Renewable Energy Microgrid Integration for Remote, Off-grid Cabins in Nunavut

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To support increased infrastructure and energy demands throughout the 20th century, diesel generators were installed in all communities across Inuit Nunangat. This continues to be the case today where new power plants are being installed and/or upgraded with additional diesel fuel generators. While fossil fuels currently support nearly all heat and electricity loads across Inuit Nunangat, there is a strong desire to develop renewable energy sources to mitigate against climate change impacts and improve resiliency. Challenging crises, such as the recent contamination of Iqaluit drinking water with fuel, remind us of the vulnerability and risk in Inuit Nunangat of relying on a single source for critical infrastructure requirements.

To help address these challenges, the project herein has three proposed key areas of work:

1. Feasibility assessments and technological evaluations for three key types of house-scale renewable energy systems well-suited to Inuit Nunangat;

2. Integration and performance evaluation of house-scale renewable energy systems and energy storage with demonstration house in Iqaluit, Nunavut; and

3. Development of remedies to barriers of renewable energy adoption in Inuit Nunangat and advancement of socio-economic development.

This project will integrate Inuit values, needs and interests with renewable energy technology evaluations and deployment in Inuit Nunangat. Remedies to barriers of renewable energy adoption will be developed in accordance with Inuit Quajimajatuqangit through coordination with the Qikiqtani Inuit Association's Inuit Qaujimajatuqangit department, the parent Inuit birthright organization of the project proponent, Nunavut Nukkiksautiit Corporation. Inuit representation is embedded in this project by the project definition and leadership, students that will contribute and advance their training, and community members that wish to participate in the project by providing paid services or community engagement with consideration. This project will contribute to Arctic energy resilience through the capacity development and de-risking of technology that will be undertaken. Training opportunities for residents of Inuit Nunangat will be available and increased demand for renewable energy technology installation, operation, and maintenance will lead to community economic development. This project will alleviate the key barriers of renewable energy deployment in Inuit Nunangat to create an easier path to follow for future proponents, regulators, and utilities.

Scientific outputs and publications arising out of this work will be adapted and translated to be accessible to a wide audience across Inuit Nunangat. Community engagement throughout the whole project will be conducted to the extent that communities and individuals wish to engage. Project progress and outcomes will be shared at key events with Inuit representation, such as trade shows, conferences, and regional meetings. Addressing the complex set of challenges for renewable energy deployment and operation in Inuit Nunangat requires the combination of work plans detailed in this project description for accelerating impact.

Project Team:			
Researcher Name	**Role**	**Organization**	**Org. Abbreviation**
Heather Shilton	PI	Nunavut Nukkiksautiit Corporation	NNC
Community Lead	Co-PI (NNC)	Nunavut Nukkiksautiit Corporation	NNC
Carsen Banister	PI (NRC)	National Research Council Canada	NRC-CONST
Other CONST staff	Co-PI (NRC)	National Research Council Canada	NRC-CONST
Julien Cousineau	Co-PI (NRC)	National Research Council Canada	NRC-OCRE
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Hua Ge	Co-PI	Concordia University	CONCORDIA
Andreas K. Athienitis	Co-PI	Concordia University	CONCORDIA
Colin Rennie	Co-PI	University of Ottawa	UOTTAWA
Cameron Johnstone	PI (UK)	University of Strathclyde	STRATH
Stephanie Ordonez Sanchez	Co-PI (UK)	University of Strathclyde	STRATH
Nick Kelly	Co-PI (UK)	University of Strathclyde	STRATH
Tim O'Doherty	Co-PI (UK)	Cardiff University	CARDIFF
Mark Allmark	Co-PI (UK)	Cardiff University	CARDIFF
Allan Mason-Jones	Co-PI (UK)	Cardiff University	CARDIFF

Work Packages

The following activities will be performed:

1. Micro Hydro-Kinetic Feasibility

Lead partner: UOTTAWA   Contributing partners: NRC-OCRE, STRATH, CARDIFF

This work package will investigate the feasibility of hydrokinetic energy to support the energy demands of off-grid structures or small communities in Inuit Nunangat. Researchers from both UOTTAWA and NRC-

OCRE will leverage findings from ongoing collaborative research (focused on developing and improving a national inventory of river hydrokinetic energy resources across Canada) to shed light on broad resource availability and potential in the study area. Researchers from UOTTAWA will contribute their expert knowledge of river instrumentation and field data collection techniques to assess available hydrokinetic energy resources.

