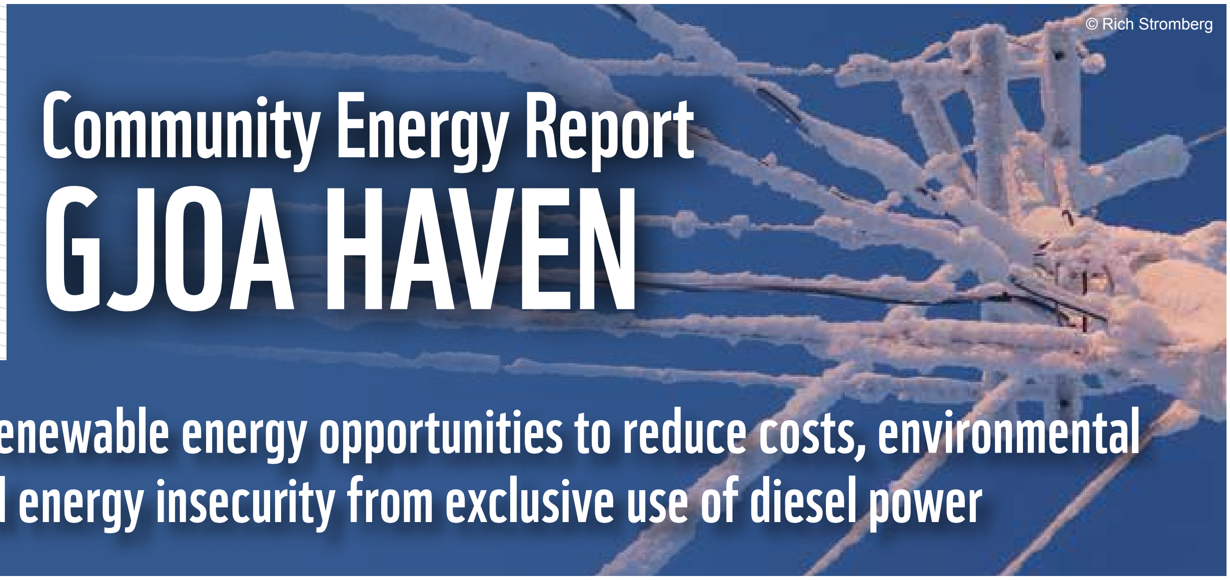


© Rich Stromberg

Community Energy Report
GJOA HAVEN

Assessing renewable energy opportunities to reduce costs, environmental impacts and energy insecurity from exclusive use of diesel power

In February 2018, at the request of the community, World Wildlife Fund Canada and the Alaska Center for Energy and Power (ACEP) visited the Hamlet of Gjoa Haven to explore the potential for renewable energy. Through meetings with community members and tours of existing infrastructure, we heard obvious interest and saw broad potential for an array of solutions to reduce reliance on diesel fuel.

Concerns about diesel use and climate change were widespread from community members, including Hamlet councilors, elders, local Qulliq Energy Corporation employees, and local government of Nunavut employees from the water board. In addition to the health and emissions concerns, it was also noted that the community has issues with unusable waste oil storage, as well as sites that have been contaminated by past diesel spills that have yet to be cleaned up.

Evaluating green energy options

Low potential · Medium potential · High potential

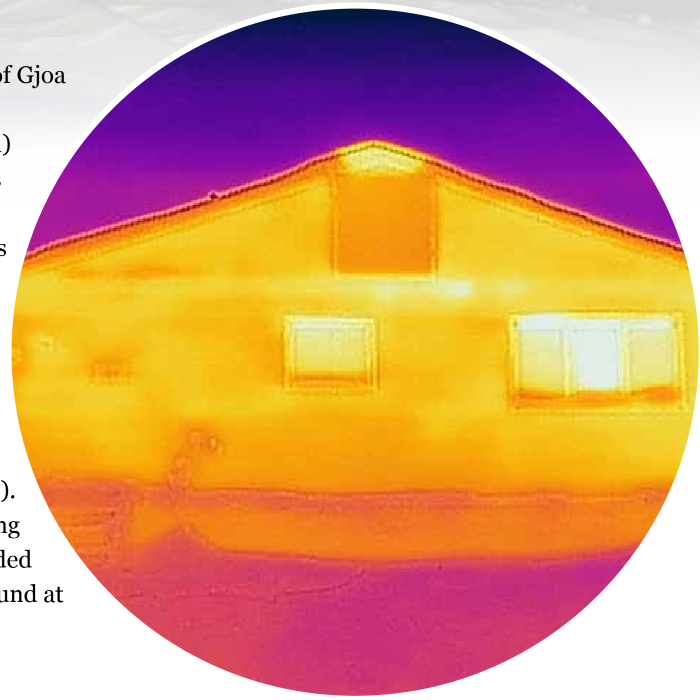
Based on input from community members, as well as the energy use data and available wind and solar data, potential renewable energy and energy efficiency projects were summarized and ranked as follows:

Initiative	Potential energy savings	Community control	Energy security	Cost	Years to implement	Payback (years)
Energy efficiency training and upgrades	Low / Medium	High	Medium	Low	1-3	1-3
Data collection: home energy information to change consumption behaviour	Low	High	Low	Low	1-3	1-3
Resume use of waste oil boiler. Implement new liquid waste management system.	Low	Medium	Low	Low	1-3	1-3
Off-grid solar installation training for recreational cabins	Low	Low / Medium	Low	Medium	1-3	3-5
Energy cooperative: purchase solar / increases efficiency	Low / Medium	High	Low	Low	1-3	1-3
Building a renewably-powered community greenhouse	Low	High	Low	Low	3-5	3-5
Building a renewably-powered community cold storage	Low	High	Low	Low	3-5	3-5
Install power plant heat recovery loop	Medium	Low	Low	Medium	3-5	5-7
Community-scale solar energy system	Low / Medium	Low / Medium	Medium	Medium	3-5	15-20
Design housing for northern climate/culture	Medium	High	Medium	Medium	3-7	10-12
Community-scale wind energy system	Medium / High	Low	High	High	7-9	15-20
Develop a community energy plan	Medium / High	High	High	Low	1-20	3-10
Local green energy jobs to support energy systems	Low	High	High	Low	1-20	3-5


© Rich Stromberg

How to use this report

This report contains a wealth of information for the community of Gjoa Haven to use to initiate renewable energy and energy efficiency projects. **Preliminary wind and solar resource data** (p.3-11) and **electrical and heating load data** (p.17-21) can be used as the design basis for a project and could be shared with potential investors and developers of renewable energy. In addition, details on a **community-wide energy efficiency initiative** (p.21), and a **solar PV installation and training program** (p.25) are the two that would provide immediate benefits in terms of education, training, jobs, and diesel reduction. **Community projects such as a Community Energy Plan, community green house, or community cold storage facility** are projects that the community expressed interest in pursuing (p.26). A relatively quick and immediate project was also identified during our site visit – a **waste-oil-to-heat project** (p.27). Recommended guidelines for community scale wind and solar projects can be found at the end of the report.


© Rich Stromberg


© Rich Stromberg

WWF-Canada and community renewable energy

Thoughtful renewable energy projects can provide viable, cost-effective alternatives to diesel fuel in Nunavut. WWF-Canada is committed to building local capacity and supporting remote northern communities realize their full potential to lead the transition to habitat-friendly renewable power.

FOR MORE INFORMATION:

Martha Lenio, associate specialist, renewable energy
WWF-Canada
mlenio@wwfcanada.org


© Rich Stromberg

WWF CANADA

© Rich Stromberg

ᓄᓇᓕᓐᒥᐅᓂᑦ ᐆᒪᖅᑯᑎᓄᑦ ᑐᓴᕐᕕᓴᖅ:

ᐅᖅᓱᖅᑑᒥ

ᖃᐅᔨᓴᖅᑐᒧᑦ ᐊᑐᐃᓇᒐᓚᔭᖅ ᐊᑐᐃᓇᐅᔪᓐᓇᖅᑐᖅ ᐅᖅᓱᖅᐸᐊᖅᒧᑦ ᐊᑭᓪᓕᕆᐊᕈᑎᓚᒧᑦ, ᐊᕙᑎᒥᐅᑕᖅᑲᓪᓗ ᐊᓪᓘᑎᓯᒪᖕᒋᓂᖅᓴᐅᖁ’ᓗᒍ ᐆᒪᖅᑯᑎᓄᓪᓗᐊᔪᖅᓴᕈᑕᐅᕙᓪᓗᓂᑦ ᐅᖅᓱᖅᐸᐊᖅᐊᑐᖅᑕᐅᕙᓪᓚᖅᓂᖕᒐᓄᑦ ᐃᓪᓂᕐᑯᑎᓄᑦ

ᕕᐸᕈᐊᕆ 2018ᒥ, ᓄᓇᓕᓐᒥᐊᓄᑦ ᑐᓯᖅᑕᐅᓯᒪᓂᓄᑦ, ᓄᓇᖅᑭᐊᖅᒧᑦ ᐊᖑᑎᓭᓕᕆᔾᑦ ᑳᓇᑕᒥᑕᐃᒪᓗ ᐊᓛᔅᑲᒥ ᐆᒻᒪᖅᑯᑎᓕᕆᔨᓂᑦ (ACEP) ᑯ’ᓂᑦ ᑎᑭᓯᒪᓕᖅᑐᑦ ᐅᖅᓱᖅᑑᒧᑦ ᕿᓂᕆᐊᖅᓱᑎᒃ ᓯᕿᓂᖅᒧᑦ ᐆᒻᒪᖅᑯᑎᓕᐅᕈᑎᒃ ᖃᓄᖅ ᐊᑐᕈᓐᓄ’ᒪᖕᒋᓛ ᑲᑎᒪᖃᑎᖃᖃᑕᖅᓂᒃᑯᑦ ᓄᓇᓕᓐᒥᐅᓂᒃ ᑕᐃᒪᓗ ᐸᓕᕋᖅᑐᓕᕆᓂᖅᒧᑦ ᐃᓪᓗᑕᕆᔭᐅᔪᓄᑦ, ᐃᓱᒪᒋᔭᐅᔪᓂᒃ ᑐᓴᖅᓯᒪᕗᒧᑦ ᑲᑎᒪᔨᓂᓪᓗ ᑐᓴᖅᑕ ᐃᓱᒪᒋᔭᐅᔪᓂᒃ ᐊᑕᐅᓯᐅᖅᒋᑦᑐᓂᒃ ᐊᑐᕐᒋᓂᖅᓴᐅᔫᓇᖅᓂᖅᒥᒃ ᐅᖅᓱᖅᐸᐊᖅᒥᒃ ᐃᓱᒫᓘᑎᒋᔭᐅ’ᒪᑦ ᐅᖅᓱᖅᐸᐸ ᐊᑐᖅᑕᐅᓂᕆᔭ ᓯᓚᒧᑦ ᐊ’ᓚᖓᖅᐸᓪᓚᐊᔾᔭᑕᐅᓂᖕᒐᓂᒃᑕᓴᓇ ᑐᖅᓇᖅᑎᑕᐅᔪᖅ ᓄᓇᓕᓐᒥᐅᑕᖅᓂᑦ ᐊᒥᓱᓂᑦ, Hᐋᒪᓗᒃᑯᑦᐃᓚᐅ’ᓗᑎᒃ. ᑲᑎᒪᔨᓂᑦ, ᐃᓄᑐᖃᖅᓂᑦ, ᐃᓐᓂᕐᑯᑎᓂᓗ ᓴᓇᔨᐅᔭᓂᑦ, ᓄᓇᓕᓐᓂᓗ ᒐᕙᒪᓂᑦ ᓴᓇᔨᐅᔪᓂᑦ ᑕᐃᒪᓗ ᐃᒪᓕᕆᔨᓂᑦ.. ᐃᓚᓕᐅᑎᓯᒪ’ᓗᓂ ᐋᓐᓂᐊᓕᖅᑕᖅᓂᖅ ᐃᓗᓇᕐᒋᓂᖅᑲᓕᖅᑕᖅᓂᖅᓗ ᐃᓱᒫᓘᑎᒋᔭᐅ’ᓗᓂ, ᐅᖃᐅᓯᐅᕆ’ᓗᓂ ᕿᖅᑕᕚᓃᑦ ᐊᑐᖅᑕᐅᓯᐃᖅᑐᑦ ᑐᑦᑯᖅᕚᖃᖕᒋᓂᕆ’ᓄᑦ, ᓄᓇᑕᔭᐅᒧᖅᓗ ᕿᓂᖅᑕᓄᑦ ᓱᕈᖅᑕᐅᓯᒪᓂᔮᓇᑦ ᐊᓯᓇᒃᑕᐅᓯᒪᔪᕝᕙᓂᖅᓄᑦ ᓱᓕ ᓴᓖᒃᑕᐅᕆᐊᖅᓯᒪᕆᑐᓄᑦ.

ᓇᓗᓇᐃᖅᑐᒐᐅᓂᖏ ᐊᑐᖅᓗᓂ ᐅᒪᖅᑯᑎᒥᒃ

ᐊ’ᓛᑦᑐᖅ ᐊᑯᓂᖅᓱᖅᑐᖅ ᖁᑉᐸᓯᒃᑐᖅ

ᐅᖃᐅᓯᕆᔭᐅᓯᒪᔪᖅ ᓄᓇᓕᓐᒥᐅᑕᖅᓂᑦ ᐊᑐᖅᓗᒍ, ᐆᒪᖅᑯᑎᒥᒃ ᐊᑐᑕᐅᓂᕋᑕᑎᑎᕐᖃᖅᑖᓄᑦ ᑕᐃᒪᓗ ᐊᓄᕆ ᐊᑐᐃᓇᐅᓂᖕᒐᓄᑦ ᓯᕿᓂᐅᑉᓗ ᓴᕿᑉᐅᒪᓂᕋᕚᓄᑦ ᑎᑎᕋᖁᑕᐅᔪᖅ ᐊᑐᖅᓗᑎᑦ, ᐃᓱᒪ’ᓇ’ᒪᕐᐆᒪᖁᑎᒥᒃ ᓯᕿᓂᖅᒧᑦ ᐊᑐᖅᑐᒧ ᐊᑐᖅᑕᐅᔪᓐᓇᖅᓂᕋᔭᓂᒃ ᓇᐃᖅᓱᕆᑦ ᓇᓗᓇᐃᔭᖅᑕᐅᓯᒪᕙᑦ ᐅᑯᑎᒎᓇ:

