

CANADIAN ONGOING AND PLANNED R&D ACTIVITIES IN HEAT PUMPING TECHNOLOGIES

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Abstract: In Canada targeted R&D activities in the area of heat pumping technologies have been conducted under separate but complementary programs operated mostly by laboratories and research centers located in government departments, universities, and power utilities, supplemented by studies and software development produced by independent research consultants. The ongoing R&D related effort is now focused on areas of technology that are relevant to Canada, especially applications in refrigeration and ground source heat pump installations. This paper presents an update of the most important ongoing and planned Canadian R&D activities in heat pumping technologies.

Key words: *research and development, heat pump, refrigeration, energy efficiency, GHG emissions*

1 INTRODUCTION

Canadian R&D activities in heat pumping technologies have been conducted under separate but complementary programs operated mostly by laboratories and research centers located in government departments, universities, and power utilities. The knowledge developed by these organizations has been deployed in different ways to collaborating partners/clients. The participation in more than 15 international joint research projects (Annexes) operated by the International Energy Agency (IEA) Heat Pump Programme over the past 20 years has also allowed Canada to consistently share R&D information on heat pumping technology. The results obtained and information gathered from these activities have provided a comprehensive source of knowledge and a wealth of experience to draw upon. Based on this solid foundation the ongoing R&D related effort is focused on areas of technology that are relevant to Canada, especially applications in refrigeration and ground source heat pump installations.

A major R&D program in Heating, Ventilation, Air Conditioning & Refrigeration (HVAC&R) systems has been focused mainly on supermarket and ice rinks. These buildings offer favourable contexts to the establishment of energy efficient technologies and practices. In both cases the integration of the HVAC&R systems as well as the adoption of secondary loops (brines, CO₂) on the hot and cold sides of the refrigeration system can drastically reduce the energy consumption and greenhouse gas (GHG) emissions. Moreover, the refrigeration system offers the opportunity to be better adapted to the Canadian climate, thus resulting in substantial energy savings.

The majority of the work on heat pumps has been concentrated on ground source and industrial heat pump applications. Ground Source Heat Pump (GSHP) system is a rational technology choice for space heating and cooling in Canada, given the seasonal temperature variations and the country's predominately higher heating load. However, its market penetration has been very low so far, impeded primarily by the often-higher initial installation costs and a lack of awareness

of the benefits of the technology. Work continues to address some of these barriers by developing innovative technologies, improved design techniques, better models for heat exchanger sizing, as well as increased monitoring of new installations to optimize performance.

Industries such as pulp and paper and petrochemicals reject large quantities of waste heat that can be upgraded by the use of heat pumps. The integration of compression, absorption and ejector heat pumps to industrial processes as well as their combination with cogeneration units (trigeneration) offer several opportunities for obtaining significant energy efficiency improvements and GHG emission reductions. These issues have been addressed by a number of research activities in Canada, including the works conducted by the NSERC (National Science and Engineering Research Council of Canada) chair in industrial energy efficiency, which was established in 2006.

Some research activities in Canada have been focused on the development of emerging technologies like magnetic refrigeration and ejector heat pumping systems. These systems are likely the least common among the heat pumping technologies. Very little research has been conducted in this field and their application is still quite rare. This is very likely due to the fact that the fundamental mechanisms of their operation are not yet well understood and also to their perceived low efficiency. Nevertheless they present several advantages and there is considerable room for improvement since progress in modeling and simulation, the availability of Computer Fluid Dynamics (CFD) assisted tools and the development of new materials have made possible to address their main drawbacks.

2 HVAC AND REFRIGERATION (HVAC&R)

The R&D work in HVAC&R has been focused mainly on supermarkets and ice rinks. These buildings are very energy intensive (500 – 1000 kWh/m²/year) and have a significant impact on global warming (the total GHG emissions of both supermarkets and ice rinks in Canada represent about 6 Mt CO₂-eq). Furthermore supermarkets and ice rinks offer similar contexts, favourable to the establishment of energy efficient technologies and practices. Besides being very energy intensive, they present zones that are simultaneously cooled and heated, and can be heated through the recovery of the thermal energy released by the refrigeration system. Moreover, the refrigeration system contains high charges of refrigerant and offers the opportunity to be better adapted to the Canadian climate, thus resulting in substantial energy savings.

