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Office of Energy Research and Development
Natural Resources Canada

Project Proposal Template

For

Program of Energy Research and Development (PERD)
End-Use Portfolio

October 2015

It is **strongly** recommended that before completing this project proposal you read the document "Guide for the Preparation of Proposal and Planning Documents 2013", available from your OERD S&T Advisor, and also refer to the Annex to this template.

Please read the instructions in each green header box and provide all the information requested. Incomplete proposals will be returned to the proponent.

IMPORTANT: It is the proponent's responsibility to ensure that this proposal has the approval of his/her management – DG (or equivalent) or as duly delegated. When submitting the proposal to OERD, please provide verifiable evidence that such approval has been obtained. Submissions that do not include that verification will be returned.

Submitted By: __Boualem Ouazia_
Date Submitted: ___November 12th 2015___

PART A	
1. Project Information	
Project Title	*Air Ventilation Systems for Housing in the Arctic*
PERD Technology Area / Theme *(right-click on appropriate box, select "Properties", and set to "checked")*	☐ BE 1 – Building System Integration and Optimization ☐ BE 2 – Building Controls ☒ BE 3 – Advanced Heating and Cooling ☐ BE 4 – Smart Communities
Project Leader	*Boualem Ouazia, NRC, Ottawa, 613 993-9613, boualem.ouazia@nrc-cnrc.gc.ca*
Anticipated completion month and year of project	*March 2020*
Is this project a direct continuation of a previous project funded by OERD?	*No*
R&D or Related Scientific Activities (RSA) Project?	*Please categorise the project according to the definitions in Section 1.1 of "Guide for the Preparation of Proposal and Planning Documents 2013". If there is overlap between two categories, please check both boxes and estimate the relative percentage of each.* ☒ R&D 60% ☒ RSA 40%
Project Type	*As further explanation to the preceding field, please indicate which of the following best describes the project.* ☐ Basic research ☒ Applied/bench-scale research ☒ Field test ☒ Pilot scale pre-demonstration test ☒ Knowledge generation (e.g. for policy development) ☐ Other (please explain)
Technology Readiness Level (TRL) change	*Please indicate the TRL level changes expected according to the definitions in Annex 1. Details of TRL are expected in section 3.* *Commencement of Project*: TRL: ☐0-1 ☒ 2-3 ☐ 4-5 ☐ 6-7 ☐ 8-9 *Completion of Project*: TRL: ☐0-1 ☐2-3 ☐ 4-5 ☒ 6-7 ☐ 8-9
Location – city, province / territory	*Ottawa ON*
Project Delivery[1]	*How will the project be delivered?* ☒ internally - federal laboratory (70 %) ☒ externally - contributing partner facility (20 %) ☒ externally - contracted out and/or by contribution agreement (10 %)
Confidentiality of Proposal	*Does this proposal contain proprietary or commercially sensitive information?* ☐ Yes (please highlight all confidential material) ☒ No

[1] The project lead must be a federal department or agency, but projects can be undertaken with, or by, external deliverers via contracts and, **for NRCan only,** by contribution agreements.

2. Project Team Members

Include only the principal members - those people who will be engaged in the project on a substantive and ongoing basis over the duration of the project. If the approximate percentage of time to be spent on the project changes significantly year-by-year, please provide an annual breakdown.

Team Member	**Role** (e.g. project leader, providing lab / technical support) **and expertise**[2]	**% of time to be spent on the project**	**Organisation** (Department, industry etc.)	**Contact information** (e-mail address and / or telephone no.)
Boualem Ouazia	Project leader/manager, coordination with project partners, Northern Stakeholders and collaboration with industry partners	30%	NRC Construction	Boualem.ouazia@nrc-cnrc.gc.ca / 613 993-9613
Ganapathy, Gnanamurugan	Lab testing, field monitoring and instrumentations specialist	20%	NRC Construction	Ganapathy.gnanamurugan@nrc-cnrc.gc.ca
Daniel Aubin	Indoor Air Quality (IAQ) scientist lead	15%	NRC Construction	Daniel.aubin@nrc-cnrc.gc.ca
Greg Nilsson	Field monitoring instrumentation specialist	10%	NRC Construction	Greg.nilssoon@nrc-cnrc.gc.ca
Stephanie So	IAQ sampling technical support	10%	NRC Construction	Stephanie.so@nrc-cnrc.gc.ca
Lealem Abebe	Technical support	10%	NRC Construction	Lealem.abebe@nrc-cnrc.gc.ca
Mike Swinton	Advisory role, coordination with external partners and clients	5%	NRC Construction	Mike.swinton@nrc-cnrc.gc.ca
Mohamed Ouzzane	Task lead	20%	NRCan Varennes	Mohamed.ouzzane@nrcan.gc.ca / 450 652-4636
Parham Eslami-Nejad	Experimental & modelling support	10%	NRCan Varennes	Parham.eslaminejad@nrcan.gc.ca / 450 652 4894
Messaoud Badache	Experimental & modelling support	25%	NRCan Varennes	Messaoud.badache@canada.ca
Martin Thomas	Task lead	15%	NRCan Ottawa	Martin.thomas@canada.ca / 613 301-8172
Erik Thorsteinson	Engineering Support	15%	NRCan Ottawa	Erik.thorsteinson@canada.ca / 613 282-8419
Kuanrong Qiu	Scientific Support	15%	NRCan Ottawa	Kuanrong.qiu@canada.ca / 613 996-9516
Duncan Hill	Task lead	5%	CMHC	dhill@cmhc.ca
Catherine Soroczan	Project Manager	15%	CMHC	csorocza@cmhc.ca

3. Project Description and Rationale

In this section, please address the following numbered points:

i) What are the objectives of the project? Please provide a brief objective statement

The global objective is to develop energy efficient and reliable air ventilation technologies for northern housing. The project will investigate means of improving the energy efficiency of providing ventilation for housing in Northern communities, improve the understanding of arctic ventilation issues and requirements, develop innovative heat/energy recovery systems that are effective at managing frost built in the North while delivering effective heat recovery and required fresh air supply. Energy-efficient housing and communities in the North will contribute to the reduction of energy consumption and GHG emissions and associated cost savings in energy and transport.