ᐃᓱᒪᒋᔭᐅᔪᓄᑦ:	ᖁᕐᓕᖅᓄᑦ ᐊᑭᓪᓗᒋᐊᕈᑕᐅᔪᓐᓇᖅᑐᖅ	ᐊᐅᓚᑕᐅᓗᓂ ᓄᓇᓕᓐᒥᐅᓄᑦ	ᐆᒻᒪᖅᑯᑎᓄᑦ ᐊᑐᓚᓐᓴᐅᖕᒋᓇᖅᓗᓂ	ᐊᑭᖕᒋᔾ	ᐊᕐᕿᒎᖅᒧᑦ ᐊᑕᐅᓯᖅᒧᑦ ᓴᓇᐅᔪᓐᓇᖅᓗᓂ	ᐊᑭᓕᐅᑎᓯᒪᔪᓄᑦ ᐅᑎᕈᑕᐅᔪᓐᓇᖅᑐᖅ (ᐅᑭᐅᒧᑦ)
ᐆᒪᖁᑎᓄᑦ ᐊᑐᖅᓂᕐᒋᓄᑦ ᐃᓕᓴᐅᑕᔪᓐᓇᖅᑐᖅ ᐃᑦᑐᐊᓯᕆᐊᑕᐅᔪᓐᓇᖅᓗᓂ	ᐊ’ᓛᑦᑐᖅ/ᐊᑯᓂᖅᓱᖅᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᐊᑯᓂᖅᓱᖅᑐᖅ	ᐊ’ᓛᑦᑐᖅ	1-3	1-3
ᑎᑎᕋᓯᒪᓗᓂ: ᐃᓪᓗᓄᑦ ᐊᑐᖅᑕᐅᓂᕆᔭᓄᑦ ᐃᓕᖕᒐᓂᐅᔪᓄᑦ ᐊ'ᓚᖑᐃᔪᓐᓇᖅᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᐊ’ᓛᑦᑐᖅ	1-3	1-3
ᐊᑐᖅᓗᓂ ᑭᓂᖅᑕᓄᑦ ᐊᑐᕈᐃᖅᓯᒪᔪᓄᑦ ᐆᓇᕐᑯᑎᒧᑦ ᐃᓗᐊᕐᑯᑕᐅᓗᓄᓗ ᐊᑐᕈᐃᖅᓯᒪᔪᓄᑦ ᐊᐅᓚᑕᐅᓂᕋᔾ	ᐊ’ᓛᑦᑐᖅ	ᐊᑯᓂᖅᓱᖅᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᐊ’ᓛᑦᑐᖅ	1-3	1-3
ᐊᓯᐊᒍᑦ ᐆᒪᕐᑯᑕᐅᔪᖅ ᑐᐱᖅᐸᓪᓄᑦ ᐊᑐᖅᑐᓐᓴᒥᒃ ᐃᒍᐅᕐᖅᑐᒍᐃᓕᓴᐅᑕᐅᔪᓐᓇᖅᑐᓂ	ᐊ’ᓛᑦᑐᖅ	ᐊ’ᓛᑦᑐᖅ/ᐊᑯᓂᖅᓱᖅᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᐊᑯᓂᖅᓱᖅᑐᖅ	1-3	3-5
ᐆᒪᖅᑯᑎᑦ ᑲᑐ’ᔾᔪᖅᑲᑎᒌᕆᑦ: ᓂᐅᕕᖅᑎᒃ ᓯᕿᓂᖅᒧᑦ ᓴᕐᒋᑦᑎᑎᕈᔾᒥᒃ/ᐊᓃᑎᖅᑲᑎᐊᓂᖅ ᐱᕚᓂᖅᓯᒪᕐᑯᔾᓗᒍ.	ᐊ’ᓛᑦᑐᖅ/ᐊᑯᓂᖅᓱᖅᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᐊ’ᓛᑦᑐᖅ	1-3	1-3
ᐃᓪᓗᑕᕐᑲᓕᖅᓗᓂ ᐊᑐᐃᓇᖅᑐᓐᓴᒥᒃ-ᐆᒪᖅᑯᑎᒥᒃ ᓄᓇᓕᓐᒥᐅᓄᑦ ᓱᕈᐃᑦᑕᐃᓕᔪᒥᒃ	ᐊ’ᓛᑦᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᐊ’ᓛᑦᑐᖅ	3-5	3-5
ᐃᓪᓗᑕᕐᑲᓕᖅᓗᓂ ᐊᑐᐃᓇᖅᑐᓐᓴᒥᒃ-ᐆᒪᖅᑯᑎᒥᒃ ᓄᓇᓕᓐᒥᐅᓄᑦ ᖁᐊᖅᔾᕕᓐᓴᒥᒃ	ᐊ’ᓛᑦᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᐊ’ᓛᑦᑐᖅ	3-5	3-5
ᐃᓕᓴᐅᓯᒪᔪᖅᑲᖅᓗᓂ ᓇᕐᓕᐅᑯᒪᒥᒃ ᐃᓐᓂᕐᑯᑎᒥᒃ ᐆᓇᕐᑯᑎᓄᑦ ᐃᓕᓯᒪᔪᒥᒃ	ᐊᑯᓂᖅᓱᖅᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᐊᑯᓂᖅᓱᖅᑐᖅ	3-5	5-7
ᓄᓇᓕᓐᒥᐅᓄᑦᓗ-ᐆᒪᖅᑯᑎᓄᑦ ᓇᓗᓇᐃᖅᑐᐃᔾᔪ’ᒥᒃ	ᐊ’ᓛᑦᑐᖅ/ᐊᑯᓂᖅᓱᖅᑐᖅ	ᐊ’ᓛᑦᑐᖅ/ᐊᑯᓂᖅᓱᖅᑐᖅ	ᐊᑯᓂᖅᓱᖅᑐᖅ	ᐊᑯᓂᖅᓱᖅᑐᖅ	3-5	15-20
ᐃᓪᓗᕐᓗ ᓴᓇᓯᒪᓂᖅᑲᖅᓗᑎᒃ ᐃ’ᔾᔪᑉ/ ᐃᓕᖕᒐᓂᖅᑲᖅᓗᑎᒃ ᐅᑭᐅᖅᑕᖅᑑᓂᖕᒐᓄᑦ	ᐊᑯᓂᖅᓱᖅᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᐊᑯᓂᖅᓱᖅᑐᖅ	ᐊᑯᓂᖅᓱᖅᑐᖅ	3-7	10-12
ᓄᓇᓕᓐᒥᐅᓂ-ᐊᓄᓇᑐ'ᒥᒃ ᐆᒪᖅᑯᑎᑕᖅᑲᓗᓂ	ᐊᑯᓂᖅᓱᖅᑐᖅ/ᖁᑉᐸᓯᒃᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	7-9	15-20
ᓄᓇᓕᓐᒥᐅᓂ ᓴᓇᓯᒪᔪᖅᑲᖅᓗᓂ ᐃᓪᓗᒥ ᐆᒪᖅᑯᑎᖅᑲᖅᕕᓐᓴᒥᒃ	ᐊᑯᓂᖅᓱᖅᑐᖅ/ᖁᑉᐸᓯᒃᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᐊ’ᓛᑦᑐᖅ	1-20	3-10
ᓱᕈᖅᑕᐃᓕᔾᔪᑦ ᐆᒪᖅᑯᑦ ᓴᓇᐅᓚᓐᓴᒥᒃ ᐃᑲᔪᖅᓯᖅᓯᒪᔪᓐᓇᖅᑐᖅ	ᐊ’ᓛᑦᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᖁᑉᐸᓯᒃᑐᖅ	ᐊ’ᓛᑦᑐᖅ	1-20	3-5

© Rich Stromberg

ᖃᓄᖅ ᐊᑐᖅᑕᐅᔪᓐᓇᒻᒪᖔᑦᑕᓵᓇ ᑐᓴᒐᔅᓴᖅ

ᑐᓴᒐᔅᓴᖅ ᑕᓵᓇ ᐊᒥᓱᓂᒃ ᑐᓴᐅᒪᔾᔪᑎᔅᓴᖅᑕᓕᒃ ᓄᓇᓕᒻᒥᐅᑕᖅᓄᑦ ᐅᖅᓱᖅᑑᒥᐅᖃᐅᓯᕆᔭᐅᔪᖅ ᖃᓄᖅ ᐊᑐᖅᑕᐅᔪᔅᓴ'ᒪᖔᑦ (ᑉ.17-21) ᓴᓇᐅᒐᔅᓴᖅ ᑕᓵᓇ ᖃᓄᖅ ᐃᓕᖓᓂᖃᕈᓐᓇ'ᒪᖔᑦ ᑐᓴᖅᓲᖅᑑ'ᔭᐅᓯᒪᔪᓐᓇᖅᓂᓗ ᐃᓚᐅᔾᔪᑎᒀᕈᒪᔪᓄᑦ ᓴᓇᔃᐅᔪᓄᓪᓗ ᓯᕿᓂᖅᒧᑦ ᐆᒻᒪᖅᑯᑕᐅᔪᒧᑦ ᐃᓚᓕᐅᑎᓯᒪᓗᒍ, ᑐᑭᓕᐅᖅᓯᒪᓗᒍ - ᓄᓇᓕᒻᒥᐅᑕᖅᓄᑦ ᑕᒪᐃ'ᓄᑦ - ᐊᑏᑎᖃᕈᓐᓇᖅᓂᖖᒐᓄᑦ ᐃᓱᒪᒋᔭᐅᓯᒪᓂᓇᔾᔭᓄᑦ (p.21) ᑕᐃᒪᓗ ᓯᕿᓂᖅᒧᑦ ᐊᑐᖅᓘᒍ ᐆᒪᖅᑯᑕᐅᓂᓇᔾᔭᓄᑦ ᑕᐃᒪᓗ ᐃᓕᓴᐅᑎᒐᓱᓄᑦ (p.25) ᒪᕿᒃ ᑖᑉᑯᐊᒃ ᐊᑐᐃᓐᓇᐅᑎᑦᑎᔪᓐᓇᖅᑐᒃ ᐃᑲᔪᖅᓯᐅᑎᓯᒪᒍᑎᒃ ᐃᓕᓴᐅᑎᒐᓱᒥᒃ, ᓴᓇᐅᒐᖅᒧᓪᓗ ᐃᓕᓴᐅᑎᔨᓴᒥᒃ, ᓴᓇᐅᒐᒐᓱᒥᓪᓗ, ᑕᐃᒪᓗ ᐊᑐᕈᑕᐅᖏᓂᖅᓴᐅᓗᓂ ᐅᖅᓱᖅᔪᐊᖅᒥᖅ ᓄᓇᓕᒻᒥᐅᓂ ᓴᓇᐅᒐᖅ ᐃᒪ'ᓇᐃᑦᑐᖅ ᓄᓇᓕᒻᒥᐅᓂ ᐆᒪᕿᑎᓗᑦ ᐃᓪᓗᑕᖅ, ᓄᓇᓕᒻᒥᐅᓂᓗ ᐃᓪᓗ ᐱᕈᖅᓰᕕᒃ, ᐅᕝᕙᓘᓃᑦ ᓄᓇᓕᒥᐅᓄᑦ ᐃᓪᓗ ᖁᐊᑦᓰᕕᒃ ᑕᓵᖁᐊᑦ ᓄᓇᓕᒻᒥᐅᓂᑦ ᐅᖃᐅᓯᓇᔭᐅᓯᒪᔪᑦ ᓴᓇᐅᒐᐅᑎᓪᓗᒍ ᐃᓱᒪᕆᓯᒪᔾᔫᑦ (p.26)ᐊᑑᑎᖃᕈᓇᕋᓱᕆᔭᐅᔪᖅᓗ ᑕᒃᕙᐃᓇᖅ ᓴᓇᔭᓴᐅᔪᓐᓇᖅᓂ ᐅᖅᓱᖅᑑᒦᑎ'ᑕ - ᑭᓂᖅᑕᑦ ᐊᑐᕈᐃᓯᒪᓂᑯᑦ ᐅᖅᓱᓇᔭᐅᓗᑎᒃ ᐊᑐᖅᑕᐅᖁ'ᕆᑦ (p.27) ᐱᖁᔭᐅᓯᒪᔪᑦ ᐊᑐᐊᒐᓴᓄᑦ ᐊᓄᓇᒧᑦ ᑲᐃᑉᔭᓴᒧᑦ ᐆᒪᖅᑯᑎᓕᐅᕈ'ᒧᑦ ᑕᑯᔭᐅᔪᓐᓇᖅᑐᑦ ᐅᒪ ᑐᓴᒐᓴᐅᑉ ᐃᓱᐊᓂ

© Rich Stromberg

© Rich Stromberg

ᓄᓇᖅᕘᐊᖅᒧᑦ ᐊᖑᑎᓴᓕᓇᖠᑦ ᑲᓇᑕᒥ ᓄᓇᓕᒻᒥᐅᓄᑦ ᐆᒪᖅᑯᑎᓄᑦ ᐊᑐᐃᓇᖅᑐᓴᓄᑦ

ᐊᑐᐃᓇᖅᑐᓴᓄᑦ ᐆᒪᖅᑯᑎᓄᑦ ᓴᓇᐅᒐᔅᓴᖅ ᐃᐊᖅᓯᓯᒪᔾᔪᑕᐅᔪᓐᓇᖅᑐᖅ - ᐊᑭᑭᓂᖅᓴᐅᓗᓂ ᐃᓇᖏᐅᑎᓯᒪᔾᔪᑕᐅᔪᓐᓇᖅᑐᖅ ᐊᑐᖏᓂᖅᓴᐅᓗᓂ ᐅᖅᓱᖅᔪᐊᖅᒥᒃ ᓄᓇᕗᑦᒥᐅᓄᑦ ᓄᓇᖅᕘᐊᖅᒧᑦ ᐊᖑᑎᓴᓕᓇᖠᑦ ᑲᓇᑕᒥ ᑲᔪᖏᐅᑎᖃᖅᑐᑦ ᓄᓇᓕᒻᒥᐅᓄᑦ ᐊᑐᖅᑐᓴᒥᒃ ᐃᑲᔪᖅᓱᖅᓯᒪᔾᔪᑕᐅᔪᓐᓇᖅᑐᒥᒃ ᓄᓇᓕᒻᒥᐅᓄᑦ ᑭᐱᔭᐅᓯᒪᓂᖅᒥᒃ ᐊᑉᖁᑎᓄᑦ ᖃᐅᔨᓯᒪᔾᔪᑕᐅ'ᒪᑦ ᐊᑏᑎᖃᕈᓐᓇᖅᓂᐅᔪᖅ ᐊᓯᕈᖅᑕᐃᓕᓯᒪ-ᔪᑕᐅᓂ ᓄᓇᒥᒃ- ᖃᓄᓇᖏᓂᖅᓴᐅᔪᒥᒃ ᐆᒪᖅᑯᑎᒥᒃ

© Rich Stromberg

ᑐᓴᐅᒪᔾᔪᑎᓴᕌᓕᖅᒧᑦ:

ᒪᑕ ᓖᓂᐅ, ᐃᑲᔪᖅᑎᐅᔪᖅ ᑲᐅᔨᒪᑕᓇᔭᐅᔪᒧᑦ, ᐊᑐᐃᓇᐅᕈᓇᖅᑐᓄᑦ ᐆᒪᖅᑯᑎᓄᑦ, ᓄᓇᖅᕘᐊᖅᒧᑦ ᐊᖑᑎᓴᓕᓇᖠᑦ ᑲᓇᑕᒥ
mlenio@wwfcanada.org

Executive Summary

Gjoa Haven is fortunate to have an array of solutions to pursue that can reduce energy costs, empower the local community and make their energy systems more resilient against external threats from economic recession, fuel shortages, environmental risks and geopolitical conflict. Table ES-1 shows the options addressed in this report. While some options should be adopted in the near term because they can produce quick results at low cost, other options have the potential for far greater energy savings but take more time and/or money to design and implement. These options should not be ignored, as they offer the greatest opportunity for energy resilience and security as well as cost savings for the hamlet and for Government of Nunavut. Further, some options should be adopted because they foster greater capacity in the local workforce and empower more of the community to determine their energy future.

Table ES-1: Gjoa Haven - Energy Roadmap Options

Iniative	Potential Energy Savings	Empowerment of Local Community	Energy Security	Cost	Payback	Timeframe
Develop a community energy plan	Medium>>High	High	High	Low	3-10 yrs	Year 1-->20+
Energy Efficiency Training and Upgrades	Low>>Medium	High	Medium	Low	1-3 yrs	Year 1-->3
Data collection: home energy monitors	Low	High	Low	Low	1-3 yrs	Year 1-->3
Resume waste oil boiler. Fix disposal problem.	Low	Medium	Low	Low	1-3 yrs	Year 1-->3
Solar Energy Training for Rec Cabins	Low	High	Low	Medium	3-5 yrs	Year 1-->3
Community greenhouse	Low	High	Low	Low	3-5 yrs	Year 3-->5
Community cold storage	Low	High	Low	Low	3-5 yrs	Year 3-->5
Energy Cooperative: Purchase solar/efficiency	Low>>Medium	High	Low	Low	1-3 yrs	Year 1-->3
Evaluate power plant heat recovery loop	Medium	Low	Low	Low	N/A	Year 1-->3
Install power plant heat recovery loop	Medium	Low	Low	Medium	5-7 yrs	Year 3-->5
Design housing for northern climate/culture	Medium	High	Medium	Medium	10-12 yrs	Year 3-->7
Solar resource assessment/prelim design	Low>>Medium	Low>>Medium	N/A	Low	N/A	Year 1-->3
Wind resource assessment/prelim design	Medium>>High	Low	N/A	Medium	N/A	Year 1-->3
Community-scale solar energy system	Low>>Medium	Low>>Medium	Medium	Medium	15-20 yrs	Year 3-->5
Community-scale wind energy system	Medium>>High	Low	High	High	15-20 yrs	Year 7-->9
Build local capacity to support energy systems	Low	High	High	Low	3-5 yrs	Year 1-->20+

Community-Scale Wind and Solar

In simple terms, the wind resource in the Gjoa Haven is very good. Preliminary wind turbine production estimates are comparable with some of the more productive wind farms in North America. Any development of wind energy on the Gjoa Haven electrical grid will depend on:

- Cooperation of the grid operator Qulliq Energy Corporation
- Integration with the current/future capabilities of controls and power generation at the local power plant
- The exact degree of frost/ice observed on the non-heated sensors during the meteorological tower study period
- Unforeseen wildlife impacts discovered during the future avian/wildlife study
- Willingness of an independent power producer to develop a project
- The cost of construction by an independent power producer (IPP)
- Whether or not a project could be built at an attractive rate to QEC and its customers.

The additional project challenges concern siting of the wind turbines relative to recreational cabins and airport navigation systems. While it is possible to find locations that are compatible with approach and take-off corridors from the airport (YHK), air navigation systems have not been upgraded to be compatible with large wind turbines that may appear as false signals to radar and other tools. Although it is possible to place wind turbines outside the 15 km zone for VOR systems, the greater distance from town increases costs due to longer transmission lines and more power poles. Any project developer should engage Nav Canada early in the process to request approval/variances of met tower and proposed wind turbine sites that would ideally be located well within 15km of Gjoa Haven.

During the community engagement in February 2018 and the extensive analysis and research of the local solar and wind energy resource potential conducted by ACEP, no factors have been uncovered that would prevent the future development of community-scale renewable energy in Gjoa Haven. Due to the complexity of these systems, however, a more detailed study of the power plant and local grid is needed along with measuring of wind energy characteristics at heights well above the weather station at the airport. Higher frequency and local measurements of solar energy potential are also needed as existing models rely on measurements taken from communities hundreds of kilometers away.

QEC provided data showing monthly energy demand, kilowatt-hours produced for each generator, station service, feeder loads and fuel efficiency for the past three years. This information was used to make coarse assessments of how the local power grid would react to a solar or wind project. While QEC has stated that they do not want to own renewable energy infrastructure, they did make it clear they are working on formal Power Purchase Agreement legislation to enable projects by outside developers to move forward. Maintaining a good working relationship with QEC to ensure projects integrate with QEC's existing grid will be critical to a project's future success. Successful partnerships between renewable energy developers and the utility could bring outside funding to strengthen the QEC power plant and grid. These projects can reduce energy costs as well as energy subsidies paid out by the Government of Nunavut that could be used to further fund improvements in QEC infrastructure as well as provide for other social needs across the territory.

It is recommended that Gjoa Haven issue a formal request for proposals from engineering firms who can conduct solar and wind resource assessments to industry standards and develop a conceptual design based on the extensive groundwork that has already been performed by the Alaska Center for Energy and Power. The full scope of the resource assessment and conceptual design are included in the *Recommended Scope for RFP* section.

Energy Cooperative focusing on energy efficiency, solar training and bulk purchasing power
In the meantime, additional recommendations are made for a formal energy efficiency program and a residential/cabin solar energy training program in the *Energy Option #1 and #2* sections of this report. The cost of these programs would be considerably less than that of a utility-scale wind or solar energy system. While the solar energy resource is not as strong as more southerly latitudes, improved technology and continual cost reduction in the industry allow for the use of photovoltaics (PV) where they were previously too expensive. Ease of installation makes solar PV a viable energy option for the many remote cabins out on the land near Gjoa Haven.

