



YUKON RESEARCH CENTRE  
Yukon College

# Challenges and Research in Northern & Remote Electric Power Systems

*Michael Ross, PhD, P.Eng.  
Industrial Research Chair in Northern Energy Innovation*



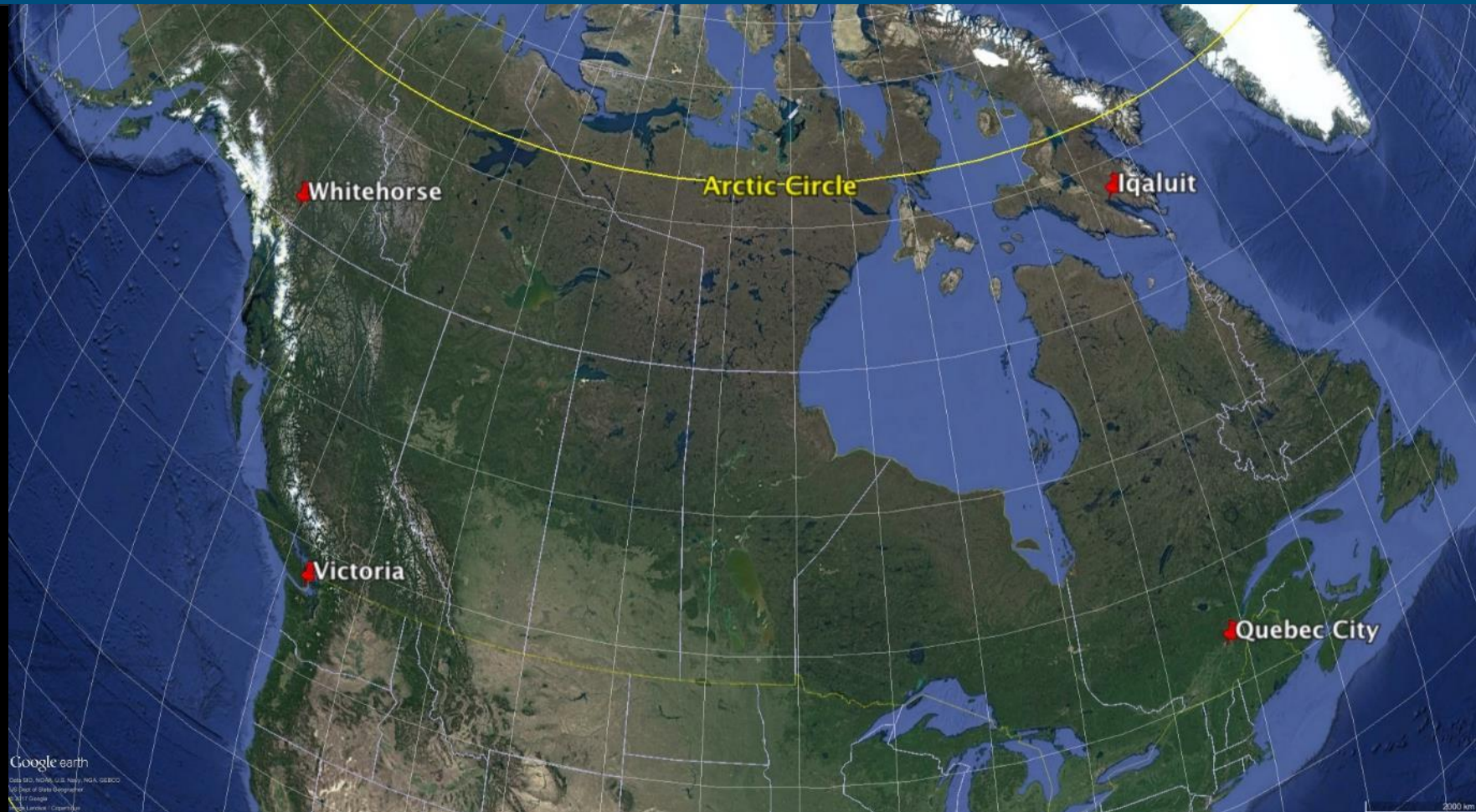
# Presentation Overview

1. Territorial energy context & challenges
2. Northern Energy Innovation overview and project examples
3. Case study: Old Crow Solar Project

