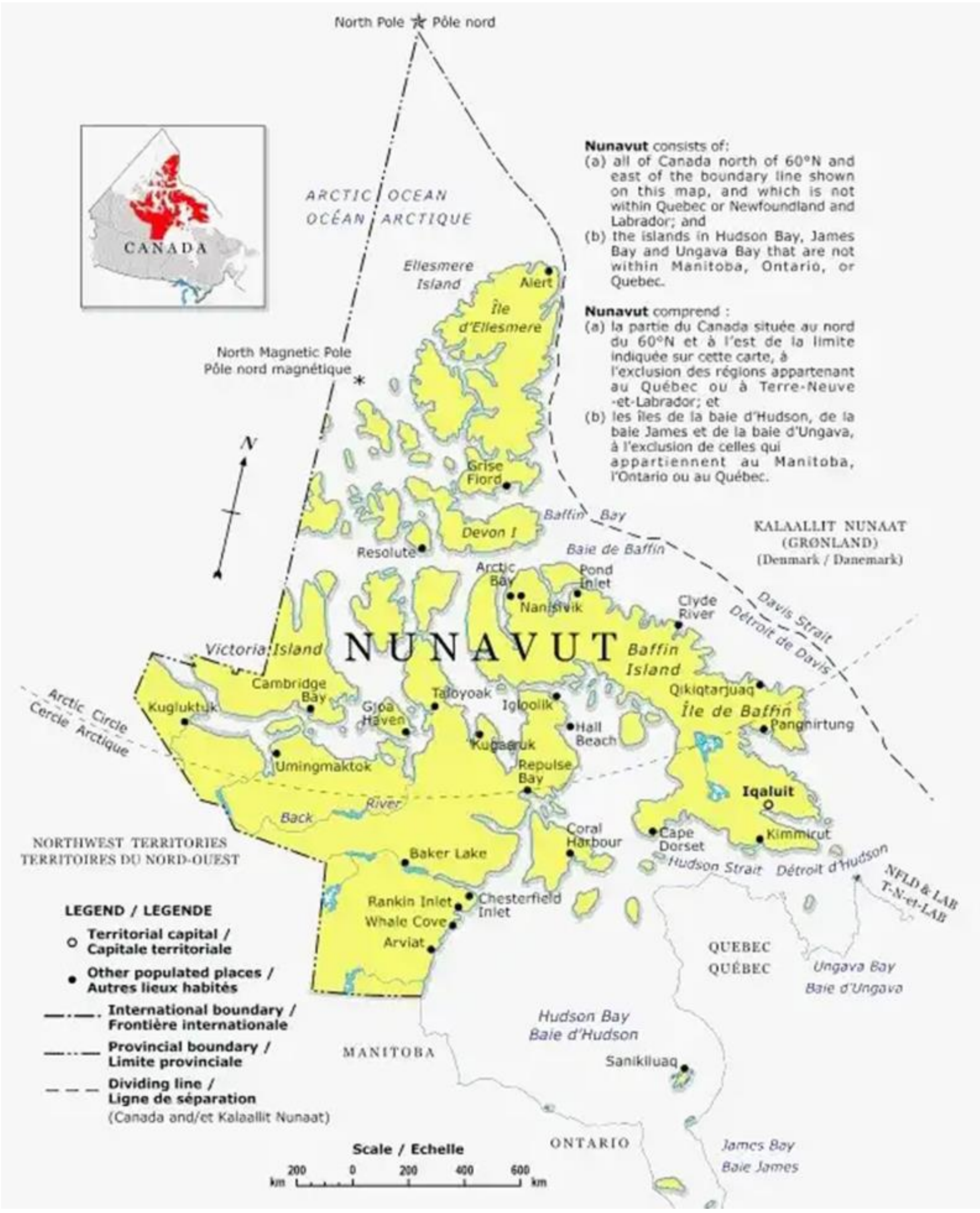

Figure 2: Location of communities analysed [7]

2. DATA AND ANALYSIS

This section of the report summarises the operational and resource data obtained for the investigation as well as the methods and analysis undertaken to develop the inputs for the models.

Obtaining even limited data sets has proved challenging, with many unavailable, or only available for one site. Best endeavours have been made to supplement existing data sets with information from previous reports, and where necessary, assumptions and methods of derivation have been stated for transparency.

2.1. Existing Assets

QEC provided updated information on the diesel fleet as at December 2018, which is summarised for all communities in Appendix A. Information on updated run-hours for these generators was not available so has not been considered in the analysis to date.

2.2. Community Electrical Loads

2.2.1. Annual Electrical Demand and Forecasts

The annual electricity generation for all power stations was available from the QEC Rate Application Report (2017). The report consisted of actuals for FY15/16/17 and forecasts for FY18 and FY19. Additionally, a demand forecast for the year 2025 was provided by QEC separately. This information is summarised in Figure 3. The annual electrical energy demand growth for Nunavut is 1.1% p.a., which varies between communities with the maximum being at Naujaat (2.0% p.a.) and the minimum being negative growth at Grise Ford (-1.8% p.a.).

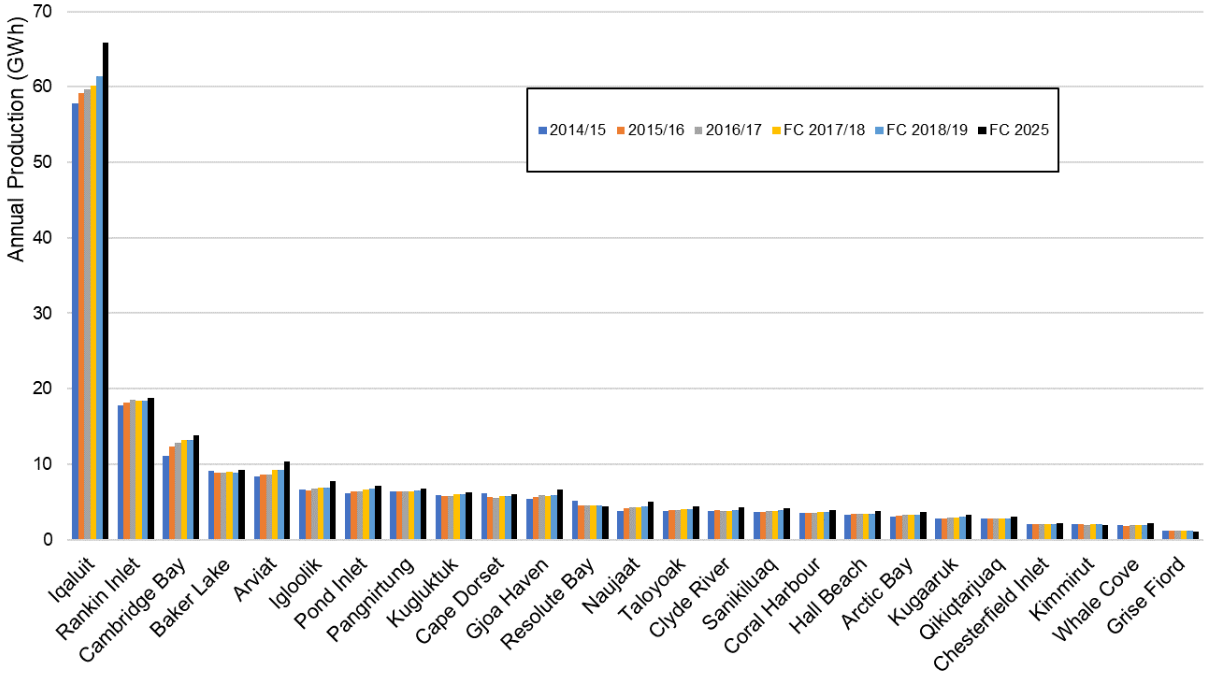

Figure 3: Historical & Forecasted (FC) annual electricity demand for each of the 25 communities

2.2.2. Load Profiles – Rankin Inlet

Time-series data for Rankin Inlet was provided in daily CSV files, covering an incomplete period ranging from June 2016 to July 2017. Sampling rate was nominally 10 seconds with the data fields including individual generator output and total station load. The data was cleaned, merged and indexed[1] for further analysis. 7 of the 13 months were found to have close to 100% of their expected records intact, but the remainder had very limited samples available.

For the hours in which at least one data point was available, the total station load was averaged to prepare the summary information for both weekdays and weekends. The load profile is shown in Figure 4 below, with the seasonal difference shown.

[1] "0" and "Null" values were removed from the data set, and further date and time conversions were used to develop necessary fields for further analysis.

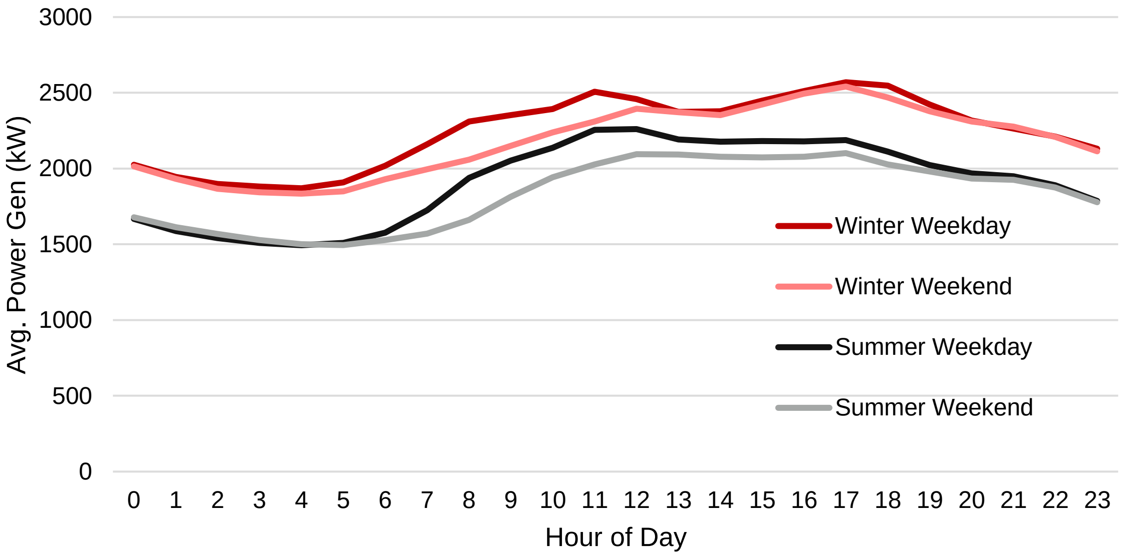

Figure 4: Recorded Rankin Inlet load profile from 2016 and 2017 data

QEC estimates Rankin Inlet's load in 2025 will be 2,140 kW. Using the 2016 and 2017 data as a basis of seasonality, the load profile was scaled to reflect this, as per Figure 5.

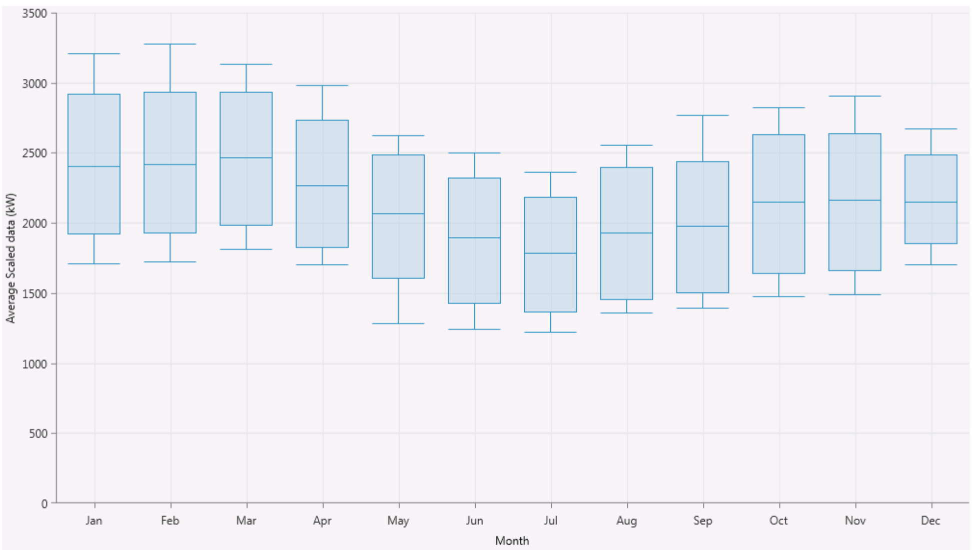

Figure 5: Generated Monthly Load Profile for Rankin Inlet in 2025

2.2.3. Load Profiles – Other Sites

Times-series data was not available for other sites, so the hourly and seasonal variations were traced from Rankin Inlet data and scaled based on the 2025 demand forecasts provided by QEC (shown earlier in Figure 3). Hour-by-hour and daily variability was altered in the simulation software to match forecasted peak loads.

As this is a pre-feasibility study, we consider this approach acceptable but note that it is of limited accuracy. Larger communities, such as Rankin Inlet, have a larger number of consumers and therefore are likely to have more commercial or industrial activity, which will result in a more daytime-biased consumption pattern and a lower diversity factor. Other communities are expected to have different load profiles and higher or lower diversity factors, which would impact key parameters of design, such as the sizing of generating equipment. This would require further data and analysis on a site-by-site basis.

2.3. Resource Data

The approach taken for resource data inputs was to use measured data wherever possible and defer to models if measured data was not available. As solar and wind data proved difficult to obtain for each site,[2] ground measurements from neighbouring airport data were used where available (source RETScreen [8]). In the communities that did not have an airport meteorological station, NASA satellite data was used and downloaded through HOMER.

Previous studies have detailed the importance of measured data compared to satellite-derived data, especially with respect to wind data. There can be significant differences between ground measurement and the NASA satellite data, so results from sites using satellite data should be treated with appropriate uncertainty. The resource data source for each site is listed in Appendix D.

[2]Resource data for Rankin Inlet was provided by Northern Energy Capital. The data covers approximately four months, which was insufficient to provide insight on seasonal variation.

3. MODELLING

3.1. HOMER Pro

HOMER - the name derived from Hybrid Optimisation of Multiple Energy Resources – is a software package initially developed by the US National Renewable Energy Laboratory (NREL) under the Village Power Program in the 1990s. The software itself simulates power system operation, allowing optimisation and study of energy balance and system economics.

There are three main tasks that can be performed by HOMER: simulation, optimization and sensitivity analysis. In the simulation process, the program models a system, determines its technical feasibility in meeting the load, and calculates life cycle costs. In the optimization process, the program performs simulations on different system configurations within a user-defined range to come up with the optimal design. In the sensitivity analysis process, the program performs multiple optimizations under a range of inputs, allowing for uncertainty in model inputs to be accounted for.

HOMER can simulate a large variety of componentry, from PV, wind and thermal plant to fly wheels, batteries and the conventional grid. HOMER has the second highest user base of design tools used for integration of renewables (on grid and off grid), second only to RETScreen. The package is extensively used by financiers, micro-grid designers and academics throughout the world. The software package is typically used at the pre-feasibility and detailed feasibility stage, as it allows easy scaling and sensitivity analysis.

3.2. Assumptions

This section describes the key assumptions that were used in the HOMER models. More detailed information on model parameters can be found in Appendix B.

3.2.1. Financial & Economic Assumptions

Economic inputs entered into the HOMER model were:

- Discount rate of 8% nominal
- Inflation rate of 2%, per the Bank of Canada's target inflation rate
- Analysis period of 15 years
- No carbon tax applied to electricity generation

Discount Rate: The discount rate is used to calculate the net present value of all future cash flows in the project. While the financing structure of any project is unknown at pre-feasibility stage, 8% was chosen in this report to reflect the expected weighted average cost of capital (WACC) that an Independent Power Producer (IPP) would pay to debt and equity financiers. A utility, such as QEC, would likely use a lower rate when assessing projects, and concessional loans may also be available. To reflect the possibility of a lower cost of capital, a 4% discount rate scenario was also studied.

Inflation: The rate at which the price of goods increases over time. The Bank of Canada aims to keep inflation between 1 – 3%. The inflation rate used in the modelling was 2%.

Analysis Period: A 15-year analysis period was chosen to assess projects from the perspective of an external investor or IPP. However, projects undertaken by QEC, Inuit Orgs, or Community Cooperatives may be comfortable with longer project timelines and payback periods on investments.

Carbon Tax: Currently electricity generation in Nunavut is excluded from the Canadian Carbon Tax. However, the Carbon Tax **does** apply to heating fuel and a number of transportation fuels. As this report accounts for savings achieved by off-setting heating fuel, the saving on the Carbon Tax is applied to these calculations, and accounted for in the increase in transportation of goods over time.