A radical light bulb replacement approach is recommended that would be completely funded by the Government of Nunavut while returning very quick payback that extends for the long-term.

Community Empowerment
Along with the proposed energy cooperative, additional paths for community empowerment were discovered during the community meetings. These include the need for developing a formal energy plan for Gjoa Haven, a community greenhouse, community cold-storage powered by waste heat from the power plant and designing optimal northern family housing that addresses the energy, cultural and social needs in Nunavut.

Value from Waste Streams
Resurrecting the waste oil burner was identified as a low-cost solution addressing energy as well as hazardous waste in the community. An improved method of collecting oil with separate collection facilities for anti-freeze and other hazardous liquids needs to be implemented so that the waste oil burner can be maintained with local resources without being damaged by these other liquids.

Presently, there is no heat recovery loop from the power plant diesel engines. Helping QEC to acquire funding for a feasibility study and system design would be a low-cost approach with the potential of saving the hamlet energy costs in nearby buildings.

Contents

Wind Resource

The wind resource in Gjoa Haven is unequivocally good. Data was pulled from the 10-meter CYHK airport meteorology station from Jan 2012 through mid-August 2017. While not as accurate as a formal wind study[1], the data set is sufficient to confirm that a formal wind energy study is warranted without risk of finding a weak energy source.

A summary of the wind data from the airport station is shown in the table to the right. The average wind speed of 7.139 meters/second (m/s) at 30 meters above ground level (AGL) is higher than the Canadian Wind Energy Atlas[2] estimate of 6.32 m/s.

Gjoa Haven Wind & Solar Application/Grant #		
Average Wind Speed @ 30 m:	7.139	m/s
Average Power Density @ 50 m:	541	W/m^2
Average Power Density @ 30 m:	437	W/m^2
Air Density:	1.353	kg/m^3
Weibull k:	2.15	
Shear Factor:	0.140	
Roughness Class:	0.022	
Turbulence Intensity @ 15 m/s:	N/A	
IEC Turbine Class:	III-B	
Wind Class @ 30 m:	4 to 5	
Associated CF:	28.0%	
Predicted CF:	31.4%	

Table 1 – Gjoa Haven Wind Summary

A wind shear value of 0.14 was used to extrapolate wind observations at 10 meters AGL. This wind shear was chosen as it correlates to a roughness class of 1, defined as "Open agricultural are without fences and hedgerows and very scattered buildings. Only softly rounded hills." From this assumption, the power law exponent of 0.14 with (which is equal to 1/7) for a known wind speed V1 at height H1, you can calculate V2 at height H2: $V2=V1*(h2/h1)^{(1/7)}$
This calculation was performed for each time step to estimate wind speeds at 30m, 37m, 50m, 75m and 80m AGL. A curve of the average wind speed versus height above group is shown in Figure 1. While a reasonable and accepted practice by with to estimate wind speed with height, actual wind speed at wind turbine hub and rotor heights can't be known without installing a 50m or 80m tower instrumented at multiple levels in a location undisturbed by buildings, as is the case with the 10m airport meteorological station.

[1] Automated Surface Observing System (ASOS) stations do not collect data continually. Rather, they take measurements on a set interval – typically hourly or every 20 minutes. This hourly measurement should not be interpreted as equivalent to an hourly average. It is in fact an hourly sample. By comparison, instrumentation for a formal wind study will sample wind speed, direction, temperature and other factors every 2 seconds and then log 10-minute average, minimum, maximum and standard deviation based on all 300 samples in that 10-minute period.
[2] http://www.windatlas.ca/index-en.php

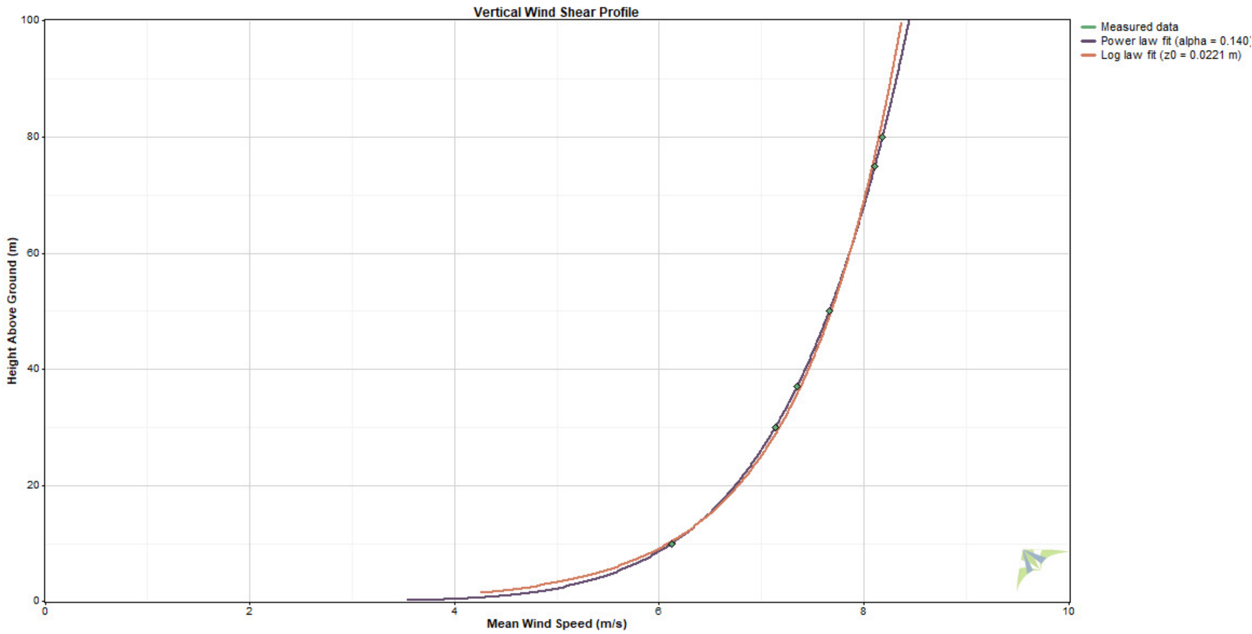


Figure 1 – Average wind speed at 10m AGL and extrapolations to 30m, 37m, 50m, 75m and 80m

Seasonally, the winds are consistent throughout the year with strongest winds in September, prior to freeze up. (Figure 2) Two of the five years reviewed showed notably lower wind speeds in the summer months. This is consistent across the northern hemisphere. Stronger winter winds are a benefit given that Gjoa Haven has a higher energy load to better match energy demand with energy supply.

Diurnal (over the course of a day) wind patterns are shown in Figure 3. <u>Caution should be used when relying on this graph as all heights other than 10m AGL are extrapolation from the 10m data set.</u> Lower level winds are driven by solar heating of the Earth's surface, so winds increase throughout the day and subside at night. Higher-level winds are dominated by stably stratified flows that sink down at night into the wind turbine rotor swept area, but get pushed higher during the day as solar-induced turbulence picks up. Thus, wind speeds experienced by megawatt-scale wind turbines will likely will be stronger at night. (Figure 4 – actual data from an Alaska wind farm.) This is one of the reasons that a formal resource study using a tall meteorological tower is needed to accurately predict the wind characteristics of any future built project.

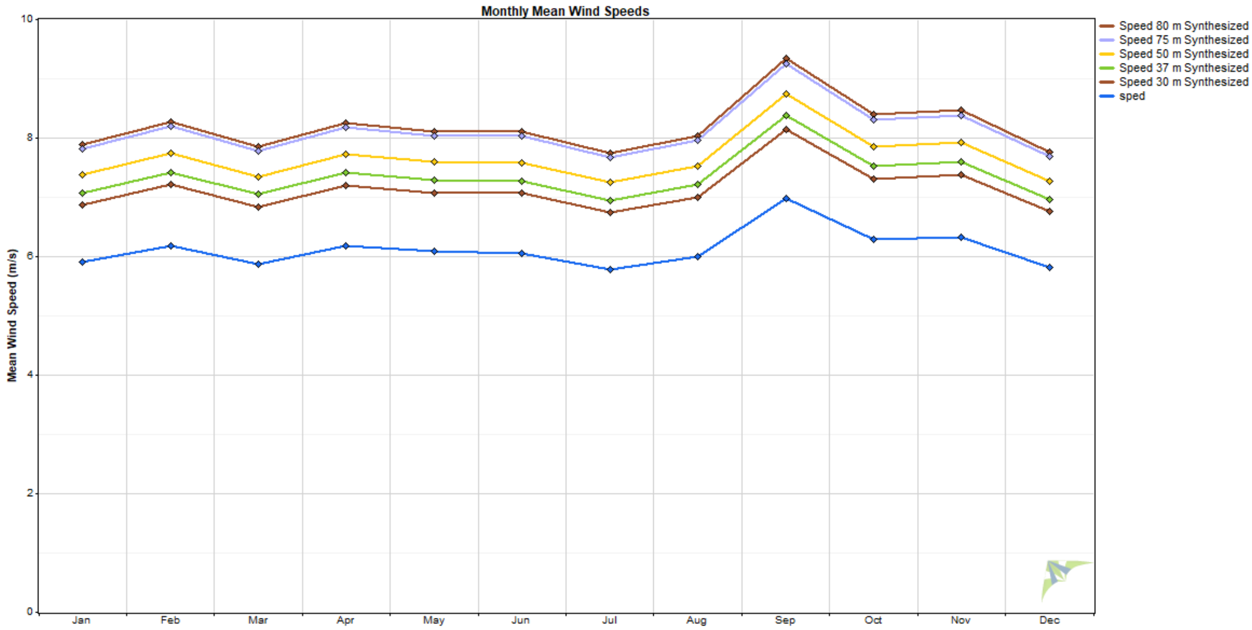


Figure 2 – Gjoa Haven monthly wind speed averages for various wind turbine hub heights

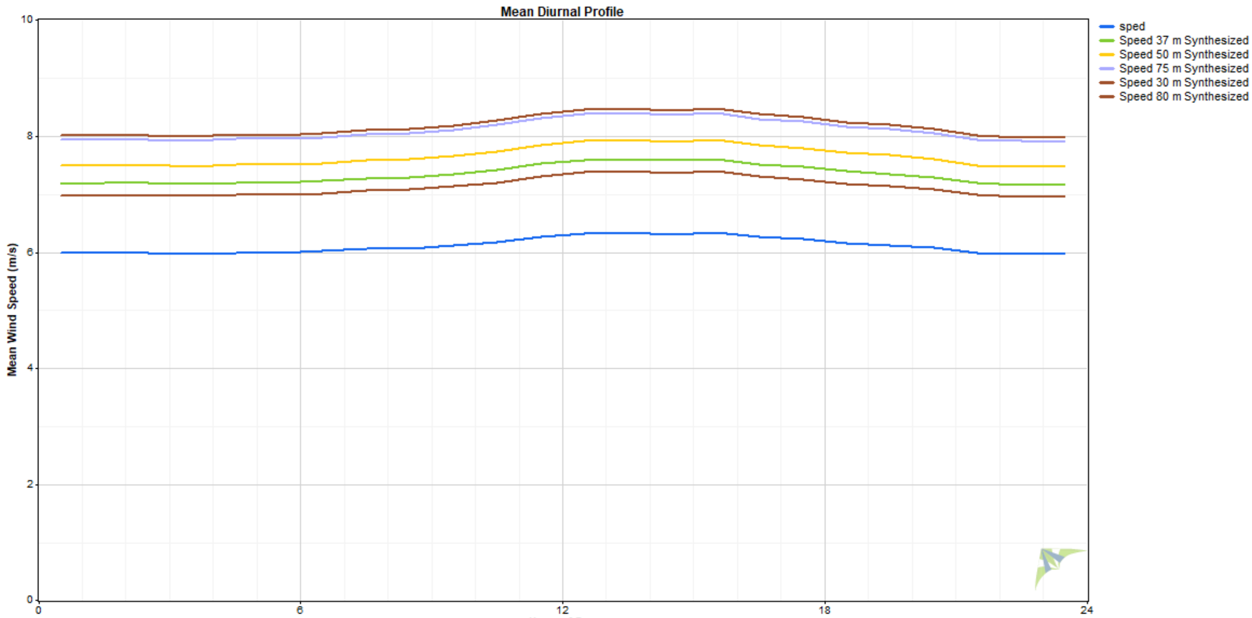


Figure 3 – Gjoa Haven wind speed estimates throughout the day. <u>These are likely only accurate for the lower heights.</u>

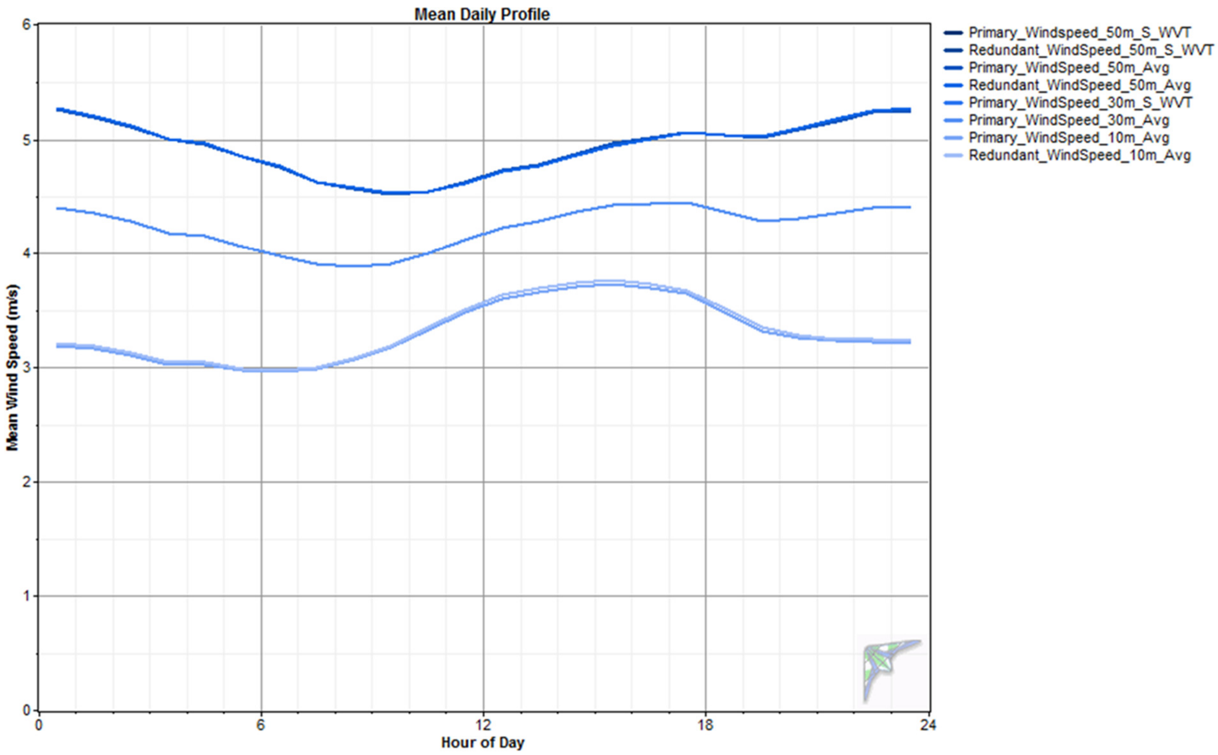


Figure 4 – Alaska wind farm showing strongest winds at 10m (bottom line) during the day while higher winds at hub height of 50m (top line) are stronger at night.

The direction is predominantly out of the north-northwest s seen in the Figure 5 wind rose. This graph is weighted by the intensity of wind speed from each direction to show which directions wind turbines would be pointed when generating the most energy. This matches the predictions from the Canadian Wind Energy Atlas. The site of the airport meteorological tower is far enough away from nearby buildings or other structures so as to not be influenced by disrupting influences. A taller meteorological tower at proposed wind turbine site(s) will be able to accurately confirm predominant wind directions in order to properly configure the location of multiple wind turbines in a manner that minimizes one wind turbine robbing wind from another.

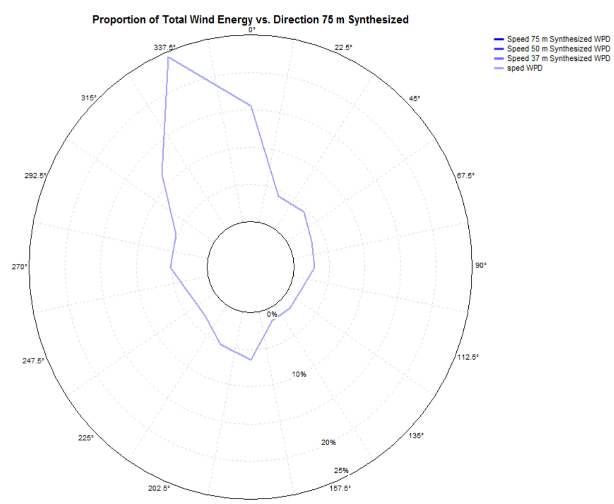


Figure 5 – Gjoa Haven wind direction rose

Temperature is an important factor in wind energy systems given that colder air is more dense and denser air has more energy for a given wind speed. A five-plus year trend of temperature is shown in Figure 6. This also bodes well for solar photovoltaic modules that produce more energy in cold temperatures.