# Presentation Overview

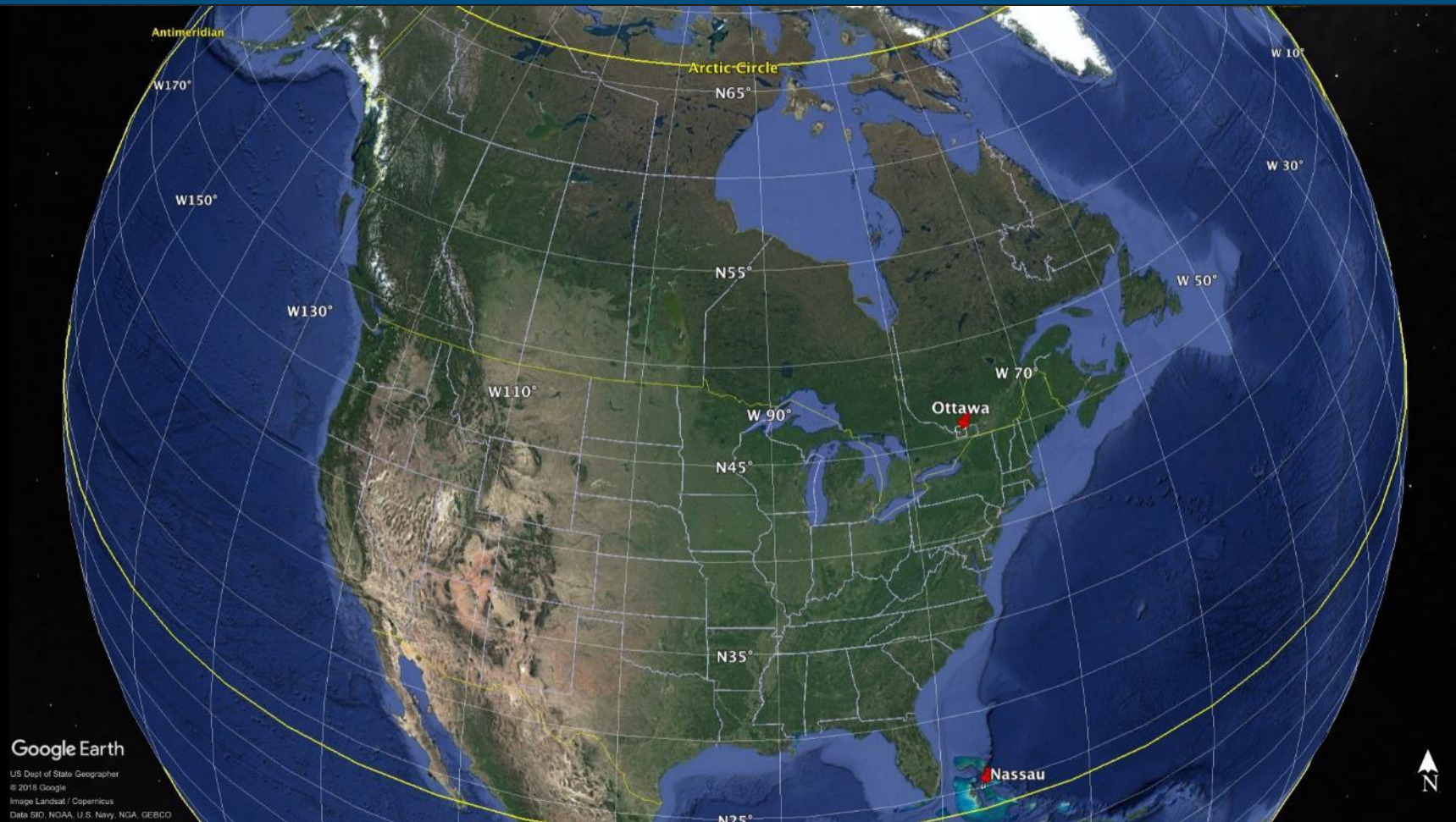
1. Territorial energy context & challenges
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## The northern context





## The northern context



## The northern context





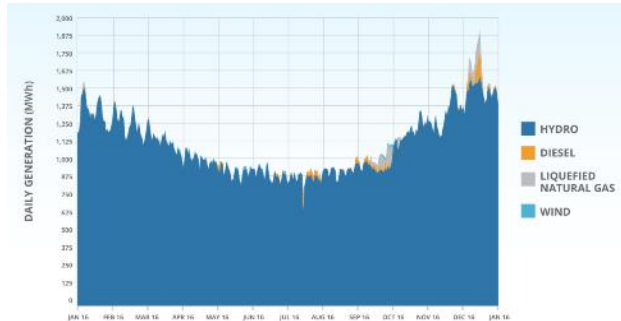
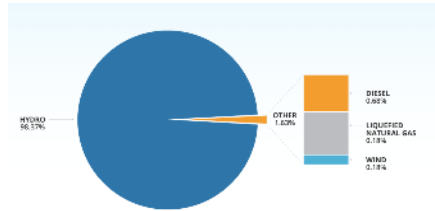
## The northern context



## The northern context



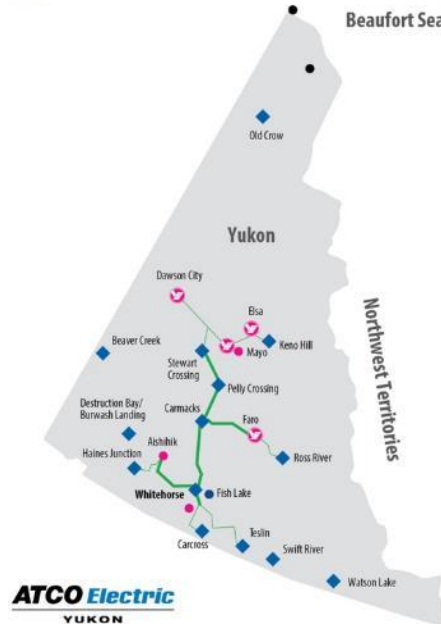




Note: In September/October our Aishihik hydro plant was down while we did repairs to the elevator. In December, it was very cold, and the thermal use was to supplement our hydro during peak times of the day.

## Service areas and facilities

- ◆ Communities served by ATCO Electric Yukon
- ATCO Electric Yukon hydro generating station
- Nasittuq Radar Sites
- ◆ Communities served by Yukon Energy
- ◆ Yukon Energy hydro generating stations
- 138 kV transmission lines
- other transmission lines



**ATCO Electric**  
YUKON

Lighting up the North since 1901

## Yukon Energy to burn more LNG and diesel to meet winter demand



Power corporation says low water level in Aishihik Lake means less hydroelectric generation at dam there

Dave Croft - CBC News - Posted: Nov 01, 2018 3:28 PM CT | Last Updated: November 1

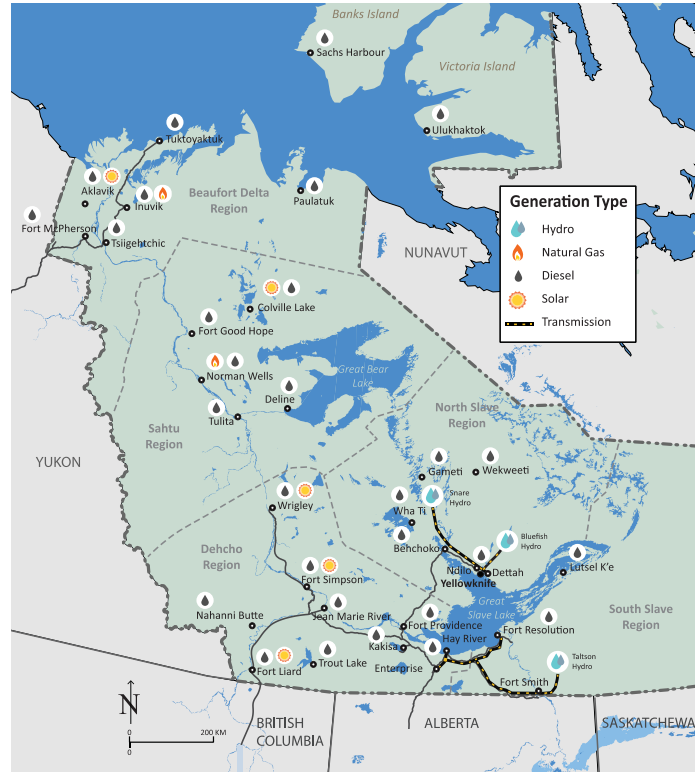
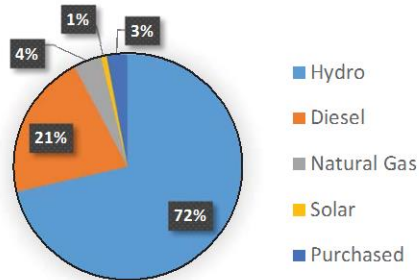