[2] Additional information can be provided on team members' expertise as attachments to this proposal.

ii) Explain the problem the project is trying to solve in order to allow the reader to understand the need for it. For example, if the project is intended to improve a technology, why does it need to be improved? What is the strategic importance of proceeding with the project? How does it align with the priorities identified in the PERD End-Use Portfolio Scope Document – Amendment 1 – August 14? What were the start points and what are the anticipated end points (e.g., where were we at the beginning of the project and where do we need to be, e.g. in terms of efficiency of the technology?)

The cost-effective delivery of adequate ventilation in air tight buildings and houses in the Arctic requires the use of a balanced mechanical/ heat recovery ventilation (HRV) system. Previous research done by NRC, NRCan and CMHC has shown that HRVs can decrease the energy used for ventilation by approximately 60%. However, two issues unique to the Arctic present problems with current HRV/ERV products that have been largely developed for southern housing:

1. Exhaust air entering the heat recovery unit can be typically 25°C and moist. The outdoor air entering the heat exchanger is around -20 to -40°C during the winter months. In existing HRV units, this temperature difference results in the exhaust air being cooled to below the freezing point of moisture, resulting in build-up of ice in the heat exchanger that disrupts the exhaust air flow and unbalances the system. To alleviate this, existing technology either pre-heats the incoming air (a complex approach that increases system costs, energy use and undermines heat recovery performance) or re-cycles indoor air through the heat exchanger until it is defrosted (decreasing air quality as the supply of outdoor air is cut off during the defrost cycles which last over proportionately longer periods in extreme cold conditions).

2. In addition ventilation intakes can become clogged with wind-driven ice crystals (spin drift) further reducing the effectiveness of the ventilation system. These light ice particles are difficult to separate from the incoming air stream and will block the heat exchanger much like dust in a dusty environment. This can result in the system effectively operating as an exhaust-only system that can cause potentially dangerous back drafting of combustion appliances. Existing solutions include locating ventilation intakes below the ground floor (for buildings built on piers or space frame foundations) and the quality of the outdoor air in such locations can be problematic.

The challenges and inefficiency faced by conventional heat/energy recovery systems in Northern climates could be overcome by innovative technologies, such as dual-core heat/energy recovery systems and thermosyphon pre-heating. This research will develop and adapt heat/energy recovery technologies to reach high performance in the North to reduce the energy consumption of houses, buildings and communities, diesel dependency in remote communities and in the North, and associated reduction of emissions of greenhouse gases (GHGs).

The following PERD priorities are addressed:

- *BE-3A – Develop or adapt heat/energy recovery technologies to reach high performance in the North. Gaps will be addressed in the areas of new dual-core systems, improved heat exchangers and pre-heating technologies.*
- *BE-3B – Develop and adapt air ventilation technologies and practices to reduce energy conception in the North (reduce diesel dependency in remote communities). Identify solutions for the North through lab performance evaluation and field monitoring of innovative heat recovery and ventilation systems.*

iii) How does it build on preceding work accomplished by the proponent (previous phases if it is a continuing project; preceding projects if it is a new project)? In addition, what is the new innovation component addressed by this project? Expand on the progression of the TRLs expected during this project.

Innovative solutions for efficient ventilation that are tailored to the unique conditions of the Arctic are required. To date, due to the relatively small northern housing market, HRV manufacturers have not invested in any significant R&D to understand and resolve these challenges. Federal R&D leadership is needed to advance solutions. The proposed work will build upon previous research done in collaboration with industry (Venmar, Hoyme, etc.) to assess the enthalpy performance of houses using heat and energy recovery ventilator technology in side-by-side test. Options to be investigated include:

<u>Dual-core HRV units</u>

***Series configuration**. This technology works by using one core as a pre-heat and the second as a booster. The configuration is designed to reduce the potential of core freeze-up. Outdoor air is brought through the pre-heat core first and then into the booster core; exhaust air passes through the booster core first and then through the pre-heat core. This allows moisture in the exhaust air to condense in the booster core and be drained away reducing the likelihood of freeze-up in the pre-heat core.*

***Parallel configuration**. In this case, as one core is defrosting, the other core is being used to pre-condition ventilation air (the active core). As the active core becomes frosted up, a set of dampers switch the air flow to the core that was defrosting. In this manner the ventilation flow rate is maintained as the outdoor air directed to each core in turn.*

This proposed technology is at TRL 5 where the technological components are proven technologies, combined in a hybrid system that will be integrated within a realistic environment to be tested in a relevant Arctic simulated environment. At the end of the research, the technology will be at TRL 8, proven to work in arctic operating environment, technology completed and qualified through test and demonstration.

<u>Thermosyphon Pre-Heat</u>

This approach consists of connecting a thermosyphon below the building to a pre-heat coil. This thermosyphon unit preheats the outdoor air supplied to an HRV unit. Consequently, it may reduce by 40% the size of the HRV by using ground source energy which is 100% renewable energy (the traditional benefit of a thermosyphon is that the permafrost under the building is maintained with the heat being exhausted to atmosphere). CO_2 will be the phase change fluid used *for the thermosyphon.*

Since the R&d related to the thermosyphon is solely for developing and testing a theoretical model, it is deemed premature to consider technology costs, maintenance and installation costs.

This technology is at TRL 1, early stage where scientific research begins the translation to applied R&D (lowest level of technology readiness). By the end of the research cycle, the investigated technology will be at the stage of active research and development to establish proof of concept (TRL 3).

High efficiency heat exchanger/solid state heat pump.

The work will focus on building 1 prototype that incorporates two technologies; an advanced high efficiency heat exchange technology and a potential defrost strategy using a solid state heat pumping from outgoing air to incoming air, that reduces the number of defrost cycles required.

The solid state heat pump based HRV should not cost more than 25% than a conventional equivalent, the installation cost should also be the same and the maintenance cost for such units should be the same too.

This technology is at TRL 2, technology development begins where the development of practical and specific applications can be initiated. By the end of the research cycle, the investigated prototype will be tested in relevant environment (TRL 6).

iv) As appropriate, briefly describe similar work being done or previously done by others and indicate how this proposed project would fill a gap.