3.2.2. Technical Assumptions

System Dispatch and Operation

The following operating settings were assumed:

- A maximum allowable annual generation capacity shortage (unmet load) of 0.1% (~9 hours)
- Operating reserve (spinning diesel generator capacity and/or battery capacity) of:
  - 10% of the annual peak load
  - 80% of solar power output
  - 50% of wind power output

Allowable Capacity Shortage: Ideally this value is 0%, however this can cause high cost increases in HOMER, the modelling program used, and so this value was set at 0.1%, or 9 hours per annum, of potentially unmet load in system designs.

Operating Reserve: Also called **spinning reserve**, this is the “buffer” between demand for energy and the amount being generated. All diesel generators undergo a short start-up sequence – or “warm-up” period - before they can connect to the power station bus and become loaded. In a situation where load increased beyond the capacity of already loaded generators and without any Operating Reserve, the time-delay to start an additional generator may result in overloading of generators or a system trip. Operating Reserve therefore ensures that there is sufficient capacity online, or “spinning”, to pick up any rapid increases in load.

When integrating renewable energy into a system, the potential for solar or wind energy to suddenly drop off needs to be taken into account as well. For a wind turbine, this means that when it’s operating, the grid needs to be able to make up for ~50% of what the wind turbine produces if it was suddenly to disappear. For solar, the grid needs to be prepared to take up ~80% of what the solar panels were generating. This can be done through fast-ramping diesel generation, battery storage, load management, or other control mechanisms.

Electrical Load

The average daily electrical load profile for each month for Rankin Inlet was used as the base profile for each site, with the total annual load scaled to equal the forecast 2025 load for each site [9].

Diesel Generators

Data on the quantity, capacity and lifetime of diesel generators at each site was retrieved from the 2016 WISE report [4].

Minimum Load Ratio: Diesel generators can operate at different percentages of their rated capacity. In order to operate as cleanly and efficiently as possible, however, they should be carrying a minimum load whenever they’re running. 40% is the minimum that is assumed based on QEC’s past wind energy study.

PV

Large, Tier 1 manufacturers such as Canadian Solar, Trina, Jinko, and JA Solar, produce roughly equivalent modules. Characteristics typical for these modules were assumed.

Other PV assumptions were:

- Ground reflectance (albedo) of 60% - this is an average, year-round number. Albedo off snow can be as high as 90%.

Wind

Two different wind turbines were modelled:

1. Northern Power NPS100-21 ARCTIC (formerly known as North Wind 100) with 25m hydraulic tilt towers (100 kW)

2. Enercon E70 57m towers (2.3 MW)

Battery Energy Storage System (BESS)

ITP has assumed that any batteries installed in Nunavut will be lithium-ion. Tesla Powerpack's have been installed in a number of large-scale systems in remote locations. They contain industry-leading thermal management systems, making them suited to the low temperatures that may be encountered. Two Tesla BESS products were modelled in HOMER:

- Tesla Powerpack 2 4hr (maximum charge/discharge rate allows for a full charge or discharge in a minimum of 4 hours)
- Tesla Powerpack 2 2hr (maximum charge/discharge rate allows for a full charge or discharge in a minimum of 2 hours)

Thermal Load

A simplified approach to thermal modelling was developed by quantifying the spilled electricity in kWh, and then converting this to the equivalent litres of fuel that would be displaced, assuming an electric boiler efficiency of 85%. This provided a figure of 1L of Arctic Heating Oil displaced per 11.4 kWh of electrical energy spilled.

For example, if there are times when a wind turbine is producing more electricity than is needed in the community, that extra electricity can instead be used to offset heating loads. The value of offsetting the carbon tax on the heating fuel is included in these calculations.

3.2.3. Cost Assumptions

Diesel Fuel

The forecast diesel fuel prices for each community in 2018/19 were retrieved from the latest QEC rate application [2]. The 2024/25 price was calculated assuming an annual increase of 1.5%, based on information that fuel prices were anticipated to increase by 3% from 2017 to 2019. With inflation rates at 2% this means the price of fuel is dropping in real terms. The resulting assumed diesel fuel prices are shown in Table 1.

Carbon Tax and Arctic Heating Oil

While fuel use for electricity generation is exempt from the carbon tax, fuel for heating purposes is not. A carbon tax of $50/tonne was used in calculating the value of spilled electricity in scenarios with renewable generation, assuming that excess electricity could be used for heating [10] [11]. Within HOMER, this approach could not be modelled directly. Instead, the excess electricity in each result was converted into the equivalent avoided heating fuel consumption.

The avoided greenhouse gas emissions were determined based on greenhouse gas and fuel use figures previously published by QEC, which indicate CO_2 emissions of 2.82 kg/L of Arctic Heating Oil combusted.

The value of the avoided heating fuel use was based on 2017/18 average Arctic Heating Oil prices sourced from fuel sale data provided by the government's Petroleum and Products Division [12] for each community. These prices were scaled up to 2024/25 assuming an annual increase of 1.5%. The resulting assumed Arctic Heating Oil prices are shown in Table 1.

Table 1: Diesel fuel and Arctic Heating Oil prices (2025)

Community	Diesel fuel price ($/L)	Arctic Heating Oil price ($/L)
Arctic Bay	$1.02	$1.13
Arviat	$0.98	$1.09
Baker Lake	$1.03	$1.10
Cambridge Bay	$1.04	$1.19
Cape Dorset	$1.03	$1.13
Chesterfield Inlet	$1.03	$1.09
Clyde River	$0.98	$1.13
Coral Harbour	$1.03	$1.09
Gjoa Haven	$1.09	$1.19
Grise Fiord	$1.02	$1.13
Hall Beach	$1.02	$1.13
Igloolik	$1.02	$1.13
Iqaluit	$1.02	$0.95
Kimmirut	$1.03	$1.13
Kugaaruk	$1.09	$1.19
Kugluktuk	$1.05	$1.19
Naujaat	$1.02	$1.13
Pangnirtung	$1.02	$1.13
Pond Inlet	$1.02	$1.13
Qikiqtarjuaq	$1.02	$1.10
Rankin Inlet	$0.98	$1.10
Resolute Bay	$1.02	$1.13
Sanikiluaq	$1.03	$1.09
Taloyoak	$1.09	$1.19
Whale Cove	$1.03	$1.09

Diesel Generators

The capital costs of diesel generators installed/replaced in Nunavut from 2014-2018 were retrieved from the latest QEC rate application [2].

A linear regression was applied to create a cost curve that was entered into HOMER for diesel generator replacement costs. The regression line is shown in Figure 6.

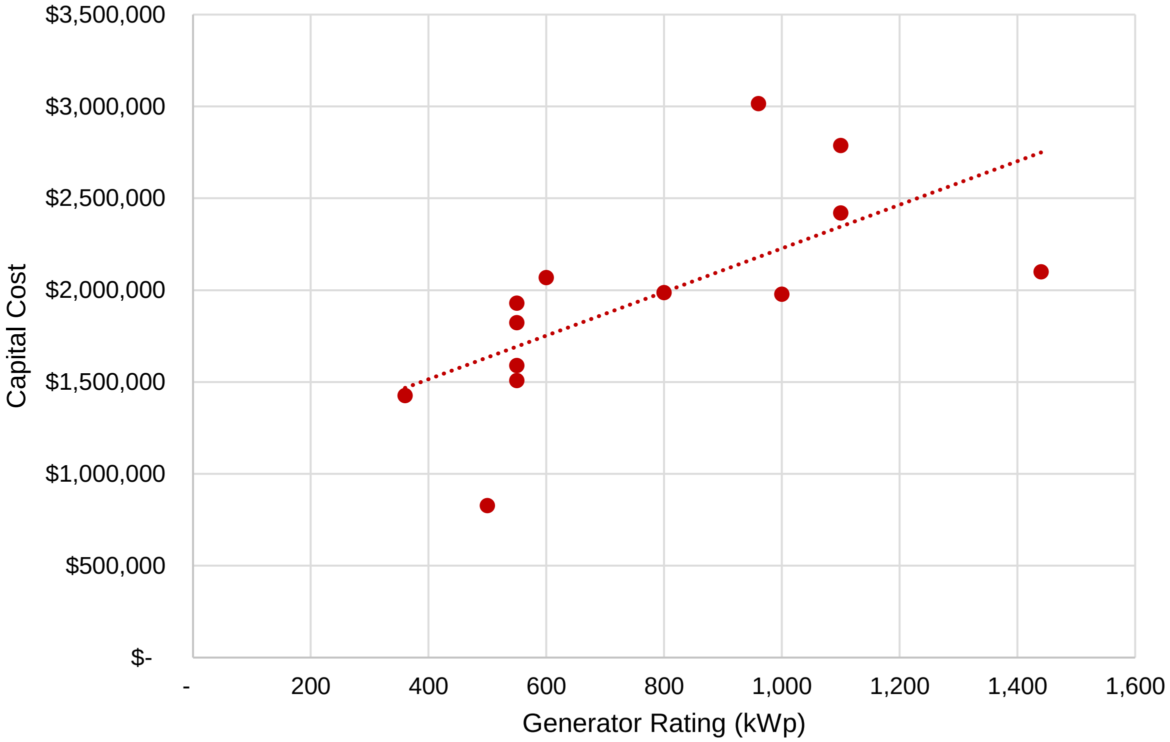

Figure 6: Diesel replacement costs with best fit line

Diesel generator O&M was assumed to be $35/MW$_{capacity}$/run-hour, matched to assumptions found in the QEC-commissioned Wind Prefeasibility Study [6].

Battery Energy Storage System (BESS)

The cost curves for Tesla Powerpack battery systems were based on ITP’s industry knowledge and project experience. The Tesla Powerpack system includes bi-directional inverters (i.e. inverters that can both charge and discharge the battery).

PV

A cost curve for PV was developed based on ITP's experience with remote projects, adjusted for the increased shipping and labour costs in the Arctic, as well as greater risk margins for contractors. The indicative cost curve developed for Rankin Inlet, for example, was \$4.37/W for a 50kW and \$3.33/W for a 2MW system. The model assumes all shipping via sea freight, and scaling as per the methodology mentioned in the *Shipping* section below. The resulting cost curve was checked against national data and found to be between approximately 1.5 - 2.0x higher than 'near future' installation costs, reflecting the higher costs of remote installation [13].

Wind

The capital costs for 1, 2, 3, 6 and 10 Northern Power turbines from [6] were used to create a cost curve which was used across all communities. This is shown in Figure 7 below.

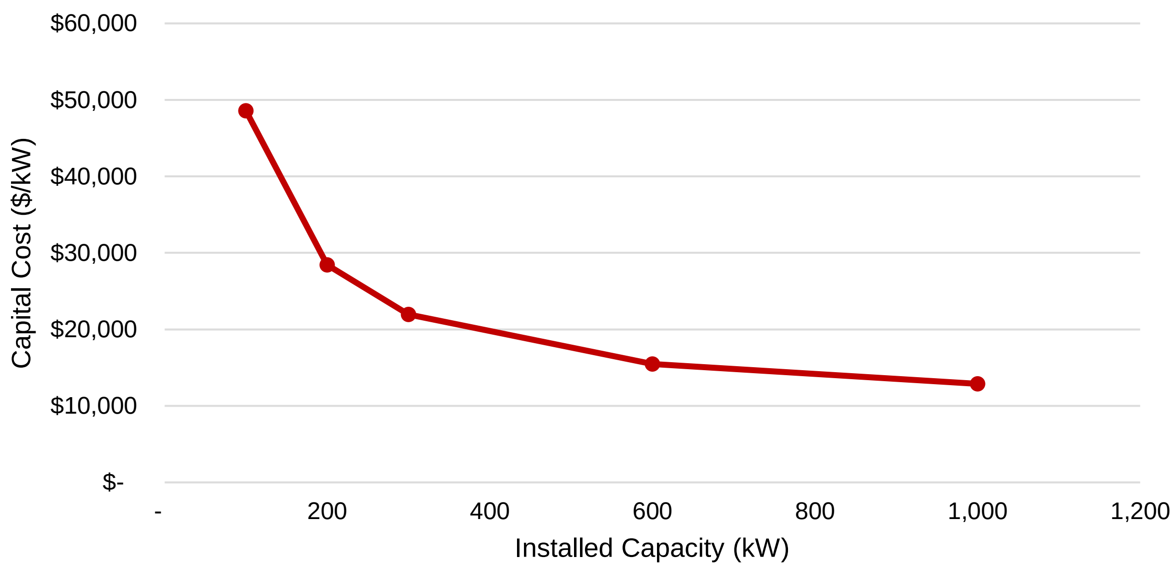

Figure 7: Northern Power NPS100C-21 100 kW turbine cost curve

Capital costs for Enercon turbines in Iqaluit, Arviat, Baker Lake, and Rankin Inlet were also set per [6]. Of these sites, Iqaluit comprised the most data points, with capital costs listed for 2, 3, 4 and 5 turbines. The resulting cost curve (Figure 8) was therefore used as the base data for the remaining sites, with scaling applied to differentiate between communities.

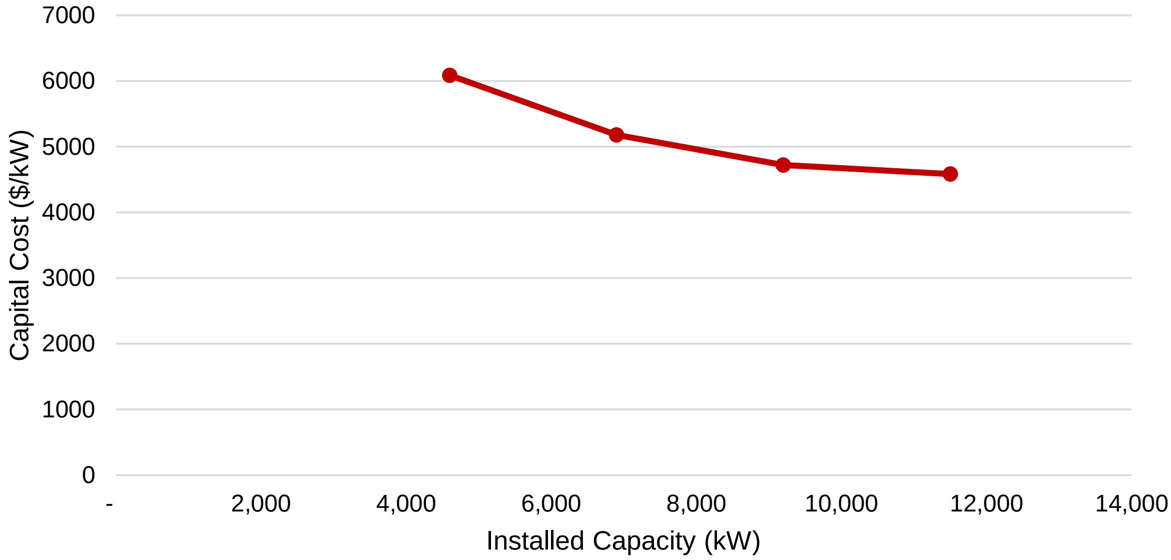

Figure 8: Enercon E-70 2.3M W turbine cost curve Iqaluit

Shipping

All equipment cost curves were approximated to be from Rankin Inlet in the first instance. To represent the differences in project costs for more remote or accessible communities, a scaling factor was applied to all component costs (including capital costs, replacement costs, and O&M costs) indicative of the additional or reduced transport costs incurred. The scaling factors are listed in Table 9 in Appendix B.2.7.

4. RESULTS & ANALYSIS

A summary of results from all sites is given in Table 2 and Table 3 below. The first column indicates the Net Present Cost (NPC) of the base case (i.e. business-as-usual, diesel only scenario for each community). Net Present Cost accounts for all system costs over the 15-year lifetime of the system, converted to present terms via the discount rate.

For each scenario of minimum RE contribution (20%, 40% and 60%) the optimal[3] configuration is presented in terms of the Net Present Value (NPV). The NPV represents the difference in NPC when compared to the base case. A positive NPV indicates a scenario that is financially attractive (based on the assumptions made), while a negative NPV indicates a scenario is unattractive. Also presented are the estimated emission reductions; the achieved renewable energy contribution, and a simplified indication of what technology was involved.

Highlighted in **green** text is the one case for each community that is considered to be financially optimal[4]. **Yellow** NPV results are those that are negative but greater than -$2m. **Red** NPV results are less than -$2m.

In some instances, the RE% achieved exceeds the minimum requirement. This indicates that a higher RE penetration is preferable over a lower RE penetration (e.g. Chesterfield with 29% penetration). Similarly, in some cases, a single optimised result fulfils both the 20% and 40% minimum RE requirement (eg. Rankin Inlet).