The Whitehorse LNG plant is used as a backup, when the hydroelectric dams cannot supply enough power. (Philippe Morin)

Source: CBC News, Nov 1, 2018



2016/17 Generation by Source



## Generator breakdown could result in higher power costs in the N.W.T.



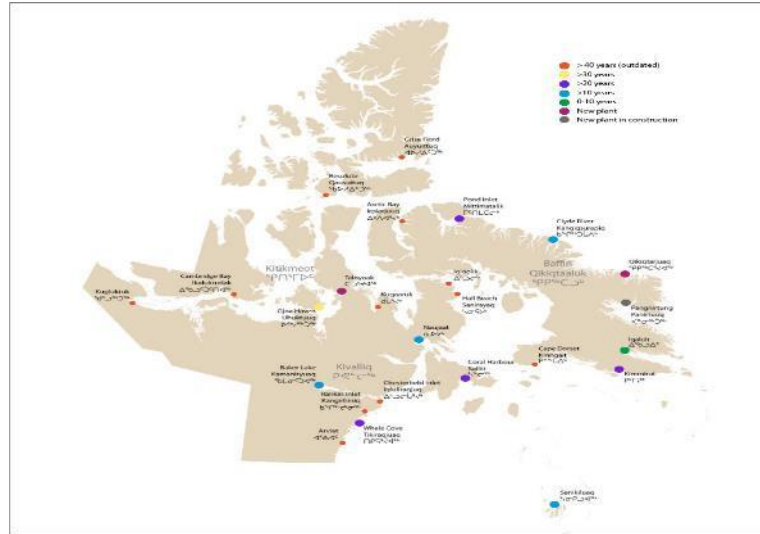
'The generator at Snare Forks will be offline for several months,' states NTPC acting president and CEO

Richard Gleeson - CBC News - Posted: Oct 12, 2018 3:15 PM CT | Last Updated: October 12



A bearing failure at the Snare Hydro System means power prices in the N.W.T. could increase. A news release from the Northwest Territories Power Corporation states there were plans to take the generator offline next spring. (Northwest Territories Power Corporation)

Source: CBC News, Oct 12, 2018



Source: Qullig Energy Corporation Annual Report 2015-2016

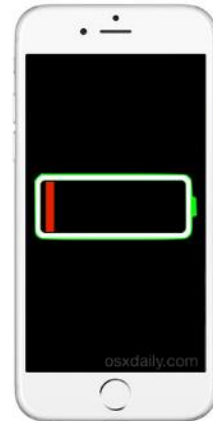
Plant Name	Constructed	Remaining Life
Grise Fiord	1963	0
Qikiqtarjuaq	1936	0
Cape Dorset	1964	0
Cambridge Bay	1967	0
Kugluktuk	1968	0
Arviat	1971	0
Pangnirtung*	1971	0
Resolute Bay	1971	0
Taloyoak	1972	0
Rankin Inlet	1973	0
Arctic Bay	1974	0
Hall Beach	1974	0
Igloolik	1974	0
Kugaaruk	1974	0
Chesterfield Inlet	1975	1
Gjoa Haven	1977	3
Coral Harbour	1988	14
Whale Cove	1991	17
Kimmirut	1992	18
Pond Inlet	1992	18
Clyde River	1999	25
Nauyasat	2000	26
Sanikiluaq	2001	27
Baker Lake	2003	29
Iqaluit	2014	40

11/55



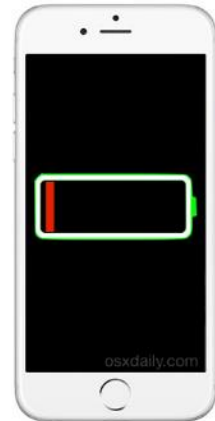
# Remote system challenges

- Equipment operation and logistics
  - Equipment must be rated to  $-60^{\circ}\text{C}$
  - Blade icing, economy of scale
  - No cranes for fly-in only communities, restricted to sealift season



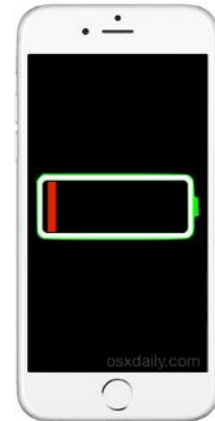
# Remote system challenges

- Lower system inertia
  - Higher volatility in load and renewable energy dynamics
  - Exacerbated with power electronic controlled systems



# Remote system challenges

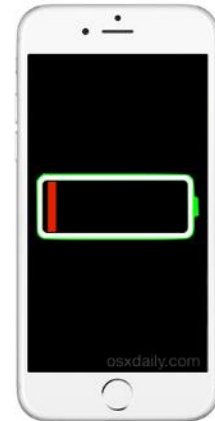
- High phase imbalance
  - Voltage can exceed thresholds
  - Balanced protection relays may not operate as expected
  - Oscillating torque on machines or oscillating voltage on dc link
  - Higher system  $I^2R$  losses