The Cold Climate Housing Research Center (CCHRC) located in Fairbanks, Alaska conducted two studies related the feasibility of ERVs in cold climates in light of past problems the systems have had operating in Alaska's interior. Eight models with different defrost strategies were studied. The study concluded that more research is required to assess the performance of installed ERVs and necessary improvements for colder climate use. The data presented showed significant differences in IAQ between the houses, partially attributable to variation in HVAC systems and in occupant interactions with these systems. The ventilation rate gets reduced either by the occupants, system failure or by the frost-protecting strategy of the unit (i.e. recirculation). With the air exchange rate too low (under ventilated homes), the concentration of CO_2 along with other pollutants increases, which may have an effect on comfort and occupants. The study concluded that introducing more advanced efficient heat/energy recovery systems will help to meet the requirements for ventilation rates in northern housing. Similarly, through the new Polar Knowledge Canada federal agency, research is being carried out at Cambridge Bay into the effectiveness of HRVs in a number of houses in that hamlet. That study is ongoing, wrapping up in 2016, so performance data results are not yet available. Regardless, building upon the outcomes of these previous studies will enable more focused research objectives in the present proposal

v) Describe what will be done in the project, including an overview of the methodology you will be using.

The research project will develop innovative energy-efficient balanced ventilation strategies for Northern dwellings and to evaluate their performance for reliable standards compliance and indoor air quality. The performance of each heat/energy recovery strategy in terms of providing adequate ventilation and its energy consumption will be assessed through lab and field trials using the CCHT twin houses, and through field monitoring of the technologies in the North. The project methodology will be as follows:

- *Understand the ventilation requirements of Northern housing, the performance of existing ventilation technologies, building on existing studies previously funded by PERD. This will lead to improved understanding of the operating conditions for HRVs and guidance for manufacturers on defrost and temperature control and other considerations including system design, installation and maintenance needs.*
- *Form an external Technical Advisory Group (TAG) to provide a common understanding of the industry and Northern stakeholders need.*
- *The TAG will include industry partners (engaged manufacturers with selected technologies) and stakeholders and communities in the North.*
- *Establish consensus on target specifications/criteria for development of new technology concepts and their deployment in the North.*
- *Develop proposed options through modeling/simulation, experimental and field validation.*
- *Successful technologies will be deployed in North for field trials featuring monitoring in collaboration with Northern housing corporations and builders.*
- *Finalize project reports and prepare technical papers.*
- *Successful designs of heat/energy recovery systems will be incorporated into guidelines for practitioners.*

vi) How will progress in the project be assessed? What indicators will be used and how will they be measured? Refer to section 2.2.2 of the Guide for the Preparation of Proposal and Planning Documents 2013.

- *Energy savings for ventilation of northern homes (by approximately 25% reduction in energy used for ventilation)*
- *Increase the reliability of balanced ventilation systems*
- *Reduce the reliance on external fuel sources (e.g. diesel) for remote communities*
- *New design and operation guidelines for Northern climate*

vii) Identify the key stage-gates ("go-no go" decision points), if any, and link them with performance metrics as applicable. Note: a detailed list of project tasks should be provided in section 6 - Project Outputs and Tasks.(it seems that you provide a list of tasks) Do not duplicate section 6

NRC Arctic management has reviewed the proposed alternative heat/energy recovery technologies for the North to secure industry participation and IRAP funding. The Arctic program will have regular review of the performance and potential of the proposed technologies through Lab performance and Field trial evaluation in Ottawa before a "go-no-go" decision to deploy the technology in the North.

The key stage-gates will be:

- *List of solutions/selected technologies and rational for selection of each.*
- *Report on Lab evaluation/proof of concept of selected technologies/solutions.*
- *Report on field evaluation of selected technologies (based on lab evaluations).*
- *Report on field monitoring of selected technologies deployed in the North.*

viii) What are the intended intermediate outcomes (medium term, e.g., 5-10 years) and final outcomes (long term, e.g., beyond 10 years)? How do the project outcomes contribute to the overall PERD Program goals and outcomes? Please refer to appropriate Logic Model for the PERD Program and refer to section 2.2.1 of the *Guide for the Preparation of Proposal and Planning Documents 2013.*

The intended (medium-term) intermediate outcomes:

- *Improve understanding of arctic ventilation issues and requirements*
- *Better understanding of product performance requirements (design and installation details)*
- *Increased capability to develop and improve technologies in Northern buildings and communities*
- *Improved energy efficiency and GHG reduction performance of energy-related technologies, integrated design, components, and methods.*
- *Concepts, prototypes and field testing to validate improved energy and GHG reduction performance of next generation energy technologies, integrated design and components, and methods.*
- *Increased involvement and collaboration of the research community and key stakeholders in the North.*
- *Increased industry capacity to integrate, adapt and utilize advanced, cost effective technologies and designs while avoiding negative health outcomes.*

Results from this research will demonstrate the potential of dual-core heat/energy recovery systems and air pre-heating concepts in Northern climates for reducing energy consumption, improving building ventilation and IAQ. Participation by few manufacturers will improve collaboration between industry and researchers, and facilitate industry uptake of the technology developed. The research study may lay the foundation for further development of residential ventilation strategies for the North. These strategies should also contribute to a wider choice of design acceptable under Northern building requirements.

The final (long-term) outcomes:

- *Advancement of climate change mitigation, end-use technologies for both Northern buildings and communities through R&D.*
- *Significant energy savings for ventilation of northern homes (by approximately 25% reduction in energy used for ventilation) and related reduced GHGs emission and environmental impacts.*
- *Reduced reliance on external fuel sources (e.g. diesel) for remote communities.*
- *Ultimately improved ventilation technology will support the development of healthy, sustainable northern communities that support economic development and sovereignty initiatives.*

The reduced energy consumption ultimately envisioned for these strategies may be modest for each installation in Northern part of Canada (i.e. above 55° parallel), but even a moderate percentage of market uptake will have a considerable impact on local reduction of GHG emissions.

