A REFRIGERATION DEPLOYMENT PROGRAM ADDRESSING CANADIAN SUPERMARKETS, ICE AND CURLING RINKS TO REDUCE THEIR GHG EMISSIONS AND ENERGY CONSUMPTION

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Abstract: A national deployment program in refrigeration aimed at reducing significantly greenhouse gas emissions and energy consumption in Canadian commercial and institutional buildings such as supermarkets, ice and curling rinks has been carried out by Natural Resources Canada. Savings are obtained with innovative designs that reduce drastically the refrigerant losses, recover the rejected heat and adapt operations to the Canadian climate. This set of technologies and practices is being promoted under the name CoolSolution. The program includes information, capacity building, demonstration and partnership activities. A labelling score has been developed and used to drive an incentive program in order to remove the first cost barrier of these innovative technologies.

Keywords: Refrigeration, supermarkets, ice rinks, greenhouse gas emission reduction, energy efficiency, technology adoption

1 INTRODUCTION

Change is always a challenge in construction techniques for the commercial and institutional building market. This challenge is even higher when one is trying to introduce innovative design best practices and system optimization strategy rather than a new generation of equipment. Bridging the gap of the so-called “valley-of-death” between the development and the adoption of innovative technologies is essential. This step is critical as it requires not only financial support but also significant technical and educative support. This is what Natural Resources Canada has undertaken in the field of refrigeration addressing first the applications in supermarkets, and ice and curling rinks in Canada. (Hosatte and Sunyé 2005; NRCan Refrigeration 2008)

The proposed improvements are focused on ways to integrate HVAC and refrigeration systems rather than introducing a new equipment. It is proposed to operate systems based on the three following elements as illustrated in Figure 1.

- Distribute cold and heat in buildings by using environmentally-friendly fluids in secondary loops rather than synthetic refrigerants. Leakage of synthetic refrigerants is 1,500 to 4,000 times more detrimental than carbon dioxide (CO_2) by emitted kilogram;

- Recover the heat rejected by refrigeration systems for space air and feed water heating in the targeted buildings (NRCan Val-des-Monts 2008; NRCan Repentigny 2008). It is possible to meet almost all heating needs with rejected heat. Most of the energy savings will be achieved by recycling the heat that refrigeration systems normally reject into the atmosphere . This recovered energy replaces electricity, natural gas, or fuel oil, which are traditionally used. The limits to the use of rejected heat are mainly due to technical feasibility or to the profitability of the investments.

- Optimize the operation of refrigeration equipment to take advantage of the Canadian climate in particular, of our cold winters. By optimizing the operation of refrigeration systems in a way that takes advantage of the Canadian cold climate (“Floating head pressure” or variable condensation pressure), one obtains further energy savings. As refrigeration systems are generally conceived for constant heat rejection temperature, they do not include control mechanisms to adjust for the great variations in temperature that we have in Canada. For example, in the Montreal area, electric power required by refrigeration equipment can be reduced by approximately 40% during 5 000 hours per year, by taking full benefit of external cold temperatures to cool the equipment. Additional control devices or strategies are necessary to achieve these savings.

Note that heat recovery and floating-head pressure strategies may be in competition, and must be optimized according to local climatic conditions and heating requirements.