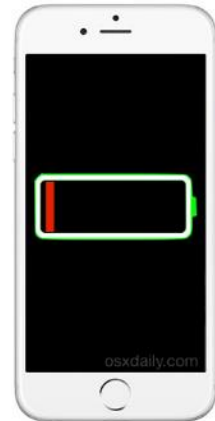
# Remote system challenges

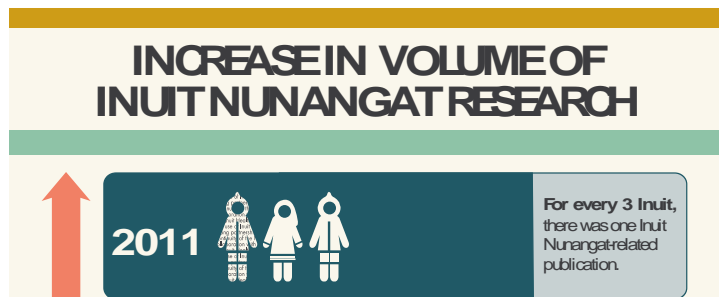
- Low X/R ratio
  - Closer to 10 instead of infinite
  - Different fault characteristics – generators slow down
  - Cannot decouple power/frequency and reactive power/voltage



# Remote system challenges

- High reliability requirement
  - A power outage in a connected system is an inconvenience.
  - A power outage in an isolated system can be critical.





## 1. Letter from ITK's President

The term research invokes strong reactions among Inuit because researchers have historically been and continue to be the primary beneficiaries of research involving our people, wildlife, and environment. While we recognize the important role research can play in informing actions that create safer, healthier, and more resilient communities, Inuit from across Inuit Nunangat have long insisted that researchers and research institutions respect Inuit self-determination in research through partnerships that enhance the efficacy, impact, and usefulness of research.

For far too long, researchers have enjoyed great privilege as they have passed through our communities and homeland, using public or academic funding to answer their own questions about our environment, wildlife, and people. Many of these same researchers then ignore Inuit in creating the outcomes of their work for the advancement of their careers, their research institutions, or their governments. This type of exploitative relationship must end.

Source: Inuit Tapiriit Kanatami, *National Inuit Strategy on Research*. March 2018

## The cost of learning: Research in Canada's North up to 25 times more expensive



Consultation with Indigenous communities and travel add costs to scientific studies



Paul Withers · CBC News · Posted: Nov 20, 2018 6:00 AM AT | Last Updated: November 20



Ice floats in Slide Fjord outside the Eureka Weather Station on Ellesmere Island, Nunavut, Monday, July 24, 2006. New research finds that hundreds of glaciers in Canada's High Arctic are shrinking and that many are likely fated to disappear. (Jeff McIntosh/The Canadian Press)

Travelling to remote locations and engaging with Indigenous communities for scientific research in the Canadian Arctic can be up to 25 times more expensive, according to a study in the journal *Arctic Science*.

The study compared the costs of the same three-person, four-week seabird research camp within the north and south of Canada, Alaska, Greenland and Norway.

### Canadian Arctic most expensive

Source: CBC News, Nov 20, 2018





Once you've seen one northern community...



Once you've seen one northern community...

You've seen one northern community

# Presentation Overview

1. Territorial energy context & challenges
2. **Northern Energy Innovation overview and project examples**
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# Research framework



**NSERC  
CRSNG**



*In the north, by the north, for the north*

énergie  
yukon  
l'énergie d'ici



**ATCO Electric**  
YUKON



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Nunavut  
Arctic College



# Multi-disciplinary approach to successful projects

**Social**  
**Technical**  
**Environmental**  
**Economic**  
**Political**



# Northern Energy Innovation research areas


*Integrating renewables in remote communities*

How can we integrate a high level of renewables into isolated communities to reduce our reliance on diesel?



# Northern Energy Innovation research areas

## *Diesel efficiencies*

A close-up photograph of a diesel engine component, likely a fuel injector or sensor, with several red and black wires connected to it. The component is metallic and has a hexagonal base. The background is blurred, showing other parts of the engine.

How can we operate existing diesel systems more efficiently or what technologies can reduce both consumption and emissions?



# Northern Energy Innovation research areas

## *Demand-side management*

How can demand-side technologies be best used to reduce winter peaks or to better match renewable generation?



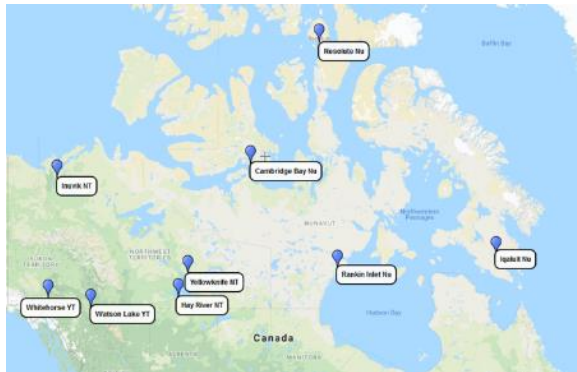


# Northern Energy Innovation research areas

*Residential and utility partnership*

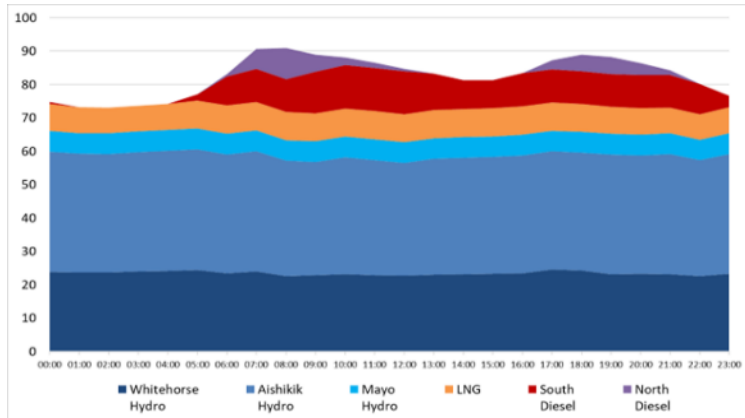
What technologies  
could support the  
public to be  
off-grid?