Most of the research work on supermarkets has been undertaken by CETC-Varennes and the Laboratoire des technologies de l'énergie (LTE) of Hydro-Québec. Both centers have established R&D and Deployment programs in refrigeration in order to develop scientific knowledge and innovative technologies, to increase expertise in refrigeration and to support the deployment activities. The exchange of information between both organizations in the refrigeration field has been facilitated by their participation in the IEA HPP Annex 26 (Advanced Supermarket Refrigeration/ Heat Recovery Systems) as well as in the IEA HPP Annex 31 (Advanced Modeling and Tools for Analysis of Energy Use in Supermarkets Systems). They also participate in the NSERC (National Science and Engineering Research Council of Canada) chair in industrial energy efficiency. This chair was established in 2006 and is coordinated by the University of Sherbrooke in collaboration with LTE/Hydro-Québec, Alcan and CTEC-Varennes.

The main Canadian HVAC&R research activities have been focused on strategies such as the adoption of secondary loops on the hot (condenser) and cold (evaporator) sides of the

refrigeration system, on new practices in refrigeration and on the integration of HVAC&R systems. These concepts can drastically reduce the energy consumption as well as the charge and leaks of refrigerant in supermarkets and ice rinks.

As per the demonstration activities, several showcases on ice rinks and supermarkets - including a 10.000 m² store with secondary loops on the hot and cold sides of the refrigeration system (Giguère et al. 2005) - have been carried out by both research centers. The main project common characteristics are the adoption of energy efficient and environmentally sound technologies and the integration of the HVAC&R systems (thermo-frigo-pump).

2.1 Secondary Loops

The R&D work on secondary loops in Canada has been carried out mostly by CETC-Varennes. The objective of this research is to study the use of brines and CO₂ secondary loops on the cold (evaporator) and hot (condenser) sides of the refrigeration system for applications in supermarkets and ice rinks. Applications to refrigerated warehouses and industrial processes are also being investigated.

With increased concerns about the impact of refrigerant leakage on global warming, new supermarket refrigeration system configurations requiring significantly less refrigerant charge are being considered. Most of the cold secondary loops currently found in supermarkets use brines or propylene glycol as a fluid. The drawback of the use of these fluids is the high energy consumed by the circulation pumps as well as the cost and space taken by the piping. The adoption of phase changing fluids like CO₂ and ice slurries in the cold secondary loops can help overcome these weaknesses due to their high energy density.

Design and simulation models for evaporators, condensers and heat exchanger operating with CO₂ have been developed (Ouzzane and Aidoun 2005) and a CO₂ secondary loop test bench has been built. Simulations and tests in the presence of frost growth in the evaporator are also being performed. This test bench permitted the collection of an extensive set of data, as well as model validation and expertise development on the use and behaviour of this fluid as a natural, environment friendly alternative to the currently encountered fluids and brines in the refrigeration industry (Poirier et al. 2006; Ouzzane and Aidoun 2007; Poirier et al. 2008).

Secondary loops on the hot side facilitate the integration of HVAC&R systems. In this strategy, the energy released by the refrigeration system (condenser) is used to heat the building and for domestic hot water. This concept can drastically reduce the total energy consumption of the building during heating seasons. Several studies in order to optimize this strategy have been performed and a number of ice rink and supermarket showcases have been realized.

2.2 New Practices in Refrigeration

Most of the refrigeration systems used in commercial buildings in Canada are not optimized for the Canadian climate. These systems work at an almost constant condensing temperature all over the year and do not take advantage of the available (and free) cold.

An instrumented refrigeration test bench has been designed and built to evaluate new refrigeration technologies (Ouzzane et al. 2003) and to adapt them to Canadian climatic conditions. A detailed simulation model of the test bench has also been developed and validated. The research is focused on the development of new components and control strategies aimed at the reduction of the energy consumption, as well as the improvement of the

capacity and reliability of the refrigeration systems. The performance of a system that works at a wide range of condensing temperatures and is therefore capable of working at low condensing temperatures under cold weather has already been evaluated and improved (Ouzzane et al. 2005). The test bench has been also used for the evaluation and optimization of other new refrigeration technologies such as: the integration of an ejector to the refrigeration system, compact heat exchangers, superheat sensor, liquid sub-cooling, flooded and overfeed evaporators and natural refrigerants.