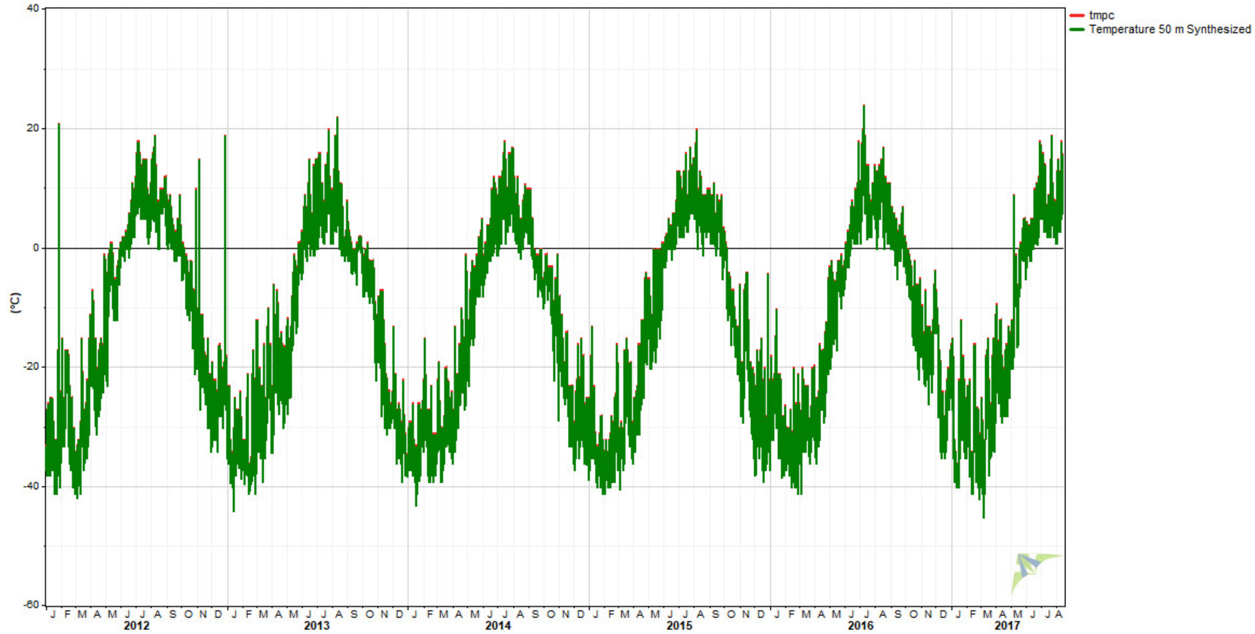


Figure 6 – Gjoa Haven temperature trend (Celsius)

The distribution of wind speeds throughout the data collection period (Figure 7) reveal that a wind would turbine rarely shut down for high wind speed (> 25 m/s for most wind turbines).[3]

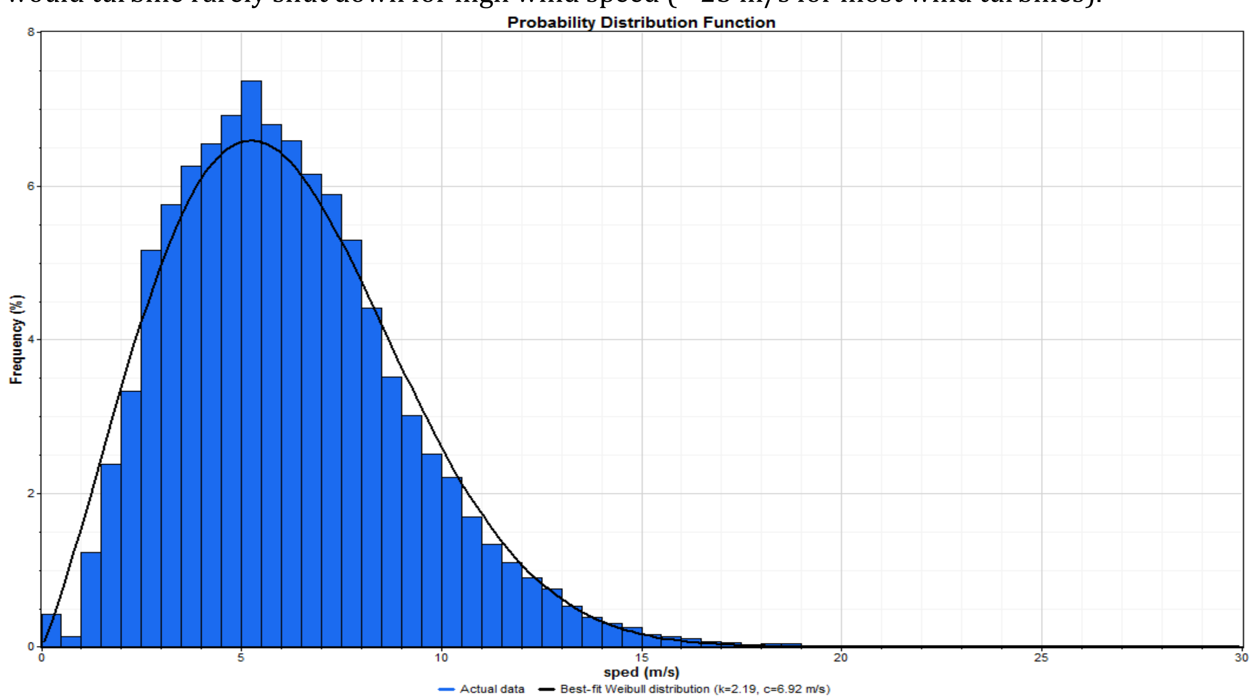


Figure 7 – Gjoa Haven wind speed distribution

[3] Most large wind turbine models will feather the blades out of the wind at speeds above 25 m/s to prevent excessive stresses on the drive train, generator or physical structure.

In addition to maximum operating speeds, statistical methods can be used to take the above distribution and estimate the probability of extreme wind events that could potentially damage wind turbines even when placed in a safe mode. The maximum extreme winds predicted are 35.2, 35.7 and 38.7 m/s (139 km/h) by the three methods used. This places the wind regime on the boundary between an IEC Turbine Class[4] II and III with II being the more severe. Given the average wind speeds at expected turbine hub heights of 50m or 75m at 7.65 and 8.1 m/s, this pushes the Gjoa Haven into an IEC Turbine Class II location. Any wind turbines selected must be designed and built to this specification.

Method	Vref (50 yr) (m/s)
Periodic Maxima	36.803
Method of Independent Storms	35.948
EWTS II (Exact)	29.394
EWTS II (Gumbel)	29.792
EWTS II (Davenport)	32.402

Table 2– Extreme winds

Three appropriate wind turbines were modeled against the CYHK airport wind data set. The EWT Directwind DW52 is a 900-kilowatt direct drive turbine that has been proven in Delta Junction, Kotzebue and Nome, Alaska. The Enercon E-44 is a 900kW turbine proven in Canada and Europe in colder climates. 900 kilowatts of power would produce 46 percent of the average power consumed by Gjoa Haven in a typical year and would require more advanced storage and controls to achieve. 600 kilowatt turbines would produce a more conservative 31% of Gjoa Haven's power needs. Both turbine models could be configured to produce no more than 600 kW[5].

Another turbine option would be to install several Northern Power Systems 100 kilowatt turbines. Cost analysis for village power systems in Alaska show that when more than three 100 kW turbines are needed at a site, project costs are lower to install a single, de-rated 900 kW turbine than four or more 100 kW turbines.

This modeling shows that wind turbines would sit idle, not producing any power, less than 4 percent of the time. Conversely, the turbines would be expected to produce maximum power up to 7 percent of the time at full rated power (> 20 percent at 600 kW configuration). The net capacity factor[6] estimates for the three turbines range between 27 and 32 percent. This is near the upper end of wind turbine performance for Alaska microgrid systems.

Turbine	Valid Time Steps	Hub Height Wind Speed (m/s)	Percentage Of Time At		Simple Mean			Mean of Monthly Means		
			Zero Power	Rated Power	Net Power (kW)	Net AEP (kWh/yr)	NCF (%)	Net Power (kW)	Net AEP (kWh/yr)	NCF (%)
Northern Power 100-21 (37m)	49,271	7.34	3.85	7.30	32.8	287,239	32.79	32.9	288,135	32.89
Enercon E-44 / 900 kW (50m)	49,271	7.65	2.79	3.45	242.5	2,124,677	26.95	243.5	2,133,302	27.06
EWT DW52-900 (50m)	49,271	7.65	2.73	6.84	281.7	2,468,033	31.30	282.8	2,477,261	31.42

Table 3 – Wind turbine output estimates

[4] Not to be confused with Class 1 through 7 wind speed classes.

[5] Of 700 kW or whatever the turbine owner and QEC agree is the appropriate maximum wind power on the grid.

[6] Gross energy produced in a year minus predicted maintenance downtime, curtailment, wind farm layout and other environmental impactors. Capacity factor is a measurement of how much power a diesel generator, wind turbine, solar module or hydroelectric generator could produce relative to its maximum power output. If a generator ran at full power output all day long for 365 days, this would equal 100 percent capacity factor. Even diesel generators run well less than 100 percent net capacity factor – typically around 60 percent. Hydroelectric generators average about 40 percent. Solar ranges between 10 and 18 percent in far northern latitudes.

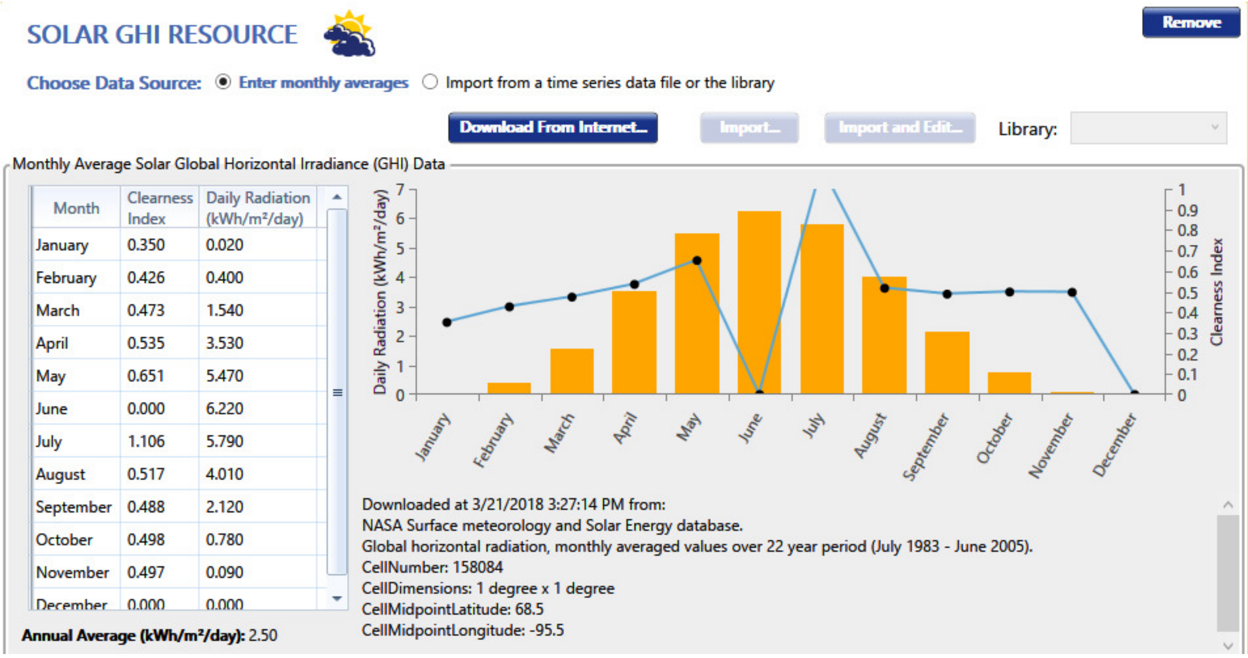
While the wind data presented is promising, it does not preclude the need to conduct a formal wind energy study. Some assumptions or extrapolations in this section may not hold when a tall tower is erected and data is collected at much higher resolution. Please see the Recommended Scope for RFP section for details.

Solar Resource

Reliable solar irradiance data is lacking in Gjoa Haven. The nearest reference point for a formal energy study is 1093 km to the southwest in Yellowknife, Northwest Territories. Estimates from Yellowknife predict a net capacity factor of 13.9%. The next closest reference station is in Churchill, Manitoba. The predicted net capacity factor in Churchill is 14.6%.

Modeling solar irradiance without the benefit of instrumentation on site is achieved by retrieving datasets of the known position of the sun in the sky for any given latitude and longitude for every hour throughout the year. Meteorological data quantifying the degree of sunny to overcast skies from airport observations is then used to derate the maximum solar irradiance that can be assumed from the positional data set. This method is only as accurate as the sun-cloud observational data.

Using the HOMER Pro Microgrid Analysis Tool, NASA solar irradiance data corrected to clear sky estimates is extracted for Gjoa Haven. The resulting estimate is an annual average of 2.5 solar hours per day. Figure 8 shows how the solar resource varies by month. The 2.5 value is slightly less than the Anchorage, Alaska empirical data of 2.74 annual average solar hours measured on the roof of the Alaska Energy Authority building at 61 degrees latitude. The maritime climate of Anchorage makes it a reasonable comparison to Gjoa Haven. Running a HOMER model with this data set estimates a net capacity factor of 11.1%. Assumption of a net capacity range from 10% to 12% would be reasonable for estimating annual average output of a roof-top solar array or off-grid cabin system, but would be inadequate for the higher resolution needed to design a utility-scale system that can integrate with an isolated microgrid such as Gjoa Haven. Instrumentation including pyranometers at latitude tilt, horizontal and south-facing vertical plus a data logger are needed to collect data for a utility-scale solar farm. Fortunately, this instrumentation is relatively low in cost and easy to install. Please see the *Recommended Scope for RFP* section for details.



Month	Clearness Index	Daily Radiation (kWh/m²/day)
January	0.350	0.020
February	0.426	0.400
March	0.473	1.540
April	0.535	3.530
May	0.651	5.470
June	0.000	6.220
July	1.106	5.790
August	0.517	4.010
September	0.488	2.120
October	0.498	0.780
November	0.497	0.090
December	0.000	0.000

Figure 8 – HOMER modeling estimates of the solar resource for Gjoa Haven (Source: NASA)

Siting

One consideration for siting of a meteorological tower and subsequent wind turbine(s) is the airport approach and takeoff corridor restrictions. Two hypothetical sites were considered: turbine site 1 (TS1) is west of town while turbine site 2 (TS1) is north of town beyond the Swan Lake water intake facility. (See figures 9 and 12). Both sites meet the minimum requirements for airport slope ration with significant margin.

Table 4 - FAA		TS1 100kW	TS1 900kW	TS2 900kW
Distance to airport	Feet	6702	6702	12000
Airport elev	Feet	130	130	130
Turbine elevation	Feet	40	40	99
Turbine hub height	Meters	37	50	50
Turbine rotor dia.	Meters	21	52	52
Turbine height	Feet	155.838	249.3408	249.3408
Slope ratio X:1	20 min.	101.79532	42.06079046	54.95995251
Transmission line	Feet	4400/12500	4400/12500	12000/25000

Another restriction that may come into play is that of airport navigation aids. There is a standard 15 km perimeter around VOR[7] systems. Any turbines sited within this 15 km radius must be evaluated by Nav Canada under a land use change approval process. If required to maintain a 15 km distance, any wind project would need to be sited right at the perimeter to avoid the need for an expensive 25keV transmission line that would be needed to keep distributed generation voltage rise to no more than 3 percent. Even inside this 15 km perimeter, the current 4,160-volt line needs to be upgraded to 12,470 volts as the existing line has a highly unacceptable voltage rise of 12.35 percent. (See table 5). A wind project could benefit QEC by upgrading the existing line out to the Swan Lake water intake building. If the 15 km VOR perimeter cannot be granted a waiver, the cost for a 15 km transmission line might render a wind project economically unfeasible. Figure 9 shows a reference for 15 km from the airport. A reduction or variance of the VOR perimeter would then shift siting focus to recreational cabins and shadow flicker.