Researchers from STRATH and CARDIFF will leverage ongoing research into lower velocity turbines to evaluate the applicability to the resource characteristics and the additional energy yield available to satisfy energy demands. Project partners at STRATH and CARDIFF will provide expert advice on commercially available and suitable hydrokinetic turbines, which in combination with the hydrokinetic resource assessment performed by UOTTAWA and NRC-OCRE, will yield an assessment of the feasibility of hydrokinetic energy for Inuit Nunangat. The research team will focus on local knowledge and capacity to support site reconnaissance and field tasks.

Research tasks include:

1. Desktop analysis and consultation of local knowledge to locate existing off-grid structures and investigate site accessibility.
2. Desktop analysis of satellite imagery and inventory of river hydrokinetic energy resources across Canada to identify potential hydrokinetic energy “hot-spots” near the locations of interest.
3. Preliminary field reconnaissance and consultation of local knowledge (e.g., photographs, advice, local concerns) to identify a case study site for detailed field assessment.
4. Collection of field data including bathymetry, water levels, and flow velocities at three river discharges.
5. Processing and analysis of field data: compare findings with the national inventory of river hydrokinetic energy resources; integrate the field data into numerical, hydrodynamic model(s) to simulate flows; define the theoretical river hydrokinetic energy resources at the selected site.
6. Desktop analysis of device suitability and potential power generation capability for the selected site.
7. Evaluation of resilience and safety in local environmental context.

2. Wind Feasibility

Lead partner: STRATH   Contributing partners: NRC-CONST, CARDIFF

Wind measurements from meteorological measurement sites will be compared to historical data held by Environment and Climate Change Canada (ECCC). This analysis will determine the applicability of community airport data collection by ECCC in estimating wind output for sites in and near communities.

A detailed market scan will be conducted to summarize mature and new community scale technologies, <10 kW nominal output. Technologies of potential suitability for installation in the Canadian Arctic will be identified and evaluated against an implementation criteria, such as: ease of installation, ease of maintenance, lifecycle cost-normalized electricity output and confidence in design, testing, and durability. Using outputs from these activities, an energy simulation tool will be used to forecasted energy and economic outputs to be analysed on a multiyear basis, broken down into finer temporal resolutions, extending prior work by CONST and CONCORDIA.

Research tasks include:

1. Desktop analysis of historical wind measurement data and consultation of local knowledge.
2. Develop and apply modelling tools for high resolution potential power generation assessment.

3. Processing and analysis of representative field data in comparison to meteorological measurement sites.
4. Applying findings to numerical turbine model(s) to simulate hourly power flows and energy yields.
5. Desktop analysis of wind technologies suitability.
6. Resilience and safety evaluation of potentially applicable technologies.

3. Advanced Solar Feasibility

Lead partner: CONCORDIA   Contributing partners: NRC-CONST, STRATH

The CZEBS team from Concordia will develop, model and test advanced building-integrated photovoltaic/thermal (BIPV/T) systems for application to Arctic regions, primarily on facades for connection with heat recovery ventilators (HRVs) to generate solar electricity, to preheat the ventilation fresh air and to reduce the need for defrost.

Research tasks include:

1. Develop an integrated tool and simulation model that integrates a BIPV and/or BIPV/T system with HRV or heat pump with various control strategies for the application of off-grid houses with possible passive solar design.
2. Design and prototype of BIPV or BIPV/T facade systems integrated with HRV/ERV or heat pump that is suitable for the Arctic climate.
3. Install and test the prototypes in the façade of a test-room in SSEC that will be exposed to temperatures down to -40°C to validate a numerical model for design and control of the system.
4. Install and test a prototype in the façade of one of the test-rooms of FBL and connected to HRV to test different control strategies and actual thermal and electricity, and frosting/defrosting performance under real weather conditions over one-year. The data collected will be used for validation and optimization.
5. Test the integrated prototype system in Iqaluit and optimize based on the tests in SSEC and FBL.
6. A 'digital twin' model will be developed and calibrated against empirical data produced from the physical testing.
7. Annual simulations will be performed for advanced solar facades operating in Arctic climatic conditions to assess the power output capacity, energy yields, and variations to be experienced on a seasonal basis. The model will be integrated with a representative dwelling's energy demand model to determine resulting energy savings, the reduction in HRV defrost hours, generated energy and reduction in carbon emissions.
8. A report with design recommendations for a wider adoption in northern region and a refereed paper will be prepared.