Further detail on each result, including the sizing of components, the OPEX impacts, fuel savings, and the potential value of spilled electricity is included in Appendix C.

[3] HOMER optimises in terms of lowest Net Present Cost.
[4] The value of spilt electricity has been excluded from this summary analysis but is included and discussed in the appendix.

Table 2: Summary of HOMER Pro modelling results – 8% discount rate scenario

Community	Annual Consumption		Minimum 20% RE Scenario					Minimum 40% RE scenario					Minimum 60% RE scenario				
	Elec (GWh)	Fuel (ML)	Tech	RE (%)	CO2-e red (kt/yr)	NPV ($M)	NPV w Heat offset ($M)	Tech	RE (%)	CO2-e red (kt/yr)	NPV ($M)	NPV w Heat offset ($M)	Tech	RE (%)	CO2-e red (kt/yr)	NPV ($M)	NPV w Heat offset ($M)
Arctic Bay	3.66	1.34	Solar + BESS	20	0.54	-2.08	-2.04	Solar + BESS	40	1.13	-5.05	-4.63	Solar + BESS	60	1.69	-15.99	-15.76
Arviat	10.30	2.98	Solar + BESS	20	1.37	-3.36	-3.15	Solar + BESS	40	2.81	-8.19	-7.58	Solar + BESS	60	4.24	-17.54	-15.40
Baker Lake	9.22	4.33	Solar + BESS	20	1.22	-2.13	-1.98	Wind + BESS	67	4.23	-4.27	-1.90	Wind + BESS	67	4.23	-4.27	-1.90
Cambridge Bay	13.80	4.66	Wind + BESS	20	1.94	-6.93	-6.93	Wind + BESS	40	3.72	-11.85	-11.80	Wind + Solar + BESS	60	5.65	-17.08	-15.98
Cape Dorset	6.09	1.33	Solar + BESS	20	0.88	-2.84	-2.76	Solar + BESS	40	1.83	-6.24	-5.83	Solar + BESS	60	2.78	-14.47	-12.18
Chesterfield Inlet	2.17	0.82	Solar + BESS	29	0.45	-0.81	-0.79	Solar + BESS	40	0.64	-1.03	-0.97	Solar + BESS	60	0.98	-2.01	-1.81
Clyde River	4.32	1.59	Solar + BESS	20	0.58	-2.76	-2.72	Solar + BESS	40	1.19	-6.49	-6.14	Wind + BESS	60	1.79	-16.56	-15.79
Coral Harbour	3.92	1.38	Solar + BESS	20	0.58	-0.51	-0.43	Solar + BESS	40	1.20	-0.98	-0.79	Solar + BESS	60	1.82	-3.19	-2.60
Gjoa Haven	6.64	2.08	Solar + BESS	20	0.88	-3.68	-3.45	Solar + BESS	40	1.81	-8.40	-7.97	Solar + BESS	60	2.74	-23.35	-20.07
Grise Fiord	1.07	0.57	Solar + BESS	20	0.15	-1.13	-1.12	Solar + BESS	40	0.32	-2.22	-2.10	Wind + Solar + BESS	60	0.47	-6.68	-6.61
Hall Beach	3.83	1.29	Solar + BESS	20	0.51	-1.25	-1.23	Solar + BESS	40	1.05	-2.89	-2.69	Wind + Solar + BESS	60	1.56	-5.46	-5.29
Igloolik	7.76	2.62	Solar + BESS	20	1.03	-2.90	-2.78	Solar + BESS	40	2.11	-7.31	-6.82	Solar + BESS	60	3.19	-21.74	-17.78
Iqaluit [5]	65.90	22.40	Solar + BESS	20	8.73	-4.06	-3.31	Wind + Solar + BESS	40	17.61	-10.78	-8.88	Wind + Solar + BESS	60	26.76	-25.74	-19.50
Kimmirut	1.99	0.70	Solar + BESS	21	0.29	-0.89	-0.89	Solar + BESS	40	0.59	-1.47	-1.33	Solar + BESS	60	0.90	-3.06	-2.60
Kugaaruk	3.33	1.21	Solar + BESS	20	0.45	-1.92	-1.89	Solar + BESS	40	0.92	-4.25	-3.97	Solar + BESS	60	1.39	-10.95	-9.23
Kugluktuk	6.32	2.69	Solar + BESS	20	0.84	-4.28	-4.21	Solar + BESS	40	1.72	-9.90	-9.44	Solar + BESS	60	2.60	-24.17	-21.07
Naujaat	5.01	1.47	Solar + BESS	20	0.69	-1.88	-1.87	Solar + BESS	40	1.40	-4.20	-3.83	Solar + BESS	60	2.12	-10.90	-9.08
Pangnirtung	6.72	2.00	Solar + BESS	20	0.97	-2.42	-2.38	Solar + BESS	40	2.02	-5.75	-5.21	Solar + BESS	60	3.07	-14.36	-11.97
Pond Inlet	7.17	2.58	Solar + BESS	20	0.96	-4.23	-4.17	Solar + BESS	40	1.95	-10.42	-9.86	Solar + BESS	60	2.95	-36.24	-30.46
Qikiqtarjuaq	3.03	1.01	Solar + BESS	20	0.46	-2.04	-1.99	Solar + BESS	40	0.89	-4.54	-4.33	Solar + BESS	60	1.31	-9.81	-8.83
Rankin Inlet	18.70	5.60	Wind + BESS	49	6.20	1.74	1.96	Wind + BESS	49	6.20	1.74	1.96	Wind + BESS	74	9.46	1.25	7.24
Resolute Bay	4.42	1.90	Solar + BESS	20	0.59	-2.12	-2.11	Wind + BESS	45	1.34	-5.02	-4.94	Wind + BESS	61	1.83	-6.20	-5.72
Sanikiluaq	4.11	1.22	Solar + BESS	20	0.55	-1.18	-1.13	Solar + BESS	40	1.13	-2.53	-2.31	Wind + BESS	62	1.76	-3.81	-3.51
Taloyoak	4.48	1.42	Solar + BESS	20	0.60	-2.72	-2.71	Solar + BESS	40	1.22	-6.28	-5.98	Solar + BESS	60	1.85	-17.21	-14.77
Whale Cove	2.15	0.69	Solar + BESS	20	0.29	-0.82	-0.79	Solar + BESS	40	0.59	-1.47	-1.36	Solar + BESS	60	0.89	-3.26	-2.83

[5] The optimal case for Iqaluit achieves 10% RE with a solar array and no wind or BESS. It has an NPV = $0.6M and reduces CO2-e emissions by 4.1 kt/yr.

Table 3. Summary of HOMER Pro modelling results – 4 % Discount Rate

Community	Annual Consumption		Minimum 20% RE Scenario					Minimum 40% RE Scenario					Minimum 60% RE Scenario				
	Elec (GWh)	Fuel (ML)	Tech	RE (%)	CO_2-e red (kt/yr)	NPV ($M)	NPV w Heat Offset ($M)	Tech	RE (%)	CO_2-e red (kt/yr)	NPV ($M)	NPV w Heat Offset ($M)	Tech	RE (%)	CO_2-e red (kt/yr)	NPV ($M)	NPV w Heat Offset ($M)
Arctic Bay	3.66	1.34	Solar, Battery	20.0	0.54	-1.36	-1.30	Solar, Battery	40.0	1.12	-3.30	-2.86	Wind, Solar, Battery	60.0	1.69	-13.73	-13.43
Arviat	10.3	2.98	Solar, Battery	20.0	1.37	-1.81	-1.54	Solar, Battery	40.0	2.81	-4.73	-3.93	Solar, Battery	60.0	4.24	-12.33	-9.52
Baker Lake	9.22	4.33	Wind, Battery	68.5	4.32	1.41	4.32	Wind, Battery	68.5	4.32	1.41	4.32	Wind, Battery	68.5	4.32	1.41	4.32
Cambridge Bay	13.8	4.66	Wind, Battery	25.4	2.41	-4.19	-4.17	Wind, Solar, Battery	40.1	3.79	-6.87	-5.68		60.0	5.63	-10.12	-8.77
Cape Dorset	6.09	1.33	Solar, Battery	20.0	0.88	-1.92	-1.81	Solar, Battery	40.0	1.83	-4.11	-3.50	Solar, Battery	60.0	2.78	-11.30	-8.28
Chesterfield Inlet	2.17	0.82	Solar, Battery	40.0	0.64	-0.18	-0.10	Solar, Battery	40.1	0.64	-0.18	-0.10	Solar, Battery	60.1	0.98	-0.65	-0.38
Clyde River	4.32	1.59	Solar, Battery	20.0	0.58	-2.06	-2.00	Solar, Battery	40.0	1.19	-4.88	-4.42	Wind, Battery	60.4	1.79	-14.25	-13.22
Coral Harbour	3.92	1.38	Solar, Battery	38.0	1.14	0.87	1.05	Solar, Battery	40.0	1.20	0.85	1.09	Solar, Battery	60.0	1.82	-0.37	0.41
Gjoa Haven	6.64	2.08	Solar, Battery	20.1	0.89	-2.53	-2.47	Solar, Battery	40.0	1.81	-5.83	-5.09	Solar, Battery	60.0	2.74	-19.51	-14.86
Grise Fiord	1.07	0.57	Solar, Battery	20.0	0.15	-0.95	-0.92	Solar, Battery	40.0	0.32	-1.75	-1.60	Wind, Solar, Battery	60.1	0.47	-6.01	-5.92
Hall Beach	3.83	1.29	Solar, Battery	20.5	0.52	-0.67	-0.63	Solar, Battery	40.0	1.05	-1.52	-1.25	Wind, Solar, Battery	60.1	1.57	-3.38	-3.20
Igloolik	7.76	2.62	Solar, Battery	20.0	1.03	-1.67	-1.41	Solar, Battery	40.0	2.11	-4.54	-3.89	Solar, Battery	60.0	3.19	-17.78	-12.23
Iqaluit	Achieved viability with 8% Discount Results above																
Kimmirut	1.99	0.7	Solar, Battery	25.4	0.36	-0.49	-0.42	Solar, Battery	40.1	0.59	-0.66	-0.47	Solar, Battery	60.0	0.90	-1.76	-1.15
Kugaaruk	3.33	1.21	Solar, Battery	20.3	0.46	-1.08	-1.05	Solar, Battery	40.0	0.92	-2.49	-2.12	Wind, Solar, Battery	60.0	1.38	-10.11	-9.46
Kugluktuk	6.32	2.69	Solar, Battery	20.0	0.84	-3.27	-3.18	Solar, Battery	40.0	1.72	-7.59	-7.00	Wind, Solar, Battery	60.0	2.57	-16.43	-15.87
Naujaat	5.01	1.47	Solar, Battery	21.3	0.74	-0.94	-0.90	Solar, Battery	40.0	1.40	-2.21	-1.70	Solar, Battery	60.0	2.12	-7.93	-5.38
Pangnirtung	6.72	2	Solar, Battery	20.5	1.00	-1.34	-1.26	Solar, Battery	40.0	2.02	-3.28	-2.56	Solar, Battery	60.0	3.07	-10.69	-7.52
Pond Inlet	7.17	2.58	Solar, Battery	20.0	0.96	-3.08	-3.00	Solar, Battery	40.0	1.95	-7.92	-7.10	Solar, Battery	60.0	2.95	-32.94	-24.90
Qikiqtarjuaq	3.03	1.01	Solar, Battery	20.0	0.46	-1.41	-1.32	Solar, Battery	40.0	0.89	-3.23	-2.85	Solar, Battery	60.0	1.31	-7.89	-6.40
Rankin Inlet	Achieved viability with 8% Discount Results above																
Resolute	4.42	1.9	Solar, Battery	20.7	0.61	-1.36	-1.35	Wind, Battery	51.2	1.53	-2.96	-2.93	Wind, Battery	62.4	1.87	-3.33	-3.27
Sanikiluaq	4.11	1.22	Solar, Battery	20.0	0.55	-0.46	-0.39	Solar, Battery	40.0	1.13	-0.91	-0.69	Wind, Battery	62.1	1.76	-1.15	-0.75
Taloyoak	4.48	1.42	Solar, Battery	20.0	0.63	-1.62	-0.69	Solar, Battery	40.0	1.22	-4.41	-4.02	Solar, Battery	60.0	1.85	-14.48	-11.25
Whale Cove	2.15	0.69	Solar, Battery	20.0	0.30	-0.35	-0.03	Solar, Battery	40.0	0.59	-0.59	-0.44	Solar, Battery	60.0	0.89	-1.83	-1.27

In Table 2, where an 8% discount rate was assumed, RE appears immediately attractive only for Rankin Inlet and Iqaluit (highlighted in green). However, nine other communities have RE cases within $2m of breakeven (highlighted in **yellow**). This suggests that, where grant funding is available, RE may be attractive in these communities and further study would be warranted.

In Table 3, a 4% discount rate is assumed, and Baker Lake and Coral Harbour joins Rankin Inlet and Iqaluit as having a case for immediate implementation of large amounts of renewable energy. This suggests that, where concessional debt financing is available, and/or investment risk can be perceived to be low, RE may be attractive in these communities and further study would be warranted.

In general, the discount rate chosen (a proxy for the cost of capital) has a significant impact on the financial viability of renewable energy projects as lifecycle costs for wind, solar PV, and battery storage technologies are predominately capital costs.

Also apparent is that, when higher RE% must be met, the optimal scenarios tend to involve a single technology type (wind or PV). Technology diversity is only optimal at higher RE fractions in a small number of sites (e.g. Cambridge Bay, Iqaluit).

Overall, Rankin Inlet stands out as the most convincing instance where renewables are immediately attractive –49% RE gives an NPV of $1.8M, an IRR of 9.2%, and simple payback of 9.6 years, leading to 6.2 kt/yr of CO_2-e abatement, and 2.4 ML of avoided fuel usage each year. This scenario utilised a single Enercon E-70 turbine with a 1.6 MW / 3.36 MWh Tesla Powerpack. This result comes most notably due to the strong wind resource and the larger size of the community. With such a high renewable energy penetration, additional value could be realised by offsetting up to 21 kL of heating fuel each year with the spilt electricity.

The optimal result for Iqaluit falls halfway between the base case and the minimum 20% RE scenario. In this case, a 10% RE scenario gives an NPV of $0.6M and leads to 4.1 kt/yr of CO_2-e abatement. This scenario has a 5.36 MW solar array, no wind and no BESS. Previous reports have indicated a promising wind resource for Iqaluit, but based on the ground measurements from the RETScreen data sets this has not been found during this study. The effect of uncertainty with respect to the available wind resource is explored in detail in the sensitivity analysis in the next section.

The most cost-effective GHG reductions (on the basis of net present cost) occur for lower RE fractions (where storage requirements, and therefore costs, are lower) and in larger communities (where RE is larger and therefore cheaper per unit). The top five sites for cost-effective emissions reduction are Rankin Inlet, Iqaluit, Coral Harbour, Baker Lake, and Chesterfield Inlet (Table 4). Note that a negative cost indicates that the scenario has a positive net present value (ie. is cost-effective even without consideration of GHG abatement).

Table 4. GHG abatement (net present) cost for five most cost-effective communities

Community	CO_2 Abatement. ($'000/t/yr)		
	20% RE	40% RE	60% RE
Rankin Inlet	-0.29	-0.29	-0.14
Iqaluit	0.47	0.61	0.96
Coral Harbour	0.86	0.83	1.76
Baker Lake	1.71	1.02	1.02
Chesterfield Inlet	1.96	1.72	2.04
Sanikiluaq	2.18	2.21	2.16

4.1. Sensitivity Results

The modelling has been undertaken using the best available information and transparent assumptions – however as with all models, establishment and usage involves uncertainty. Sensitivity analysis is a useful tool to give a better understanding of the impact of such uncertainty, and HOMER Pro facilitates such analysis on almost all variables within the model. In consultation with WWF, Rankin Inlet, Kugluktuk and Sanikiluaq were selected for further analysis, each representing one of the three regions of Nunavut.

Firstly, two variables were considered most important for this analysis and to inform the audience – discount rate and diesel price. A project's discount rate will vary depending on the perspective of the investor(s). Typically, a public utility will have a lower discount rate than a private Independent Power Producer (IPP). Discount rate was therefore varied across this spectrum between 4% and 14% (varying with 2% step changes).

Diesel prices have also historically been volatile on global markets, and geopolitical developments are likely to continue this trend. The diesel fuel price was therefore varied between $0.70/L and $2.20/L (varying with $0.30 step changes).

Modelling across both sensitivities (6 x 6) means that there will be a total of 36 optimised results for each community. The results for Rankin Inlet are plotted in Figure 9.