Table 5 - Voltage Drop/Rise		
Single phase VD = (2 * L * R * I) / 1000 ft		
Distance in miles	4.84	Miles
Equivalent feet	25,555	Feet
Wire Type	1/0 Raven	
Resistance in Ohms/1,000 feet from chart at right	0.1394	Ohms/1000'
Max power (Watts) from all wind turbines	600,000	Watts
Voltage rating of transmission line	4160	Volts
Single phase amps from wind turbine	144.23	Amps
Convert to 3-phase (Div by sqrt of 3) gives load in amps from turbine	83.27	Amps
Using above bold formula, voltage drop/rise is ------>	593.31	Volts
Percentage of voltage drop/rise	14.26%	Percent
3-phase VD = SPVD * (1.732/2) Drop between any 2 phases		
3-phase voltage drop/rise is----------------------------->	513.82	Volts
Percentage of voltage drop/rise	12.35%	Percent

[7] VHF omni-directional radio range

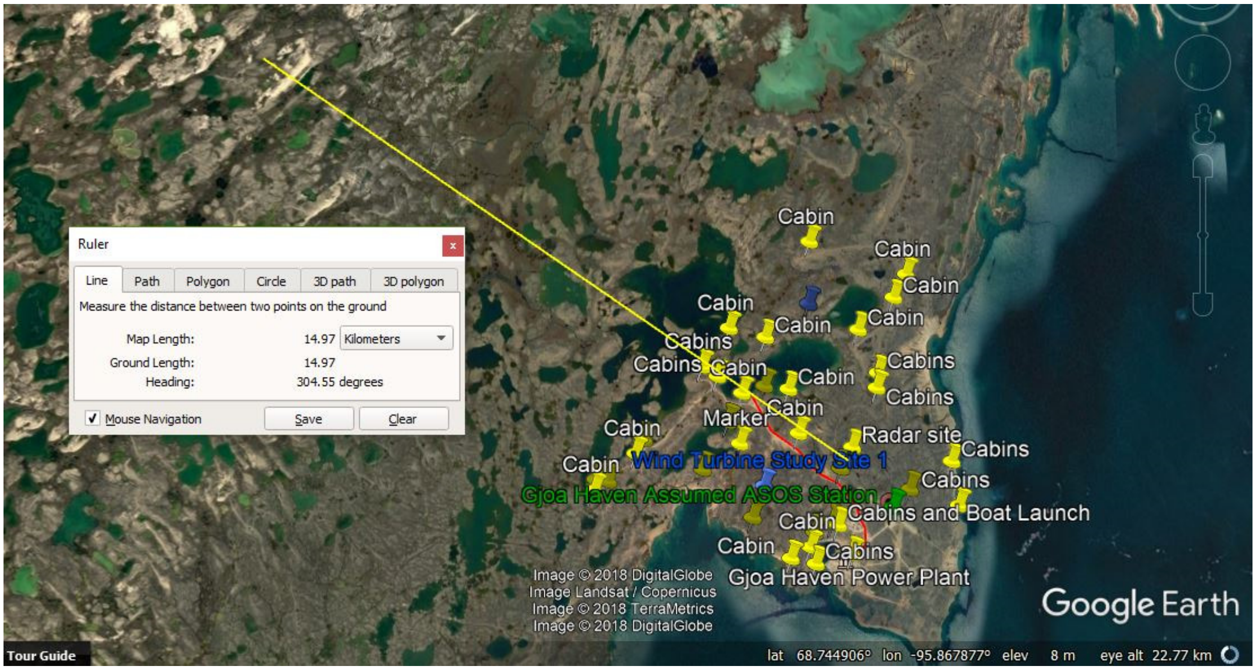
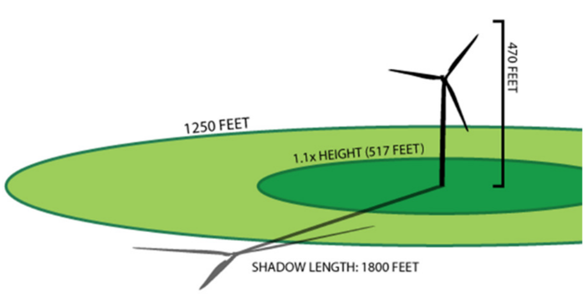
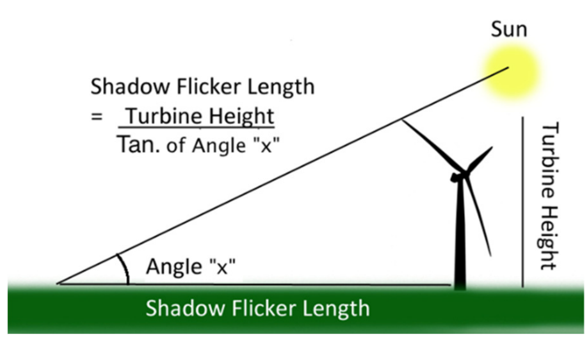


Figure 9 – 15 km distance from YHK airport. Note partial inventory of recreational cabin sites.

Shadow Flicker

An additional limitation to siting is the presence of numerous recreational cabins that begin about 2 km out of town and extend to at least 7 km. These sites were identified by scanning satellite imagery on Google Earth at high zoom. It is possible that some smaller cabins were missed using this method. Ground truthing of any proposed wind turbine site should be required early in the wind turbine siting process. Wind turbines would need to be sited a minimum of 0.4 km from any occupied buildings to provide a safe perimeter from unexpected collapse or ice throw. An additional concern is shadow flicker, where the sun's path across the sky can cast a shadow of the spinning turbine blades on occupied buildings. This can be an annoyance to anyone inside and guidelines have been set at no more than 30 hours per year of shadow flicker being cast on an occupied building. One consideration is that these recreational cabins are not occupied full time, so that may allow for extra margin.





Figures 10a & b – Example of shadow flicker being cast on the surrounding landscape

Once wind turbine sites have been narrowed down, a shadow flicker model (Figure 11) should be run and compared with nearby recreational cabin locations to determine if the proposed wind turbine sites will create conflict.

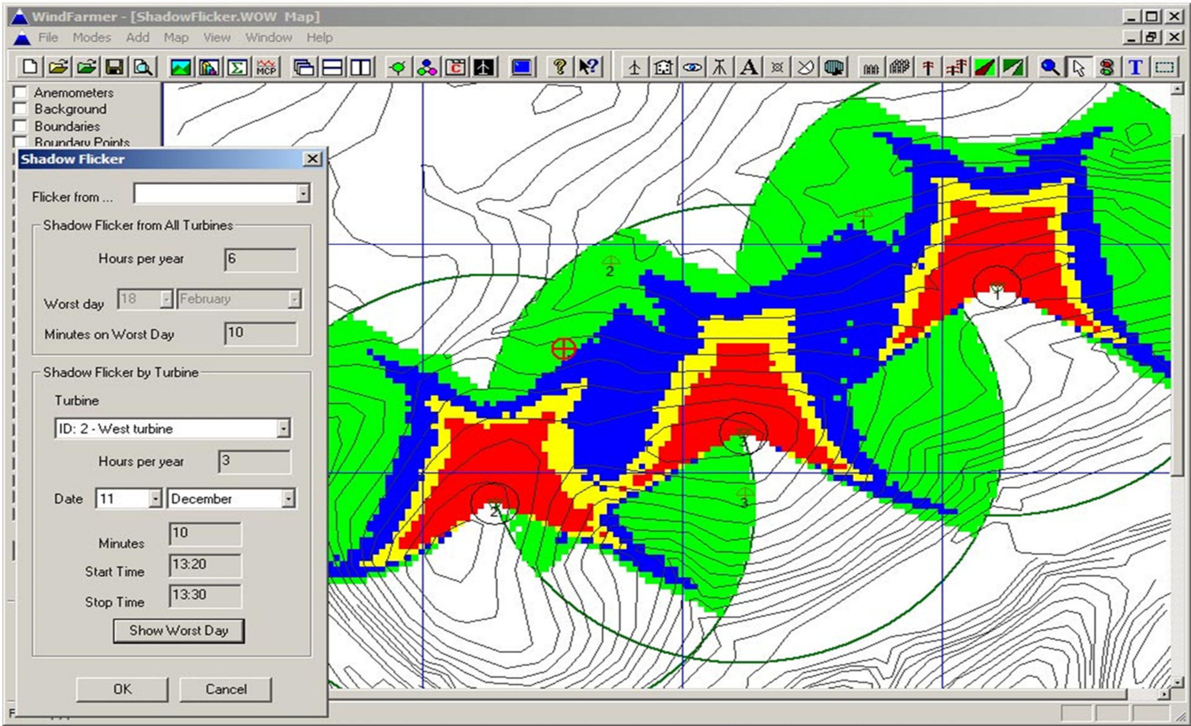


Figure 11 – Example shadow flicker model showing regions around wind turbine of no flicker, low flicker (green) and excessive flicker (red).

Figure 12 shows two recommended turbine sites that meet height restrictions for runway approach and takeoff, but would still need an exception to the VOR 15 km perimeter. Using the same calculation method as shown in Table 4, Site #1 is 3.64 km out of town along a likely transmission line path and would require a transmission line energized to 12,470 volts with a distributed generation voltage rise of 0.64% - below the 3% limit.[8]

Site #2 (Preferred) at 5.17 km out of town would see a voltage rise of 1.37% on a 12,470-volt line with the capacity to support as much as 1,300 kilowatts of wind turbines in the future. Site 2 would have less shadow flicker impact on known recreational cabins. Site 2 also has the benefit of being suggested by some participants of the Feb 2018 community meetings. If the community has other locations to recommend, these should ideally be proposed before issuing a request for proposals on the meteorological tower study. Similar analysis of the above factors can be performed on other possible sites at very low cost.

[8] A 4,160-volt line would produce voltage rise of 5.77% - nearly twice the allowable rise.

Wind Farm Footprint

The other siting consideration is the footprint required to space turbines apart to minimize rotor wake effects. It is assumed that one 900 kw turbine (de-rated to maximum 600 kW output) would be placed at the turbine site. An alternate configuration of six 100 kW turbines was evaluated, but not recommended. The Enercon wind turbines would require a farm footprint of 44 meters by 44 meters while the EWT would require 52 meters by 52 meters. (Table 5) Turbines would still need to be a minimum of 0.4 km from the coast or from an occupied building or main road.

Turbine spacing	Enercon	EWT 52	NPS100
Rated power (kW)	900	900	100
Rotor diameter (m)	44	52	21
Rows of turbines	1	1	1
# of turbines in rows	1	1	6
Min. farm length (m)	44	52	441
Min. farm width (m)	44	52	21
Total area (sq. meters)	1936	2704	9261
Area:sq.m per kW	2.15111	3.00444	15.435

Table 6 – Wind farm minimum footprint

Figure 12 – Potential wind turbine sites near Gjoa Haven. Site #1 is low confidence due to shadow flicker. Site #2 is higher confidence but would still need a VOR waiver from Nav Canada.

Geotechnical Concerns

Surface observations by the ACEP/WWF team identified tundra with minimal active layer and rock outcroppings with numerous fractures. Permafrost conditions are assumed to 300 meters.

In 2010, the Government of Nunavut commissioned a terrain and soil analysis.[9] This report should be referenced to exclude any known areas of ice wedge polygons and thermokarst features, specifically "[t]he community of Gjoa Haven is situated in an area with very little topography and

[9] http://www.climatechangenunavut.ca/sites/default/files/nunavut_terrain_and_soil_analysis_-_2011.pdf

bedrock outcrops. Most areas are covered with small vegetation, i.e. tundra. The optical images show patterned grounds with large polygons, indicating ice wedges, and thermokarst features around the edges of ponds and areas of surface run-off and deep gullies. Ice-rich conditions, with frozen grounds likely containing a high salinity, are expected for the whole region."

Permafrost is up to 300m with an active layer (summer thawing) between 0.25m and 1.8m. Geotechnical reports from previous local construction projects should be referenced for both wind turbine foundation design and meteorological tower anchors. Pile foundations should be assumed for wind turbines along with assessing the long term need for thermopiles. Geotechnical drilling/sampling will eventually be needed, but not until after completion of a wind resource study and conceptual design report.

Terrain Flow Modeling

ACEP modeled the wind resource with respect to the interaction between prevailing wind directions and intensity compared with the surrounding terrain using Continuum 2.2 software. Turbines sites #1 and #2 (shown in Figure 13 as red squares) were compared to the wind data collected at the airport (represented as a green square).

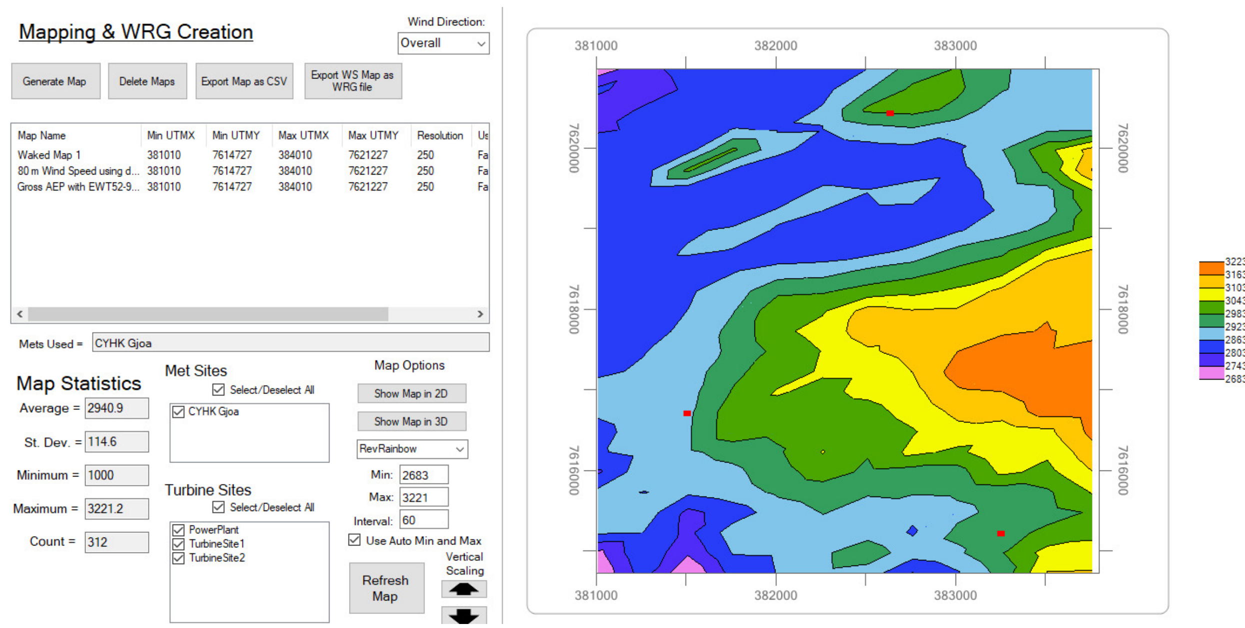


Figure 13 – Terrain flow model for Gjoa Haven. Turbine site #1 is red square in the lower left. Turbine site #2 is red square in upper middle. Power plant is red square in bottom right. Graph scale is gross annual megawatt-hours of electricity expected for a single 900-kilowatt wind turbine.

While the scaling of the map appears to show distinct differences between the sites, both proposed wind turbine sites are projected to be high-producing. Assuming 17.26% losses for curtailment, equipment availability, environmental factors and line losses[10], the model projects net annual energy production of 2,404 megawatt-hours per year. This equates to a net capacity factor of 30.5 percent – very good for remote Arctic wind installations.

---

[10] These are consistent with actual wind turbine performance observed on Alaska microgrids.

Turbine Net Estimates Roughness model NOT usec Flow Sep. model NOT used

Continuum Model: Default Model Wind Direction: Overall

Site	String #	Elev., m	WS, m/s	Net AEP, MWh	Net CF	Wake Loss	Weibull k	Weibul
PowerPlant	1	15	7.863	2452	31.10%	0.0%	2.22	8.88
TurbineSite1	2	14.4	7.777	2404	30.49%	0.1%	2.18	8.78
TurbineSite2	3	30	7.921	2485	31.51%	0.0%	2.28	8.94

Figure 14 – 900-kilowatt wind turbine annual megawatt-hour (Net AEP) and capacity factor estimates for Gjoa Haven sites.

Energy Infrastructure

Qulliq Energy Corporation (QEC) has provided Gjoa Haven monthly data for total kilowatt-hours produced and for each generator from March 2015 through February 2018. Figure 15 shows the past three years of energy load, averaged by month. June through September are consistently the lowest months for electricity demand with December and January the highest demand months. Year-over-year growth is currently around 2 percent, but expected to jump with the completion of new housing units. For 2017, the overall electrical demand ranged from a low of 400 instantaneous kilowatts to a high of 1100 kilowatts. (Not shown in graph.)

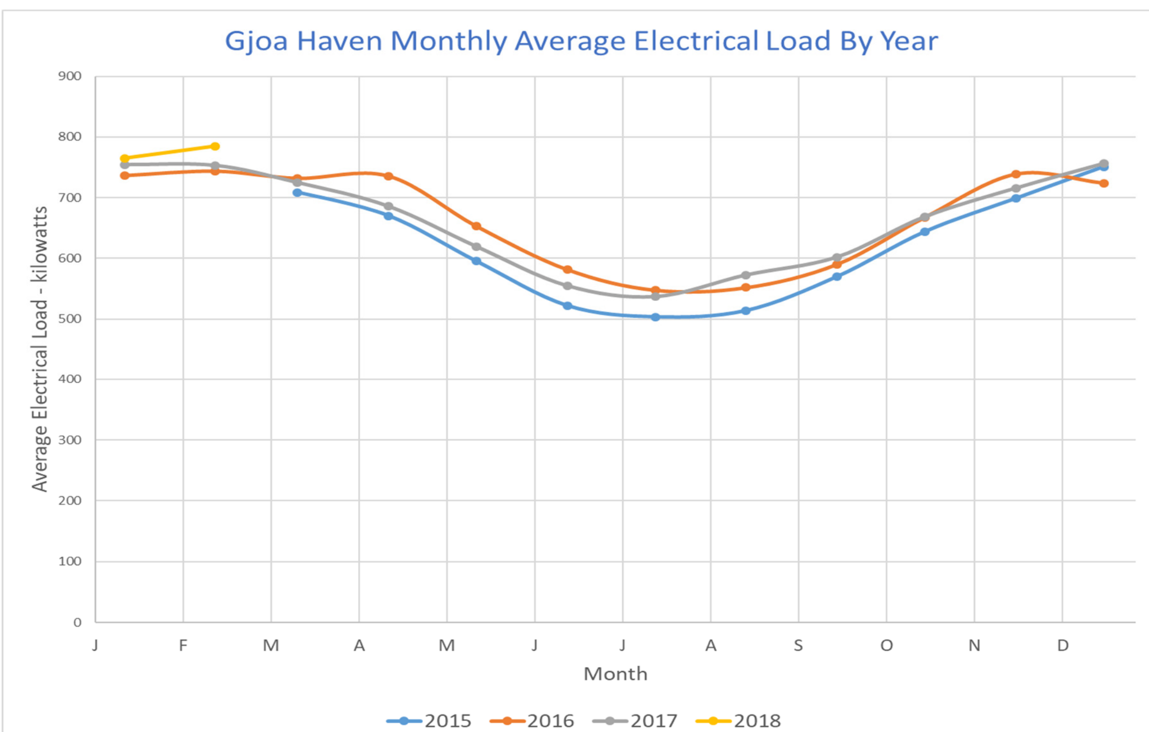


Figure 15 – Gjoa Haven monthly average kilowatt load. Present year-over-year growth is around 2 percent, but expected to jump with the completion of new housing units.

From this data set, ACEP was able to build an annual hourly load profile for use in HOMER modeling using custom Java code. Daily and hourly variation was estimated from Rankin Inlet 1-minute actual data that was scaled down to the Gjoa Haven load demand range.