4. Specific Assessment Criteria

In this section, please address **all** of the following numbered criteria, which will be used in conjunction with the other information provided in this proposal as assessment criteria.

i) Explain how the project will address Government of Canada and PERD Portfolio priorities in terms of closing technological and/or knowledge barriers and gaps, and/or testing of concepts, before emerging clean energy technologies can be brought to the stage of "real world" trials.

The Arctic is undergoing rapid changes, from the impacts of climate change to the growth of Northern and aboriginal governments and institutions, along with the increasing interest in the abundant natural resources that it contains. But it is a very fragile environment and it is widely acknowledged that specialized technology is required for the Arctic's successful growth. Although the Northern housing and building sector is a very small targeted market, it is deemed an important government priority.

The housing sector in the Arctic has traditionally been conservative in adopting improved energy efficient constructions, especially in remote communities where construction and heating costs are much higher and the cost of repair and replacement of failed components can be significant. Therefore, there is a strong incentive to uphold specifications that have a good track record in the North, which represents a disincentive to implement improved energy technologies to significantly improve the performance of Arctic houses and small buildings, such as energy efficient ventilation strategies.

This research will contribute to the development of technologies that ensure sustainable, low impact development of the North while increasing the quality of life for Northern population. The outcomes will add value beyond the testing and evaluation through the knowledge, experience and comprehensive tools to deliver objective, accurate technology solutions and information to Northern communities and stakeholders.

ii) Identify the particular Canadian opportunities and challenges (for example, urban versus remote community needs; climatic extremes in Canada, both seasonally and geographically; and unique resources) and explain how the project responds to them.

The extremes of the Arctic climate pose severe challenges on housing energy systems. Energy consumption and demand for space heating for remote community buildings are very high. In the Arctic/northern regions of Canada the average temperature during winter is -25°C or less and the design temperature of heating systems is -40°C. Previous field work by the proponents has shown that many homes are heated to over 25°C resulting in significant loads on systems. Typical energy supply (diesel) to Arctic/northern communities is logistically difficult to organize/supply resulting in an electricity price of up to $1/kWh in some Nunavut communities. Technologies that deliver energy savings provide increased affordability, energy security, autonomy and reduce the dependence of diesel supply. Additionally the benefit for the environment is also important as reducing fuel consumption reduces CO_2 *and other pollutant emissions and reduces the environmental risks associated with the transportation, storage, distribution and consumption of fuel oil. The expected expansion of economic development and sovereignty initiatives in the North needs improved management of energy demands. As a part of the overall effort to reduce space heating requirements, buildings need to be built air tight to reduce infiltration/exfiltration heat losses. However, airtight buildings require energy efficient and effective ventilation systems to maintain acceptable indoor air quality and comfort and to protect the building envelope from moisture damage. While heat recovery ventilation systems have been used to meet these needs, the performance achieved to date has been inadequate due to equipment failures, freezing of the heat recovery cores, controls problems, high energy consumption, noise and comfort problems. This situation must be resolved if energy efficient buildings are to be successfully delivered in the North.*

Typical energy supply (diesel) to Arctic/northern communities is logistically difficult to supply resulting in a very high electricity price. Housing built airtight to reduce heat losses, requires energy efficient and effective ventilation systems to maintain acceptable IAQ, comfort and to protect the building envelope from moisture damage. Maintaining healthy IAQ in cold climate can be challenging due to the need for sufficient fresh air intake. Heat recovery systems used in the north to meet these needs have been inadequate due to equipment failures, freezing of the heat recovery cores, high energy consumption etc. This situation must be resolved if energy efficient housing are to be successfully delivered in the North.

Finally, Northern housing stakeholders face challenges associated with the performance of heat recovery ventilators (HRV's) installed in individual dwelling units in extreme cold environments. The intention to build multi-unit residential buildings (MURBs) in the north, in addition to the few hundred that currently exist, is regionally dependent. In Nunavut, for example, there is a strong emphasis on building multiplexes due to lower construction and infrastructure costs, land availability and development reasons. In the Yukon and Northwest Territories, new MURBs are more likely to be constructed in urban centres (such as Whitehorse and Yellowknife) than in outlying rural communities where the construction of single family dwellings still dominates (but HRVs are still required). Heat/energy technologies are being assessed in southern markets, but they need to be adapted and assessed in northern climate locations through small building construction practices to ensure that their energy efficiency benefits are fully realized in extreme northern climates and various occupancy conditions. An important objective is to ensure that these technologies deliver the energy savings while avoiding more problems, such as premature failure.

The key to the successful application of HRV/ERV products and systems in Northern communities is a demonstrated track record of reliable and predictable performance based on extreme cold climate conditions. This PERD funded research project on innovative heat/energy recovery systems will improve the reliability of energy efficient balanced ventilation systems in Northern communities and demonstrate its benefits in reducing the energy consumption and maintaining healthy homes.

iii) Explain how an adequate delivery capacity (e.g. ability to complete the project) exists or will be established and maintained over the life of the project. Show how the proposed project team provides the necessary expertise to conduct and manage the project. Explain how the facility (laboratory and/or field) in which the project will be conducted has the necessary infrastructure (e.g. equipment, technical support) and capability to support the proposed work. What are the delivery risks (e.g. loss of expertise or equipment) and how will they be managed? Define the role of partners and include their confirmation or letters of support if available. Note: this criterion will be assessed in conjunction with the information provided in section 2: Project Team Members / Partners.

Three federal partners will collaborate on the project: NRC, NRCan and CMHC. The work will build on the expertise of the partners in the following areas; HVAC, residential ventilation, heat and energy recovery technologies, field monitoring, and modeling and simulation. In addition, the project has access to state-of-the-art laboratories and facilities such the twin houses of the Canadian Centre for Housing Technology.