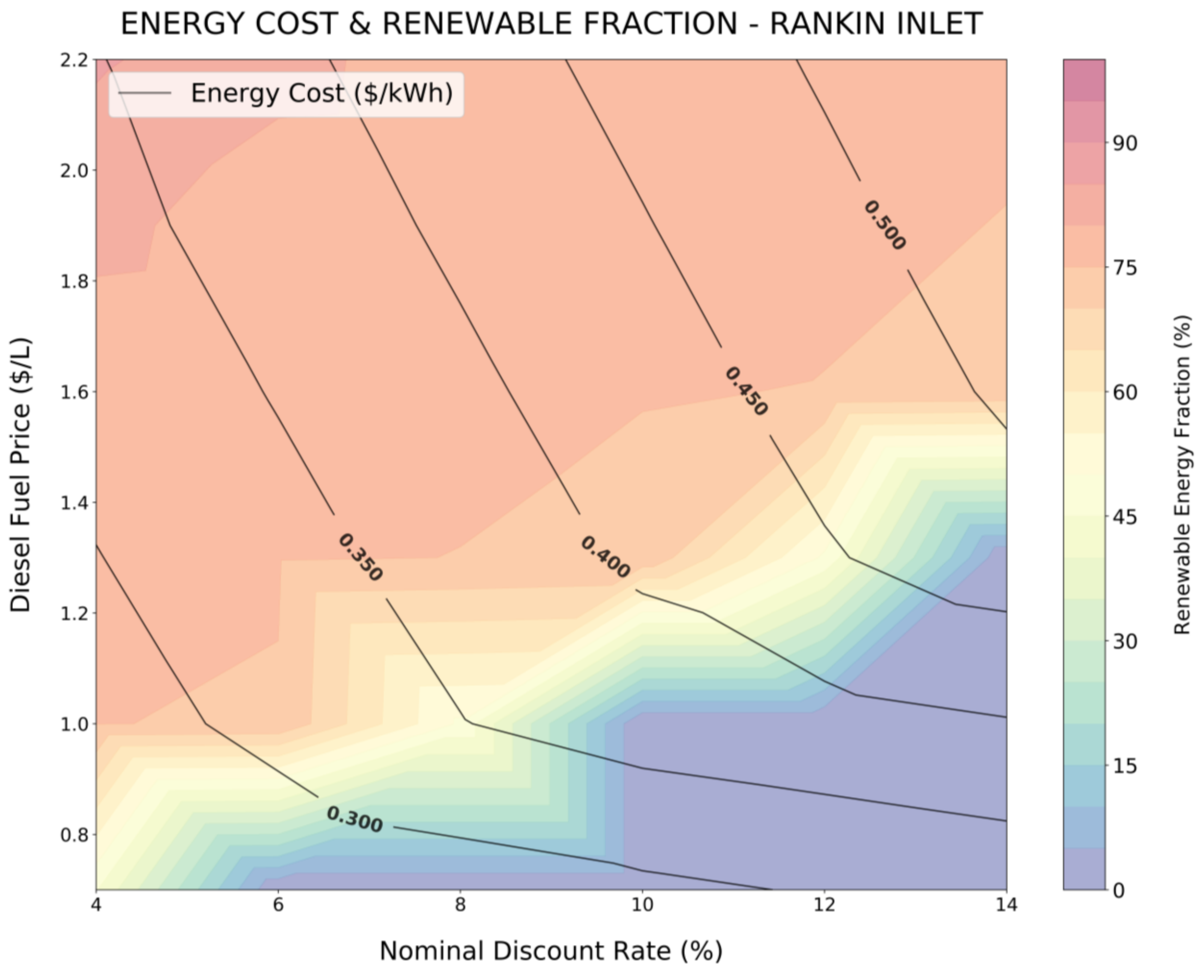

Figure 9: Sensitivity results for Rankin Inlet

The 36 markers represent each modelled case, and for each of these the resulting levelized cost of energy generation (in $/kWh) is printed.[6] The iso-lines on the graph represent the levelized cost of energy generation. The background colour (or “heatmap”) in this chart represents the RE% that HOMER found to be optimal for the sensitivity variables on the x and y axes, as per the legend provided.

As could be expected, the optimal RE fraction has a strong dependence on both the diesel fuel price and the discount rate. Moving first vertically from bottom of the chart to the top, a higher diesel price will evidently penalise the configurations that use more diesel. Moving left to right, higher discount rates will favour technical configurations with a lower initial capex, as is evident in the 0% RE (diesel only) scenarios in blue becoming increasingly favourable. There is also a

[6] It can be noted that the levelized cost of energy generation is substantially lower than the stated Cost of Supply (COS) in the QEC General Rate Application (e.g. 78.16c/kWh for domestic non-government) and the tariff rate born by consumers. This is because HOMER does not account for transmission/distribution costs, transmission/distribution losses, or administrative costs.

dramatic step change in which the optimal result changes from low to high renewable energy mostly due to the optimal componentry being a relatively large step change from zero, one and then two x 2.3 MW wind turbines.

The reader should note that the results are also heavily site dependent. High RE fractions were feasible in Rankin Inlet under a much broader range of conditions than both of the other sites. This is because of the strong wind resource and the larger electricity demand, which allows for larger turbines and the associated economies-of-scale.

For Kugluktuk and Sanikiluaq, the results are shown in Figure 10 and Figure 11 respectively. For Kugluktuk, renewable energy scenarios are quite a long way from being economically feasible and really only optimal in the top left quadrant, with feasibility requiring a discount rate below 6% and a diesel price increase of around 50%. As solar is most economical given the poor wind resource, the flexibility in its sizing capacity means the move from high to low RE% is a much more gradual change.

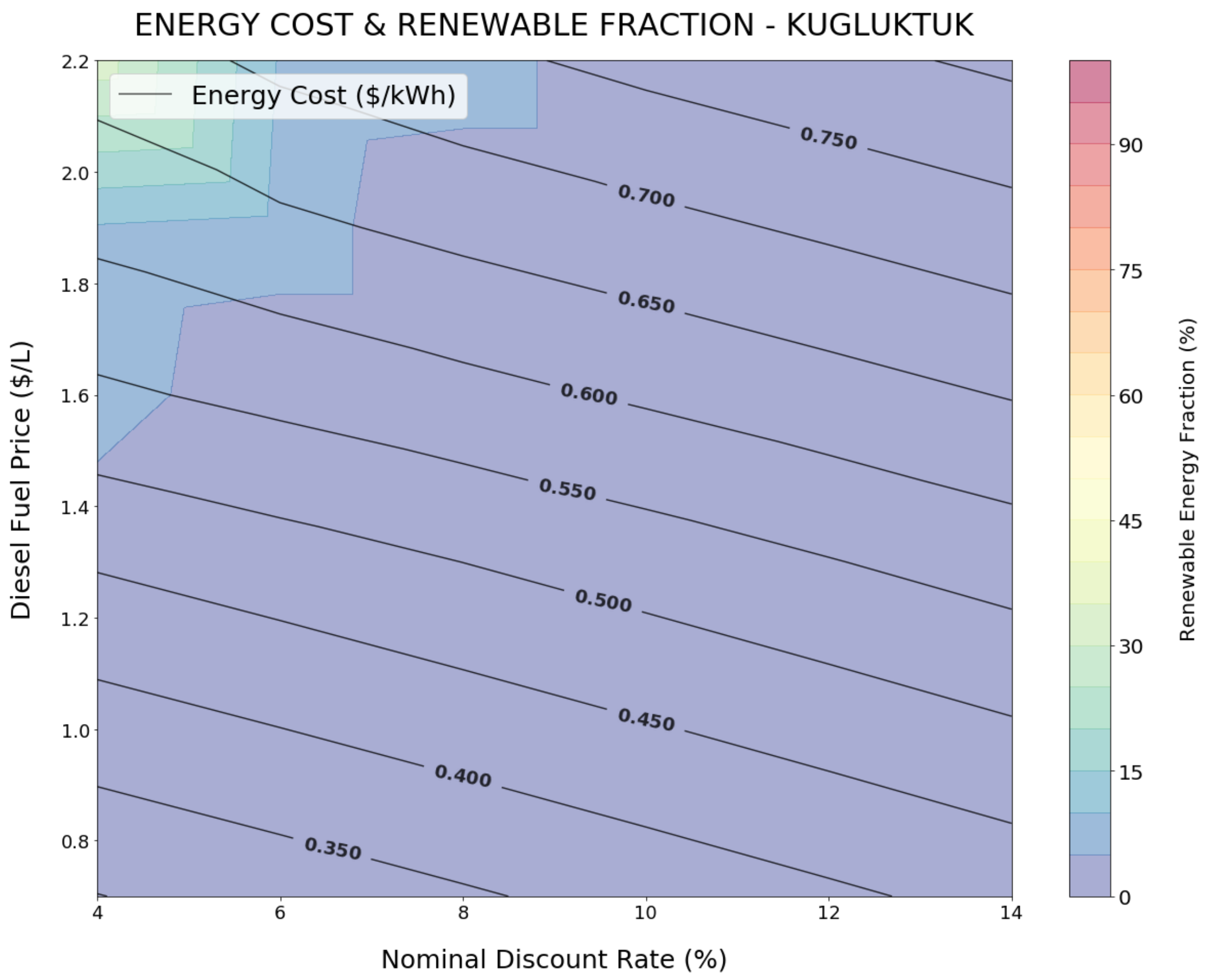

Figure 10: Sensitivity results for Kugluktuk

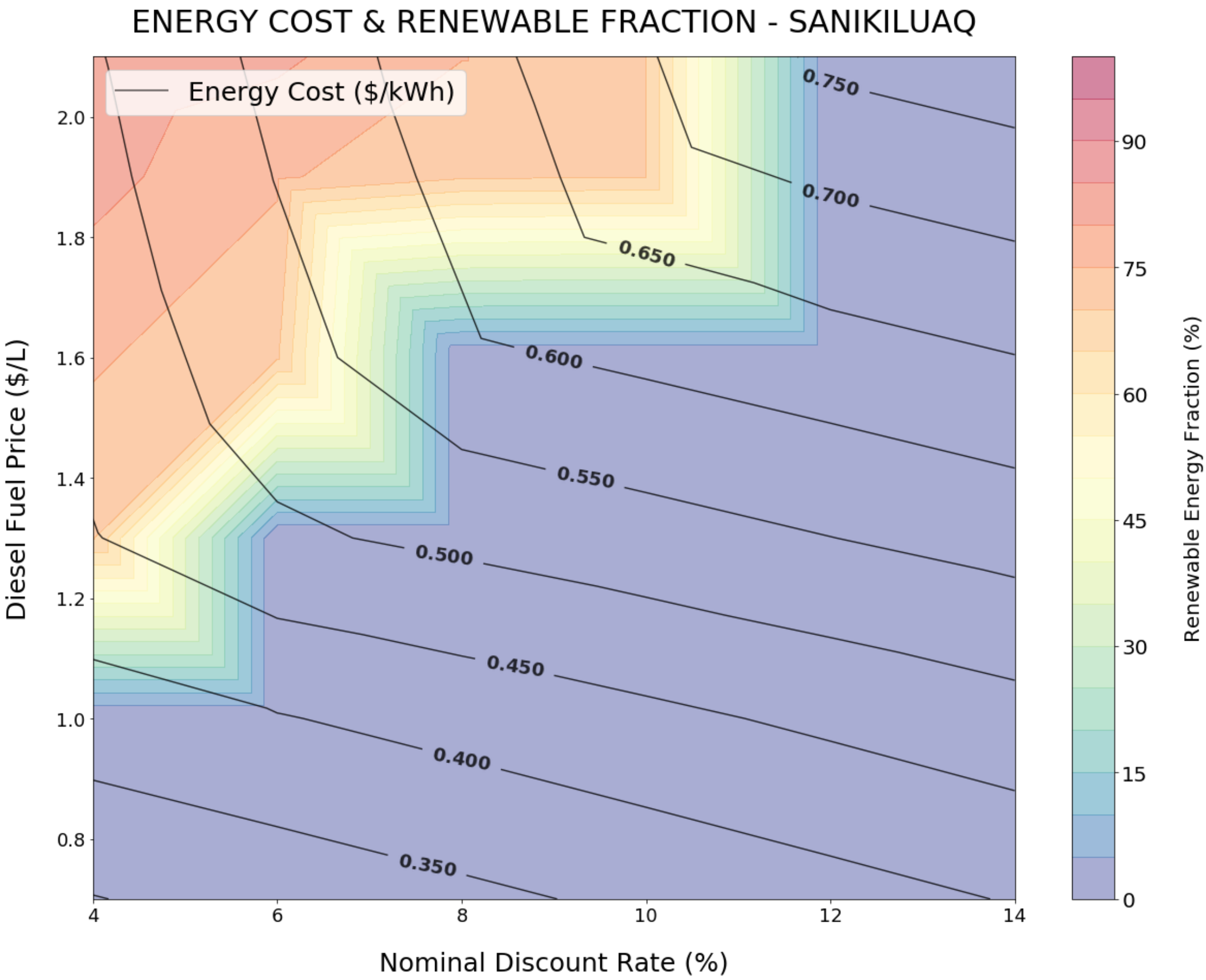

Figure 11: Sensitivity results for Sanikiluaq

Similar to Rankin Inlet, Sanikiluaq shows a step change from low to high renewable energy generation, but at a much higher diesel price.

Another variable that can impact results significantly is that of the available wind resource. This is evident in Iqaluit most notably, where previous analysis had estimated average winds speeds in excess of 7.4 m/s at hub height [6], a result certain to make wind technology much more attractive. However, as analysis in this report has been based on ground-measured RETScreen data and more conservative assumptions of scaling factors, the average wind speed was estimated at about 6 m/s at hub height. The impact of varying wind speed on the modelled results was examined in a further sensitivity case, varying wind speeds between 4 – 8 m/s as measured at 10 meters height, and also altering discount rate from 6% to 12%. The results are presented in Figure 12 below.

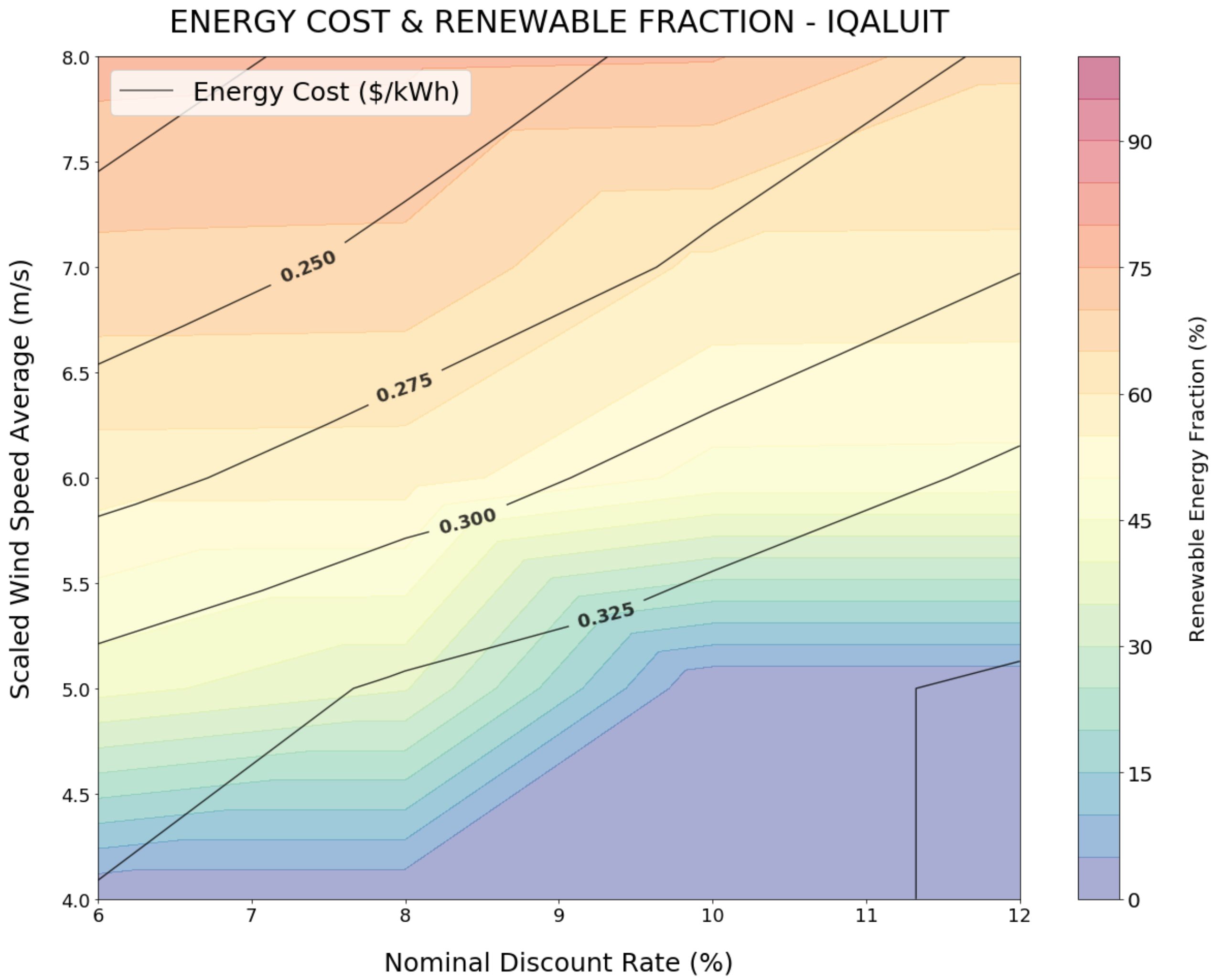

Figure 12: Wind speed and discount rate sensitivity results for Iqaluit

As can be seen by comparing the vertical results for the 10% discount case, a difference of 1 m/s average wind speed at ground level can be the difference between an optimal result of no RE vs an optimal result of approximately 50% RE. The limitations of scaling wind data from such low hub heights are well known, and this underlines the importance of obtaining reliable wind data at intended hub heights for communities such as Iqaluit.