2.3 Integration of HVAC and Refrigeration Systems

The integration of HVAC&R is an efficient strategy to reduce the energy consumption in ice rinks and supermarkets. Nevertheless, their design and operation are very complex due to the strong interconnection between these thermodynamic systems and the building envelope. Therefore this strategy will not provide its potential benefits without detailed and accurate simulation and design optimization tools that take into account the full complexities presented by the interconnection of HVAC and refrigeration systems as well as the building envelope. The main activities in this area have been focused on the development and validation of simulation and design tools for ice rink and supermarkets.

At first two ice rink simulation tools have been developed: a DOE 2.1 energy analysis model and a 2D CFD model. In order to develop the DOE 2.1 model for ice rinks, some changes had to be introduced in the original DOE 2.1 code and new algorithms have been incorporated to it: ice load, chiller and pumps, heat recovery, domestic hot water, hot and cold storage systems. The model was validated with data from an ice skating ice rink commonly found in Québec. Eight fact sheets presenting the influence of new practices and technologies on the building overall energy consumption were developed, based on simulations carried out for a typical ice rink. A 2-D steady state Computing Fluid Dynamics (CFD) model (PHOENICS) aimed at understanding and optimizing thermal and air flows in ice rinks have been developed and validated. The validation was carried out with data from field measurements performed at an ice rink in the Montreal region. One of the major scientific contributions of this activity is the detailed radiation module that has been developed and integrated to the CFD code. A sensitivity analysis has been conducted with the last version of the model and new fact sheets and energy efficiency guidelines are being developed (Bellache et al. 2005).

In order to facilitate the progress in this field a collaborative partnership between CETC-Varennes R&D and the Universities of Sherbrooke (THERMAUS group) and Concordia (Building Department) has been established. These three institutions established a collaborative partnership for R&D activities seven years ago and have since been working together on research projects on ice rinks. Among these collaborative activities we can mention a research contract awarded by ASHRAE (Sunyé et al. 2007) to develop and verify methods for determining ice sheet cooling loads as well a 3 year funding for a research project (Development of tools for the design and operation of ice rink HVAC&R systems) granted by NSERC (Natural Sciences and Engineering Research Council of Canada).

The ASHRAE project was finalized recently and was aimed at Developing and Verifying Methods for Determining Ice Sheet Cooling Loads. This research enabled the development of technical and scientific knowledge needed to improve the energy efficiency of North-American ice rinks and to reduce their GHG emissions (Bellache et al. 2005 and 2006). The main objectives were to:

- Develop a two-dimensional transient CFD model capable of simulating ice sheet heat transfer with transient operating conditions, for several typical floors and cooling system designs.
- Incorporate into the model the ability to predict average daily ice sheet cooling loads.
- Conduct continuous, long-term measurements of appropriate parameters to verify and calibrate the numerical model on at least two differently arranged ice sheet cooling systems (Ouzzane et al. 2006).
- Perform sensitivity analyses with the model to determine how the cooling load is affected by changes in design and operating characteristics including ice thickness, sub-floor insulation, ice surface temperature, ceiling emissivity, air motion, air temperature and enthalpy, and coolant temperature.

A well instrumented ice rink prototype has also been built in order to help validate the models and to get a better understanding of the heat and mass transfer phenomena that take place between the air and the ice. A 3-D CFD model was developed for this test bench.

Several experimental and simulation activities are also being carried out, including the development of a 3D transient zonal model using TRNSYS (Daoud 2007) and a portable experimental unit for data acquisition in ice rinks and supermarkets.

A considerable amount of effort has been applied to the development of supermarket simulation tools also. CETC-Varennes and LTE/Hydro-Québec have actively participated in the IEA HPP Annex 26 (Advanced Supermarket Refrigeration/ Heat Recovery Systems) as well as in the ongoing IEA HPP Annex 31 (Advanced Modeling and Tools for Analysis of Energy Use in Supermarkets Systems) where Canada is the vice-operating agent.

3 HEAT PUMPS

The majority of the work on heat pumps in Canada has been focused on ground source and industrial heat pump applications.

3.1 Ground Source Heat Pumps

Ground Source Heat Pumps (GSHP) are one of the fastest growing applications of renewable energy in the world, with annual increases of 10% in about 30 countries over the past 10 years. However, even though the worldwide market diffusion of GSHP systems is growing, it has been limited so far, and Canada, compared to European countries and the United States is lagging behind.

