

Clean Energy Fund Public Project Report

Project: F11.009 Cold Climate Heat Pump Development and Demonstration

January 1, 2011 to March 31, 2015



A2A Forced air unit



compressor unit



outdoor unit



A2W indoor unit

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1 Executive Summary

Ecologix, with help from its Industry partners has developed a variable capacity heat pump capable of delivering heat at -20C and colder.

This is a Canadian made product for heating homes in the Canadian winter.

We now manufacture and market this series of equipment as the “Cold Climate Heat Pump” (CCHP).

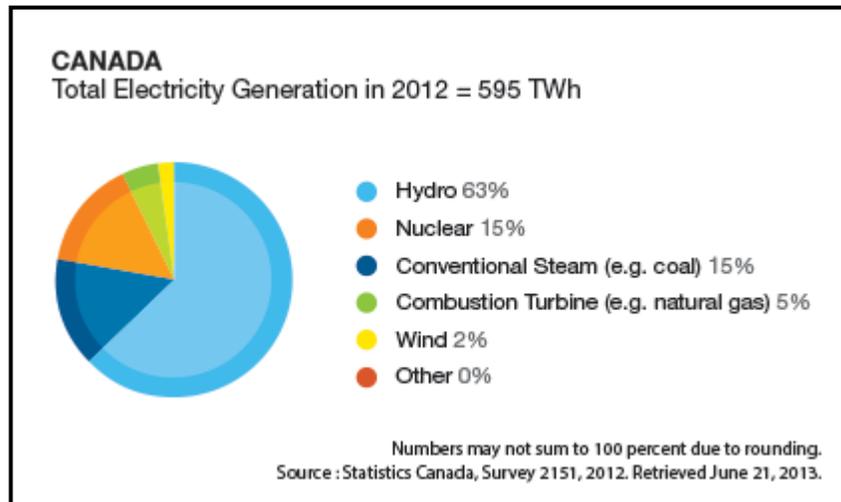
The CCHP is a low carbon and potentially carbon neutral technology that delivers up to 100% of the home’s space heating and cooling needs, even as cold as -20C and delivers 50 to 70% of the homes domestic water heating needs at very high efficiency.

During summer months, heat that is normally rejected outside during air conditioning, is recovered and used to heat domestic water, coming to the home owner at almost zero incremental cost.

The CCHP is capable of challenging the fossil fuel furnace to become the carbon neutral standard for new home construction and existing home heating system replacements.

Carbon neutrality, or having a **net zero carbon footprint**, refers to achieving net zero **carbon emissions** by balancing a measured amount of carbon released with an equivalent amount sequestered or offset, or buying enough **carbon credits** to make up the difference. (Wikipedia)

The price difference between on peak electricity and the cost of natural gas in Ontario has moved from 3 to 1 at the start of the product development in 2009 to more than 6 to 1 as of March 31, 2015. This has made the economics of any ground source or air source heat pump very unattractive in urban



areas where natural gas is present. The cold climate heat pump is not an exception. Where natural gas is available the payback for the system is over 10 years. For homes where natural gas is not present and the only available energy is oil, propane or electric heat, the payback can be well under 5 years.

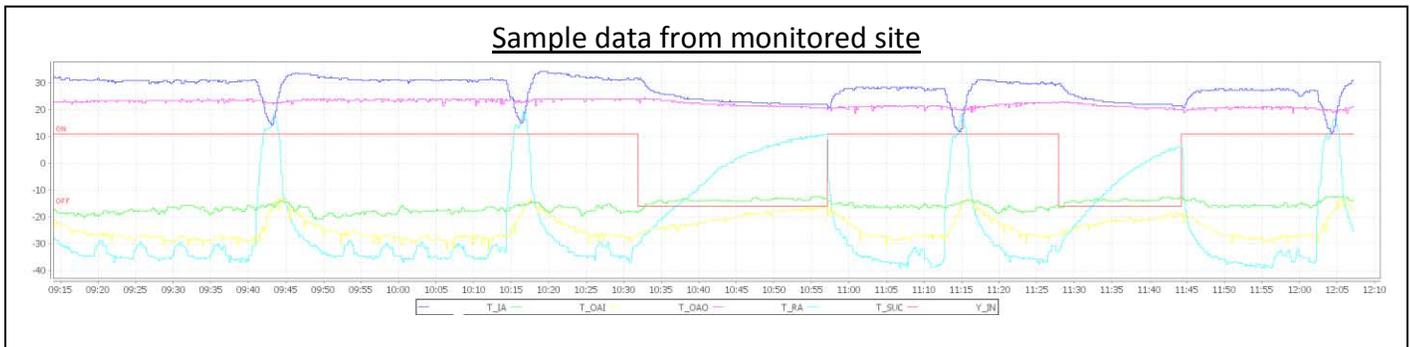
In new construction the payback can be less than 3 years compared to an electric, oil or gas high efficiency furnace with variable speed drive and a conventional two stage air conditioner.