27/55

# Northern Energy Innovation research projects

## *Broadcasted demand-side management*



## What Can You Do To Save Energy During a Peak Alert?



### Shift Appliance Use



Use major appliances during off-peak hours

### Reduce Heat

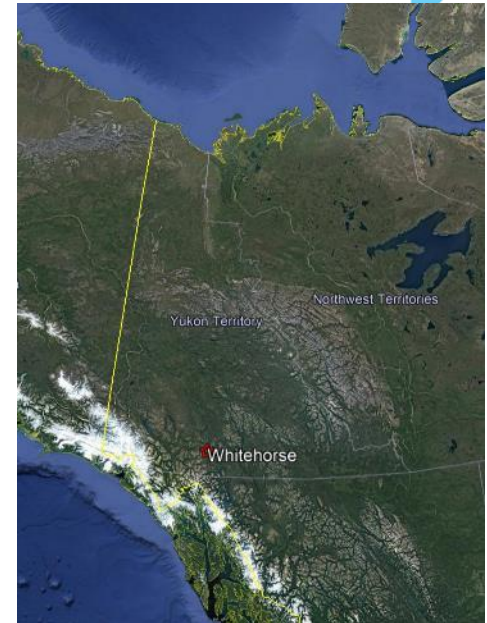


Heating 56% 44% Other

Lower the thermostat to reduce consumption

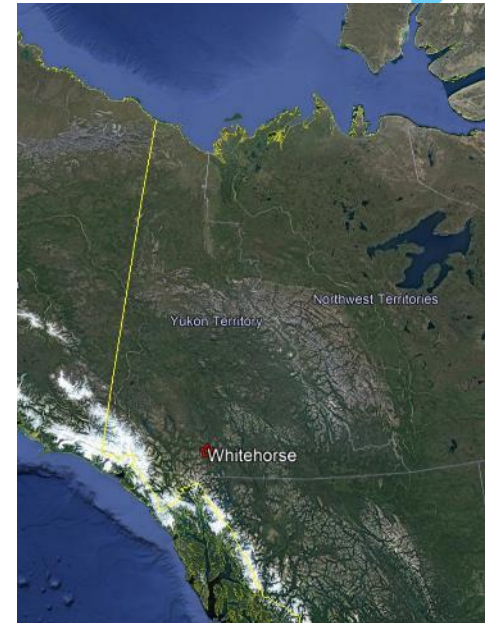


REGISTER FOR OUR PEAK ALERT SYSTEM TODAY BY TEXTING "PEAK" TO 79000 OR VISITING [WWW.YUKONCOLLEGE.YK.CA](http://WWW.YUKONCOLLEGE.YK.CA)



# Northern Energy Innovation research projects

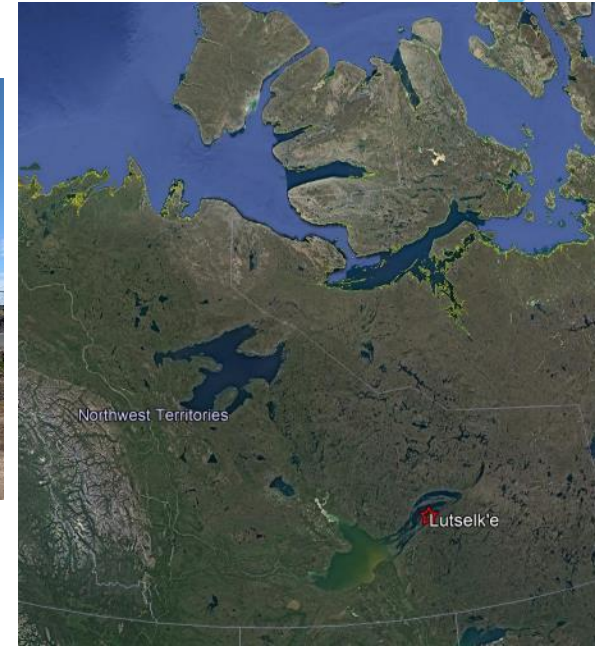
## *Electric Thermal Storage project*





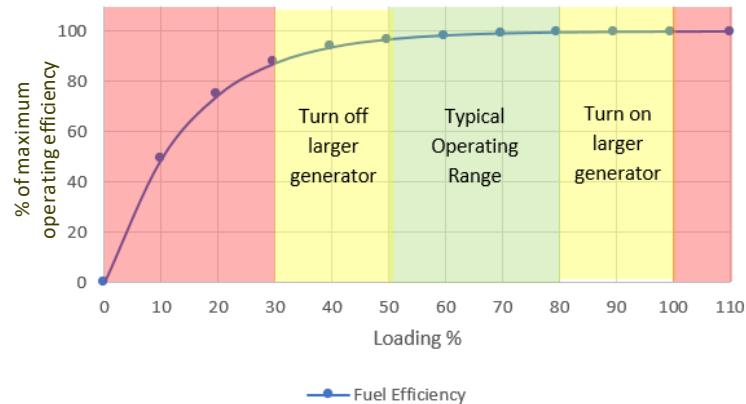
# Northern Energy Innovation research projects