4. Energy Supply Integration

Lead partner: STRATH   Contributing partners: CARDIFF, NRC-CONST

The objective of this work package is to establish a balanced lower carbon energy supply strategy to meet dwelling-based thermal and electrical energy demands. Energy models will be developed, calibrated and applied to evaluate renewable energy technologies supply integration in terms of:

- time of energy supply occurrence, for both renewable technology adoptions singularly and integrative;
- the requirement of power capacity (kW) and the consequences on resource capture area and availability within building structure/community installation area;
- the resulting energy yield (kWh) and goodness of match to demand occurrence;
- variability in single renewable technology type and integrated heterogeneous renewable technology energy delivery through the seasons and over the year;
- scalability of most applicable renewable energy supply technologies to mitigate any naturally/climatic induced seasonal fluctuations; and
- evaluation of the potential need for both thermal and electrical storage and minimal capacity requirements to attain energy autonomy and security.

5. Design and Optimization of Building Envelope, Energy Storage, and Renewables Integration

Lead partner: NRC-CONST   Contributing partners: NNC, CONCORDIA, STRATH, CARDIFF

Small scale renewable energy and storage systems will be deployed and integrated at an existing NNC research building in Iqaluit in partnership with NRC-CONST. The focus will be on energy production and the use of dynamic building simulation tools to establish building energy demands and assessment of the energy demand-supply match. This will inform the integration of energy conversion technology and specification of energy storage systems to be employed. Electrochemical and thermal storage will be used to assess the interaction of the renewable energy production with local building energy loads and develop guidelines for system components and sizing required to operate a building-integrated renewable energy system in the Arctic. This will include what was required to successfully adapt the technology for the Arctic environment and the expected performance if scaled up, applied to different energy loads, or installed in other Inuit Nunangat locations. The amount of offset diesel usage and associated carbon emissions reduction will be quantified.

The building energy model will be used to investigate alternate integration scenarios and system configurations, including:

- At the small off-grid building level (small Arctic homes, cabins and shelters), assess emissions reduction and thermal/electrical resiliency.
- At the grid-tied single family residential dwelling level, assess diesel consumption reduction and associated emissions as a function of system size.
- At a micro-grid level (e.g., a non-exporting collection of buildings), optimize system configuration according to emissions and cost savings opportunities.

6. Alleviating Renewable Energy Barriers for Inuit Nunangat

Lead partner: STRATH   Contributing partners: CARDIFF

Harmonizing engagement with the territorial government, Indigenous community leaders and the local Crown-owned utility to identify concerns and perceived barriers to renewable energy uptake. The identified barriers will be categorized and prioritized. Engaging with the successful respondent to the NRCan and CIRNAC RFP. This will include addressing perceived technical challenges using experiences and alleviation strategies proven to be valuable in addressing similar issues in remote community renewable energy projects in Scotland (and in European Arctic communities) and evaluated for suitability/applicability in the context of Inuit Nunangat. Perceived barriers such as economic viability and reliability and concerns over stranded assets will be identified and addressed. Demonstration of how these have previous been addressed and lessons learned from other UK activities will be drawn upon for reference and form the basis of demonstrable impact case studies.

By aligning this work with the Government of Canada's policy directions, the project team is expected to establish a dialogue based upon the premise that change is coming and it is necessary to determine which technologies, configuration of technologies and strategies to reduce energy use are likely to make the transition successful from the perspective of all parties.

7. Socio-Economic Development

Lead partner: STRATH   Contributing partners: CARDIFF

Through engagement with representative Inuit Nunangat communities, perceived existing barriers to the uptake of local renewable energy systems will be established via a series of town hall engagement meetings, working with local and regional Inuit representatives and facilitators. Research identifying and quantifying the local resource and location will evolve to identify and inform community vocation transition and upskilling opportunities in order to embed the technical and operational skill sets to aid installation, operation and maintenance of hardware and infrastructure necessary for a sustainable, renewable based community energy supply. The range of skill sets existing and needing developed and embedded will be quantified; and drawing on the UK experiences, mechanisms on how to potentially support embedding these within communities will be evaluated for cultural and practical suitability for implementation.

A contractor supply chain analysis study will be undertaken to inform the up-skilling and capacity building attainable and identify opportunities to inform the implementation of training initiatives to realise new RE-based economic opportunities. A Cost of Energy study will establish the wider socio-economic impact to be attained by the community through the alleviation of fuel poverty/extreme fuel poverty and the provision of a secure, affordable and sustainable energy supply from the development and servicing of energy conversion from ideal local candidate sites. The potential economic enhancement associated with the evolution and use of a local supply chain in the installation, operation and maintenance of the clean energy infrastructure in Arctic environments will be evaluated in a market analysis for exporting these new capabilities to a wider national and international economy and the creation and delivery of new on-site training and up-skilling of a wider work force generating higher caliber local employment opportunities.