During the project, three versions of the CCHP were developed and put into market trials:

- The air to air (A2A) CCHP replaces a furnace and air conditioner to provide year round heating and cooling and provides anywhere from 50% to 70% of the homes domestic water heating.

- The Multi-Unit Residential Building (MURB) CCHP was developed to be a viable retrofit option for the existing stock of electric baseboard heated high rise suite located in most urban centers of Canada.
- The air to water (A2W) CCHP was developed to replace or supplement boiler systems for homes where an existing home may have in-floor heating or water based radiators. In addition, the system provides anywhere from 50% to 70% of the homes domestic water heating.

A commitment as part of the CEF contribution was to monitor a significant number of suites to demonstrate the efficacy of the system. To achieve this, Ecologix developed of an integrated Control and Monitoring system for the heat pump. This new control platform means that all heat pump equipment sold by Ecologix now comes with built in monitoring and remote diagnostics through an internet connection. Basic monitoring services and ability to troubleshoot over the internet comes as part of the equipment purchase at zero incremental cost. Detailed monitoring services can be provided by Ecologix at a small monthly fee



depending on length of service and type of control point being monitored.

Real time data logging of equipment for service or performance checking has been extremely successful and has changed the Ecologix marketing and training strategy.

With an internet connection at start up, any heat pump system can be checked by factory personnel that it is set up correctly and is operating as intended. When homeowners call in, we usually can identify and remotely fix many of the weather related issues such as ice, snow or freezing rain build up without the need or expense of a service call.

Ecologix has successful installations for market trial locations in Ontario Newfoundland and Quebec. By 2020 we will have complete seasonal operating data collected from over 100 sites across this region.

Ecologix developed the CCHP as a low temperature heat pump technology to provide domestic hot water heating with space heating and cooling, complete with web enabled full remote monitoring, diagnostics and control. We anticipate that integrated domestic hot water and space heating systems will grow in popularity and monitoring of internal components will become much more main stream in heating appliances.

Our monitoring over the next four years should demonstrate conclusively the financial, environmental and energy benefit to the end user.

2 Introduction

The cold climate heat pump development and demonstration project began in 2008 by Ecologix with industry partners.

In January 2011 the project “Cold Climate Heat Pump Development and Demonstration” was awarded funding from the Clean Energy Fund (CEF). The project focused primarily on completing the development of a cold climate heat pump system and installing a block of systems that would be monitored over a period of years. The project ended in March 2015 and we are now in the monitoring phase.

The objectives were, in declining priority:

- Complete the development of the cold climate heat pump.
- Install a significant number of field units that would be fully monitored to provide real world seasonal operating data.
- Develop a monitoring and control system to allow for easy monitoring of the sample group required in this project. A secondary objective was to integrate this monitoring into the system controls so it could cost effectively be made available to all future heat pump systems sold by Ecologix.
- Work with industry partners and research bodies to develop a set of innovative prototype systems to test as examples of potential future generation equipment.

Typical residential application



outdoor unit

Typical commercial installation



indoor units

3 Background

The development and demonstration of a cold climate heat pump was started by Ecologix in 2008, prior to the CEF project. In the fall of 2009 a prototype was constructed and put into friendly test homes for evaluation. Two early version cold climate heat pumps were used by the University of Waterloo for the Canadian entrant to the Solar Decathlon held on Washington in the fall of 2010 where the entry placed 4th out of 12 international entries.