The role of each partner is as follow;

NRC Arctic program: NRC will lead the project and will collaborate with industry partners on innovative dual core HRV/ERV *units. The units will be tested using a climatic chamber, and twin houses at the Canadian Centre of Housing technology (CCHT) before deployment for field testing in the north. NRC has state-of-the-art facilities such as environmental chamber capable of simulating northern outdoor conditions of -40°C, CCHT twin houses to conduct side-by-side testing of the energy performance of an innovative technology compared to a conventional one. NRC has expertise in IAQ monitoring and tracer gas techniques to evaluate the ventilation effectiveness.*

NRCan Varennes: Building on heat pump, thermosyphon and CO_2 expertise NRCan Varennes will develop the necessary components of the thermosyphon pre-heater. This unit will be tested initially at NRCan Varennes before deployment to the North for field testing. NRCan Varennes has a long experience in research related CO_2 applications, ground source heat pumps and supermarket refrigeration systems. Their existing test setup for experimental evaluation of small scale geothermal boreholes (built during ecoEII 2014-2016) can be easily adopted to test thermosyphon heat recovery system.

NRCan Ottawa: The Bells Corners lab will develop two novel technologies, an advanced high efficiency heat exchange technology (i.e. wire fin) and a potential defrost strategy (i.e. solid state heat pumping from outgoing air to incoming air) that could reduce the number of defrost cycles. These technologies will be tested initially at Bells Corners (using their climatic chamber) and CCHT before deployment to the north for field testing.

CMHC: Building on the current program of work in the north with our northern partners and stakeholders, CMHC will support research to baseline the performance of current approaches and investigate and validate the performance of the HRV technologies in the field. CMHC will also explore design, installation, operation and maintenance considerations associated with the new approaches and work with northern stakeholders to increase awareness, knowledge and uptake.

iv) Identify the technical risks to the project's successful completion, and explain how they will be managed. Note: this criterion will be assessed in conjunction with the information provided on other, non-technical risks in section 7: Non-Technical Risks to Project.

Identified Risk (pre-mitigation)	**Mitigation Strategy / Risk Response**	**Residual risk (L, M, H)**
Technologies employed in the Prototype development do not work.	This project is going to involve the development of 3 or so prototypes employing several component parts. As the project evolves, bench testing results of components and assembled prototypes will enable early detection of unsuitable technologies, as part of a stage-gate process. Starting with multiple prototypes increases the team's probability of success that at least one suitable technology can be developed to target TRLs indicated above for each stream of research.	L
Performances of some technology simulations / prototypes and/or field tests do not meet expectations	Mid-year and year-end reporting will present interim assessment results for technologies being developed. Should performance issues be recognised, funding may be allocated to prototype technologies.	L
Rapidly deployable Northern ventilation systems validation	The project team will demonstrate performance in Ottawa, lab testing and field trials, an then validate their performance in the North.	M

v) Describe the receptor capacity for the results of the project – that is, the "who and what" capacity within the Canadian energy innovation system to take what is produced farther along the innovation chain, or within the policy and strategic planning community to use the knowledge produced (e.g. for input to regulations or longer-term strategic plans for energy R&D).

Two industry partners, Tempeff North America Inc. and Venmar Ventilation Inc. (manufacturers of heat/energy recovery systems), have expressed a strong interest in this project. Tempeff has already agreed to provide and innovative dual-core (parallel cores) energy recovery system as in-kind contribution to the project. Venmar will do the same with a dual core heat/energy recovery unit (sensible core and enthalpy core in series). Venmar is a major manufacturer of HRV/ERVs with market share of 60% of North American market. Currently single core heat/energy recovery ventilation systems dominate the market. Dual-core systems can be an efficient alternative to single core HRV/ERVs leading to innovative products and increased market penetration for Canadian HRV/ERV industry. Canadian ventilation product manufacturers will benefit from a technology advantage, staying ahead of the competition. Carnot Refrigeration, an industrial partner of CANMET-Varennes, has developed expertise specifically in CO_2 as a refrigerant but also in CO_2 thermosiphons for data centres cooling. The technology is already implemented. This expertise will be profitable to the application in the North.

Government initiatives to encourage more energy efficient housing for the North are ready and eager to implement the results of these technology improvements in their requirements. As the R-2000 program adopts new technologies, the conventional housing construction industry generally moves to keep pace meeting market pressures. This will further encourage the manufacturing industry and the home heating industry to adopt theses technology improvements.

Northern stakeholders will engaged and play a key role in the established external Technical Advisory Group (TAG) to provide a clear understanding of the situation of air ventilation systems applied in the North, the challenges they are facing *and help in deploying the successful technologies in the Northern communities.*

Technology transfer (reporting, presentations, design and installation guidelines & workshops): We will develop best practice guides for the North and we will disseminate knowledge gained in this project to Northern territories, communities and stakeholders.

The scientific publications will provide the credibility for dissemination of these technology improvements to utilities, the manufacturing sector and the public. Governments energy-efficient housing programs can be expected to include these technologies in their next rounds of demonstration projects – further publicizing the benefits.

vi) Describe any expected environmental co-benefits from the intermediate and final outcomes of the project. Would they be quantifiable should there be a requirement for that (but beyond the scope of the project to do so)? How?

Balanced ventilation using heat or energy recovery ventilation systems will have environmental co-benefits because it reduces heating energy (electricity, gasoil) by as much as 50% in extreme cold climates. This energy savings will be more and more important as the prices for energy keep going up in the North. The reduced energy demand is also associated with a reduction of GHG emissions associated with the emission fuels such as gasoil. In addition, the use of balanced ventilation will help houses to meet ventilation rate requirement and maintain healthy indoor environment for occupants and reduce the health impacts.

vii) Describe any expected socio-economic co-benefits (e.g. improved health of Canadians, job creation, international market opportunities) from the intermediate and final outcomes of the project. Would they be quantifiable should there be a requirement for that (but beyond the scope of the project to do so)? How?

This work will provide support to market penetration and expansion of heat/energy recovery ventilation systems. The adoption of the proposed energy/IAQ efficient heat/energy recovery technology will increase the market share of Canadian manufacturers. The development of an advanced and integrated heat/energy recovery product by Canadian manufacturers will also create circumpolar and other international market opportunities where there is currently a need for low energy heating and ventilation technologies. In addition, this work will benefit all Canadian in reducing energy consumption and improving IAQ and occupants health in Northern residential buildings.

Given the positive energy savings and environmental prospects of the proposed technologies, it is likely that their adoption will be further encouraged through provincial, territorial and federal incentive programs leading to an even more accelerated penetration in the market place.