According to a survey conducted in 2004-2006 by the Canadian GeoExchange Coalition, three major market barriers are slowing the growth of the ground source heat pump market: (1) High first cost; (2) Lack of market infrastructure; and (3) Lack of consumer awareness and confidence. Other barriers were also identified in other market studies: (4) System designs have not been standardized and actual system performance has sometimes fallen short of its promise; (5) Economies of scale are rarely exploited. A major market transformation of the industry is currently taking place, addressing the second and third barriers mentioned above.

The issue of high first cost is still very much at the forefront of the industry priorities, and there is a consensus that significant R&D efforts should be directed towards the component that is responsible for the highest proportion (30-50%) of the total acquisition and installation cost of a GSHP system: the underground heat exchanger circuit.

The R&D work in this area has been conducted so far under separate programs or projects, mostly by research groups from laboratories and research centers located in government departments, universities, and power utilities from all over Canada. Those groups continue to address important GSHP issues by developing innovative technologies, improved design techniques, better models for heat exchanger sizing, and increased monitoring of installations to optimize performance (Bernier et al. 2006, Yolova et al. 2007, Kummert et al. 2006).

The LTE/Hydro-Québec has maintained a strong activity in this area for more than 15 years. The main approach of LTE has been to contribute to the development and laboratory/in-field demonstration of the most promising and efficient technologies suited to the Canadian cold climate, mostly in collaboration with different private and public partners. Specifically:

- demonstration of residential, commercial and institutional buildings, containing open and closed-loop systems with horizontal and vertical conventional heat exchangers (schools, offices, hospitals, cinemas, hotels, restaurants)
- development of residential and small industrial/agricultural direct expansion, mono-fluid heat pumps with horizontal ground heat exchangers, radiant floor heating, hot water preheating and exhaust air heat recovery (pig nursery, greenhouse).

Current LTE/Hydro-Québec applied research projects (Minea 2005, 2007) are aimed at:

- development of a new, integrated GSHP heating and cooling system for the most common greenhouses sold in Canada (including floor heating, direct air cooling, heat recovery and seasonal energy storage)
- optimization of a vertical direct expansion (DX) ground source heat pump
- design strategies to reduce the total initial costs of geothermal systems.

3.1.1 GS2000TM Version 2.0

GS2000 is a software program developed by Caneta Research Inc. for sizing of in-ground heat exchangers for GSHP. Development work on GS2000 began in 1991, when it became clear that many existing methods for sizing resulted in oversized heat exchangers by as much as 90% (ASHRAE Transactions –NY-91-17-5). By 2000, under license to Natural Resources Canada, Caneta had distributed over 200 copies of Versions 1 and 2 to engineers and others throughout Canada and the US. The program is now freely available and can be downloaded from the Internet from the Buildings Group at Natural Resources Canada (<http://www.sbc.nrcan.gc.ca>).

3.1.2 GSHP Deployment - The Canadian GeoExchange Coalition

The Canadian GeoExchange Coalition was established in 2002. It is dedicated to the creation of a large, competitive, self-sustaining market for geothermal heating and cooling systems ("geoexchange") in both the residential and commercial HVAC markets of Canada. In this transformed market, consumers and business owners will be aware of and consider clean,

renewable geoexchange technology on par with other kinds of high-end heating and cooling systems. The Coalition has been established to achieve four primary objectives:

1. Expand the market in Canada for geoexchange products and services;
2. Facilitate business development in a way that complements the participants' core business;
3. Promote the Coalition's contribution to the Canadian economy through increased sales revenues, jobs creation, and enhanced export opportunities; and,
4. Improve environmental performance, including the reduction of greenhouse gas emissions.

The Coalition has three major sets of strategies: (1) Overcoming market barriers; (2) Serving as a vital information source; (3) Delivering value to partners and allies.

3.2 Industrial Heat Pumps

A market study carried out recently (Stricker et al. 2006) shows that the energy and emissions reduction potential associated with waste heat recovery in the Canadian industry is very large, in the order of 1680 PJ and 112.5 MT of GHG respectively. Thermal heat pumping systems are one of the most promising technologies to address the heat released by the industrial sector, since they allow to upgrade it to a higher level of temperature and re-inject useful heat into the process, to generate cooling from it, to do both simultaneously (dual cooling/heating machine) or even to perform trigeneration (cooling, heating and power) when associated with cogeneration units.

Work in this area has been conducted mostly by the Pulp and Paper Engineering Research Centre (PPERC) of the École Polytechnique de Montréal and the LTE/Hydro-Québec.