In 2008 the only cold climate heat pumps available were in Europe. These were air to water systems that cost between \$18,000 and \$25,000 plus installation.

The innovation breakthroughs we were targeting were in cost, performance and in application. Our CCHP is the only heat pump in North America where the compressors are located inside the home so that domestic water heating could be harvested from the compressor heat that is usually lost to the outdoors. With Emerson’s help Ecologix developed and tested a digital compressor system that could operate at low temperatures without damage to itself. In 2009 there was only North American residential equipment manufacturer (Hallowell) that published heat pump capacity and performance numbers below -8C. Heat pumps were not considered very practical for cold climates such as Canada. The typical North American heat pump had

controls that shut off the compressor and relied on back up electric heat for outdoor temperatures below 0 Celsius.

Emerson International in 2009 had more than 50% of the world compressor market. Their expertise in helping us make the correct compressor and equipment selection choices was invaluable in getting us launched quickly. Emerson had specific industry knowledge about commercial operation of cold systems such as chillers and access to equipment we would otherwise have a difficult time sourcing. We were able to demonstrate that we could build the equipment profitably at the target price and potentially create a new class of product that could challenge gas furnaces in urban installations.

If natural gas and electric prices had remained stable, the CCHP would have been very attractive replacement for a gas furnace in an urban home.

Since 2009 the cost of natural gas has moved steadily downward and the cost of electricity in Ontario has more than doubled. In January 2009 the price of NG was 31 cents/m³. By the start of the project the price had dropped to 21 cent/ m³. Ontario electricity prices in the same period went for 4.2 cents/KW to 5.2/ KW off peak. This price inversion was considered very temporary. By 2015 the price of off peak power has moved from 4.2 cents / KW to 8.3. On-peak power moved from 9.1 cents to 17.5 cents. The price of Natural gas has moved from its high point of 31 cents per M³ in 2009 to a price of 12.0 cents / M³ as of March 31, 2015. Rates are published on the OEB website at <http://www.ontarioenergyboard.ca> . This means the Ontario average cost of energy between gas and electricity has moved from 1.5 to 3.0 times the cost of gas depending on time of use to a ratio of 3 to 6 times the cost of gas depending on time of use between January 2009 and March 2015. One of the original goals of this project to compete economically with natural gas technologies was an easy stretch in 2010. It now is temporarily out of reach due to changes in market conditions.

Interest in the CCHP is very strong in rural areas where the fuel choice is oil, propane or electric resistance heating. In rural applications our early trials indicate cost savings of more than ½ the original fuel costs and pay back periods of less than 5 years. Data collection over the next few years will show conclusively the benefits that are at present only projected.

4 Results of Project

4.1 Development

In January 2011 Ecologix obtained support from the Clean Energy Fund to finalize the development of the CCHP and provide a monitored demonstration of the technology. Construction of a climate chamber and development of a control platform with integrated web based monitoring started immediately after the signing of the agreement.

4.1.1 Compressor technology development

With the help of Emerson and University partners, Ecologix developed and tested a number of compressor options and settled on detailed testing of three compressor technologies:

- Digital scroll compressors with vapour injection for cold climate operation.
- Variable-frequency drive compressors with liquid injection for cold climate operation.

- Two-speed compressor technology for air to water systems coupled to a thermal storage buffer.

4.1.2 Application Development

Three versions of the CCHP were developed and put into market trials:

The air to air (A2A) CCHP replaces a furnace and air conditioner to provide year round heating and cooling and provides anywhere from 50% to 70% of the homes domestic water heating.

The MURB CCHP is a multi-unit residential building (MURB) version of the A2A CCHP. It was developed to tackle the existing electrically heated high rise market as a low GHG option for new construction condominium and rental apartments. This system provides heating, cooling and up to 100% of the domestic hot water needs for a suite, allowing a complete in-suite package to replace fossil fuel equipment at a lower operating cost, when fixed costs such as meter charges are taken into account.