5. Project Linkages

In this section, please address the following:

- As appropriate, explain briefly how this project builds sequentially on previous ones funded by initiatives managed by OERD – e.g. ecoEII (ecoEnergy Innovation Initiative), Clean Energy Fund (CEF), ecoENERGY Technology Initiative (ecoETI) - as well as projects funded from other sources.
- Identify any linkages with PERD, ecoEII, CEF, or ecoETI, projects (including project titles and identification numbers) and, as appropriate, with projects from other funding sources (e.g., through an International Energy Agency Implementing Agreement or equivalent, national or provincial initiatives).
- If applicable, describe anticipated international collaborations, and indicate the Canadian contribution (dollars, expertise, etc.). How will this engagement promote Canada's global energy leadership?
- Explain the value of the linkages – e.g. building synergies; applying concepts / practices in one energy technology area to another or from one jurisdiction to another.

CEF and EcoEii programs have funded NRCan Varennes previous research activities related to the development of a new ground source heat pump using CO_2 as a refrigerant in phase change. Two configurations have been considered; system with a secondary loop (the flow is ensured by a pump) and system with direct expansion (the circulation is ensured by the compressor). Among the interesting results reached, is that the thermophysical properties of CO_2 allow him to be considered among the best fluids to be used for natural circulation. In the proposed project, the innovation consists on using ground source heating system based on a natural circulation of a CO_2 (without pump neither compressor).

Within the last PERD Cycle no specific activities relating to ventilation were identified within the Outputs & Tasks of "Affordable and Efficient Mechanical and Renewable Energy Systems for Low Load Housing and Buildings" – D12.015, however, ventilation is a key element of the heat load of such buildings and a technology watch was maintained.

Funding outside of the OERD envelope was used to initiate the development of a prototype High Efficiency HRV. The materials gathered and knowledge gained, will be used as a basis to complete a prototype of an HRV for Northern climates. Basic studies have been conducted on the Northern Home located at the Bells Corners Complex. The work done to date included carbon dioxide (CO_2) build-up studies and the evaluation of different CO_2 control measures at the Northern Home.

Within the next 4 year PERD Cycle, there will be links between the project work proposed here and the research theme areas of BE1-1C,"Northern Housing & Buildings" and BE2-2B, "Control of Advanced HVAC". Northern Housing will need to ensure that homes and workplaces are adequately ventilated to ensure the health of the population. In addition, the energy required to ventilate a structure will need to be minimized.

This project contributes to and draws on knowledge from a number of collaborative working arrangements with the following international and national initiatives and memberships, most notably:

- American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)
- Heating, Refrigeration and Air Conditioning Institute (HRAI)
- American Council for an Energy Efficient Economy (ACEEE)
- Consortium for Energy Efficiency (CEE)
- Affordable Comfort Conferences on Advancing Home Comfort (ACI)
- Canadian Standards Association (CSA)

Proponents of this project will continue to engage in a number of international collaborations on a project-by-project basis. As has been the case in the past, this engagement promotes Canada's global leadership by showcasing Canada's manufacturing and innovation strengths. For example, proponents of this project proposal are regularly invited to speak at events organized by ASHRAE, HRAI, ACEEE, IEA and ACI and as such, have become recognized leaders in their respective fields of expertise.

Under the last PERD cycle, CMHC explored models of sustainable northern housing. Performance monitoring of the projects revealed that heat recovery ventilators were not operating as expected. As HRVs are critical for the success of any effort to safely reduce residential energy consumption. Research is needed to support development of reliable, effective and energy efficient appliances.

6. Project Outputs and Tasks[3]

Please ensure that you clearly link each principal output to the immediate, intermediate and final outcome(s) (immediate and/or intermediate and/or final) to which it is directed. Refer to the Technology Area Logic Model (provided as attachment).

I find this is too much detailed. Think that every 6 months you will have to fill reports to indicate what has been done.

Try to have less tasks in each output and simplify them.

Intended Outputs / Link to outcome	**Task(s) for Output**	**Performance Metrics / Dates of Completion**
Output 1 ▪ *Design and evaluate dual-core heat/energy recovery systems that has improved energy performance through reduced or eliminated defrost requirement and efficient heat recovery, and deliver effective ventilation to maintain acceptable IAQ, comfort and to protect the building envelope from moisture damage* ▪ *This output is primarily directed towards the immediate outcome of BE3-3B "Develop and adapt technologies & practices to reduce diesel dependency in remote communities and the North" and Immediate Outcome 7 in the BE Logic Model. The work will lead to the Intermediate Outcome of "Advanced HVAC Systems that improve energy efficiency and reduce*	***Task(s) for Output 1*** *The following tasks are to be carried out by the NRC Arctic program and Construction Portfolio/V&IAQ group* • *Review research done on heat/energy recovery systems installed in the North and the associated problems (collaboratively with other project partners, and study the ventilation requirements of northern housing based on occupancy (overcrowding) and moisture generation and others indoor condition specific to the north.* • *Establish advisory panel experts form NRC, NRCan, CMHC, industry and stakeholders in North to discuss and develop a 4-year research plan.* • *Engage industry partners to identify innovative heat/energy recovery systems to be tested and facilitate the objectives of this output.* • *Propose 2 to 3 technologies for evaluation using laboratory (existing climatic chamber), CCHT (side-by-side testing) and field monitoring in the North.* • *Laboratory Evaluation of selected technologies* *Upgrade and configure EEEF climatic chamber to provide high ambient moisture at sub-zero temperatures. Instrument test facility and technology under test to monitor the heat/energy recovery performance in terms of heat recovery and icing under different ambient conditions.* *Test Technology 1, Dual-core energy recovery unit, Report Results, recommendations for design and field testing.*	*Expected dates of completion (and performance metrics where applicable)* *October 30th 2016* • *Completed review of literature on heat/energy recovery system situation/performance in cold climate* • *Advisory panel experts formed and industry partners engaged to build prototypes or provide technologies.* • *Environmental chamber (EEEF) upgrade, commissioned and experimental plan developed* *March 31st 2017* • *Lab and CCHT testing of the technology 1 completed and project reports written.* *March 31st 2018* • *Lab and CCHT testing of technology 2 completed,*