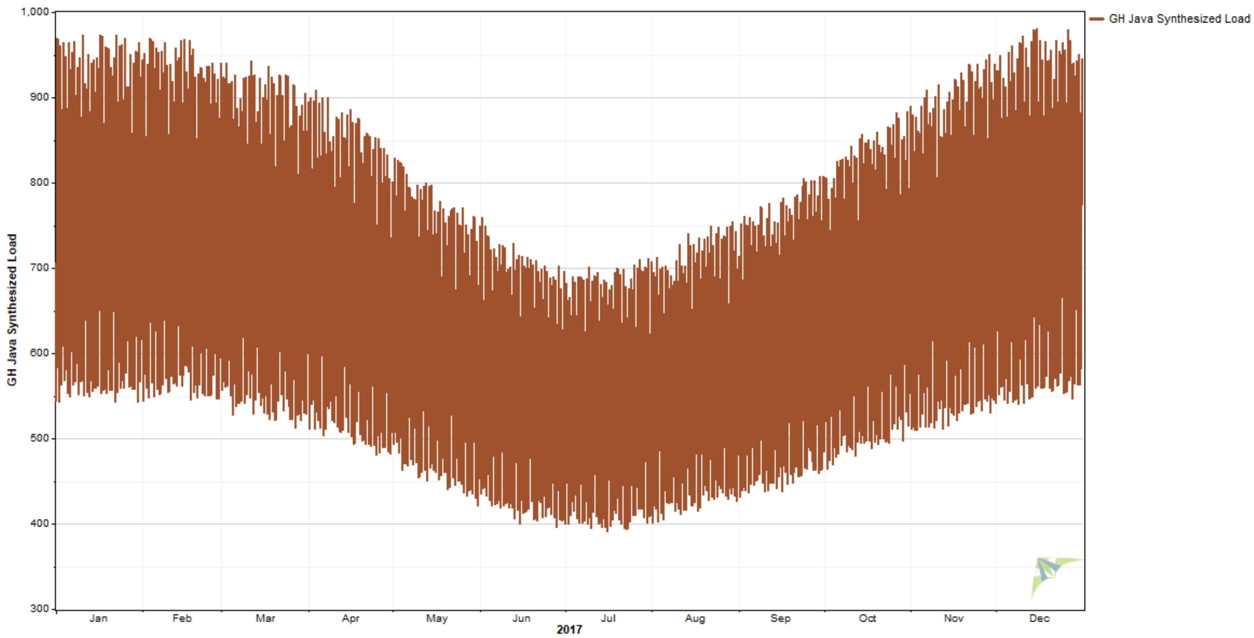


Figure 16 – Simulated load model derived by custom Java code based on scaled Rankin Inlet empirical variation plus monthly generation values for Gjoa Haven provided by QEC.

In order to integrate renewable energy into the Gjoa Haven grid, the following information will be required from QEC if a project is to be properly designed:

- What are the station service loads?[11]
- Are there existing diversion electrical loads in the community? Are there electrical loads that could be converted to dispatchable loads if needed?
- What is the make and model of each diesel genset? What are the fuel curves for each unit? What type of mechanical or electronic throttle controls exist? What are the actual reported kWhrs per gallon of fuel for this facility?
- What kind of switch gear exists – make, model, manual/automatic? Can the existing system be expanded for the proposed wind turbine and secondary loads? What kind of SCADA[12] currently exists?
- Are upgrades or replacements planned for any key system components?
- For a hypothetical waste heat recovery system, what loads could it feed? How would those heat loads monitored/quantified? How much heat would be lost in the system? Is there capacity to serve additional heat loads in the community?
- Are there additional potential electrical loads in the community that are not currently being met? Are any new electrical loads being planned?
- Where are the major electrical loads located in the community from a geospatial perspective?

[11] There is a curious increase from the historical level of around 1.5% of total generation to 3% of total generation that began in November 2017.
[12] Supervisory control and data acquisition.

- How well are the phases balanced in the distribution system? How are the transformers in the community loaded or overloaded? Where is there phase or transformer capacity to add additional loads?
- What is the condition of the distribution lines, transformers and poles?
- Provide a map showing single versus three-phase power lines and varying voltage levels?
- What are the parasitic and other system losses?

Engine Make/Model Serial #	Generator Make/Model Serial #	Year Hours	Min Load %	Rated Capacity (kW) (kVA)	Average Load on Genset	Average Load on Genset w/ Wind
Gen 1			25%	725	91%	52%
Gen 2			25%	550	120%	69%
Gen 3			25%	550	120%	69%
Gen 4 Cat 3508B		2018	25%	550	120%	69%
Comments: Power plant built in 1979						

Figure 17 – Gjoa Haven power plant summary based on available information

Commercial Heat Loads

Large heat loads in a community provide an alternate destination for excess solar and wind energy after all electrical loads are being met and diesel generators are running at minimum capacity. Fuel consumption data has been provided for several large buildings in Gjoa Haven by the Hamlet:

- Hamlet Office

Hourly heat loads have been built for each of these buildings to determine how much excess solar and wind energy could be absorbed for any hour of the year. This information is essential to maximize the benefit of any renewable energy system and not waste potential kilowatt-hours. It will be needed for the HOMER model in the conceptual design report.

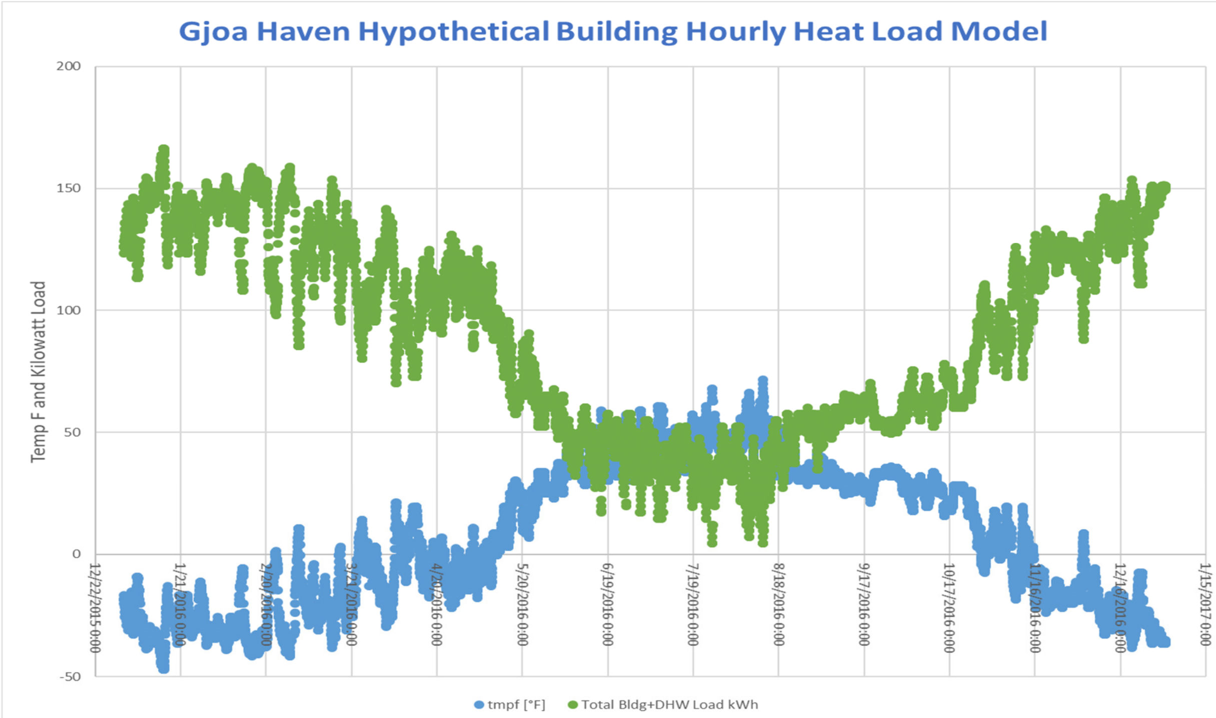


Figure 18 – Hourly heat load (green) and temperature (blue) for Gjoa Haven Hamlet Office

Figure 19 shows the degree of fit between the hourly model using ACEP's and Western State's method[13] of apportioning annual fuel consumption across heating degree hours by hourly delta T calculations.

The heat load analysis performed across all buildings confirms the confidence in heat load models for Gjoa Haven and indicates that three or more buildings would need to be connected to an electric boiler to absorb excess solar and wind energy and minimize burning of heating oil. HOMER modeling with true power plant load data, true solar and wind data and these high-confidence heat load profiles will be needed to design an optimal system.

[13] Stromberg, Rich (2015) Modeling Alaska heat loads quickly with better accuracy. Alaska Wind Working Group - 1Q 2015.

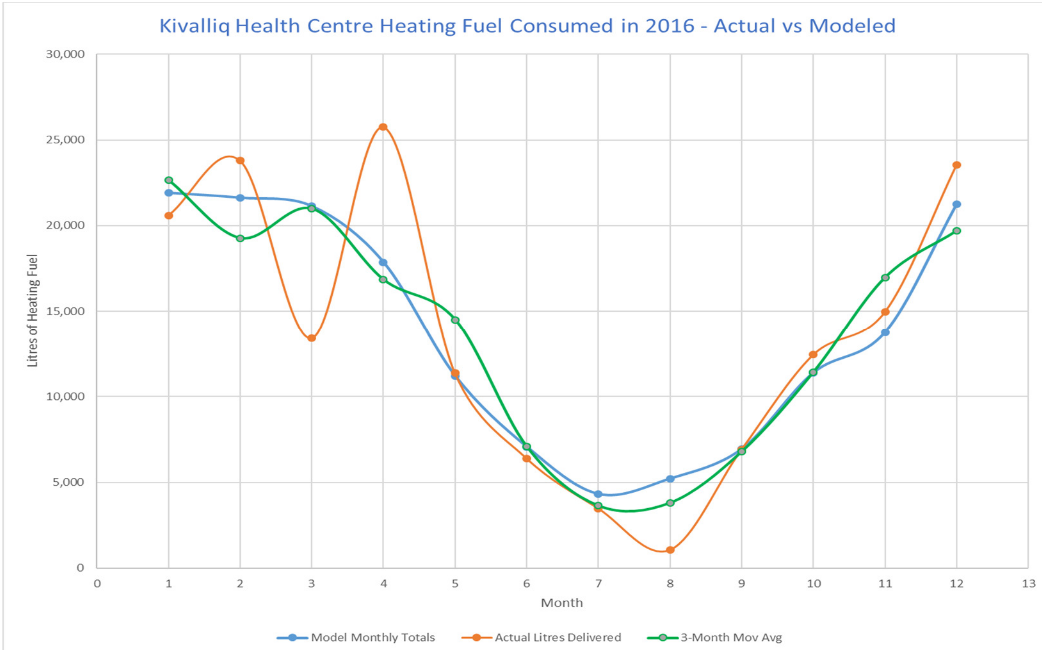


Figure 18 – A comparison of the modeled health centre energy loads based on hourly heat loss calculations versus actual heating fuel delivery (Rankin Inlet Data)

Additional Energy Option #1 – Efficiency

A community-wide energy efficiency initiative is recommended as a high priority because these measures:

- Offer a quick payback on investment
- Are generally low cost to implement
- Do not have to wait for energy infrastructure upgrades
- Will be compatible with both current and future energy infrastructure
- Relieve energy loads on existing power grid
- Reduce the cost of future energy upgrades due to efficient/reduced energy loads
- Address both electrical and heat energy demands
- Provide for local training and employment of energy advisors/raters and installers/tradespeople
- Can be split into separate commercial and residential efforts to optimize approach, outreach and implementation

For commercial buildings and large residential structures, a complex and thorough energy audit is recommended using Natural Resources Canada's CIPEC (Canadian Industry Program for Energy Conservation) audit methods and tools.[14] [15] This approach would entail hiring outside, trained contractors or recruiting local residents with construction experience to become trained to the CIPEC certification standards. To fully develop local human capacity, employees should apprentice with

[14] http://www.nrcan.gc.ca/energy/efficiency/industry/cipec/5161

[15] http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/publications/infosource/pub/cipec/energyauditmanualandtool.pdf

existing commercial energy advisors before working independently. This may require working outside the hamlet or territory during the apprenticeship or it could involve negotiating with outside contractors to hire and train local people on audit and retrofit projects for a year or longer.

For residential buildings housing one to four family units, local energy advisors and retrofitters can be recruited and trained through Natural Resource Canada's EnerGuide Rating System (ERS).[16] Energy advisors must show knowledge and experience in areas such as:

- EnerGuide Rating System
- Residential construction practices for low-rise housing
- Energy efficiency renovation practices
- Building science
- Basic arithmetic, geometry and computers skills
- Data collection requirements
- Energy simulation modeling using HOT2000, and
- Good client relations[17]

For both the commercial and residential energy audit and retrofit programs, significant funding must be secured or budgeted to build a structured program that will operate for a five- to 10-year period. Natural Resources Canada has multiple funding opportunities, grants and initiatives that could support a community-wide energy efficient program (Green Infrastructure and others[18]). The hamlet would need to decide if federal funding applications should cover the initial startup and training phases with ongoing support provided by fees charged for audits and retrofits, ask for additional monies to provide audits at no cost to business owners and resident or ask for even more monies to cover 50-percent matching on energy efficiency retrofits. Scope and funding amount requested should be weighed against perceived likelihood that federal funding will be awarded when compared with other community applicants.

Western State Colorado University developed the Gunnison Valley Home Energy Quick Assessment Tool (GV-HEQAT) for homeowners and renters who cannot afford a $250 energy audit using the RESNET Home Energy Rating System (HERS).[19] The advantages of this no-cost Excel™ based tool are:

- Ease of use
- Includes local electricity and natural gas rates
- Incorporates an accurate hourly heat load profile
- Allows the user or community energy volunteer auditor to model the home as-is and then calculate the energy cost reduction of a wide variety of retrofits/upgrades
- All funds spent by the homeowner or renter go toward actual improvements that save money

The HEQAT tool has been modified for use in Gjoa Haven by using metric scale inputs and outputs where appropriate, using hourly heat load data specific to Gjoa Haven, using local electric and heating oil rates and most importantly, reflecting the subsidy contribution paid for by the Government of Nunavut. Calculating the financial impact on the territorial government highlights where there may

[16] http://www.nrcan.gc.ca/energy/efficiency/housing/home-improvements/5005
[17] Source: http://www.nrcan.gc.ca/energy/efficiency/housing/new-homes/16631
[18] http://www.nrcan.gc.ca/energy/funding/4943
[19] https://www.resnet.us/hers-index

be financial incentives for territorial funding of energy efficiency upgrades that could reduce future GN costs. (See Figures 23a & b.)

					Nunavut Home Energy Quick Assessment Tool				GN Subsid
							Electric Rate per kWh:	$0.06000	
							Heating oil $/liter	$1.32	
					Gjoa Haven Heat Profile		Elec Rate Unsubsidized	$0.49800	$0.43800
Rich Stromberg, Research Faculty	restromberg@alaska.edu				All costs/prices are in Canadian $				
# of people in Houshold:		4	Address (Optional)	1313 Inukshuk St	Town:	Gjoa Haven			
House	Length (m):	10	Width (m):	8	Footprint (sq m):	80	Insulation R-Factors		
Dimensions	Ceiling height:	2.6	Exterior Walls (sq m):	93.6	R-Factor:	19	Uninsulated exterior wall OSB or Plywood (garage)		0.62
	Number of floors:	1					Uninsulated exterior wall OSB/Plywood+Drywall		1.07
Total Energy Loss Through Walls Per Year (kWh)		7,482	Annual Cost			$448.95	Insulated exterior wall 2x4 wood studs		13
							Insulated exterior wall 2x6 wood studs		19
Garage	Length (m):	0	Width (m):	0	Footprint (sq m):	0	Rigid foam insulation board - add R-5 per inch thick		5
Dimensions	Ceiling height:	2.8	Exterior Walls (sq m):			0	Attic insulation 4-5" deep		15
	Attached?	N	If no garage, zero out blue fields and select 'N' for attached				Attic insulation 6-7" deep		21
	Heated?	N	Insulation R-Factor:				Attic insulation 13-14" deep		38
							Attic insulation 16-17" deep		49

Figure 20 – Gjoa Haven Home Energy Quick Assessment Tool data entry sample portion

				Nunavut Territory Home Energy Quick Assessment Tool Summary Report			
Address	1313 Inukshuk St	Town:	Gjoa Haven	Nunavut Heat Profile			
# people in household	4						
Size of home (sq m)	80						
Number of floors	1						
Total Energy Loss Through Walls Per Year (kWh)	7482	Annual Cost (elec)	$448.95	Annual Cost (heat oil)	$1,612.41		
Total Energy Loss Through Doors Per Year (kWh)	224	Annual Cost (elec)	$13.41	Annual Cost (heat oil)	$48.17		
Total Energy Loss Through Attic Per Year (kWh)	4297	Annual Cost (elec)	$257.83	Annual Cost (heat oil)	$926.00		
Total Energy Loss Through Windows Per Year (kWh)	5697	Annual Cost (elec)	$341.80	Annual Cost (heat oil)	$1,227.58		
Total Heat Loss (kWh):	17,700	Annual Res Cost to Heat:	$1,061.99	Monthly Avg:	$88.50	GN Subsidy:	$7,752.51
Total Heat Loss (L heatoil):	2,887	Annual Cost to Heat:	$3,814.15	Monthly Avg:	$317.85		
Total Energy For Lighting Per Year (kWh)	853	Annual Cost	$51.20	Monthly	$4.27		
Total Energy For Showers Per Year (kWh)	9,285	Annual Cost	$557.09	Monthly	$46.42	Annual Cost (heat oil)	$1,500.61
Total Energy For Other Appliances/Loads Fall>>Spring	5,019	Annual Cost	$301.16	Monthly	$37.65		
Total Energy For Other Appliances/Loads Summer	2,170	Annual Cost	$130.22	Monthly	$43.41		
Annual Energy Load (kWh equivalent)	35,028	Annual Res Energy Cost (All Elec)			$2,101.66	GN Subsidy:	$15,342.09
		Annual Res Energy Cost (Elec & HeatOil)			$4,296.72	GN Subsidy:	$3,522.81