The air to water (A2W) CCHP was developed for homes where an existing home may have in-floor heating or water based radiators. This was expected to be a very small subset of our total sales but has quickly grown to be more than ½ of our sales in Canada since the project ended in March 2015.



4.1.3 Monitoring and Controls Development

By the end of the development phase of the project Ecologix was successful at integrating low cost monitoring into all versions of the CCHP. Ecologix is continuously working to improve the capacity and features of the monitoring package.

Real time data logging of equipment for service or performance checking has been extremely successful and has changed our marketing and training strategy. With an internet connection at start up, the system can be checked by factory personnel that it is set up correctly is operating as intended. This may come across as a subtle marketing feature but it has made a significant change in the way we can conduct business. Once equipment is installed, and is actively monitored, we can work with the end user to oversee the equipment operation over its lifetime. This ensures performance and longevity by confirming proper operation.

4.2 Market Trials

Test sites for the technologies developed above were found and equipment installed for the market trial starting in late 2012 and continued through to the end of the project.

Ecologix originally planned on over 200 sites to be installed and monitored. The final number of sites with a signed agreement that were installed or under construction by March 2015 was 110 units.

51 units were installed and commissioned and were actively being monitored on March 31, 2015. The remaining sites are under construction or waiting for the commissioning to be completed.

Most of the sites are in Ontario. One site is in Newfoundland and one site is in Quebec.

The Ontario sites are clustered predominantly in the Ottawa and Southwestern Ontario regions. We have a few sites in the North Bay /Huntsville area. No sites are located in Northern Ontario (North of Sudbury).

4.3 Development Partners & Next Generation Sites

Ecologix partnered with seven companies to develop the cold climate heat pump.

4.3.1 Emerson Climate Technologies Canada

Emerson has been a major contributor in compressor technology, hardware and expertise. Their contribution is highlighted throughout the document. Emerson’s support was a key factor in our compressor selection and development.

4.3.2 Ranger Heating & Air Conditioning Products

Ranger heating products is a fabrication partner that was instrumental in developing low cost prototyping capabilities so we could cost effectively manage the development and launch of the cold climate heat pump.

4.3.3 University of Waterloo

University of Waterloo was instrumental in the heat pump cycle development and in the early part of the project and provided laboratory testing of the early equipment in their thermal lab. They also were also the lead in the “North House” construction for the Solar Decathlon. Since Waterloo’s involvement, the North House was donated to RARE charitable foundation in Blair Ontario that manages a conservation area and uses the North House as a learning and test center.



4.3.4 RARE Charitable Foundation

RARE has been very active in participating with upgrades and continued testing of our equipment at the North House since it was reconstructed on their property in 2013.

4.3.5 Carleton University

Carleton University joined as a contributor in later 2013. Ecologix currently is working with Carleton on W2W custom CCHP for in-house thermal load storage and a custom A2A CCHP coupled to rock bed ground storage. Both technologies are presently under test at the C-RISE test house (Urbandale Centre) on Carleton campus



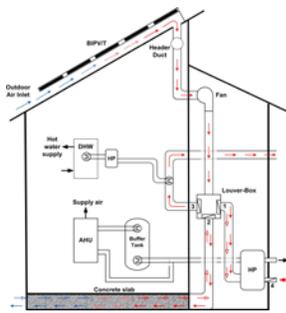
4.3.6 Ryerson University

We are working closely with Ryerson University to provide a custom CCHP for harvesting heat from solar panels. Ryerson is leading a building

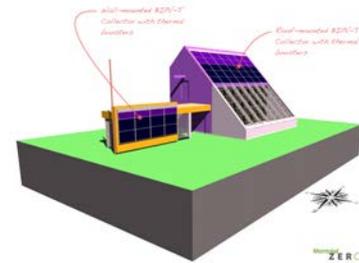
consortium that is managing the construction of a Building Integrated Photo Voltaic / Thermal (BIPV/T) solar test hut at the Kortright Centre on Toronto and Region Conservation Authority (TRCA) property in Vaughan.