4.2. Discussion

In comparison to previous reports, it is noteworthy that optimised scenarios have generally involved a single technology type (wind or PV) instead of a diversity of technologies. This is expected to be reflective of the steep initial cost curves and also the reduced costs of storage compared to previous analysis. As storage costs fall, the value of resource diversity is reduced (e.g. solar complementing periods of low wind, and vice versa).

Data collection proved difficult, both in terms of determining community electrical and thermal load profiles and also the wind and solar resource, which is often typical at pre-feasibility but are fundamental inputs for design. Rankin Inlet was the site for which there was the most certainty in these aspects, with good detail on the load profile that was used to complement information available for other sites. Meteorological station data was provided by a developer, however the short duration of the data (4 months) meant that the data could only be used to validate that average values aligned with those from RETScreen. While this was found to be the case, larger wind projects would typically need at least 2 years of measured resource before becoming financeable.

Diesel generator costs were developed based on published information from QEC, but ITP notes that these are much higher than expected, even for remote locations. We suggest further clarification with QEC to understand what specifically drives such high costs, and the practicalities of offsetting this investment with high penetration renewables.

Conservative RE construction costs have been assumed. A large degree of uncertainty remains about the actual RE costs in these communities, and that implies feasibility of a pilot project in the largest population towns (either Iqaluit or Rankin Inlet) would be the most suitable pathway forward.

Given the assumption of an 8% discount rate, only Rankin Inlet and Iqaluit were found to present an immediate case for RE. However, a 4% discount rate makes RE attractive at Baker Lake and Coral Harbour also. This highlights the need for access to capital at low interest rates, which could be improved by better data availability (load and resource data), or even concessional financing.

Importantly, all HOMER PRO models have been provided to WWF for their future use. In the short term, these may be updated if and when more detailed data becomes available. Over the medium to long term, a number of foreseeable developments will also change this analysis. This includes:

- Increase in diesel fuel prices (the implications of which are shown quite evidently in the sensitivity analysis).
- Declining costs of energy storage.

- Declining cost of solar PV and wind.
- Electricity generation potentially being included in the carbon price.

4.3. Conclusions

This investigation has completed a high-level assessment of the feasibility of renewable energy integration at 25 sites in Nunavut, across increasing stages of renewable energy penetration. While available data on renewable energy resource, energy use and diesel generation were found to be limited in most communities, the intended purpose of the pre-feasibility study is to identify the sites and technologies for detailed investigation. At the current price of diesel and renewable energy, both Rankin Inlet and Iqaluit are expected to be promising sites for future RE development. If concessional financing is available, then Baker Lake and Coral Harbour also appear suitable for RE integration.

For the remaining sites, renewable energy may not be an attractive proposition in the short-term, but analysis shows that high renewable energy contributions can be achieved at a small premium to the current scenario, and this premium may be reduced by a number of factors, such as falling technology costs or thermal load offsets. Moreover, decreased reliance on diesel fuel would reduce negative environmental impacts and improve energy reliability and security.

Recommended next steps are:

- reduce uncertainty in wind and solar resource data by installing ground-mounted monitoring systems;
- reduce uncertainty in wind and solar PV cost estimates by informally approaching the market (eg. via a Request for Information process);
- conduct feasibility studies for the most prospective sites that consider:
  - potential RE sites
  - the condition of the existing generation and distribution infrastructure
  - the control logic of the existing generation
  - the impact of RE on the existing distribution network (including protection systems)
  - investment plans for generation and distribution infrastructure
  - sources of grant and debt funding, and the expected terms of such funding
  - community support/opposition for RE developments

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APPENDIX A. NUNAVUT COMMUNITIES, FUEL USE & GENERATOR FLEET

Table 5: Population and fuel consumption for each community

Region	Community	Population (2017)	Annual Fuel Cons Elec ('000 L)	Annual Fuel Cons Heating ('000 L)
Qikiqtaaluk	Iqaluit	8,011	14,915	22,446
Kivalliq	Rankin Inlet	3,106	4,884	5,598
Kivalliq	Arviat	2,687	2,353	2,975
Kivalliq	Baker Lake	2,197	2,299	4,332
Kitikmeot	Cambridge Bay	1,985	3,473	4,662
Qikiqtaaluk	Pond Inlet	1,790	1,717	2,580
Qikiqtaaluk	Pangnirtung	1,678	1,900	2,001
Qikiqtaaluk	Igloolik	1,677	1,696	2,620
Kitikmeot	Kugluktuk	1,664	1,575	2,690
Qikiqtaaluk	Cape Dorset	1,623	1,704	1,330
Kitikmeot	Gjoa Haven	1,484	1,577	2,080
Kivalliq	Naujaat	1,099	1,123	1,474
Qikiqtaaluk	Clyde River	1,088	992	1,593
Kitikmeot	Taloyoak	989	1,068	1,416
Qikiqtaaluk	Arctic Bay	973	992	1,339
Kivalliq	Coral Harbour	915	1,045	1,380
Qikiqtaaluk	Sanikiluaq	914	1,009	1,217
Kitikmeot	Kugaaruk	860	754	1,214
Qikiqtaaluk	Hall Beach	855	919	1,290
Qikiqtaaluk	Qikiqtarjuaq	631	787	1,008
Qikiqtaaluk	Kimmirut	514	562	699
Kivalliq	Whale Cove	454	512	688
Kivalliq	Chesterfield Inlet	395	584	820
Qikiqtaaluk	Resolute Bay	247	1,248	1,902
Qikiqtaaluk	Grise Fiord	142	374	569

The sale volumes of P50 Heating Oil for all communities for the fiscal year 2017/2018 is shown below for each customer 'Class' and 'Subclass'. Note that sales data only records Commercial Bulk Sales for Iqaluit but the reason for this is unclear.

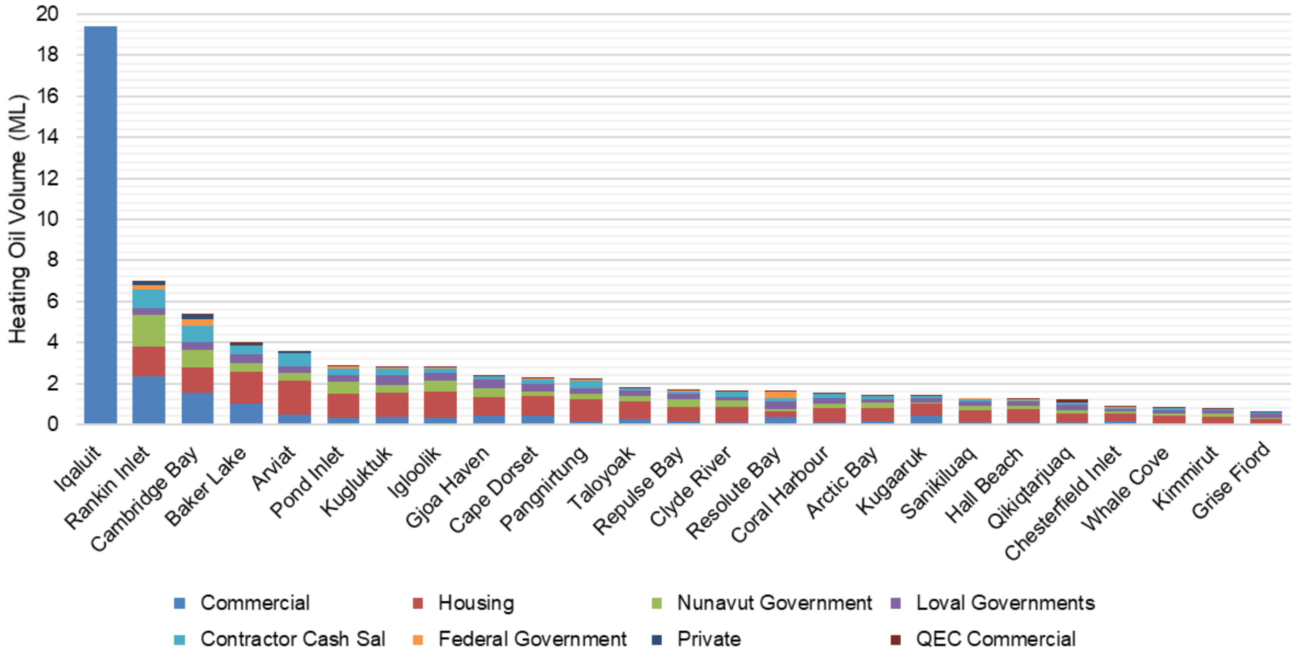


Figure 13 – Annual Heating Oil consumption by use for the 25 Communities based on PPD sales information (2017/2018) [12]

From the sales data, WWF identified a few select categories of end users that could be seen as potential off takers for excess renewable electricity to be used for heating purposes. The recorded fuel sale volumes for these users in 2017/2018 is recorded in Table 6 below.

Table 6: Recorded fuel sale volumes based on PPD sales information (2017/2018) [12]

Community	User Type	P50 Fuel Volume (L)
Rankin Inlet	Nunavut Government	1,557,869
	Housing	1,465,425
Cambridge Bay	Housing	1,231,514
	Nunavut Government	854,889
	Local Governments	392,029
Baker Lake	Housing	1,584,784
	Local Governments	441,971
	Nunavut Government	421,886
Arviat	Housing	1,638,775
	Nunavut Government	422,709
	Local Governments	316,526
Igloolik	Housing	1,268,767
	Nunavut Government	525,632
	Local Governments	383,419
Pond Inlet	Housing	1,220,180
	Nunavut Government	560,158
	Local Governments	330,112
Kugluktuk	Housing	1,183,982
	Local Governments	455,144
	Nunavut Government	370,191
Gjoa Haven	Housing	940,473
	Nunavut Government	422,761
	Local Governments	404,582
Pangnirtung	Housing	1,067,789
	Nunavut Government	285,710
	Local Governments	272,011
Cape Dorset	Housing	964,470
	Local Governments	400,445
	Nunavut Government	207,586
Repulse Bay	Housing	667,480
	Nunavut Government	381,965
	Local Governments	261,541
Clyde River	Housing	782,136
	Nunavut Government	275,320
	Local Governments	202,216
Coral Harbour	Housing	663,433
	Local Governments	282,034
	Nunavut Government	215,295
Taloyoak	Housing	838,221
	Nunavut Government	295,318
Arctic Bay	Housing	670,263
	Nunavut Government	268,880
	Local Governments	143,117
Hall Beach	Housing	630,325

	Local Governments	227,910
	Nunavut Government	137,940
Sanikiluaq	Housing	581,927
	Nunavut Government	225,973
	Local Governments	171,829
Qikiqtarjuaq	Housing	456,754
	Local Governments	225,032
	Nunavut Government	173,733
Kugaaruk	Housing	566,639
	Local Governments	205,071
	Nunavut Government	72,457
Resolute Bay	Local Governments	363,003
	Housing	264,108
	Nunavut Government	120,975
Whale Cove	Housing	353,448
	Local Governments	169,913
	Nunavut Government	104,246
Kimmirut	Housing	305,358
	Local Governments	150,564
	Nunavut Government	143,600
Chesterfield Inlet	Housing	345,648
	Nunavut Government	127,261
	Local Governments	100,098
Grise Fiord	Local Governments	216,643
	Housing	173,670
	Nunavut Government	56,695

Table 7 Existing generator fleets [9]

Community	Model	RPM	Rating (kW)
Arctic Bay	CAT D 3508	1200	480
	CAT D 3406	1200	290
	Detroit Series 60	1800	330
	Detroit Series 60	1800	320
Arviat	CAT D 3512B	1200	850
	CAT D 3508B	1200	550
	CAT D 3516B	1200	1100
	CAT D 3512B	1200	800
Baker Lake	CAT D 3516B	1200	1100
	CAT D 3512B	1200	850
	CAT D 3516B	1200	1050
	CAT D 3508B	1200	550
Cambridge Bay	Detroit 16V4000	1200	1100
	CAT D 3508B	1200	550
	CAT D 3512B	1200	1100
	Detroit 16V4000	1200	1100
	Detroit 16V4000	1200	1100
Cape Dorset	16V4000 G73 MTU	1200	1100
	16V4000 G73 MTU	1200	1100
	8V4000 M63 MT	1200	525
	12V4000 G73 MT	1200	830
Chesterfield Inlet	Detroit Series 60	1800	320
	Detroit Series 60	1800	320
	CAT D 379	1200	400
Clyde River	CAT 3508B	1200	480
	CAT D 3508B	1200	550
	Detroit Series 60	1800	330
	CAT D 3508B	1800	550
Coral Harbour	CAT D 3508	1200	480
	CAT D 3508	1200	420
	CAT D 3508	1200	420
Gjoa Haven	CAT D 3512	1200	720
	MTU 8V4000 M63	1200	500
	Gauscor SF360TA	1200	550
	CAT 3508B	1200	550

Community	Model	RPM	Rating (kW)
Grise Fiord	TAD1344GE	1800	255
	TAD1344GE	1800	255
	TAD1344GE	1800	255
	TAD1350GE	1800	170
Hall Beach	CAT D 3406	1200	165
	CAT D 3508B	1200	500
	Detroit Series 60	1800	330
	CAT 3508B	1200	550
Igloolik	Detroit 12V4000	1200	850
	CAT D 3508	1200	480
	CAT D 3512	1200	720
	Detroit Series 60	1800	320
Iqaluit	Wartsila R32	720	3000
	EMD20V645	900	2500
	CAT D 3612	720	3300
	Wartsila 12V200	1200	2000
	Wartsila 12V32	720	4300
	Wartsila 12V32	720	5000
	Wartsila 12V32	720	5000
	Detroit Series 60	1800	330
	CAT D 3406	1200	320
Kimmirut	Volvo TAD 1344GE	1800	360
	Detroit Series 60	1800	300
	CAT D 3412	1200	330
	CAT D 3406	1200	350
Kugaaruk	Detroit Series 60	1800	320
	CAT D 3508B	1200	550
	CAT D 3508B	1200	550
Kugluktuk	Detroit DD4000	1800	875
	Detroit Series 60	1800	320
	Detroit Series 60	1800	320
	CAT D 3512	1200	720
Naujaat (Repulse Bay)	CAT D 3508B	1200	550
	CAT D 3508B	1200	550
	CAT D 3508B	1200	550
	CAT D 3508B	1200	550
Pangnirtung	Cummins DQGAF QSK-50-G5-S	1800	1100

Community	Model	RPM	Rating (kW)
	Cummins DQGAF QSK-50-G5-S	1800	1100
	Cummins DQGAA QST=30-G5	1800	680
	C27 Caterpillar MJE03777	1800	550
Pond Inlet	CAT D 3512	1200	720
	Detroit12V4000	1200	850
	Gauscor SF360TA	1200	550
	Gauscor SF360TA	1200	550
Qikiqtarjuaq	MTU 8V1600 B3OS	1800	300
	CAT D 3508B	1200	550
	CAT D 3508B	1200	550
	CAT C15	1800	370
Rankin Inlet	CAT D 3516	1200	950
	CAT D 3606	900	1500
	EMD 8V710	900	1450
	EMD L12V710	900	2150
	Detroit 12V4000	1200	820
Resolute Bay	Detroit Series 60	1800	320
	F2895 Waukesha	1200	350
	Detroit 8V400	1200	500
	CAT D 3406E	1200	320
	CAT D 3406E	1200	320
Sanikiluaq	Detroit Series 60	1800	330
	CAT D 3508B	1200	550
	CAT D 3508B	1200	550
Taloyoak	CAT C15	1800	370
	CAT 3508B	1200	550
	CAT 3508B	1200	550
	CAT C15	1800	370
Whale Cove	CAT D 3412	1200	300
	CAT D 3412	1200	300
	CAT D 3406	1200	150
	Detroit Series 60	1800	320

APPENDIX B. HOMER MODEL PARAMETERS

B.1. System Dispatch and Operation

The following operating settings were assumed:

- Load-following dispatch strategy
- Allow system with multiple generators
- Allow systems with two types of wind turbines
- Allow generators to operate simultaneously
- Allow system with generator capacities less than peak load
- Allow diesel-off operation.