Figure 21 – Gjoa Haven Home Energy Quick Assessment Tool summary report

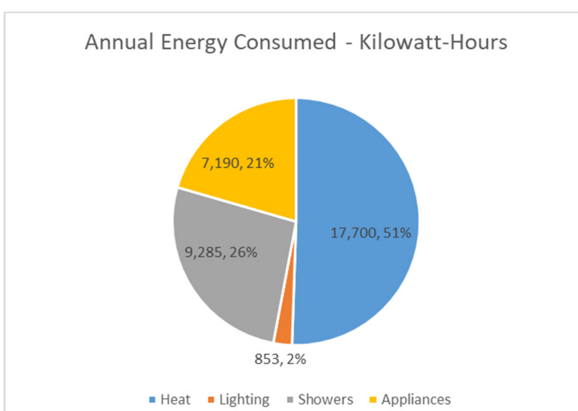
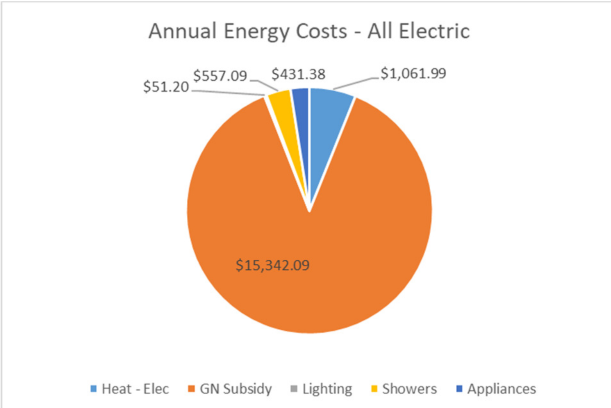
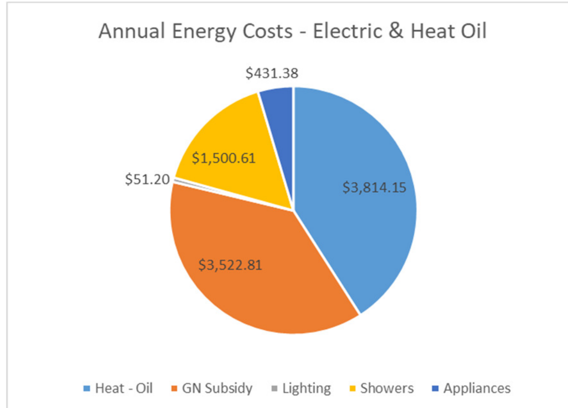


Figure 22 – Residential energy load for electricity and heat sources





Figures 23 a & b – Energy costs for same house comparing all electric (including heat loads) and electric plus heating oil for water and home heating. Note conflicting impact to homeowner costs and GN subsidies.

A structured program could be developed with the hamlet to train local people to become HEQAT auditors. The hamlet would need to determine how auditors are compensated and whether a sufficient local construction trades workforce exists to implement the more complex energy retrofits beyond simple lighting and appliance improvements.

Free LED Light Bulbs – A Radical Solution With Fast Payback

Because of the structure of Government of Nunavut residential electric subsidies, ACEP recommends that GN work with the Qikiqtaq Co-op, Northern Store and any other local supplier to

1) cease the stocking/supply of all incandescent and compact fluorescent (A19 style) light bulbs
2) provide coupons to all residents for free LED lightbulbs purchased from these local stores.

For residents living in Nunavut Housing Corporation buildings who pay 6 cents per kilowatt-hour, a $5 LED bulb (60-watt equivalent, 9-watt actual) does not seem like a wise option when compared with a $1.25 incandescent or $1.50 compact fluorescent (CFL) bulb. Even if the resident were to calculate the energy savings from LED bulbs, the payback to replace an incandescent is 6.5 months and to replace a CFL is more than 10 years.

<u>From the perspective of GN, however, paying a subsidy of 44 cents per kilowatt-hour changes the economic payback to less than a month to replace an incandescent and 9 months to replace a CFL.</u> This does not include the added benefit of eliminating trace amounts of mercury in each CFL from the waste stream that could end up in the landfill and leach into the water table.

For residents living in non-NHC housing who pay approximately 25 cents per kilowatt-hour with GN picking up the other 25 cents, the payback for the resident **<u>and</u>** GN to replace an incandescent is 1.5 months and to replace a CFL is 1.5 years. While the CFL payback is longer in this scenario, free LED light bulbs are still recommended so that a single rebate/coupon system can be easily administered with equity among all members of the community.

If each of the approximately 255 residences in Gjoa Haven were to replace 10 LED bulbs, the cost would be $12,750. Assuming 225 of those residences are through NHC and the light bulbs are used 9 hours per day, the savings to GN in the first year is $162,129.60. If the other 30 residences are non-NHC, the savings to GN in the first year is $12,198.60. The net savings to GN after subtracting the cost of the light bulbs would be $161,578.20 that could be directed to other social needs in the community.

The longer life of LED bulbs (replace every 7 years) compared with CFL (replace every 3 years) and incandescent (replace every 4 months) means subsequent years will require far fewer free light bulb coupons to be funded and there will be fewer light bulbs in the solid waste stream.

Energy Cooperative

During the February 2018 community engagement meetings, the concept of a local energy cooperative was discussed. The cooperative could be a focal point for initiating action, applying for grants and other assistance, as well as an entity that functions as a conduit for bulk purchases of energy efficient lighting, appliances, insulation/weatherization materials and solar photovoltaic system components. The cooperative could also coordinate energy efficiency training, loan/share energy monitoring equipment and even develop jobs to support regional energy efficiency needs.

Additional Energy Option #2 – Solar Photovoltaic Training

The map in Figure 12 shows a partial inventory of the many recreational cabins sited in the outlying regions of Gjoa Haven. These cabins represent energy loads that should also be considered as they have real, measurable impact on the residents of Gjoa Haven. Besides the potential for energy efficiency impacts listed in the previous section, these cabins could benefit from reduced generator fuel and noise through the installation of off-grid battery-based solar photovoltaic (PV) systems at each cabin.

The hamlet or Kitikmeot Inuit Association could structure a solar PV installation and community bulk purchase program funded in part through the Arctic Energy Fund, Green Infrastructure or other available federal programs. A request for proposals could be issued for training in the design and installation of simple PV systems that are tailored to the needs of recreational cabin owners in the region. Solar training could cover:

- Inventory and sizing of current energy loads
- Determining number of PV modules required
- Mountain options for panels
- Voltage, serial and parallel configurations of modules and batteries
- Battery technologies and why sealed (e.g. absorbed glass mat/AGM) batteries are preferred for cabin applications to eliminate buildup of hydrogen gas during charging
- Wire sizing
- Selecting the appropriate charge controller and inverter
- Safety equipment and safe working practices
- Proper system grounding
- Calculating expected energy generation by month and overall economic payback

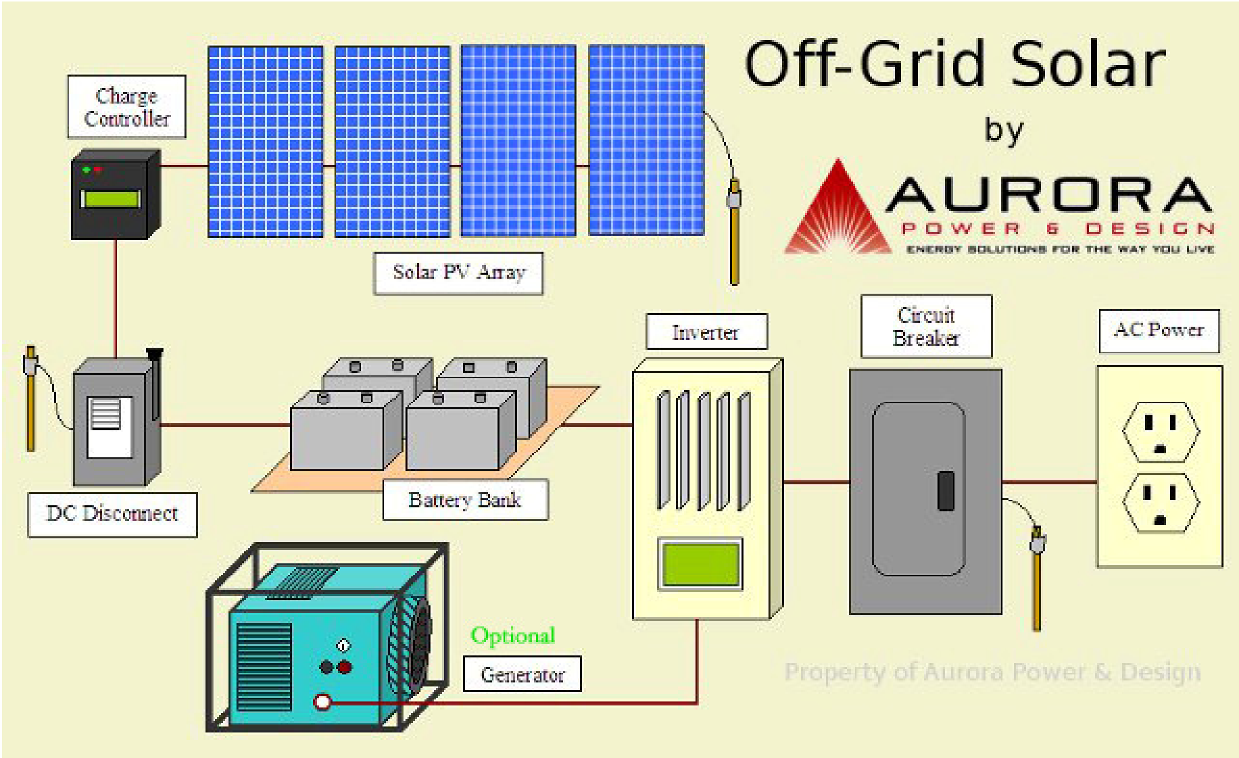


Figure 24 – Sample schematic for typical recreational cabin power system

Some cabins near Gjoa Haven already have solar PV systems. Proliferating this technology to all cabins will result in fuel savings, reduced environmental risk of fuel spills and a more pleasant experience out on the land through the elimination of generator noise.

Funding for a one-time training seminar could be done with minimal investment and during the next summer season. Requests for federal matching of solar PV equipment purchase and delivery to Gjoa Haven would require more coordination, planning and time but could greatly expand the participation level and improve system payback times.

Additional Energy Option #3 – Community Empowerment

Along with the proposed energy cooperative, additional paths for community empowerment were discovered during the community meetings.

- A formal energy plan for Gjoa Haven is an approach commonly used by remote communities in far northern latitudes. Community energy plans begin by looking at the existing energy structure and how electricity, heating fuel and transportation fuel are used throughout the hamlet and surrounding lands. Next, the plan identifies potentially available energy sources (hot springs, flowing rivers, fossil fuels, solar irradiance, tides, wind) and selects which ones should be a priority for formal resource assessment. The community then considers future energy needs and creates a vision for what their future energy system looks like. Lastly, the hamlet residents would agree on a roadmap and timeline to execute their priorities for resource assessment, funding, design and permitting, construction and long-term operations, maintenance and training.

- A community greenhouse was suggested as a way to improve local food security, increase the growing season and add to the variety of fresh produce available. Greenhouses have been integrated into high school curriculum in Alaska. The type proposed is a conventional greenhouse with no supplemental heat, although some communities use waste heat from buildings or power plants to extend harvest into late fall and begin planting in early spring. If interest is high, multiple greenhouses can be sited within a community. Greenhouses also offer an opportunity to repurpose leftover materials from local construction projects.
- A community cold-storage facility could be powered by waste heat from the power plant (if available after other heat demands are met) to provide a common space for freezing/storage of fish and game meat. "An absorption chiller has been operating at the Kotzebue, Alaska power plant since the mid '90s to make ice for the local fishing fleet. The Kotzebue chiller is powered by 74 deg C jacket water from a diesel generator. The system uses a three pressure ammonia/water absorption cycle, and had been in operation for 10 years."[20] This system has also been used successfully at the Chena Hot Springs Ice Museum for more than 10 years.
- Collaborative design of optimal northern family housing that addresses the energy, cultural and social needs in Nunavut. The Cold Climate Housing Research Center has conducted design charrettes with Tagiugmiullu Nunamiullu Housing Authority in Anaktuvuk Pass and the Yup'ik village of Quinhagak in which members of the community collaborate with the center to design energy efficient housing solutions that incorporate cultural and traditional activities, design and uses into new housing solutions.

Additional Energy Option #4 – Value from Waste Streams

Resurrecting the waste oil burner in the hamlet garage was identified as a low-cost solution addressing energy as well as hazardous waste in the community. The existing system has been idled because waste materials other than oil were being poured into the receptacle that feeds the boiler.

The exact specifications and capabilities of the existing waste oiler burner need to be assessed. Once it is known exactly which weights of crankcase oil and any other oils (hydraulic or transmission fluid) can be used in in the burner, the system should be cleaned/repaired by a qualified technician. An improved method of collecting oil with separate collection facilities for anti-freeze and other hazardous liquids needs to be implemented so that the waste oil burner can be maintained with local resources without being damaged by these other liquids. It is recommended that storage receptacles for non-compliant fluids be placed outside of the garage shop with proper labeling and containment. Receptacles for oils that can be safely burned should be located inside the garage shop near the waste oil burner such that employees can monitor what is being poured into the system. Signage and education at public events/meetings should also be implemented.

If the existing waste oil burner is beyond repair, replacing with a newer system[21] capable of burning a wider range of fluids and offering easy cleaning/maintenance should be pursued. Funding may be available from a variety of federal energy and hazardous waste programs.

[20] "ABSORPTION CHILLER FOR THE CHENA HOT SPRINGS AURORA ICE MUSEUM" Sep. 2006. Holdmann, G., Erickson, D. GHC Bulletin. https://www.oit.edu/docs/default-source/geoheat-center-documents/quarterly-bulletin/vol-27/27-3/27-3-art3.pdf?sfvrsn=4

[21] https://www.energylogic.com/waste-oil-heaters/

Presently, there is no heat recovery loop from the power plant diesel engines. Helping QEC to acquire funding for a feasibility study and system design would be a low-cost approach with the potential of saving the hamlet energy costs in nearby buildings.

It is assumed that the existing diesel generators in the power plant are dry manifold rather than marine jacketed engines. Dry manifold engines can provide up to 15 percent of the energy content of each liter of fuel burned into a heat recovery loop. Marine jacketed engines can provide up to 41 percent of the energy content of each liter burned. Given the fuel consumed by the power plant in 2017, 15 percent is equal to 8,584 MMBtu or 213,780 kWh of potential energy.

Since some of this energy will be lost in the insulated piping run to other buildings, a heat recovery loop can be optimized by using it in as close proximity to the power plant as possible. Recommended customers for a heat recovery loop would include the four hamlet garage buildings, Nunavut Housing Office, NU Water Board and the Heritage Center.

Recommended Scope for RFP (Request for Proposals)

Solar and Wind Data Collection Equipment

A qualified contractor with experience installing meteorological towers in remote locations should install the following equipment that can either be sourced directly from suppliers such as NRG Systems, Vaisala or Campbell Scientific or provided by the firm hired to install the meteorological tower, write the wind resource study and develop a conceptual design. The recommended equipment includes:

- A minimum 50-meter[22] meteorological tower to collect wind speed, wind direction, temperature and solar irradiance. Standard non-heated anemometers must be used in order to assess potential ice and frost impacts at the wind turbine site.[23] A red and white painted tower option should be used for aviation safety/visibility.
- This system should be instrumented at heights of 10m, 30m and 50m above ground level with a minimum of two anemometers and one vane at each height - three anemometers and two vanes should be considered for redundancy in the harsh environment.
- Temperature and solar irradiance should be measured between 1m and 3m above ground sufficient to remain above the highest snow accumulation. A backup temperature sensor and SCM card should be installed as these have a ~10 percent failure rate in extreme cold climates.
- The recommended example kit below will also need an additional wind vane and 2.4m boom, additional/backup temperature sensor, three Li-Cor pyranometers with SCM cards and plane-of-array booms mounted horizontally, vertical south-facing and at latitude tilt south facing.
- https://www.nrgsystems.com/products/complete-met-systems/wind-resource-assessment-systems/detail/50m-xhd-now-system

[22] 60-meter or 80-meter recommended. See below for details. The actual project developer/investor should decide whether the added expense and logistics of the 80-meter tower are justified by the additional data across the rotor swept area. A 60-meter tower would be a reasonable compromise.

[23] This is non-negotiable. Do not let a contractor deviate from this requirement.

- The install kit with tools, gin pole and winch will need to be ordered. https://www.nrgsystems.com/products/accessories/tool-kits/detail/install-kit-60m-hd-50m-xhd-60m-xhd-talltowers
- Leave the gin pole on site attached to the meteorological tower. Do not under any circumstances allow the contractor to disconnect the gin pole nor ship the gin pole to another location.[24]
- The data logger will need an SD card, iPack GPS/3G/GSM for uploading data to the internet, 15-watt solar panel and USB cable for configuration - https://www.nrgsystems.com/products/data-loggers/detail/symphoniepro-data-logger
- A 60m or 80m tower can also be considered to quantify more of the wind resource in the rotor swept area. Instrument the same heights as specified for a 50m tower, plus at 60m or 80m depending on the height chosen. Note that the 80m tower requires special training to erect and may require more complex anchor and base construction. Make sure your installer is qualified to install this 80-meter system.
- The installer will need to assess the needed anchor systems based on preexisting geotechnical studies in the community.
- Collect 10-minute or better resolution data. 1-minute resolution could be collected for a short period to determine high-resolution variability and the need for any regulation storage in the power system, but long-term collection at this resolution can actually hamper data analysis and is not needed for industry-standard (10-minute) reports.
- Collect 10-minute power plant data concurrent with the wind study, including kilowatts, volts/amps by phase, power factor, frequency, heat recovery loop temperature.
- All data collected must be shared with the hamlet and the funding entity within one month of each data pull. The data collected cannot be considered proprietary to the contractor.
- Utilize local labor for the installation of the met tower and monthly monitoring to the greatest extent possible to foster local community involvement and sense of ownership.
- Community consultation should be a part of this and subsequent project development phases.
- Wildlife considerations and potential conflicts should be addressed with local experts and territorial agencies when selecting a met tower site. Moving the proposed project site is much easier and less costly to do early in the process timeline.