[3] Refer to section 2 of *Guide for the Preparation of Proposal and Planning Documents 2012* for definitions of project, task, output, outcome etc. **Please note in particular the difference between "output" and "intention".**

GHG emissions” and the Long Term Outcome of an Energy-Efficient Built Environment.	*Test technology 2, Dual-core heat and energy recovery system, Report Results and recommendations for design and field testing.* *Test technology 3, TBD, Report Results, recommendations for design and field testing.* • *Side-by-side evaluation of selected technologies* *Configure the CCHT houses to compare the performance of innovative technologies (installed in the test house) with conventional heat/energy recovery unit (installed in the reference house) as a reference.* *Test Comparison 1, Dual-core energy recovery unit versus single core HRV/ERV unit, Report Results, recommendations for field monitoring in the North.* *Test Comparison 2, Dual-core heat and energy recovery system versus HRV/ERV unit, Report Results, recommendations for filed monitoring in the North.* *Test Comparison 3, Technology 3 (TBD) versus HRV/ERV unit, Report Results, recommendations monitoring in the North.* • *Field monitoring in the North* *Select most promising technology/system, engage manufacturer to build final unit(s) and partner in the North to deploy the technology for extended Field Testing in the North.* *Deploy selected (best) technology in Northern Housing and conduct long term field monitoring.*	*and project reports on technology 2 written.* *March 31st 2019* • *Lab and CCHT testing of technology 3 completed and project reports written.* • *Technologies to be deployed in the North and deployment site selected.* *March 31st 2020* • *Long term field monitoring in the North completed and project reports written.*
Output 2 ▪ *Design, build and evaluate one prototype HRV that has improved heat transfer efficiency, a reduced defrost requirement, low power consumption and a resistance to exterior terminal frost or snow blockage.* ▪ *This output is primarily directed towards the immediate outcome of BE3-3B “Develop and adapt technologies & practices to reduce diesel dependency in remote communities and the North” and Immediate Outcome 7 in the BE Logic Model. The work will lead to the Intermediate Outcome of “Advanced HVAC Systems that improve energy efficiency and reduce GHG emissions” and the Long Term Outcome of an Energy-Efficient Built Environment.*	***Task(s) for Output 2*** *The following Tasks are to be carried out by the Alternative Energy Lab. (AEL), Buildings & Renewables Group (BRG) at the Bells Corners Complex (BCC)* *1. Background research (collaboratively with other project partners) develops a common understanding for typical ventilation loads to be met and Identified problems with existing HRV / ERV systems. Specify evaluation test conditions required.* *Identify possible components that will facilitate the objectives for this output, e.g. wire-fin heat exchange, ceramic heat exchanger, vent baffles, demand control, and solid state heat pumping. Identify efforts made to-date using these technologies, list Pros and Cons of each. Collaborate with project task to reduce icing of vents used with condensing equipment in “Next Generation Natural Gas Technologies”* *Enter Components into a virtual system model based on bench test performance characteristics in the lab. Model HRV / ERV use in a cold climate and identify whether a central or zoned approach is preferable. Use virtual model to assess component combinations (include cost assessments).* *2. Propose three designs for evaluation in a laboratory setting based on the results of Task 1.* *Configure BCC cold climate test facility to provide high ambient moisture at sub-zero temperatures.*	• *30/09/2016 - A statement of the commonly understood issues and the test evaluation criteria to be used, are written.* • *31/03/2017 - A Technical Report on HRV / ERV Component parts and their Pros and Cons is written* • *31/03/2017 - A progress report on the development of a virtual HRV/ERV model is written.* • *31/03/2018 - Project Reports on Test Facility set-up (1 Report) and prototype design testing results (3 Reports), written.* • *31/03/2019 - A manufacturer is engaged to build a prototype.* • *31/03/2020 - A manufacturer produced Northern HRV is installed at*

	Instrument test facility and prototype HRV to monitor the heat exchange efficiency, the rate of heat exchanger icing, the degree of vent icing and the total energy consumption under different ambient conditions and ventilation loads. *Test Design 1, Report Results, Provide More Detail to Virtual Model, Suggest improvements and refine design.* *Test Design 2, Report Results, Provide More Detail to Virtual Model, Suggest improvements and refine design.* *Test Design 3, Report Results, Provide More Detail to Virtual Model, Suggest improvements and refine design.* *Configure BCC cold climate test facility to allow testing of blowing wet/dry snow conditions.* *Test Design 1, Report Results, Provide More Detail to Virtual Model, Suggest improvements and refine design.* *Test Design 2, Report Results, Provide More Detail to Virtual Model, Suggest improvements and refine design.* *Test Design 3, Report Results, Provide More Detail to Virtual Model, Suggest improvements and refine design.* *3. Select most promising option and engage an interested manufacturer to build a final prototype Cold-Climate HRV that has improved heat transfer efficiency, a reduced defrost requirement, low power consumption and a resistance to exterior terminal frost or snow blockage. Submit prototype for extended testing at NRC and Field Testing at CHARS.* *4. Employ technology with the Rapidly Deployable Northern Home located at BCC, as a long term real-use test and a demonstration to visitors and interested stakeholders.*	*the Rapidly Deployable Northern House at BCC*
Output 3 ▪ *New scientific and technical knowledge and its dissemination to the wider public.* ▪ *This output is primarily directed towards the Immediate Outcome 7, "New information on potential solutions to reduce diesel dependency in remote and northern communities is available to stakeholders", in the BE Logic Model. The work will lead to the Intermediate Outcome of "Advanced HVAC Systems that improve energy efficiency and reduce GHG emissions" and the Long Term Outcomes of an energy-efficient*	***Task(s) for Output 3*** *The following Tasks are to be carried out by the Alternative Energy Lab. (AEL), Buildings & Renewables Group (BRG) at the Bells Corners Complex (BCC) in collaboration with our partners at Varennes, NRC, and CMHC.* *1. The Preparation of Technical Reports relating to the test facilities set-up, the performance evaluation methods and the test results from the evaluation of components or prototype HRV / ERV technologies.* *2. The Presentation of the results of this work, as papers, through Conferences such as ASHRAE and/or CMPX.* *3. Engagement activities with the ventilation equipment industry (e.g. workshops, technical advisory groups, discussions with industry associations, or individual manufacturer consultation).*	• *31/03/2018 - 1 Report / 1 Presentation on Facilities and Evaluation Methods Completed.* • *31/03/2020 - 3 Reports on Evaluation Results, Written.* *1 Presentation / Paper on Evaluation Results Presented.* • *31/03/2019 - One Engagement Activity Completed.*