4.3.7 Montreal Zero

Montreal Zero is an architectural development and research body that is building a BIPV/T test facility outside of Montreal similar to the BIPV/T facility being built by the Ryerson / TRCA consortium.



The Montreal Zero system is air to water based and incorporates a greenhouse and fish raising pond as well as water thermal storage. The CCHP system with a custom heat source unit is scheduled to ship to the facility in April, 2016. It is expected to be commissioned and fully operational by mid-summer 2016.



4.4 Follow on work

Since the project end, in March 2015, Ecologix has continued development work. Ecologix has invested in a major renovation of the climate chamber and surrounding lab facility in preparation to testing equipment under agreement with Ryerson University and other industry partners.

4.5 Benefits

4.5.1 Benefit to Consumers

The cold climate heat pump will offer Canadian homeowners an environmentally friendly, carbon neutral alternative to fossil-based heating systems at an affordable price.

CCHP systems as described in the CA were successfully developed and launched. Proposed price targets set at the beginning of the project were met.

The spread between the market price of natural gas and electricity exacerbates the sales potential of heat pumps. As installed price comes down, this will be less of a decision factor for homeowners.

We have been able to drop our sell price on the CCHP by 25% over the past three years. The price of the CCHP will drop again over the next 24 months. The current market movement making gas equipment less expensive and gas fuel significantly lower in cost to electricity threatens the technology if we do not introduce lower pricing.

So far all cold climate heat pump technologies including Ecologix CCHP represent less than 1% of total annual heating equipment sales. The competition remains fossil fuel fired equipment, not competitor heat pump products entering the market.

4.5.2 Benefit to Industry

Provide integrated monitoring to all heat pump systems installed in the program. Create a control platform where monitoring is part of each unit at no cost to the end user.

Benefits:

- the homeowner by allowing easy monitoring of performance and remote tracking of system operational status for reliability.
- the service technician or installer by providing fast access to operating parameters before even going to site to allow for quick diagnosis of field or service issues.
- the manufacturer by allowing operating conditions to be reported to ensure proper installation and operating within parameters. Can greatly reduce warranty failures caused by poor operating conditions or improper commissioning..

The controls platform proposed in the Contribution Agreement was developed and is being provided with each unit sold. The real benefit will come long term over the system's life through reduced cost to service and operate equipment.

4.5.3 Benefit to the Environment

At the beginning of the project the greenhouse gas (GHG) savings were estimated to be 1.0 million tonnes of CO₂e between the start of the project and 2020.

The cost between gas and electricity has widened greatly since the start of the project.

Competitors that will contribute to the total number of installed systems have come forward as was forecast, but neither they nor Ecologix are reaching the sales projected because of the fuel price spread between electricity and gas. Competitors are very welcome in a new market because they help the awareness building process and help legitimize the technology to potential consumers. At present the market share for the technology is extremely small. The goal of 1 million tonnes of CO₂e will not be achieved by 2020. Our revised forecast based on current market conditions would have us reach approximately ½ million tonnes of CO₂e saved by 2025. Despite the pricing issues there is still a significant contribution being made over the next 10 year period.

4.5.4 Benefit to Canada

A successful market demonstration and product launch will give Canada a technical head start with respect to Asian, European and the US based manufacturers in an affordable, high performance centralised air source heat pump system, potentially integrated with solar assist, natural refrigerants or load shifting thermal storage to optimize electrical grid use. Competition from European products never materialised as anticipated. Japanese manufacturers that have recently entered the market are proving to be the competitive technology at present. Market trial sites we have in place will validate our competitive position. Technology demonstrations in progress with local industry partners are providing an opportunity for Canadian manufacturers to take advantage of Canadian innovations. The technology development in other nations is definitely not standing still. We face competition we did not foresee five years earlier. The market trial work done in this project helps to keep Canadian technology abreast of what is happening abroad.