See *Appendix A* for additional met tower specs and example tower profile.

Scope of a formal solar/wind energy study and conceptual design

These are the bare essential aspects that should be addressed when developing wind feasibility studies. Wind turbines are not a stand-alone component, but rather an energy source that must be integrated into an over-arching power generation and distribution system for the community. Conversely, a Conceptual Design Report with an overly broad scope wastes time and money and can make it more difficult to recommend next steps.

Wind Resource Study

---

[24] This mistake has been made in numerous installations across Alaska and elsewhere in the US. Any savings in sharing a gin pole with other locations has been lost in the shipping costs and occasional urgent need to lower a met tower.

How reliable is the overall data? Are there gaps? Did any sensors or data logger fail? Was a log sheet filled out during tower erection?
How fast is the wind? Average speed, maximum, std. dev.?
How does the wind speed vary throughout the day? Month to month?
What does the wind speed distribution look like? Weibull K? Is it bi-modal with periods of calm then severe storms? Is the distribution more continuous?
How does the wind shear change with elevation (power law exponent)? How turbulent is the wind? What are the predicted maximum speeds over 20 and 50 years?
How much icing is experienced at the site? How thick is the icing and how long does it last?
What is the air temperature and density?
How consistent is the wind data from one year to the next? How does it compare with long-term trends?
How was the met tower site chosen? Are there nearby obstructions?
How does the wind speed and wind rose compare with the national wind resource model for that location?
How closely will wind turbines be placed near the met tower site?
How does the wind rose affect siting for multiple turbines?
What issues were raised by the Nav Canada, Canada Wildlife Service and Nunavut Impact Review Board during the met tower permitting process?
What is the estimated net production for turbines being considered, assuming no wasted/excess power? Windographer defaults to an 82% availability. This is a reasonable estimate.

Solar Resource Study

How does the solar resource vary over the course of the year?
How would the power from a solar array vary from minute to minute?
How do clouds affect variability on partly-cloudy days?
What array orientations work best for your location?
How does your projected power production match up against energy demand throughout the day and the seasons?
How much benefit will you see from snow bounce?

Existing Electrical System Overview

How does the community electrical load vary throughout the day? Month to month? What is the average, peak and minimum?
Are there seasonal loads due to commercial or traditional activities? How do the residential electrical loads compare with industrial and commercial loads throughout the day and month to month? What are the station service loads?
Are there existing diversion electrical loads in the community? Are there electrical loads that could be converted to dispatchable loads if needed?

What is the make, model, kW rating and age of each diesel genset? What are the fuel curves for each unit? What type of mechanical or electronic throttle controls exist? What are the actual reported kWhrs per gallon of fuel for this facility?
What kind of switch gear exists – make, model, manual/automatic? Can the existing system be expanded for the proposed wind turbine and secondary loads? What kind of SCADA currently exists?
Are upgrades or replacements planned for any key system components?
Is there a heat recovery system? What loads does it feed? How are those heat loads monitored/quantified? How much heat is lost in the system?
Are there additional potential electrical loads in the community that are not currently being met? Are any new electrical loads being planned?
Where are the major electrical loads located in the community from a geospatial perspective?
How well are the phases balanced in the distribution system? How are the transformers in the community loaded or overloaded? Where is there phase or transformer capacity to add additional loads?
What is the condition of the distribution lines, transformers and poles?
Provide a map showing single versus three-phase power lines and varying voltage levels?
What are the parasitic and other system losses?

Heat Loads Overview

What is the heat recovery percentage of each diesel genset? What heat loads are tied into the heat recovery system? How are those heat loads monitored/quantified? How much heat is lost in the system? What additional capacity is available?
Pull heating fuel consumption/purchase records (minimum one year) for the buildings being considered and provide annual estimates (high/low) for each. Provide building dimensions.
What is the daily and month-to-month profile of each heat load? Preferred: use ACEP's hourly heat load spreadsheet to generate heat data for HOMER modeling. ACEP can assist in setting this up.
If the heat load is a water treatment/storage/delivery system, provide details of annual fuel consumption records, storage tank size (gallons and dimensions) and insulation, distribution piping and distances, incoming water temperature in winter and summer, water system temperature target and maximum temperature set points. Use ACEP's hourly heat load spreadsheet for water systems to generate a heat model for HOMER modeling.
If the heat load is a washeteria, provide annual fuel estimates and number of washers/dryers/showers. Estimate daily and seasonal demand profile.
Where are the major heat loads located in the community from a geospatial perspective? Which could connect to an existing or planned heat recovery loop? Which could be clustered together for a remote electric boiler?
Are there additional potential heat loads in the community that are not currently being met? Are any new heat loads being planned? Where are they located relative to the powerhouse?

- What is the efficiency of current boilers? Where is space available to add electric boilers?
- What is the thermal mass in the heat load and how much excess energy can it temporarily absorb as a buffer?
- Run a HOMER model for the turbine types being considered comparing excess wind energy throughout the year and how that is aligned with the heat load profile(s).
- Are heat loads better served by connecting an electric boiler to the existing heat recovery loop or placing electric boilers in other community buildings?
- What are the trade-offs between a few large electric boilers versus numerous nodes throughout the community?
- What agreements are needed to establish heat sales with customers?

Compiling the Final Conceptual Design Report

In addition to answering all of the above questions, please provide the following materials in your report.

- Proposed electrical system line drawings showing turbines, transmission lines, distribution system and powerhouse. Label voltage and phase of lines, plus conductor type, size and resistance factor at 0 deg Celsius.
- How will turbine type, quantity and location affect power quality issues such as reactive power, power factor, voltage rise and other distributed generation issues? Does a basic voltage drop/rise calculation indicate the need for additional analysis using the DG Toolbox or running a load flow analysis? Is complex Power System Simulation for Engineering (PSS/E) modeling required?
- Detailed line drawing showing how wind power connects to the powerhouse through switchgear and how wind, diesel and diversion loads integrate with each other.
- Proposed and existing SCADA system drawing and description.
- Proposed physical layout at turbine site, powerhouse and transmission route.
- Proposed and existing diversion load drawing and description.
- Wind turbine models, sizes and quantities considered. Power curves for each turbine. Which qualified third-party test facility has certified the proposed turbines?
- Proposed budget and schedule based on current turbine pricing and construction estimates.
- A list of what permits will be needed for the project.
- A copy of the geotechnical reconnaissance report.
- HOMER model with accurate wind resource, electrical load, thermal load, wind turbine power curves, turbine availability, diesel power curves and diversion loads. Pay special attention to the excess power in the system and how that can be put to value-added use. (Include the electronic HOMER file in your submission, but limit the printed report to HOMER output from the proposed system.)
- Show how the economies of scale are affected by using different types and quantities of turbines. How do these options vary the overall system cost, the cost per installed kilowatt and unusable excess power? This analysis should reflect that offsetting electrical load has greater

economic benefit than offsetting heat loads due to the varying efficiencies of diesel generators versus oil-fired boilers.

If the project involves, or could involve, the intertie of two or more communities, analysis becomes more complex to determine where diesel and wind power generation are located relative to community loads. Cost and efficiency of reliable communication between the wind site and the powerhouse should be considered. Savings may be gained through consolidation of bulk fuel facilities or idling of power plants. Further, the larger load of the combined communities may allow for larger turbines with better economies of scale. These benefits should be weighed against any loss of rural employment or higher heating oil delivery costs for communities losing power plants.

Common Pitfalls

Placing all focus of the design at the wind turbine site - Much of the needed design activity deals with integrating wind power with the existing power plant, distribution system and community heat loads.

Not realizing that most modeling tools estimate turbine performance on the national grid where all wind power can be absorbed by the grid – Greater than 40% capacity factors aren't reasonable estimates and they degrade the impression of your report.

Ignoring the excess kilowatt hours reported by HOMER – This number must be subtracted from your total kilowatt hours to accurately estimate diesel fuel savings. Proposed projects should find a dispatchable load that can use this excess energy. Bear in mind that the economic benefit of offsetting a heat load is less than offsetting diesel electric generation.

Insufficient analysis of heat loads in the community. Simply placing an electric boiler on the heat recovery loop is likely the best choice if 80-percent of the BTUs being added to the HR loop are being consumed by users to offset heating oil. If only 30-percent of the HR energy is being used to offset heating oil, a different building that cannot tie into the HR loop would be the better location.

Consider hiring an independent technical advisor to review designs and reports on behalf of the hamlet, GN and QEC.

Oversized diesel generators may negate any assumed benefits from wind power – Wind diesel systems require small, medium and large gensets so that as wind power comes online, smaller diesel generators can be selected based on which generator is currently in the optimum part of the fuel efficiency curve for the net system load. A 1MW wind system proposed in Nome resulted in no actual fuel savings under the existing diesel configuration. Adding smaller gensets to the SCADA system provided for ~ 900,000 gallons of diesel savings per year with the proposed wind turbine. Further, lowering the minimum load setting on a generator may result in sending unburned fuel up the exhaust stack.

Small (<400kW) 1200-RPM generators do not respond quickly enough to variable wind power to maintain frequency control on the system. 1800-RPM engines in this size range have proven to be more effective in wind-diesel systems - preferably with electronic controls. Larger (500kW and up) 1200-RPM generators have not been an issue to date.

Oversizing the proposed wind system – A 250kW wind turbine on a system with an average load of 70kW is a potential disaster. Simply adding battery storage and an inverter may sound like a trivial solution, but this has proven more challenging in Alaska. Large turbines can trip diesel gensets offline.

Proposing unproven wind, storage or controls technology. New technology falls under the scope of research or technology development and should be proven out in a more accessible location than remote Arctic communities.

Proposing turbines that are not certified by an independent 3rd party – Turbine manufacturers make optimistic claims on the performance of their product. ACEP recommends wind turbines that have been verified by a certified test facility.[25] These turbines also need cold weather packages.

Ignoring the O&M challenges of a wind system – Communities who have personnel that are trained on wind systems and are comfortable climbing exposed towers to perform maintenance have a better chance at meeting the output projections of your design. Major impacts to production are seen the more remote a community is if there is no local trained support.

Building a wind-diesel project without a remote SCADA system that allows for performance data collection and offsite troubleshooting.

Building a wind project without performing a structured wind resource analysis. Building a wind project when the wind resource analysis indicates poor wind conditions.

Once a project is ready to begin permitting and final design, a power purchase agreement (PPA) must be negotiated with the utility. Failure to obtain a PPA early has stalled projects.

Conclusions

In simple terms, the wind resource in the Gjoa Haven is very good. Preliminary wind turbine production estimates are comparable with some of the more productive wind farms in North America. Wind energy systems of 600 to 700 kilowatts in size were modeled and are considered feasible if built with proper integration, controls and minimal short-term storage. Key factors to development of wind energy on the Gjoa Haven electrical grid lie with engaging the grid operator Qulliq Energy Corporation, the current capabilities of controls and power generation at the local power plant, the willingness of an independent power producer to develop a project, the cost of construction by an independent power producer (IPP) and whether a project could be built at an attractive rate to QEC and its ratepayers.

The additional project considerations concern siting of the wind turbines relative to recreational cabins and airport navigation systems. While it is possible to find locations that are compatible with approach and take-off corridors from the airport (YHK), air navigation systems have not been upgraded to be compatible with large wind turbines that may appear as false signals to radar and other tools. While it is possible to place wind turbines outside the 15 km zone for VOR systems, the greater distance from town increases costs due to transmission lines and towers.

[25] NREL, Intertek, RISO, Bureau Veritas, TUV, DNV GL or similar.

Due to the complexity of utility-scale renewable energy systems, a more detailed study of the power plant and local grid is needed along with measuring of wind energy characteristics at heights well above the weather station at the airport. Higher resolution and local measurements of solar energy potential are also needed as existing models rely on measurements taken from communities hundreds of kilometers away. Local collection of solar irradiance data is needed before system sizes and efficiencies can be properly modeled.

Close cooperation is needed from Qulliq Energy Corporation. Although QEC has made it clear that they do not have the bandwidth to develop renewable energy generation projects, their assistance in sharing detailed operational data, equipment configurations and grid specifications is essential to designers and developers who could bring outside funding for clean energy projects. A well-designed project would reduce energy costs as well as energy subsidies paid out by the Government of Nunavut that could be used to further fund improvements in QEC infrastructure as well as provide for other social needs across the territory.

It is recommended that Gjoa Haven issue a formal request for proposals from engineering firms who can conduct the formal solar and wind resource assessment to industry standards and develop a conceptual design based on the extensive groundwork that has already been performed by the Alaska Center for Energy and Power.

In the short term, additional recommendations are made for a formal energy efficiency program, an energy cooperative, a solar energy training program, community greenhouse, community cold storage, housing design charrette, using waste oil for heating and study of a power plant heat recovery loop. The cost of these programs would be considerably less than that of a utility-scale wind or solar energy system. While the solar energy resource is not as strong as more southerly latitudes, improved technology and continual cost reduction in the industry allow for the use of photovoltaics (PV) where they were previously too expensive. Ease of installation makes solar PV a viable energy option for the many remote cabins out on the land near Gjoa Haven.

This report was made possible by funding from World Wildlife Fund Canada.
(http://www.wwf.ca/about_us/)

Author

Rich Stromberg is a member of the research faculty with the Alaska Center for Energy and Power at University of Alaska Fairbanks. He managed the wind and solar programs for the State of Alaska for 6 and 3 years, respectively between 2009 and 2015. He is presently pursuing a Master's Degree in Environmental Management with an emphasis in sustainable and resilient communities from Western State Colorado University with an expected completion date of May 2018.

Any questions with this report can be directed to the author at restromberg@alaska.edu

Report last updated in March, 2018.

Appendix A: Meteorological Tower Specs and Profile

Meteorological Tower Specs for Rankin Inlet	
Minimum Requirement	**Optional Configuration(s)**
50-meter tall guyed tubular tower with gin pole to collect wind speed, wind direction, temperature and solar irradiance. Gin pole must remain attached to tower and gin pole anchor. The painted tower option should be used for aviation safety.	60- or 80-meter tall guyed tubular tower with gin pole. 80-meter guyed lattice tower if intended to for 20+ year monitoring. Note that the 80m tower requires special training to erect. Make sure your installer is qualified to install this system.
The installer will need to assess the needed anchor systems based on preexisting geotechnical studies in the community. Anchors must be sufficient through summer thawing of active permafrost layer.	
Winch and pulley system using locally sourced equipment.	If not locally available, a suitabale winch and pulley system must be purchased and remain in town in case the tower needs to be lowered in an emergency.
Standard non-heated anemometers must be used in order to assess potential ice and frost impacts at the wind turbine site.	Heated sensors are only allowed if accompanied by a full array of non-heated sensors.
Instrumented at heights of 10m, 30m and 50m above ground level with a minimum of two anemometers and one vane at each height. Instrument booms should place anemometers and vanes a minimum of 4 feet from the tower. Anemometer booms should be oriented at least 90 degrees apart. Recommend 270 deg and 90 deg based on bprevailing wind direction. Boom configuration must be consistent at all heights (10m, 30m, 50m).	Three anemometers and two vanes at each height. Add instument suite at 60 or 80 meters if taller tower is used. Orient optional third anemometer at 0 deg.
Temperature and solar irradiance should be measured between 1m and 3m above ground sufficient to remain above the highest snow accumulation. A backup temperature sensor and signal conditioning module card should be installed as these have a ~10 percent failure rate in extreme cold climates.	Humidity and air pressure sensors can be added but are not required.
Two pyranometers to measure solar irradiance: one oriented horizontally and one at latitude tilt, south facing.	Third pyranometer oriented vertical, south facing.
Collect 10-minute or better resolution data. Mean, miniumum, maximum and standard deviation vaalues logged for each time step is required for each sensor.	1-minute resolution could be collected for a short period to determine high-resolution variability and the need for any regulation storage in the power system, but long-term collection at this resolution can actually hamper data analysis and is not needed for industry-standard reports.
Collect 10-minute power plant data concurrent with the wind study, including kilowatts, volts/amps by phase, power factor, frequency, heat recovery loop temperature.	
Data is stored to an SD (or similar) card that is retrieved at least monthly by a local agent/contractor.	Data is stored to an online shared drive via cell-phone communication.
Data logger is powered by batteries with are replaced by a local agent/contractor often enough to prevent any data loss.	Solar panel compatible with data logger that is mounted vertical, south facing and above the highest snow accumulation level.
All data collected must be shared with the hamlet and the funding entity within one month of each data pull. The data collected cannot be considered proprietary to the contractor.	

Meteorological Tower Configuration Profile		
		Tower is painted red/white according to aviation safety requirements
80 meters -->		Optional 2 or 3 unheated anemometers and 1 or 2 vanes. Anemometer booms must be oriented
		at least 90 degrees apart from each other. Recommend 270 deg & 90 deg for first two and 0 deg for
		optional 3rd. Anemometer and vane boom configuration must be consistent across all measured heights.
70 meters		
60 meters -->		Optional 2 or 3 unheated anemometers and 1 or 2 vanes
50 meters -->		2 or 3 unheated anemometers and 1 or 2 vanes
40 meters		
30 meters -->		2 or 3 unheated anemometers and 1 or 2 vanes
20 meters		
10 meters -->		2 or 3 unheated anemometers and 1 or 2 vanes
1 to 3 meters -->		Data logger, 2 temperature sensors, 2 or more pyranometers, optional data logger PV panel, humidity
		and air pressure sensors.