B.2. System Components

B.2.1. Electrical Load

The day-to-day variability and timestep variability for each site were set so that the resulting peak annual load in HOMER was close (within ±2%) to the forecast 2025 peak load.

B.2.2. Diesel Generators

Generic HOMER diesel generator models were used, as the HOMER library contains only a limited selection of specific generator models. Within each site, the same generic model was used for all generators, including fuel curve and cost curve, with only the capacity adjusted.

B.2.3. PV

All PV was assumed to be south-facing. The optimal tilt angle for each site was determined to within 5° by modelling a range of angles in HOMER. These are shown in Table 8.

Table 8 Optimised PV array tilt angles

Community	Tilt Angle
Arctic Bay	70°
Arviat	55°
Baker Lake	60°
Cambridge Bay	60°
Cape Dorset	60°
Chesterfield Inlet	60°
Clyde River	60°

Community	Tilt Angle
Coral Harbour	60°
Gjoa Haven	60°
Grise Fiord	70°
Hall Beach	60°
Igloolik	60°
Iqaluit	60°
Kimmirut	55°
Kugaaruk	60°
Kugluktuk	60°
Naujaat (Repulse Bay)	60°
Pangnirtung	60°
Pond Inlet	70°
Qikiqtarjuaq	60°
Rankin Inlet	55°
Resolute Bay	70°
Sanikiluaq	50°
Taloyoak	60°
Whale Cove	55°

PV parameters entered were:

- Efficiency at STC of 16%
- Temperature coefficient of -0.4%/°C
- Derating factor of 80%. The derating factor is a scaling factor used to represent overall efficiency of the system, taking into account real-world operating conditions. It accounts for factors such as soiling of the panels, wiring losses, shading, module aging, etc. Since the inverter was not explicitly modelled as a separate component (see below), it also accounts for the inverter efficiency.

The PV component was modelled on the AC bus in HOMER. The inverter was not explicitly modelled as a separate component. This means that the inverter is automatically sized to match the PV. Modelling and sizing of particular inverter models is recommended at the feasibility stage, but would have negligible impact on results at the pre-feasibility stage.

B.2.4. Wind

The 2016 wind report [6] discussed modelling of two different wind turbine models in Nunavut. ITP has chosen to use the same wind turbines due to the cost data available in the report for these models.

The Enercon E70 and Northern Power NPS100C-21 are both available as pre-built models within HOMER. The hub heights were chosen as 57m and 25m respectively to match the specifications in the report.

B.2.5. BESS

The Tesla Powerpack 4hr was available as a pre-built model within HOMER. The Tesla Powerpack 2hr model was created by copying the 4hr model and changing the relevant parameters.

Tesla Powerpacks do not require a separate inverter, as the inverter technology is built-in to create an all-in-one solution. However, HOMER requires a separate Converter component. To model this, a generic, large capacity Converter component was added to the model, with cost set to zero and efficiency set to 100%. The efficiency of the Powerpack as a whole unit, including the inverter component, is taken into account in the Battery component round-trip efficiency.

B.2.6. Component Lifetimes

HOMER applies a salvage value to all components which are not at the end of their life at the end of the project analysis period (15 years, in this case), which is counted as positive cashflow. For most components, it is in fact unlikely that any value will be able to realised from the assets at this point. Batteries are an exception (e.g. batteries can be expected to retain value depending on their age and usage, and could be sold by an IPP to QEC at the end of the project period). Therefore, in order to avoid an unrealistic salvage value at the end of the modelled project lifetime, where possible the component lifetime for the other components was set to either the project analysis period (zero salvage value), or a factor of the project analysis period (to minimise the total salvage value).

- PV (and inverter): 15 years
- Wind turbines: 15 years
- Batteries: 10 years or 3,500 cycles
- Generators: The expected lifetime (in run hours) was based on the 2016 WISE report. We note that this will result in a salvage value for the generators at the end of the project; however, the effect on results is minor.

B.2.7. Shipping

Table 9 Shipping cost scaling factors

Community	Scaling factor
Arctic Bay	1.07
Arviat	1.00
Baker Lake	1.00
Cambridge Bay	1.25
Cape Dorset	0.93
Chesterfield Inlet	1.00
Clyde River	1.07
Coral Harbour	1.00
Gjoa Haven	1.25
Grise Fiord	1.07
Hall Beach	1.01
Igloolik	1.01
Iqaluit	0.82
Kimmirut	0.93
Kugaaruk	1.07
Kugluktuk	1.25
Naujaat (Repulse Bay)	1.01
Pangnirtung	0.93
Pond Inlet	1.07
Qikiqtarjuaq	1.07
Rankin Inlet	1.00
Resolute Bay	1.07
Sanikiluaq	1.04
Taloyoak	1.25
Whale Cove	1.00

APPENDIX C. DETAILED RESULTS

C.1. Results

The results for each community are displayed in tables below. The first row in each table presents the base case, which can be considered ‘business as usual’ – i.e. no renewable energy and no capital costs. The proceeding rows are the category winners for each of the minimum RE% constraints considered in this analysis (20%, 40%, 60%). The table summarises the scenarios that achieve the lowest Net Present Cost (NPC) while still meeting the RE% constraint. The NPC of each base case is presented, and the Net Present Values (NPV) of RE scenarios (relative to the base case) are presented in the same column, such that positive NPV’s indicate a financially attractive project. For these cases, the Nominal Internal Rate of Return (Nom. IRR) has been calculated.

Lines that have been presented in grey text are repeats of lower RE% constraint results that continue to win the NPC optimisation for higher RE% values.

			Solar	Wind		BESS		Results								Compared to Base Case	
								Without Heating Offset						With Heating Offset			
Community	Minimum RE% constraint	RE% achieved	PV (kW)	E-70 2.3MW	NPS100 100kW	PP2 2hr	PP2 4hr	NPC_{BC}/NPV ($M)	COE ($/kWh)	CAPEX ($M)	OPEX ($M/yr)	Fuel Elec (ML/Yr)	Spilt Elec (MWh/yr)	Spilt Elec (Eq. kL)	NPC_{BC}/NPV ($M)	Nom IRR (%)	Reduction CO_2-e (t/yr)
Arctic Bay	Base case	0	0	0	0	0	0	18.1	0.49	6.3	1.2	1.1	0	0	18.1	-	-
	20%	20	812	0	0	5	0	-2.1	0.55	10.3	1.0	0.9	30	4	-2.0		543
	40%	40	1942	0	0	0	18	-5.1	0.63	15.6	0.8	0.7	328	40	-4.6		1133
	60%	60	1842	0	6	0	40	-16.0	0.93	27.8	0.6	0.4	176	21	-15.8		1687
Arviat	Base case	0	0	0	0	0	0	37.3	0.37	8.1	3.0	2.7	0	0	37.3	-	-
	20%	20	2036	0	0	7	0	-3.4	0.40	16.1	2.5	2.2	164	20	-3.2		1372
	40%	40	4303	0	0	0	37	-8.2	0.45	26.2	2.0	1.6	479	58	-7.6		2808
	60%	60	7421	0	0	0	78	-17.5	0.54	40.2	1.5	1.1	1694	206	-15.4		4244
Baker Lake	Base case	0	0	0	0	0	0	35.3	0.39	8.4	2.7	2.4	0	0	35.3	-	-
	20%	20	1570	0	0	7	0	-2.1	0.41	14.9	2.3	2.0	118	14	-2.0		1225

			Solar	Wind		BESS		Results								Compared to Base Case	
								Without Heating Offset						With Heating Offset			
Community	**Minimum RE% constraint**	**RE% achieved**	PV (kW)	E-70 2.3MW	NPS100 100kW	PP2 2hr	PP2 4hr	NPC_{BC}/NPV ($M)	COE ($/kWh)	CAPEX ($M)	OPEX ($M/yr)	Fuel Elec (ML/Yr)	Spilt Elec (MWh/yr)	Spilt Elec (Eq. kL)	NPC_{BC}/NPV ($M)	Nom IRR (%)	Reduction CO_2-e (t/yr)
	40%	67	0	1	0	0	23	-4.3	0.44	28.7	1.1	0.8	1873	228	-1.9		4229
	60%	67	0	1	0	0	23	-4.3	0.44	28.7	1.1	0.8	1873	228	-1.9		4229
Cambridge Bay	Base case	0	0	0	0	0	0	53.1	0.39	13.8	4.0	3.6	0	0	53.1	-	-
	20%	20	0	0	8	3	0	-6.9	0.44	28.4	3.2	2.9	5	1	-6.9		1940
	40%	40	0	0	16	11	0	-11.9	0.48	38.9	2.7	2.2	34	4	-11.8		3722
	60%	60	602	1	0	0	26	-17.1	0.52	51.0	2.0	1.5	809	98	-16.0		5646
Cape Dorset	Base case	0	0	0	0	0	0	25.0	0.42	7.8	1.8	1.8	1	0	25.0	-	-
	20%	20	1355	0	0	8	0	-2.8	0.47	13.4	1.5	1.4	64	8	-2.8		882
	40%	40	2967	0	0	0	29	-6.2	0.52	20.0	1.1	1.1	316	38	-5.8		1831
	60%	60	5824	0	0	0	57	-14.5	0.66	31.0	0.9	0.7	1764	214	-12.2		2783
Chesterfield Inlet	Base case	0	0	0	0	0	0	10.6	0.50	4.4	0.6	0.6	0	0	10.6	-	-
	20%	29	460	0	0	4	0	-0.8	0.54	6.8	0.5	0.5	15	2	-0.8		455
	40%	40	665	0	0	0	8	-1.0	0.55	7.8	0.4	0.4	47	6	-1.0		640
	60%	60	1073	0	0	0	17	-2.0	0.60	10.2	0.3	0.3	158	19	-1.8		980
Clyde River	Base case	0	0	0	0	0	0	19.0	0.45	6.9	1.2	1.1	0	0	19.0	-	-
	20%	20	975	0	0	6	0	-2.8	0.51	11.7	1.0	0.9	31	4	-2.7		582
	40%	40	2213	0	0	0	22	-6.5	0.60	17.6	0.8	0.7	264	32	-6.1		1186
	60%	60	0	0	17	0	16	-16.6	0.84	29.5	0.6	0.5	596	72	-15.8		1792
Coral Harbour	Base case	0	0	0	0	0	0	19.0	0.50	4.7	1.5	1.2	0	0	19.0	-	-
	20%	20	657	0	0	0	4	-0.5	0.51	7.6	1.2	0.9	62	8	-0.4		575
	40%	40	1357	0	0	0	14	-1.0	0.52	11.1	0.9	0.7	148	18	-0.8		1199
	60%	60	2251	0	0	0	31	-3.2	0.58	15.8	0.6	0.5	468	57	-2.6		1819
Gjoa Haven	Base case	0	0	0	0	0	0	31.0	0.48	8.6	2.3	1.7	0	0	31.0	-	-
	20%	20	1431	0	0	0	7	-3.7	0.53	16.0	1.9	1.4	167	20	-3.5		884
	40%	40	2907	0	0	0	30	-8.4	0.61	25.0	1.5	1.1	316	38	-8.0		1814

Community	Minimum RE% constraint	RE% achieved	Solar	Wind		BESS		Results								Compared to Base Case	
								Without Heating Offset						With Heating Offset			
			PV (kW)	E-70 2.3MW	NPS100 100kW	PP2 2hr	PP2 4hr	NPC_{BC}/NPV ($M)	COE ($/kWh)	CAPEX ($M)	OPEX ($M/yr)	Fuel Elec (ML/Yr)	Spilt Elec (MWh/yr)	Spilt Elec (Eq. kL)	NPC_{BC}/NPV ($M)	Nom IRR (%)	Reduction CO_2-e (t/yr)
	60%	60	6218	0	0	0	67	-23.3	0.84	42.7	1.2	0.7	2411	293	-20.1		2741
Grise Fiord	Base case	0	0	0	0	0	0	8.2	0.78	5.6	0.3	0.3	0	0	8.2	-	-
	20%	20	301	0	0	2	0	-1.1	0.89	7.3	0.2	0.3	14	2	-1.1		154
	40%	40	690	0	0	0	7	-2.2	1.00	9.3	0.1	0.2	89	11	-2.1		322
	60%	60	257	0	3	0	4	-6.7	1.42	14.3	0.1	0.1	49	6	-6.6		473
Hall Beach	Base case	0	0	0	0	0	0	16.7	0.45	6.1	1.1	1.0	0	0	16.7	-	-
	20%	20	655	0	0	4	0	-1.2	0.48	9.2	0.9	0.8	15	2	-1.2		512
	40%	40	1446	0	0	0	16	-2.9	0.52	13.0	0.7	0.6	156	19	-2.7		1047
	60%	60	339	0	6	0	8	-5.5	0.59	17.8	0.5	0.4	136	16	-5.3		1564
Igloolik	Base case	0	0	0	0	0	0	29.7	0.39	7.0	2.3	2.0	0	0	29.7	-	-
	20%	20	1541	0	0	7	0	-2.9	0.43	13.6	1.9	1.6	94	11	-2.8		1033
	40%	40	3333	0	0	0	34	-7.3	0.49	22.0	1.5	1.2	377	46	-6.8		2110
	60%	60	7328	0	0	0	79	-21.7	0.68	39.3	1.2	0.8	3047	370	-17.8		3189
Iqaluit	Base case	0	0	0	0	0	0	216.2	0.34	32.7	18.7	17.2	0	0	216.2	-	-
	10%[7]	10	5360	0	0	0	0	0.7	0.33	46.7	17.3	15.6	31	4	0.7	8.9%	4104
	20%	20	11811	0	0	46	0	-4.1	0.34	68.2	15.5	13.8	671	82	-3.3		8730
	40%	40	7899	4	0	48	0	-10.8	0.35	102.2	12.8	10.5	1710	208	-8.9		17608
	60%	60	14887	6	0	0	175	-25.7	0.38	148.4	9.6	7.0	5600	681	-19.5		26757
Kimmirut	Base case	0	0	0	0	0	0	11.0	0.57	5.3	0.6	0.6	0	0	11.0	-	-
	20%	21	394	0	0	3	0	-0.9	0.61	7.3	0.5	0.5	3	0	-0.9		291
	40%	40	878	0	0	0	8	-1.5	0.64	9.2	0.3	0.4	110	13	-1.3		588
	60%	60	1510	0	0	0	17	-3.1	0.72	12.1	0.2	0.2	359	44	-2.6		899
Kugaaruk	Base case	0	0	0	0	0	0	15.6	0.48	5.1	1.1	0.9	0	0	15.6	-	-

[7] This is the only case where a system with <20% RE has a positive NPV. It is included because it is the optimal case for Iqaluit.