4.6 Project costs

Project Title	Cold Climate Heat Pump Development and Demonstration
Project Identification Number	F11.009
Proponent	ECOLOGIX HEATING TECHNOLOGIES INC,
Total Project Cost (\$000s)	13,217,400
Total Contribution from Proponent and partners (\$000s)	8,702,400
Total CEF Contribution (\$000s)	4,500,000
Total Government Contribution (\$000s)	4,515,000

4.7 Performance Statistics for the Project

Overall Statistics and Replication Potential		
Measure	Value	Description/Assumptions
Capacity installed (kW)	1140	GHG Calculations used in this table prepared by T.Strack & Associates "CGC Calculations for Various Cities-N10". Sales forecast for Ecologix and competitor equipment provided by S. Davies
Estimated replication potential (Capacity Installed (kW x1000) for Canada	2,332	kW Year 1
	83,212	kW Year 5 (2020)
	343,920	kW Year 10 (2025)
Estimated replication potential - energy generated or saved (kWh/yr x 1000) for Canada	5,596	kWh/yr – Year 1
	199,705	kWh/yr – Year 5 (2020)
	825,397	kWh/yr – Year 10 (2025)
Estimated replication potential displaced volume of fossil fuels (koe/yr kilograms oil equivalent, for Canada	481	koe/yr – Year 1
	17172	koe/yr – Year 5 (2020)
	70,971	koe/yr – Year 10 (2025)
GHG Savings for Project	213	. (tonnes of CO2e)
GHG Savings Replication potential	692	tonnes of CO2e - Year 1
	68,476	tonnes of CO2e - Year 5 (2020)
	487,243	tonnes of CO2e - Year 10 (2025)
Estimated total job creation replication potential.	2	Job creation – Year 1 (actual)
	26	Job creation – Year 5 (2020) (estimated)
	63	Job creation – Year 10 (2025) (estimated)

4.8 Challenges and Barriers

4.8.1 Performance Standards and the definition of CCHP

Existing performance standards test at mild temperatures (+8C) and do not test at the CCHP design conditions (-20C). The industry definition of cold climate heat pump is poorly defined. So far it appears to be acceptable for manufacturers to just be operating at -20C to call their product cold climate capable. The standard allows extrapolation of the performance envelope from +8C to lower temperatures. This is creating a huge bias towards variable speed equipment that is not reflecting the reality of operation below the freezing point.

This barrier will limit the uptake of real cold climate systems and stifle innovation. Lack of a cold temperature in the test procedure skews the efficiency and performance towards variable speed heat pumps that are not tested to operate in cold temperatures.

The Federal Office of Energy Efficiency (OEE) is working on Heat Pump standards updates. There appears to be industry agreement that this issue needs correction. We expect to see changes to the standards over the next five years.

Changing the standards so that cold climate equipment can be recognized and tested to consistent relevant reference conditions will sort out a lot of the miss information that is being generated about cold weather performance and open up the industry to equipment manufacturers to build true cold climate heat pumps.

4.8.2 Public perception of traditional heat pumps

Public perception is that heat pumps don't work in cold weather. This is true for conventional heat pumps because they must be shut down at temperatures typically below -8 C to protect themselves from damage. Heat pumps designed for cold weather do not have this limitation but there is a lack of awareness that these new products exist and confusion as to what differentiates one from the other.

The largest struggle to sell CCHP equipment at this point is not competitors but the lack of awareness that the technology exists and is viable in our climate.

The field data that will be collected over the next few years will be a huge benefit in correcting this misperception.

High profile demonstrations with universities, conservation groups and industry partners peak interest in the public and educates the public on what is available.

4.8.3 Demonstrating tangible performance and savings with credibility

Control and monitoring systems are too expensive to implement on a large scale. There is a need to prove by direct measurement on local homes that the energy consumption and savings are real. Industry generated laboratory testing is just not considered credible by the public and many times is manipulated by manufacturers to create biased outcomes.

To overcome this barrier Ecologix now builds all heat pumps with a control platform that can include the monitoring. This instrumentation is installed as the unit is constructed. An internet gateway is included with each unit so the customer needs only to connect a cable to his in-home internet connection to start logging data. There are over 30 points of measurement that are capable of being

logged for each heat pump installed. This data can be recorded for all points on a minute by minute basis for an entire year. This represents savings of over a thousand dollars per home to instrument a comprehensive data logging system in the field. This system opens up this information to homeowners and service techs for their own use in managing efficiency and operation of the system.