built environment and increased economic activity.		
Output 4 ▪ *Air pre-heating ground source heat system using CO2 in natural circulation (thermosiphon)*	***Task(s) for Output 4*** *The following Tasks are to be carried out by the Buildings Group NRCan at Varennes.* • *Development of a theoretical model.* • *Conception, design and construction of experimental setup.* • *Perform experiments and validation of the theoretical model.* • *Based on the developed model, theoretical analysis will be performed to investigate the effect of different parameters and configurations.* • *An economic assessment study on the deployment of this technology* • *Results dissemination.*	• *2016/17 - First version of the theoretical model and conception and design of the experimental setup.* • *2017/18 - Construction of the test bench and starting experiments and validation of the model.* • *2018/19 – Performing experiments, improving the model and parametric study.* • *2019/20 – Results, economic and dissemination.*
Output 5 ▪ *Knowledge of HRV performance and techniques for improvement*	***Task(s) for Output 5*** *The following tasks are to be carried out by CMHC* • *Survey of HRV units, design, installation, O&M, industry capacity, common problems across the North* • *Assessment of the monitoring data expected from the Cambridge Bay HRV installation/monitoring and Yukon studies* • *Support the field testing of the HRV technologies developed by project partners (NRC and any others) at CHARS or other site.* • *Develop and test troubleshooting and performance remediation guidelines for the existing HRVs already in northern housing to optimize energy and IAQ performance.*	• *16/17, Completed review of HRV situation in northern housing, identification of energy implications* • *16/17, documentation and analysis of airflow, temperature conditions and other performance metrics, hosting of webinar with HRV industry stakeholders on findings* • *18/19 – 19/20, published reports on field testing of new HRV technologies including IAQ, energy, occupant impacts, industry views.* *17/18, published guidelines for improving ventilation and energy performance of existing HRVs*

7. Non-Technical Risks to Project

Please identify the *key* non-technical risks associated with the successful implementation of the project, the mitigation strategy for each, and an assessment of the "residual risk", that is the level of risk even after the mitigation strategy. Refer to section 3 of *Guide for the Preparation of Proposal and Planning Documents 2013.* Examples are provided in Appendix 3 of the Guide, but please consider others that are specific to the proposed project.

Identified Risk (pre-mitigation)	**Mitigation Strategy / Risk Response**	**Residual risk (L, M, H)**
Technology appears inappropriate in terms of capacity, availability, maintenance and/or affordability.	Close collaboration between NRCan Ottawa, NRCan Varennes, NRC, CMHC and the Housing Group, will ensure researchers are kept well informed of target system capacities and affordability goals. As research and development work proceeds, if it is determined that these criteria are not being met, the technology development pathway may be adjusted accordingly (e.g., shift of focus from majority efficiency improvement to majority cost reduction). If this is not possible, funds may be allocated to other prototype developments showing stronger progress.	L

Inability to find deployment sites in the Arctic to whom the technology / knowledge can be transferred for development/monitoring.	Ensure the stakeholders and housing sector partners / market receptors in the North are aware of developments through engagement activities and that any demonstrations are adequately supported. Collaboration with BE1-03 tam and their northern stakeholders will be explored, as the technologies are complementary.	L
Inability to find Canadian companies to whom the technology / knowledge can be transferred for further development / commercialization.	Ensure the industry partners / market receptors are aware of developments through engagement activities and that any demonstrations are adequately supported.	L

8. Technology / Knowledge Transfer and Dissemination

Please explain how the technology and /or new knowledge arising from this project will be made available to stakeholders. Consider: technical reports, publications, web sites, databases, presentations at conferences and workshops etc. Will any aspect of it be confidential? If yes, please explain.

Note: OERD requires a copy of *final* versions of knowledge assets derived from its Program funding, in electronic format, and an indication of whether there is any restriction on their availability to others (for example, restricted to collaborative partners; restricted to internal federal government use; restricted by legal and security constraints; intended for commercialisation).

With regard to final knowledge assets arising from activities it funds, OERD may:

- make available those that have not been published in professional journals, and for which availability is classified as unrestricted, in electronic format, via a web site, or by other means as may be deemed appropriate; and
- provide on its web site references to scientific and technical papers published in professional journals.

Refer to section 4 of the *Guide for the Preparation of Proposal and Planning Documents 2013.*

- *Industry uptake by participating manufacturer(s) is expected.*
- *Focused workshops and presentations at suitable trade expositions will aid transfer of this technology to industry.*
- *Publication of results in scientific literature (e.g. ASHRAE Transactions, etc.) and trade publications as appropriate.*
- *Benchmarked performance data and scientific publications will provide credibility for uptake and implementation by demonstration housing projects by government agencies (e.g., NRCan, R-2000, CMHC Northern Housing Initiatives, and Nunavut Housing Authority).*
- *Contribution to publications by agencies such as NRCan, CMHC, etc., aimed at house builders and homeowners.*
- *New technologies promoted in Northern part of the country seminars.*
- *Participation of project team members on committees such as CSA Standard F326, Technical Research Committee of CHBA, and ASHRAE TC 5.5 will further promote these heat/energy recovery ventilation systems/strategies.*

9. Compliance with the *Canadian Environmental Assessment Act 2012* *(Refer to http://www.ceaa.gc.ca/default.asp?lang=En&n=16254939-1)*	
Will the proposed work require an environmental assessment prior to the start of the project?	No
If no, why not?	The technologies considered in this project have no environmental impacts.
If yes, when will the environmental assessment be completed? (OERD will not transfer the funds until it has received a copy of the assessment).	