Project Activities and Major Milestone Groups		Lead Org.	Anticipated Start Date	Anticipated Completion Date
Activity #1: Micro Hydro-Kinetic Feasibility		UOTTAWA	16-May-2022	12-Dec-2024
1.1	Desktop Review of site-specific hydrokinetic potential including any field-level investigations	UOTTAWA	16-May-2022	26-Aug-2024
1.2	Report on resource evaluation and feasibility assessment of micro hydro-kinetic energy conversion technologies	STRATH	12-Sep-2022	12-Dec-2022
Activity #2 Wind Feasibility		STRATH	16-May-2022	21-Apr-2023

2.1	Desktop Analysis of historical wind measurement data at selected site(s)	STRATH	16-May-2022	8-Aug-2022
2.2	Processing & Analysis of representative field data	STRATH	15-Aug-2022	16-Jan-2023
2.3	Report on resource evaluation, modeling, and suitability of small wind turbines	STRATH	17-Jan-2023	21-Apr-2023
Activity #3: Advanced Solar Feasibility		CONCORDIA	16-May-2022	18-Dec-2023
3.1	Design and laboratory data collection for advanced solar prototype testing complete	CONCORDIA	16-May-2022	10-Jul-2023
3.2	Report on and solar photovoltaic technologies assessment and evaluation of advanced solar concepts potential in Inuit Nunangat	CONCORDIA	11-Jul-2023	18-Dec-2023
Activity #4: Energy Supply Integration		STRATH	16-May-2022	11-Jul-2023
4.1	Holistic Model of small shelter and integrated systems developed	STRATH	16-May-2022	12-Dec-2022
4.2	Report on design and optimization of building envelope, energy storage, and renewables integration to achieve at least 50% reduction of emissions compared to current building code performance requirements, while considering the impact on the local environment	STRATH	16-Jan-2023	11-Jul-2023
Activity #5: Design and Optimization of Building Envelope, Energy Storage, and Renewables Integration		NRC-CONST	16-May-2022	25-Feb-2025
5.1	Transportation of cabin structure to the selected site in Iqaluit, NU	NNC	16-May-2022	2-Sep-2022
5.2	Procurement of equipment and approval of installation plans for Iqaluit Installation	NNC	9-Jan-2023	15-May-2023
5.3	Installation and integration of commercially available technologies for energy conversion and storage at site in Iqaluit, Nunavut	NNC	17-Jul-2023	11-Sep-2023
5.5	Interim Data Report – One Year Operational Data Collection (Distributed to team for review)	NRC-CONST	16-Sep-2024	6-Oct-2024
5.4	Report on measured performance of demonstration building and integrated systems, including challenges encountered and comparison to predicted	NRC-CONST	6-Jan-2025	25-Feb-2025
Activity #6: Alleviating Renewable Energy Barriers for Inuit Nunangat		STRATH	16-May-2022	25-Feb-2025
6.1	Report on alleviating renewable energy	STRATH	16-May-2022	22-Feb-2024

	integration barriers in Nunavut			
6.2	Best practices guide for renewable energy deployment in Arctic Canada to accelerate impact of project outputs and for reference to regulatory bodies, utility agencies, and policy-makers	STRATH	16-May-2022	25-Feb-2025
Activity #7: Socio-Economic Development		STRATH	16-May-2022	25-Feb-2025
7.1	Best practices guide for capacity building and developing socio-economic opportunities through Inuit self-determination	STRATH	16-May-2022	25-Feb-2025
Other				
8.1	Verification of the level of Inuit involvement in the project.	NNC	16-May-2022	15-May-2023
8.2	Implementation of a revised engagement, capacity-building and training plan.	NNC	16-May-2022	15-May-2023
8.3	Approximately one to three scientific papers will be published for each work package, with the content being adapted to an accessible format and translated for community member and stakeholder audiences	All		Multiple

A.1 Recipient expected deliverables

1. Resource evaluation and feasibility assessment of micro hydrokinetic energy conversion
2. Resource evaluation, modelling and suitability of small wind turbines
3. Solar voltaic technology assessment including advanced concepts
4. Building envelope, energy storage & renewable integration optimization
5. Iqaluit site performance report
6. Alleviating renewable energy integration barrier in Nunavut
7. Best practices guide for capacity building through Inuit self-determination
6. Final Report (comprehensive, including all tasks)