The homeowner no longer needs to guess if the system they paid for is working correctly. They can have a technician or the manufacturer take a look at how the system is operating without requiring a service call to the home.

5 Conclusion and Follow-up

Ecologix successfully completed the development and launched three cold climate heat pump products. Over 100 systems will be monitored for a two year window and results of the monitoring will become publically available on the Ecologix web site as it becomes available.

The technology developed is proven to be a low cost high performance system that has successfully operated over two winter seasons.

The system is different from any other heat pump system currently available. The Ecologix system not only can pull a significant amount of heat from the environment at -20C, it also provides up to 100% of the domestic hot water needs of the household at that operating condition. In summer months we also provide 100% of the domestic water heating needs of the house at extremely high COP from the waste heat that would otherwise be rejected to the outdoors in air conditioning season.

The heat pump systems are also zone capable. We can supply up to four zones of heating and cooling. That is fully integrated into the control logic of the heat pump system to optimize the energy use of the home. Some competitors have zoning available as an add-on feature that does not integrate or optimize energy use. The net result is a system that actually increased energy consumption over the year instead reducing it.

All heat pumps from Ecologix are now shipped with a control platform that is monitoring capable. Field implementation of remote monitoring for a factory configured system is achieved by simply plugging into an internet connection in the home.

5.1 Potential for Replication

Total of all cold climate heat pump sales in Canada represent less than 1% of all heating sales in 2015. With the correct incentives and market changes this can change dramatically. It is anticipated that carbon neutral technologies such as the CCHP will grow to dominate the heating market and replace furnaces over the next 25 years. This must happen if we are to honour our climate change commitments as a Nation.

The installed cost of the equipment started at \$20,000 over three years ago and is now down to approximately \$14,000 installed cost for the market trial sites.

Cold climate heat pump systems are necessarily more complex and costly to build than furnace/air conditioner combinations. We do not expect the installed cost of a CCHP system to drop below the cost of a gas furnace/AC system. We do expect to get our equipment cost down to the point where

the premium to install a CCHP over a gas furnace and AC system will be less than \$2000 within five years.

As the price comes down over the next five years, there should be a shift from fossil fuel intensive technologies like the forced air furnace to carbon neutral technologies like the cold climate heat pump.

5.2 Next Steps

Next Steps for Technology:

Ecologix is first to market in North America with an air to air heat pump system and an air to water heat pump system that can deliver over 50% of the domestic needs of a household along with up to 100% of the space heating and cooling needs.

The next generation demonstration projects have given us a number of paths to pursue for follow on development work.

The control and monitoring platform is still developing. The opportunities for this technology have not been fully explored. Low cost, full monitoring of Net Zero and low energy homes to insure compliance and aid the homeowner to drive efficiency in the home is an obvious first step. .

We will continue the development work with our Industry partners to prove the efficacy of ground storage and heat harvesting from solar collectors to reduce home energy needs. This work is still very experimental but may lead to a new product class where solar electric and thermal panels are integrated directly into the thermal heating and cooling of a home.

Next Steps for Regulatory Improvement:

We believe that the CCHP technology does not need government incentives to gain market acceptance. It is the barriers to market that need to be removed.

We understand that work is underway to update CSA / ANSI heat pump standards to include weather conditions consistent with the Canadian climate. We will monitor and participate where we can to aid in implementation and adoption of these new standards.

At present heat pump performance standards greatly overstate the performance in cold weather operation by allowing extrapolation of conditions from warm weather tests.

Climate change legislation that will create a preference to low carbon intensive home heating options and correct the price imbalance between natural gas and electricity will spur growth in this market sector. The Federal Government can be the biggest influencer of the adoption of cold climate heat pump technology through their effort to implement global warming reduction legislature. A carbon tax or cap & trade regime will reduce the market preference for fossil fuel solutions and improve the uptake of the cold climate heat pump and other fossil fuel neutral technologies.