## *Lutsël K'é microgrid project*



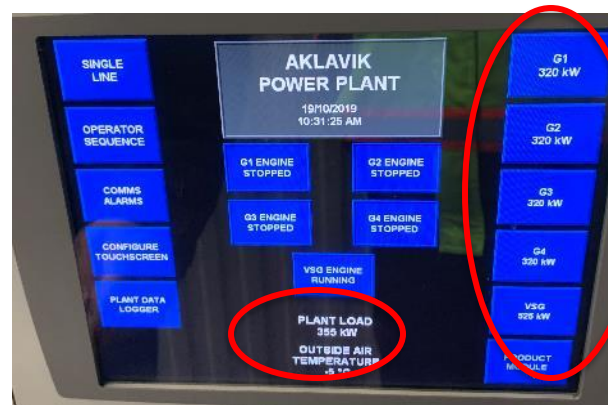
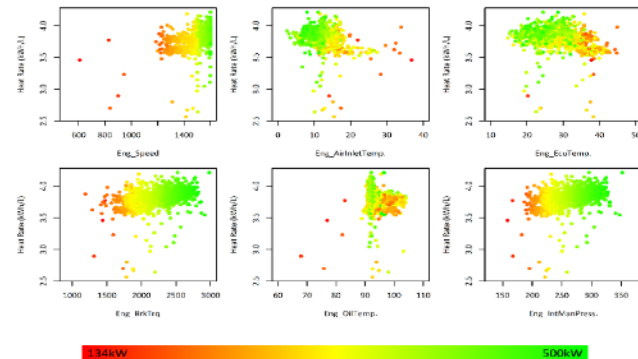
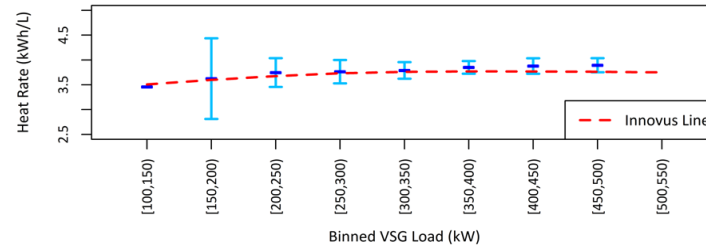
# Northern Energy Innovation research projects

## *Colville Lake solar-battery-diesel hybrid plant*



# Northern Energy Innovation research projects

## Variable Speed Generator analysis



# Northern Energy Innovation research projects

## *Kinngait Power System Impact Study*

FRIDAY, 25 JANUARY, 2019

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**FEATURES** 6 DECEMBER, 2018 – 10:30 AM EST

## Study sizes up Cape Dorset's power grid for renewables

Outcome should show how much wind, solar could be supported, while keeping the lights on





# Northern Energy Innovation research projects

## *Arviat Clean Energy Project*



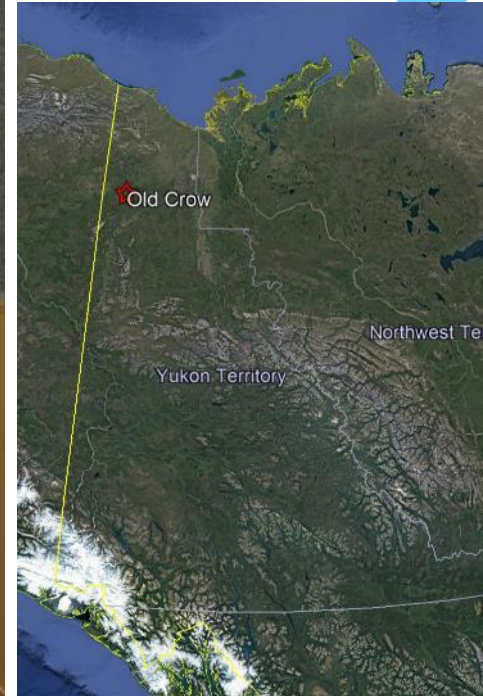
## Beaver Creek Power System Impact Study



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# Old Crow and Vuntut Gwitch'in First Nation







# Considerations of integrating renewables

## *Utility objectives and considerations*

Primary objective:

To provide safe and reliable power to their customers



# Power System Impact Studies

*Developing strong indigenous & community partnerships*



Vuntut Gwitchin Government



YukonCollege

**ATCO Electric**

YUKON



Indigenous and  
Northern Affairs Canada

Affaires autochtones  
et du Nord Canada





# Opportunities through research

*Integration of renewable generation in a responsible manner*

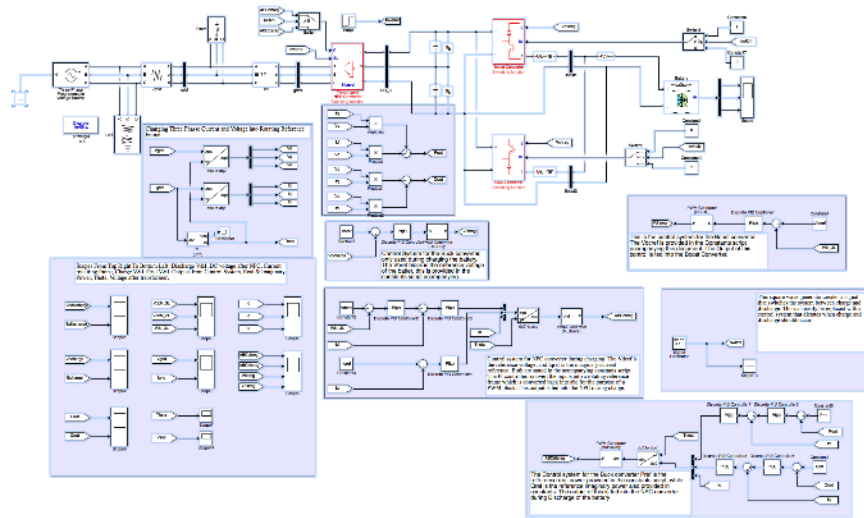
How much renewables can be integrated while maintaining stability and reliability?





## Modelling and Study Approach

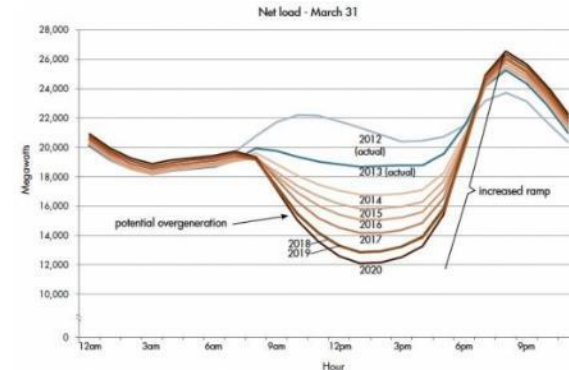
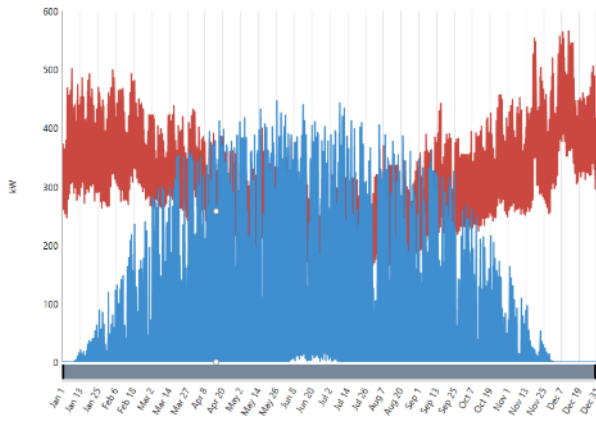
- Real equipment parameters, supplemented with industry standard models
- Discrete time studies
  - Large disturbance stability
  - Contingency analysis
- Phasor quasi-static time series
  - Energy balance
  - Voltage profiles
  - Line loading limits
  - Equipment acceptable operation
- System protection
  - Protection coordination
  - Fault analysis