			Solar	Wind		BESS		Results								Compared to Base Case	
								Without Heating Offset						With Heating Offset			
Community	Minimum RE% constraint	RE% achieved	PV (kW)	E-70 2.3MW	NPS100 100kW	PP2 2hr	PP2 4hr	NPC_{BC}/NPV ($M)	COE ($/kWh)	CAPEX ($M)	OPEX ($M/yr)	Fuel Elec (ML/Yr)	Spilt Elec (MWh/yr)	Spilt Elec (Eq. kL)	NPC_{BC}/NPV ($M)	Nom IRR (%)	Reduction CO_2-e (t/yr)
	20%	20	709	0	0	5	0	-1.9	0.54	8.8	0.9	0.7	17	2	-1.9		451
	40%	40	1617	0	0	0	16	-4.2	0.61	13.1	0.7	0.5	200	24	-4.0		920
	60%	60	3424	0	0	0	34	-10.9	0.82	21.3	0.5	0.4	1268	154	-9.2		1390
Kugluktuk	Base case	0	0	0	0	0	0	27.3	0.44	8.5	1.9	1.7	0	0	27.3	-	-
	20%	20	1312	0	0	7	0	-4.3	0.51	15.7	1.6	1.3	50	6	-4.2		841
	40%	40	2913	0	0	0	28	-9.9	0.60	24.6	1.3	1.0	332	40	-9.4		1717
	60%	60	6160	0	0	0	59	-24.2	0.83	41.3	1.0	0.7	2286	278	-21.1		2596
Naujaat	Base case	0	0	0	0	0	0	22.6	0.46	6.8	1.6	1.3	0	0	22.6	-	-
	20%	20	972	0	0	7	0	-1.9	0.50	11.5	1.3	1.1	10	1	-1.9		692
	40%	40	2235	0	0	0	21	-4.2	0.55	16.9	1.0	0.8	296	36	-3.8		1403
	60%	60	4311	0	0	0	45	-10.9	0.68	26.1	0.8	0.5	1438	175	-9.1		2119
Pangnirtung	Base case	0	0	0	0	0	0	28.5	0.43	7.7	2.1	2.0	0	0	28.5	-	-
	20%	20	1411	0	0	9	0	-2.4	0.47	13.5	1.8	1.6	32	4	-2.4		972
	40%	40	3246	0	0	0	30	-5.8	0.52	20.8	1.4	1.2	420	51	-5.2		2020
	60%	60	6132	0	0	0	66	-14.4	0.65	32.7	1.0	0.8	1840	224	-12.0		3073
Pond Inlet	Base case	0	0	0	0	0	0	29.3	0.42	7.8	2.2	1.9	0	0	29.3	-	-
	20%	20	1629	0	0	10	0	-4.2	0.48	15.5	1.8	1.5	47	6	-4.2		959
	40%	40	3701	0	0	0	38	-10.4	0.57	25.4	1.5	1.1	433	53	-9.9		1955
	60%	60	9669	0	0	0	103	-36.2	0.93	52.5	1.3	0.8	4456	542	-30.5		2954
Qikiqtarjuaq	Base case	0	0	0	0	0	0	15.2	0.51	6.7	0.9	0.8	71	9	15.1	-	-
	20%	20	766	0	0	4	0	-2.0	0.58	10.4	0.7	0.6	98	12	-2.0		460
	40%	40	1588	0	0	0	16	-4.5	0.67	14.6	0.5	0.5	228	28	-4.3		886
	60%	60	2899	0	0	0	34	-9.8	0.84	21.2	0.4	0.3	816	99	-8.8		1312
Rankin Inlet	Base case	0	0	0	0	0	0	65.2	0.36	13.4	5.3	4.9	0	0	65.2	-	-
	20%	49	0	1	0	16	0	1.7	0.35	34.5	3.0	2.5	171	21	2.0	9.2	6196

			Solar	Wind		BESS		Results								Compared to Base Case	
								Without Heating Offset						With Heating Offset			
Community	**Minimum RE% constraint**	**RE% achieved**	PV (kW)	E-70 2.3MW	NPS100 100kW	PP2 2hr	PP2 4hr	NPC_{BC}/NPV ($M)	COE ($/kWh)	CAPEX ($M)	OPEX ($M/yr)	Fuel Elec (ML/Yr)	Spilt Elec (MWh/yr)	Spilt Elec (Eq. kL)	NPC_{BC}/NPV ($M)	Nom IRR (%)	Reduction CO_2-e (t/yr)
	40%	49	0	1	0	16	0	1.7	0.35	34.5	3.0	2.5	171	21	2.0	9.2	6196
	60%	74	0	2	0	0	46	1.2	0.35	46.7	1.8	1.3	4742	576	7.2	8.5	9459
Resolute Bay	Base case	0	0	0	0	0	0	20.6	0.48	7.9	1.3	1.2	0	0	20.6	-	-
	20%	20	861	0	0	6	0	-2.1	0.53	12.2	1.1	0.9	15	2	-2.1		593
	40%	45	0	0	6	4	0	-5.0	0.59	18.6	0.7	0.6	61	7	-4.9		1343
	60%	61	0	0	9	0	9	-6.2	0.62	21.9	0.5	0.5	369	45	-5.7		1834
Sanikiluaq	Base case	0	0	0	0	0	0	17.7	0.44	4.9	1.3	1.1	0	0	17.7	-	-
	20%	20	730	0	0	0	4	-1.2	0.47	8.3	1.1	0.9	41	5	-1.1		552
	40%	40	1564	0	0	0	13	-2.5	0.50	12.2	0.8	0.7	178	22	-2.3		1130
	60%	62	0	0	7	5	0	-3.8	0.53	16.4	0.5	0.4	242	29	-3.5		1756
Taloyoak	Base case	0	0	0	0	0	0	22.3	0.51	7.9	1.5	1.2	0	0	22.3	-	-
	20%	20	878	0	0	6	0	-2.7	0.57	13.1	1.2	0.9	12	1	-2.7		600
	40%	40	1983	0	0	0	21	-6.3	0.65	19.4	0.9	0.7	218	26	-6.0		1223
	60%	60	4390	0	0	0	46	-17.2	0.90	32.2	0.7	0.5	1795	218	-14.8		1849
Whale Cove	Base case	0	0	0	0	0	0	10.6	0.50	4.0	0.7	0.6	0	0	10.6	-	-
	20%	20	402	0	0	2	0	-0.8	0.54	5.9	0.6	0.5	24	3	-0.8		288
	40%	40	853	0	0	0	8	-1.5	0.57	8.1	0.4	0.3	89	11	-1.4		588
	60%	60	1475	0	0	0	17	-3.3	0.66	11.2	0.3	0.2	340	41	-2.8		890

C.2. Site Commentary

Commentary for each of the sites is provided below, summarising the results and highlighting any interesting aspects of the scenario. It is not an exhaustive discussion.

- **Arctic Bay:** $2M of grant funding could make 20% RE financially attractive. This represents about a 12% increase on the base case NPC based on our initial assumptions and currently available wind and solar data. There were no ground measurements available, so further data collection on the wind and solar resource should be conducted.
- **Arviat:** No immediate financial case for RE is apparent, however there were data gaps for this community. PV was favoured over wind in all the optimised scenarios. There were no ground measurements for wind and solar data available. Further investigation is needed, and it is acknowledged that the data being collected at NRStor's met tower may be supplying better information on the viability of renewable energy projects for Arviat.
- **Baker Lake:** Baker Lake is a community that warrants further study. Based on currently available data, there is no immediate financial case for RE, but around $2M of grant funding could make 20% RE financially viable. This represents about a 6% increase on the base case NPC. The optimisation favoured PV for the 20% RE case and wind for the higher % RE cases. Ground measurements were available for both solar and wind resources. Top-five community for cost-effective CO_2 reduction and highest average solar resource. The consumption of heating oil is high relative to consumption for generation, which suggests that offsetting heating with RE is worth further investigation. If the heating potential of the spilt electricity can be realised, 67% RE would be financially viable with around $2M in grant funding. This is a borderline case that warrants further investigation, particularly the potential for offsetting heating with RE. In addition, the financial sensitivity analysis revealed that Baker Lake is significantly affected by the rate at which they can access capital for projects. A 4% discount rate showed that 68.5% renewable energy penetration becomes immediately attractive for the community, so effort spent on securing favourable financing terms would be worthwhile.
- **Cambridge Bay:** No immediate financial case for RE is apparent. Wind power was favoured in the optimisation, with a small amount of PV included to achieve 60% RE. Top five community for highest average wind resource. Ground measurements were available for both solar and wind.
- **Cape Dorset:** No immediate financial case for RE is apparent, however there were significant data gaps for this community. Solar power was favoured in the optimisation for all scenarios. No ground measurements of the wind or solar resources were available.

- **Chesterfield Inlet:** A case can be made for renewable energy in this community with only a modest increase in price, and reducing the discount to 4% made significant changes to the attractiveness of renewable energy and warrants further study. The optimisation favoured PV over wind in all cases. Top five community for most cost-effective CO_2 reduction, highest average solar and wind resources. Ground measurements were available for both solar and wind resources.
- **Clyde River:** No immediate financial case for RE is apparent. Wind power was favoured in the 60% RE scenario, while PV was favoured for the lower RE cases. Ground measurements were available for wind speeds, but not the solar resource.
- **Coral Harbour:** Coral Harbour is a community that warrants further study. RE was found to be financially viable at a 4% discount rate, while ~$1M in grant funding could make 40% RE financially viable at an 8% discount rate. This represents about a 5% increase on the base case NPC. In all optimised scenarios, PV was favoured over wind. Top five community for most cost-effective CO_2 reduction and highest average solar resource. Ground measurements were available for both the solar and wind resources.
- **Gjoa Haven:** No immediate financial case for RE apparent, however there are some significant data gaps for this community. In all optimised scenarios, PV was favoured over wind. No ground measurements were available for either the wind or solar resources. Further data collection on the wind and solar resource should be conducted.
- **Grise Fiord:** Around $2.2M grant funding could make 40% RE financially viable. This represents about a 27% increase on the base case NPC. Grant funding of $1.1M could enable 20% RE, representing a 13% increase on the base case NPC. PV was favoured in the 20 and 40% RE cases, while a mix of PV and wind was favoured in the 60% RE case. The consumption of heating oil is high relative to the population, which suggests that offsetting heating with RE is worth further investigation as it may improve the viability of RE. No ground measurements were available for either the wind or solar resources, so further data collection on the wind and solar resource should be conducted.
- **Hall Beach:** Around $1.2M grant funding could make 20% RE financially viable. This represents about a 7% increase on the base case NPC. PV was favoured in the 20 and 40% RE cases, while a mix of PV and wind was favoured in the 60% RE case. Ground measurements were available for solar and wind resources.
- **Igloolik:** No immediate financial case for RE is apparent. The optimisation favoured PV in all three scenarios. As ground measurements were not available, further data collection on the wind and solar resource should be conducted.
- **Iqaluit:** There is an immediate financial case for 5.4 MW of PV, achieving 10% RE. Around $4M grant funding could make 20% RE financially viable, representing a 2% increase in the

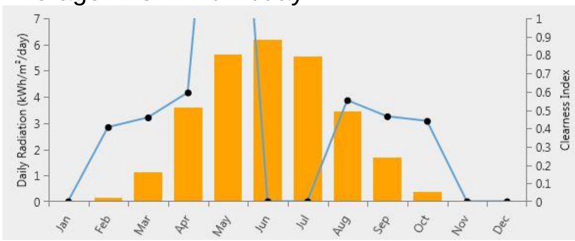
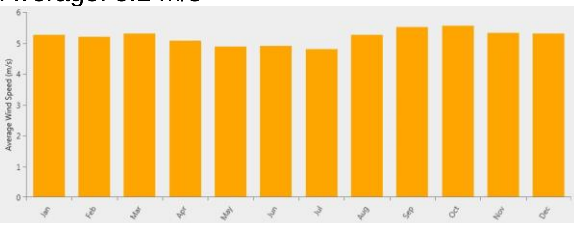
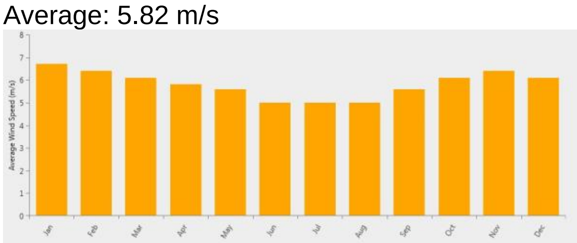
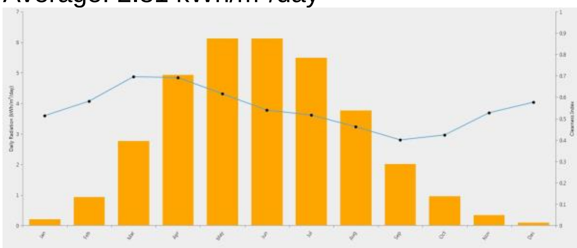
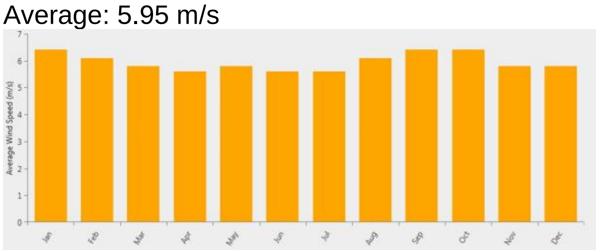
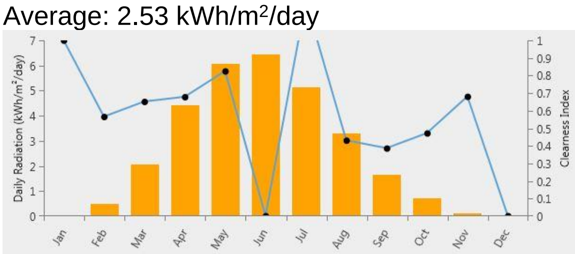
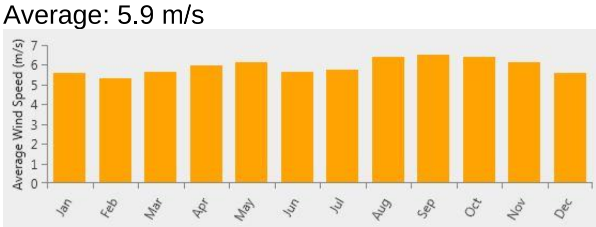
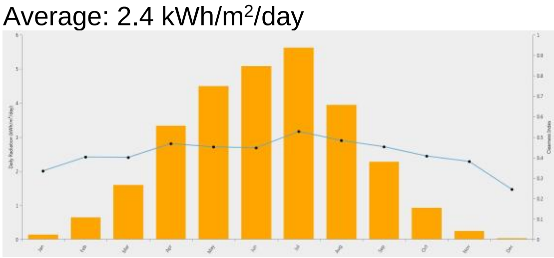
base case NPC. This scenario has the most cost-effective CO_2 reductions at 2.15t/yr per $1000 invested. A mix of PV and wind was favoured in the 40 and 60% RE cases, but only PV was favoured in the 20% RE case. Top five community for most cost-effective CO_2 reduction. Ground measurements were available for solar and wind resources.

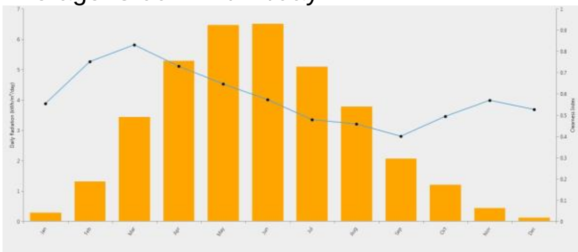
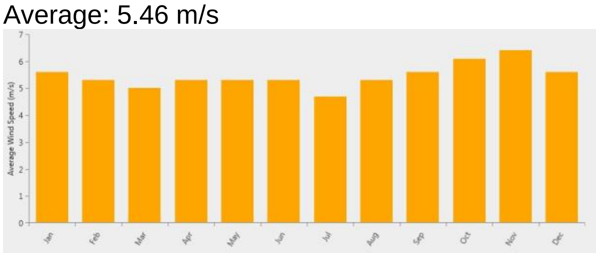
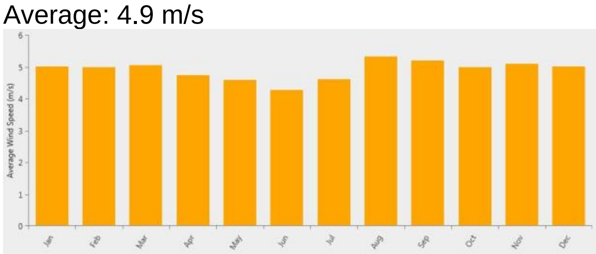
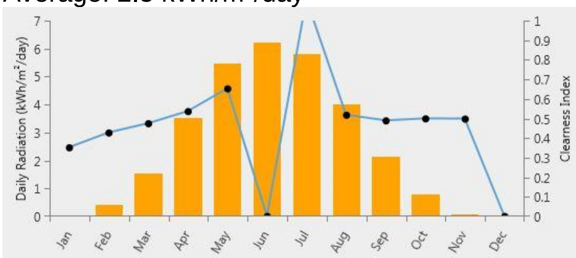
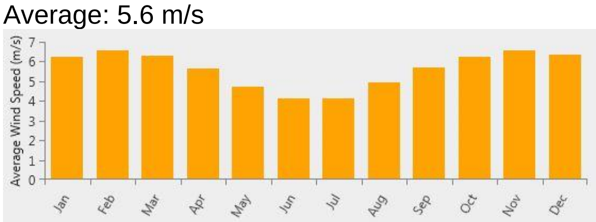
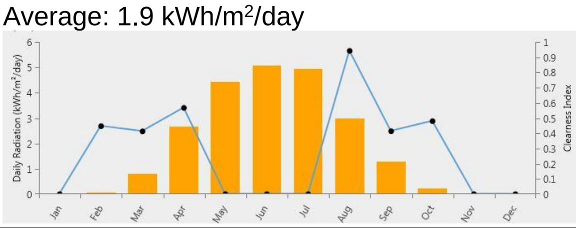
- **Kimmirut:** $1.5M in grant funding could make 40% RE financially viable. This represents about a 14% increase on the base case NPC. In all optimised scenarios, PV was favoured over wind. Top five community for highest average wind resource. No measured resource data was available, so further data collection on the wind and solar resource should be conducted.
- **Kugaaruk:** Less than $2M grant funding could make 40% RE financially viable. This represents about a 12% increase on the base case NPC. In all optimised scenarios, PV was favoured over wind. No measured resource data was available, so further data collection on the wind and solar resource should be conducted.
- **Kugluktuk:** No immediate financial case for RE is apparent, though data gaps were found for this community. In all optimised scenarios, PV was favoured over wind. Sensitivity analysis showed that 5-10% RE became optimal for a discount rate of 4% and a diesel price of $1.60/L (about a 50% increase in diesel price). These are significant changes from the current situation. The consumption of heating oil is high relative to consumption for generation and population, which suggests that offsetting heating with RE is worth further investigation. Ground measurements were available for the wind resource but not for solar.
- **Naujaat:** Around $1.9M grant funding could make 20% RE financially viable. This represents about an 8% increase on the base case NPC. In all optimised scenarios, PV was favoured over wind. No measured resource data was available, so further data collection on the wind and solar resource should be conducted.
- **Pangnirtung:** No immediate financial case for RE is apparent. The optimisation favoured PV in all scenarios. No ground measurements were available for either wind or solar resources, so further data collection should be conducted.
- **Pond Inlet:** No immediate financial case for RE is apparent. The optimisation favoured PV in all scenarios. Ground measurements were available for wind but not the solar resource.
- **Qikiqtarjuaq:** Around $2M grant funding could make 20% RE financially viable. This represents about a 13% increase on the base case NPC. In all optimised scenarios, PV was favoured over wind. Ground measurements were available for wind resource but not solar.
- **Rankin Inlet:** There is an immediate financial case for installing 1 x Enercon E-70 2.3MW wind turbine and 16 Tesla PP2 2hr batteries. This achieves 49% RE. If the full heating potential of spilt electricity can be realised, there is a financial case for 2 x E-70 turbines and