The PPERC has been investing a considerable amount of effort into the development of more efficient and compact absorption heat pump systems (Jahnke et al. 2005) as well as on their integration to industrial process and more specifically to the Pulp and Paper Industry (Costa et al. 2004). It has also established a vast network of national and international collaborations with major players in the development, implementation and use of industrial heat pumps, such as universities, research centres, chairs, governmental institutions, international organizations and private companies.

In terms of the integration of heat pumps to industries, the PPERC has been studying innovative approaches such as trigeneration (combination of a co-generator and an absorption thermotransformer to produce power, heat and cold) (Costa et al. 2005), energy efficiency eco-industrial clusters in industrial processes (by focusing on two cluster components: the mill supplying energy and the surrounding community using it) and development of methodologies such as pinch analysis in order to optimize the integration of heat pumps to industrial processes (Bakhtiari et al. 2007).

The LTE/Hydro-Québec has been doing research on heat pumps for the residential, commercial and industrial sectors. In terms of industrial applications, it has developed and demonstrated high and low temperature heat pumps for wood drying in partnership with the Canadian wood research institute (FORINTEK CORP.), heat pump manufacturers, Canadian control companies, equipment suppliers and sawmills (Minea 2007, LeLostec et al. 2008).

4 EMERGING HEAT PUMPING TECHNOLOGIES

A significant amount of effort has been deployed in Canada in order to better understand and improve the efficiency of emerging technologies such as ejector and magnetic heat pumping systems.

4.1 Ejector Heat Pumping Systems

The use of ejector was limited until recently to the industrial sector. It has operated worldwide on low pressure steam from process heat, mainly in the pulp and paper industry. The research work in Canada is concentrated in different systems since it is aimed at heat pumping applications.

Ejectors are simple devices, with no moving parts, that play the role of a thermally driven compressor. The main difference between Thermally Driven System (TDS) and mechanical vapour compression systems (MVCS) is in the driving energy. Whereas MVCS are driven by electricity (a high quality energy), TDS are activated mainly by thermal energy. Ejectors present several advantages over other TDS such as simplicity, smaller size and lower cost. Unlike other TDS, ejectors can be activated by energy sources at a very large temperature range (energy from solar collectors; waste heat from cogeneration units; low, medium and high temperature waste heat from industrial processes, etc...). Another advantage presented by ejectors is their flexibility, since they can be used either as a thermally driven heat pumping system (single stage ejector heat pumping system) or combined with mechanical or thermally driven (absorption and adsorption) heat pumping units to form a variety of multi-stage and/or hybrid systems.

Even though ejector heat pumping systems present several advantages, very limited research has been conducted in this field. Moreover they are likely the least common among the TDS technologies and their application is still quite rare and limited mostly to industrial processes (vapour ejector). This is very likely due to the perceived low efficiency of existing ejectors. Moreover they perform well only at the (narrow) range of operating conditions for which they were designed, their design is mostly empirical and the fundamental mechanisms of their operation are not yet well understood (especially for two-phase flow ejectors).

Nevertheless there is considerable room for improvement since progress in modeling and simulation and the availability of Computer Fluid Dynamics (CFD) assisted tools have made possible to address those drawbacks. These tools have also allowed the development of ejector knowledge for heat pumping applications and new fluids. The challenge consists in developing the knowledge to properly design the ejector for specific configurations, capacities, temperatures, pressures and fluids.

Most of this work in Canada has been carried out by CETC-Varennes that has been investing a considerable amount of effort into the development of new ejector heat pumping systems. The work focus on the development of design and simulation models for ejector component and systems (Bartosiewicz et al. 2005, 2006; Scott et al. 2008; Aidoun et al. 2004), experimental testing, the integration of ejectors to heat pumping cycles and cogeneration units and the deployment of the knowledge developed. The target sectors are industrial processes that need cooling, refrigeration or heat upgrading such as food process plants, plastics, petrochemicals, as well as buildings (integration of ejectors to cogeneration or solar systems).

The R&D efforts have been focused mostly on one-phase flow ejectors. This is due to the fact that the fundamental mechanisms of their operation are less complex than the ones of two-

phase flow ejectors. Nevertheless due to the high potential presented by two-phase flow ejectors, additional efforts have been directed towards the development of this technology and a first two-phase flow ejector model and test bench are on the works.

The work is leveraged by national and international collaborations, including the participation in the NSERC industrial energy efficiency chair and in the IEA HPP annex 34 (Thermally Driven Heat Pumps).