# Considerations of integrating renewables

## Adequacy

The ability to supply the required power and energy without exceeding system ratings or operating limits.

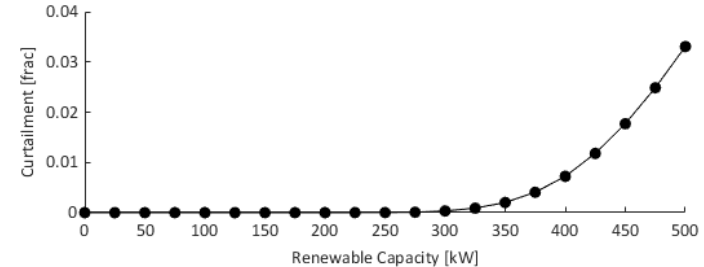


# Power system impact studies

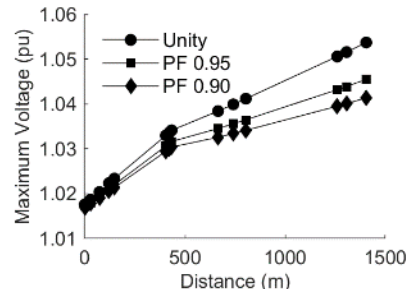
## Adequacy

### Adequacy → Energy balance studies

- Phasor quasi-static time series
  - Energy balance
  - Load flow analyses
  - Voltage profiles
  - Line loading limits
  - Equipment acceptable operation



Fraction of total solar energy curtailed for a varying solar plant capacity operating with a unity power factor.



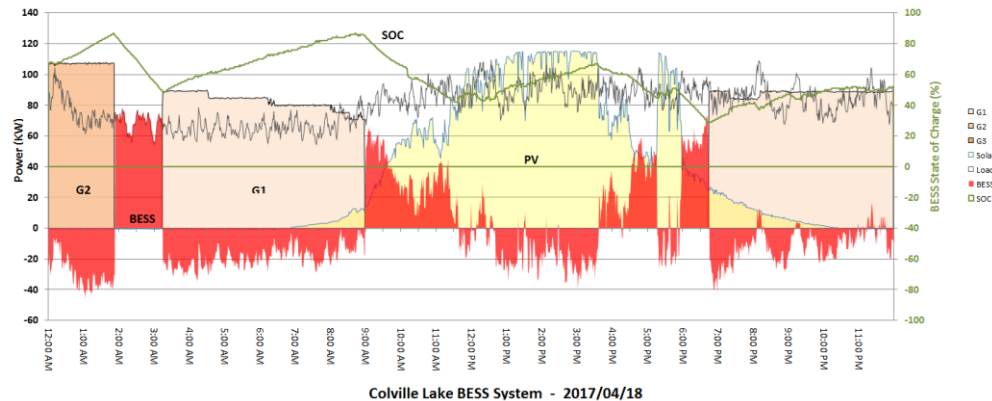
Maximum voltage from the diesel plant to the solar plant for varying solar plant power factor.

# Considerations of integrating renewables

## Resiliency

### Resiliency

The ability to recover from perturbations in the system.



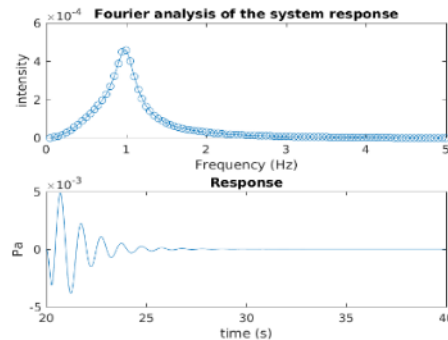


# Power system impact studies

## Resiliency

### Resiliency → Small signal stability

- Linearization
  - Linearization domains
  - Modal analysis
  - Eigenvalue and eigenvector analysis

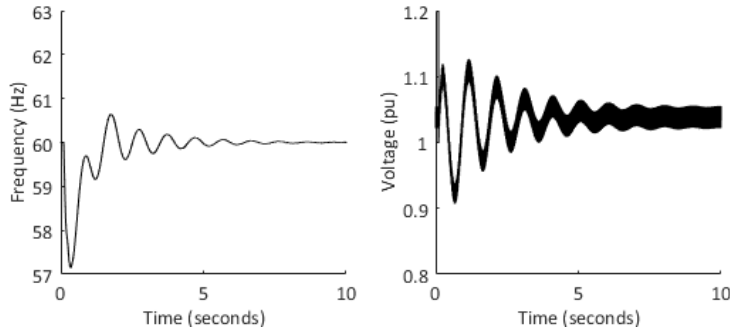


# Considerations of integrating renewables

## Security

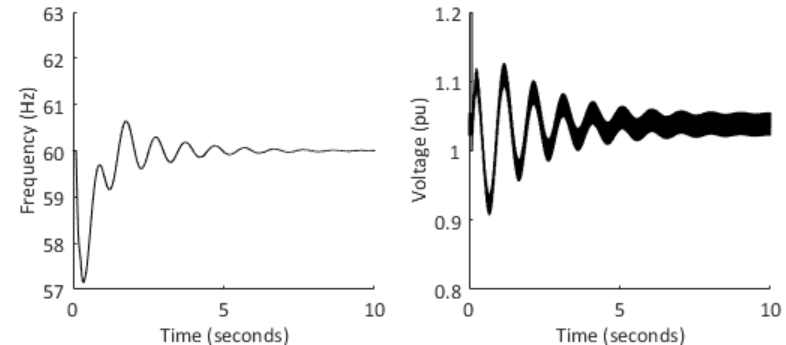
### Security

The ability to tolerate a credible event without loss of load, over-stress of equipment, or deviation from voltage and frequency tolerances.