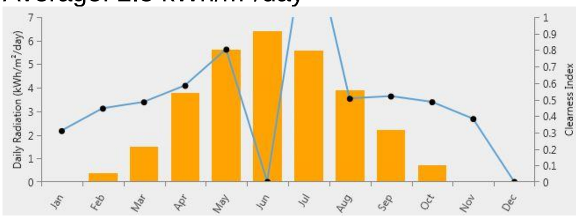
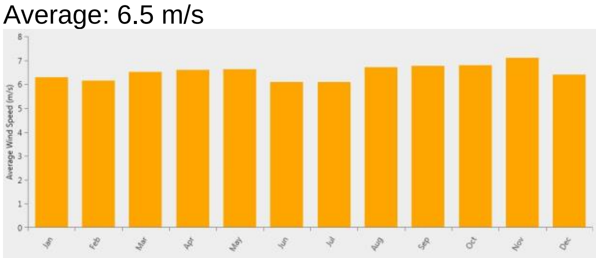
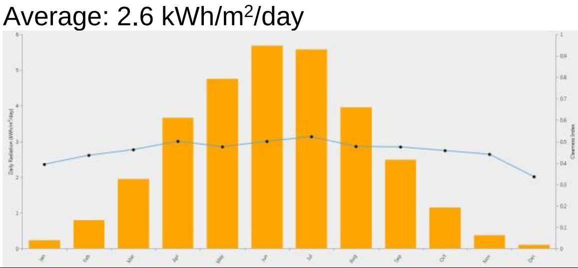
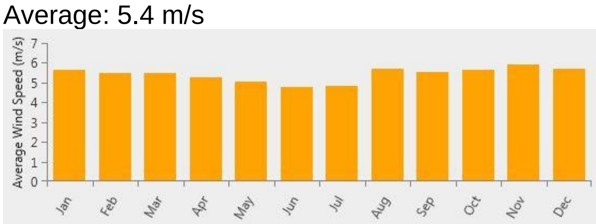
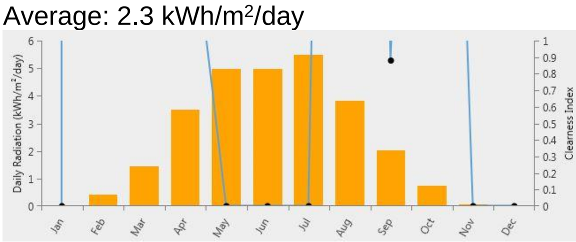
46 x 4hr Tesla Powerpack's, achieving 74% RE. Top five community for most cost-effective CO_2 reduction. Sensitivity analysis showed that either a lower discount rate or higher diesel price slightly increases the optimal amount of RE. For a higher diesel price (20% increase), the scenario modelled here is still viable at a discount rate as high as 12%. Top five community for cost-effective CO_2 reduction, highest average solar and wind resources. Very low heating oil consumption relative to fuel for electricity. Ground measurements were available for wind resource but not solar.

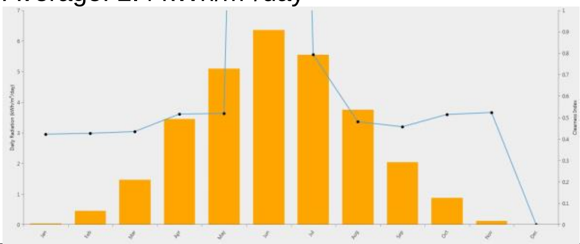
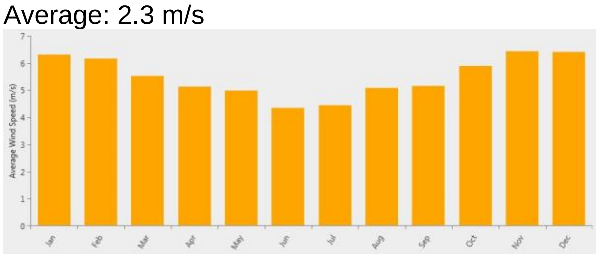
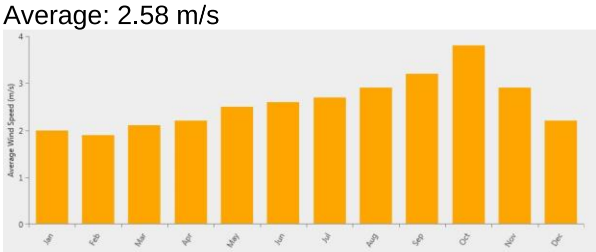
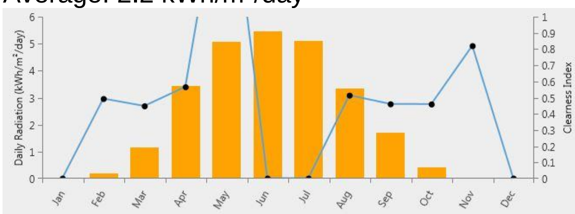
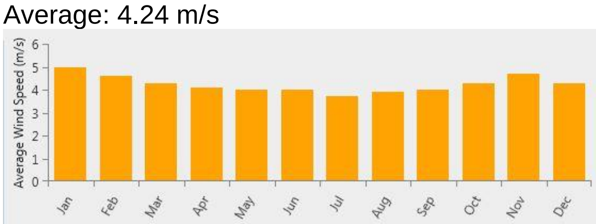
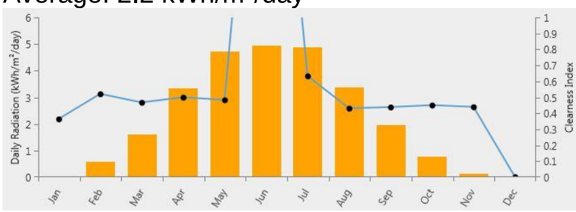
- **Resolute Bay:** Around $2.1M grant funding could make 20% RE financially viable. This represents about a 10% increase on the base case NPC. PV was favoured in the 20% RE case, while wind was favoured in the 40 and 60% RE cases. The consumption of heating oil is high relative to consumption for generation and population, which suggests that offsetting heating with RE is worth further investigation as it may improve the financial case. Ground measurements were available for solar and wind resources.
- **Sanikiluaq:** Less than $2M grant funding could make 20% RE financially viable. This represents about a 14% increase on the base case NPC. This could be reduced if the full heating potential of the spilt electricity is realised. PV was favoured in the 20 and 40% RE cases, while wind was favoured in the 60% RE case. Sensitivity analysis showed that a moderate increase in the diesel price and moderate drop in the discount rate makes RE much more attractive. For a discount rate of 6% and diesel fuel price of $1.50/L (45% increase), a high level of RE penetration becomes viable. Highest average solar and wind resources. Ground measurements were available for wind resource but not solar.
- **Taloyoak:** No immediate financial case for RE is apparent, however there are still significant data gaps for this community. The optimisation favoured PV in all scenarios. No ground measurements were available for either wind or solar resources, so further data collection is warranted.
- **Whale Cove:** There is no immediate financial case for RE, however there are significant data gaps for this community. Around $1.5M grant funding could make 40% RE financially viable. This represents about a 15% increase on the base case NPC. In all optimised scenarios, PV was favoured over wind. No ground-measured renewable resource data was available, and it is recommended this data be collected and shared in order to better assess the financial viability of RE projects here.

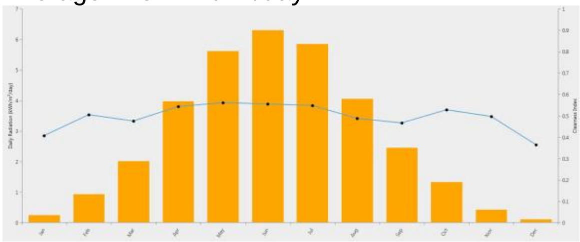
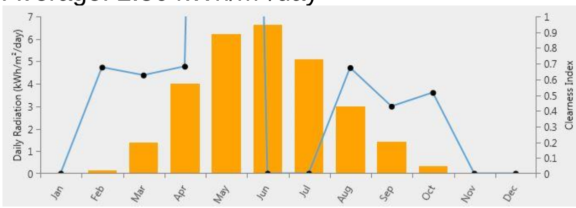
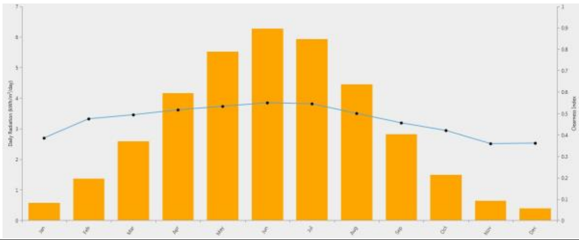
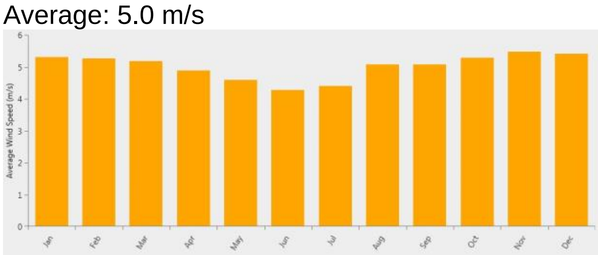
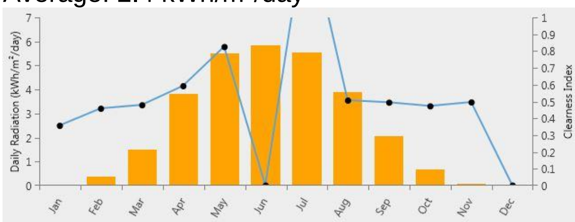
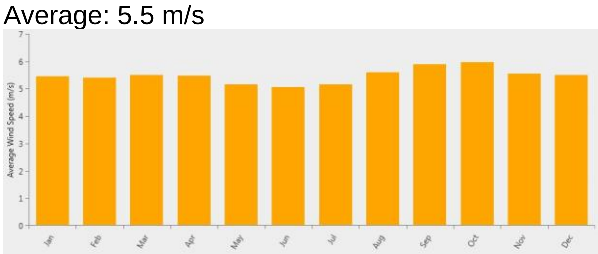
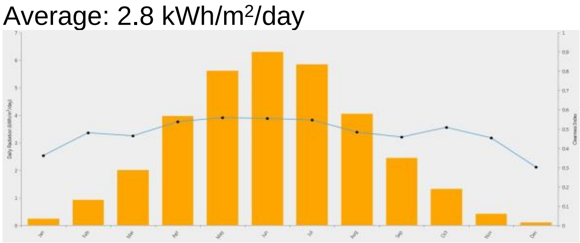
APPENDIX D. RESOURCE DATA

	Wind Speed	Solar Irradiation
Arctic Bay	Source: NASA Average: 4.9 m/s 	Source: NASA Average: 2.3 kWh/m²/day 
Arviat	Source: NASA Average: 5.2 m/s 	Source: NASA Average: 2.7 kWh/m²/day 
Baker Lake	Source: Ground (RETScreen) Average: 5.82 m/s 	Source: Ground (RETScreen) Average: 2.81 kWh/m²/day 
Cambridge Bay	Source: Ground (RETScreen) Average: 5.95 m/s 	Source: Ground (RETScreen) Average: 2.53 kWh/m²/day 
Cape Dorset	Source: NASA Average: 5.9 m/s 	Source: NASA Average: 2.4 kWh/m²/day 

	Wind Speed	Solar Irradiation
Chesterfield Inlet	Source: Ground (RETScreen) Average: 6.07 m/s 	Source: Ground (RETScreen) Average: 3.00 kWh/m²/day 
Clyde River	Source: Ground (RETScreen) Average: 4.38 m/s 	Source: NASA Average: 2.2 kWh/m²/day 
Coral Harbour	Source: Ground (RETScreen) Average: 5.46 m/s 	Source: Ground (RETScreen) Average: 2.90 kWh/m²/day 
Gjoa Haven	Source: NASA Average: 4.9 m/s 	Source: NASA Average: 2.5 kWh/m²/day 
Grise Fiord	Source: NASA Average: 5.6 m/s 	Source: NASA Average: 1.9 kWh/m²/day 

	Wind Speed	Solar Irradiation
Hall Beach	Source: Ground (RETScreen) Average: 5.88 m/s 	Source: Ground (RETScreen) Average: 2.64 kWh/m²/day 
Igloolik	Source: NASA Average: 4.9 m/s 	Source: NASA Average: 2.5 kWh/m²/day 
Iqaluit	Source: Ground (RETScreen) Average: 4.44 m/s 	Source: Ground (RETScreen) Average: 2.53 kWh/m²/day 
Kimmirut	Source: NASA Average: 6.5 m/s 	Source: NASA Average: 2.6 kWh/m²/day 
Kugaaruk	Source: NASA Average: 5.4 m/s 	Source: NASA Average: 2.3 kWh/m²/day 

	Wind Speed	Solar Irradiation
Kugluktuk	Source: Ground (RETScreen) Average: 4.42 m/s 	Source: NASA Average: 2.4 kWh/m²/day 
Naujaat (Repulse Bay)	Source: NASA Average: 5.3 m/s 	Source: NASA Average: 2.5 kWh/m²/day 
Pangnirtung	Source: NASA Average: 2.3 m/s 	Source: NASA Average: 5.5 kWh/m²/day 
Pond Inlet	Source: Ground (RETScreen) Average: 2.58 m/s 	Source: NASA Average: 2.2 kWh/m²/day 
Qikiqtarjuaq	Source: Ground (RETScreen) Average: 4.24 m/s 	Source: NASA Average: 2.2 kWh/m²/day 

	Wind Speed	Solar Irradiation
Rankin Inlet	Source: Ground (RETScreen) Average: 6.44 m/s 	Source: NASA Average: 2.8 kWh/m²/day 
Resolute Bay	Source: Ground (RETScreen) Average: 5.90 m/s 	Source: Ground (RETScreen) Average: 2.36 kWh/m²/day 
Sanikiluaq	Source: Ground ("Wind Measurements in Sanikiluaq" [15]) Average: 6.76 m/s 	Source: NASA Average: 3.0 kWh/m²/day 
Taloyoak	Source: NASA Average: 5.0 m/s 	Source: NASA Average: 2.4 kWh/m²/day 
Whale Cove	Source: NASA Average: 5.5 m/s 	Source: NASA Average: 2.8 kWh/m²/day 

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