4.2 Magnetic Heat pumping Systems

Magnetic heat pumping (MHP) systems use the magnetic-caloric effect of certain magnetic materials in order to exchange heat between a hot source and cold source. This is accomplished by the temperature change upon adiabatic magnetization/demagnetization of the magnetic refrigerant. The main difference between compression heat pumping (CHP) technologies and MHP systems lies in the cycle efficiency. In the CHP systems, compressors and expansion engines are major sources of inefficiencies. In contrast, there is virtually no energy loss during adiabatic magnetization/demagnetization cycles in MR, leading to potential efficiencies up to 50% higher than for conventional CHP. MR systems are also more compact, more reliable (since they employ solid working materials instead of a gas), and present less components. The availability of new simulation tools and the development of new materials have open new opportunities to the development of MR for application in refrigeration and heat pumps.

Most of the research in this field in Canada has been carried out by the Institut de recherche sur l'hydrogène (IRH) and the LTE/Hydro-Québec. Whereas the LTE/Hydro-Québec is developing this technology for general heat pumping applications (Bouchard et al. 2005), the IRH is targeting the development of more efficient and cost-effective small-scale hydrogen liquefiers (Richard et al. 2004; Zhuo et al. 2003). The work is focused mainly on new materials (identification, preparation and characterization) as well as on system modeling and simulation. Experimental analyses have been carried out on test benches.

5 RETSCREEN INTERNATIONAL CLEAN ENERGY PROJECT ANALYSIS SOFTWARE

The RETScreen International Clean Energy Decision Support Centre seeks to build the capacity of planners, decision-makers and industry to implement renewable energy and energy efficiency projects. This objective is achieved by: developing decision-making tools (e.g. RETScreen Software) that reduce the cost of pre-feasibility studies; disseminating knowledge to help people make better decisions; and by training people to better analyse the technical and financial viability of possible projects.

The RETScreen International Clean Energy Project Analysis Software is a unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used worldwide to evaluate the energy production and savings, life-cycle costs, emission reductions, financial viability and risk for various types of energy efficient and renewable energy technologies (RETs).

The modules that have been developed for heat-pumping applications are: Ground-Source Heat Pumps Project Model, Combined Heat and Power (CHP) Project Model and Energy Efficiency Project Analysis for Supermarkets and Arenas Module.

5.1 Ground-Source Heat Pump Project Model

This model can be used world-wide to easily evaluate the energy savings, life-cycle costs and greenhouse gas emissions reduction for the heating and/or cooling of residential, commercial, institutional and industrial buildings. The model can be used to evaluate both retrofit and new construction projects using either ground-coupled (horizontal and vertical closed-loop) or groundwater heat pumps.

5.2 Combined Heat and Power (CHP) Project Model

This model includes various heat pump technologies and can be used to evaluate any one or a combination of the following applications: power; heating; cooling; single buildings or multiple buildings; industrial processes; communities; district heating and district cooling. Furthermore, it permits analysis with a wide range of renewable and non-renewable fuels (which can be used in parallel), including landfill gas; biomass; bagasse; biodiesel; hydrogen; natural gas; oil/diesel; coal; municipal waste, etc. Finally, these fuels can be evaluated using multiple types of power, heating and/or cooling equipment, including reciprocating engines; gas turbines; gas turbine combined cycle; steam turbines; geothermal; fuel cells; micro turbines; boilers, compressors, absorption chillers, heat pumps, etc., all working under various operating conditions.

5.3 Energy Efficiency Project Analysis for Supermarkets and Arenas Module

The Refrigeration and RETScreen program teams at CETC-Varennes have collaborated to develop the RETScreen model for assessing the viability of energy efficient arena (i.e. skating & curling rinks) and supermarket projects, with a focus on heat recovery from refrigeration systems. The Beta version of this decision-support tool is on-line since January 2007 and can be downloaded from the RETScreen Website under the "Arenas & Supermarkets" heading.

This tool was funded by the Refrigeration Action Program for Buildings (RAPB), the CETC-Varennes deployment program targeted to reducing energy consumption and greenhouse gas emissions of ice and curling rinks and supermarkets. This pre-feasibility study tool incorporates standard RETScreen capabilities and features. It aims at supporting decision makers, building owners, managers, and consultants of these sectors to evaluate different options for the implementation of new or retrofit HVAC&R systems. The RETScreen arena model is available. The model for evaluating energy efficient supermarket projects is currently under development.

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