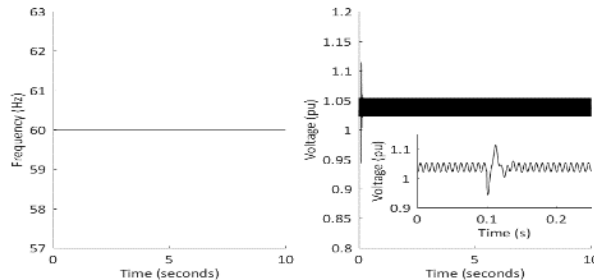


### Security → Large disturbance stability

- Discrete time studies
  - Large disturbance stability
  - Contingency analysis



Voltage and frequency response to a large disturbance, when the solar PV at 100% disconnects instantaneous.



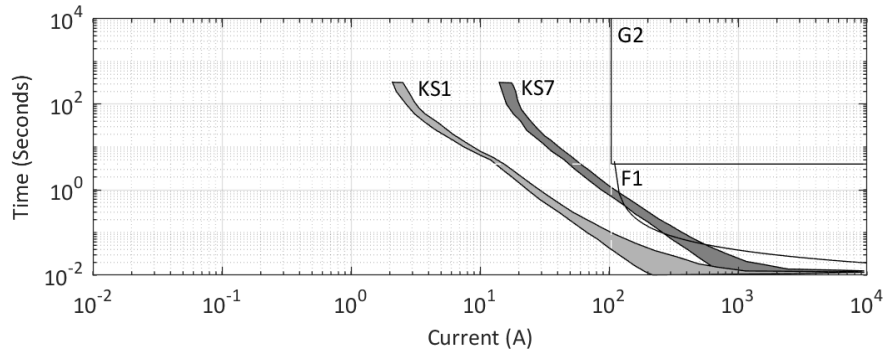
BESS Frequency and Voltage after  
Instantaneous Loss of 400kW of Solar PV

# Considerations of integrating renewables

## Safety

### Safety

The ability to identify and protect from hazardous operation like faults, while staying in operation for all credible events.





### Safety → Protection system studies

- Analytical and discrete time studies
  - Protection zones
  - Fault current
  - Reverse power flow
  - Protection coordination

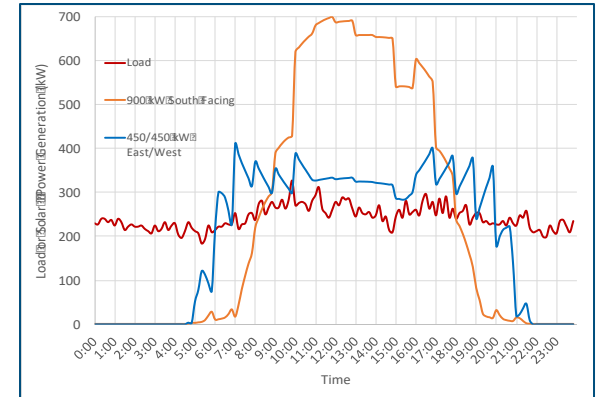
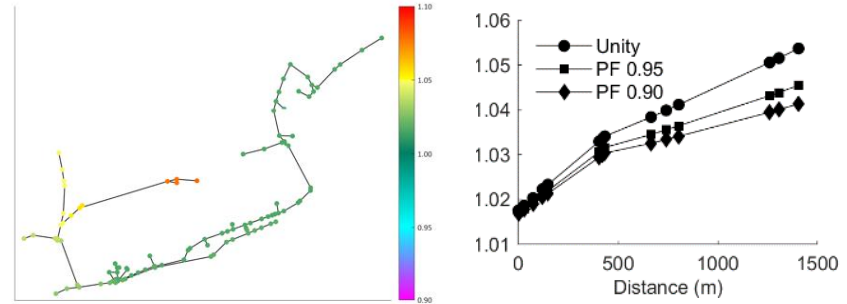
	Protection disconnects	Protection stays connected
Protection should disconnect	Dependable - certainty of correct operation during a fault	Non-detection zones
Protection should stay connected	Nuisance tripping	Secure - ability to avoid incorrect operation

# Case studies

## Old Crow Solar Project, Yukon

### Project considerations

- Community wanted to operate diesel off
- Battery ownership (utility/community partnership)
- Reactive Power Support
- 600 kVA transformer size/weight
- East/west configuration
- No fence



# Project Outcomes

## *Old Crow Solar Project*

Solar: 940 kW PV, 480 kVA converter  
Battery: 612 kWh, 500 kVA converter  
Offset diesel generation (190,000 L)



Source: Yukon News, Jun 25, 2018



# Community Engagement

## *Old Crow Solar Project*





# Fostering relations and supporting renewable projects

“Dr. Michael Ross... and his team of technical professionals at Northern Energy Innovation brought technical expertise to our project team that contributed directly to establishing a **strong and trusting working relationship** between the Vuntut Gwitchin Government and ATCO Electric Yukon as we advanced the project through the feasibility and design stages.

Furthermore, Northern Energy Innovation showed a strong commitment to the success of our project by **developing meaningful relationships with our community**. Dr. Michael Ross visited Old Crow several times to meet with our staff, and with Chief and Council. He and his project team **engaged the residents** of Old Crow at community meetings, and **met with our children** at the local school. We received regular technical updates on the progress of the grid impact study.

**Northern Energy Innovation clearly understands the role of science and technology at the community level .”**

**- Chief Dana Tizya-Tramm, Vuntut Gwitch'in Government, March 26, 2019**



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