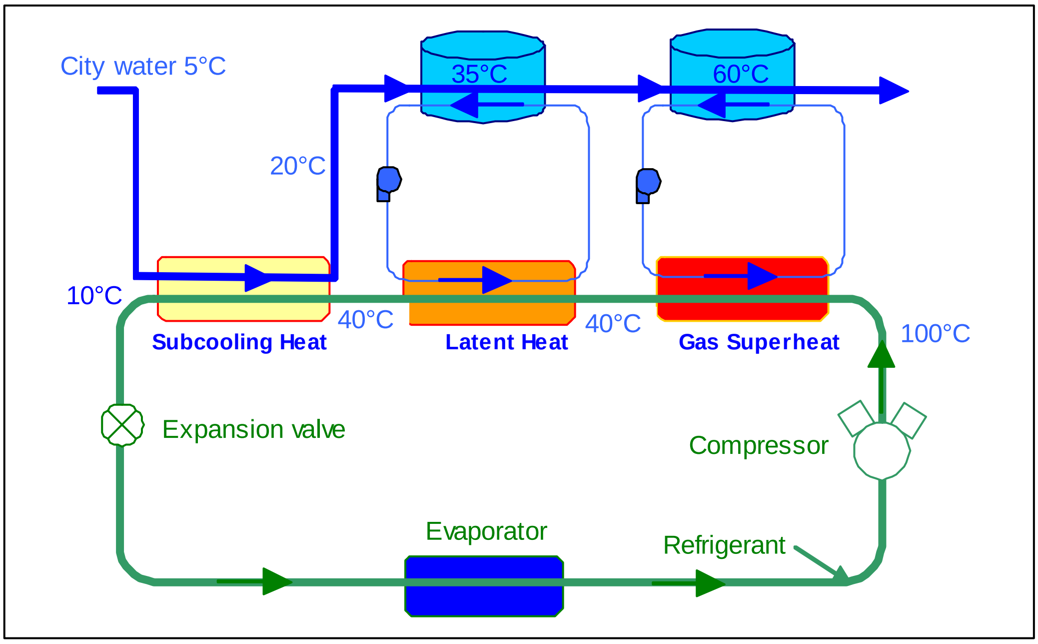

Figure 1: Schematic of the technologies and practices proposed

2 CONTEXT

Supermarkets, ice rinks and curling rinks where regrouped in the same refrigeration program because they deal with the same technology issues and have similar potential energy savings.

- They are energy intensive buildings (500 to 1000 kWh/m^2 /year). Supermarkets are the most energy intensive buildings of the commercial sector with an average energy consumption of 800kWh/m^2 /year;

- They offer high potential for the reduction of GHG emissions for these sectors. The reductions are both direct, from the reduction of fossil fuel consumption and synthetic refrigerant leaks, and indirect from electricity savings;

- They are important users of synthetic refrigerants. The average supermarket in Canada, for example, contains 1 000 kg of synthetic refrigerant (these refrigerants produce per kilogram, according to their type, a greenhouse gas effect that is 1 500 to 4 000 times greater than CO_2 for each emitted kilogram;

- They are subject to important refrigerant leaks. In conventional applications, commercial refrigeration systems are designed in such a manner that refrigerant leaks are significant (approximately 25% of the refrigerant charge is lost each year); (Clodic 1998; IPCC/TEAP 2005; Johnson 1999; Sand et al. 1997)

- They have simultaneous important refrigeration and heating requirements. In these buildings the refrigeration process represents 40 to 50% of the building's total energy consumption. Some spaces even require both heating and cooling. This is the case for instance around refrigerated cabinets in supermarkets and in the bleacher area in ice rinks;

- They have a positive energy balance (exothermic buildings). The refrigeration system rejects to the atmosphere more heat than it is necessary to fulfill the building's space and hot water heating needs. Because of this context, the potential for heat recovery is huge;

- There systems are generally designed to operate at constant heat rejection temperature and do not take benefit of the cold Canadian climate. Substantial energy savings could resulted from variable heat rejection temperature operation.

2.1 Supermarkets

There are approximately 15 millions m^2 of supermarket area in Canada that have a mechanical room, and therefore can use the proposed technologies. Their refrigeration systems use large quantities of synthetic refrigerant (roughly 1 000 kg of HCFC or HFC per store), which circulates under pressure, from the mechanical room to the refrigerated display cases, through kilometers of piping with hundreds of brazed joints responsible for leaks. The supermarket sector has, for the past few years, known exceptional growth. Corporate reorganization of the leading banners, followed by massive investments in new constructions and major renovations, offer unique opportunities for intervention in the short and medium term. A supermarket is renovated, on average, every seven years. (Ducker Worldwide 2004)

2.2 Ice and curling rinks

Across Canada, there are 2 431 ice rinks and 1 047 curling rinks that use artificial ice, maintained by a refrigeration system. Many of these are in aging buildings, the average age of which is more than 25 years. An estimated 30% to 40% of both ice rinks and curling rinks are operating beyond their projected lifespan. Because many of these facilities will be replaced or upgraded in the next years, there is a window of opportunity to introduce the most efficient technologies in these projects. These facilities will be in operation for the next 30 years. It is therefore important to have them adopt sustainable technologies. Ice rinks are generally the property of municipalities. They usually are the municipal buildings with the greatest energy expenditure, an average of over $100,000 per year. Rising energy costs threaten the survival of some ice and curling rinks, especially in small municipalities.

Even if they are smaller buildings, curling rinks are comparable to ice rinks and have very similar energy characteristics. The pool of curling rinks in Canada also presents aspects of aging similar to ice rinks. There are fewer curling rinks than ice rinks, but they consume nearly as much energy as ice rinks per unit area. In addition, the owners of curling rinks are generally non-profit organizations. Their interest in minimizing the energy cost of their establishments is quite strong, which makes them highly interested parties. (Marbek Resource Consultants 2005)

3 BENEFITS/ IMPACTS

The benefits of implementing these technologies are significant. They include:

- Outstanding reduction of greenhouse gas emissions (4.0 Mt-eq./y potential); (NRCan Refrigeration 2008)
- Savings of electricity and fossil energy equal to 1,700 GWh-eq./y (potential) representing a value of $120 million per year; (NRCan Refrigeration 2008)
- Operation cost savings for the targeted clients;
- In supermarkets, the use of secondary fluids allows a better control of the temperature (i.e. increased temperature stability) in the refrigerated cabinets and therefore a longer shelf life for produce;
- For ice rinks, the secondary fluid technology allows slab heating of bleachers for spectator comfort and makeup air heating for better indoor air quality at no extra operating cost. This is an important feature particularly in small municipalities;
- Creation of jobs around specialized contractors;
- Creation of favorable conditions for the development of a Canadian refrigeration equipment industry;
- Increase of Canadian competencies in refrigeration, particularly for consulting engineers;
- Precautionary measures towards international regulation of refrigerants;
- Potential to export Canadian know-how to international markets;
- Possibility of expanding the scope of this program to include refrigerated warehouses and industrial applications of refrigeration.

4 BARRIERS TO TECHNOLOGY ADOPTION

A number of barriers had to be addressed to succeed in transforming the way refrigeration is done in Canada:

- **Higher first cost:** the payback period is often outside the range that municipalities can afford, especially small towns. In the commercial sector, even if the payback period is shorter due to the size of the installation, it remains too long for the private sector. It is therefore proposed to offer incentives to bring the payback time to acceptable levels.
- **ROI assessment approach:** For new buildings as well as for major retrofits, investment decisions are generally made independently of the building energy and maintenance costs. Payback period analysis does not take in account savings that are

occurring over the payback term. This barrier can be overcome only through the promotion and adoption of total cost analysis over the life cycle (life cycle cost analysis) in making investment decisions.

- **Replacement of synthetic refrigerants:** The refrigeration sector is faced with the replacement of synthetic. It is important to provide this sector with solutions that address both the energy and environmental issues. This program is reducing synthetic refrigerants witch are regulated internationally by the Montreal Protocol. This issue is becoming more important with the recent decisions taken at the 2007 Montreal Protocol Conference. (Hosatte 2007; Coulomb 2007)

- **Market structure:** In Canada, refrigeration is considered a specialty and requires particular competencies. Non-refrigeration technicians generally do not know the physical principles of design and operation of refrigeration systems, and generally only deal with heating issues. This situation is reinforced by regulations that, for safety reasons, protect the domain of refrigeration technicians against competition from other trade associations. Thus, the integration of refrigeration and heating is complex; refrigeration technicians and heating specialists each exercising their specialties in silos.

  These same barriers exist between the professionals (consulting engineers, equipment suppliers, installers) who work with the design and construction of these buildings. The equipment suppliers deal often directly with customers, which perpetuates the barriers between them and heating specialists.

- **Procurement procedures:** Usually, ice rinks are municipally owned and curling rinks are usually owned by not-profit organization financially supported by local governments. In this cluster of the market, public call for tenders is the mandatory rule for procurement. This also applies to professional services tenders. In this environment, higher initial cost for a new technology is a major barrier.

- **Lack of knowledge to implement this technology:** There is a need for capacity building activities (information, training and technical support) to transfer the knowledge required to ensure the success of the uptake of this new technology. The owners and managers of these buildings, with whom rests the decision to adopt these technologies, are not aware of these new technologies nor their benefits. According to the application the technological choices made today have a lifespan of 10 to 25 years, the next possible date for reevaluating a refrigeration system is far in the future.

5 STRATEGY - ACHIEVEMENTS

Market transformation of this magnitude cannot be done by the industry alone. There is a need to target all stakeholders and provide them with the appropriate training tools: decision-making process, pre-feasibility and feasibility studies, design, and operation manuals. , The first implementations must also have technical and financial support. Building codes and standard must support the new technologies.

In particular a bridge between the different technical stakeholders is essential in achieving integration of HVAC and refrigeration systems. Refrigeration technicians and heating specialists must work as a team to carry out a project to guarantee its success. This is the first barrier to overcome.

Since the barriers to implementation are the same, the intervention strategy is essentially the same in each of the three types of applications. The implemented strategy consisted of the following activities:

- Naming and labeling
- Partnerships
- Capacity building for
    - Decision-makers
    - Consulting engineers
    - Operators
- Demonstration projects
- Incentives
- Technical support

5.1 Naming and labelling

The technologies proposed have been designated under the name "CoolSolution"[1] in order to facilitate the promotion these innovative technologies and practices. CoolSolution is defined as:

COOLSOLUTION

- Integrated Refrigeration, Heating, Ventilation and Air Conditioning systems to allow maximum recovery of the heat released by the refrigeration system for the building purposes and other purposes eventually

- Adaptation to Canadian climatic conditions (by floating head pressure or variable condensing temperature) with optimization of the control strategies

- Utilization of natural refrigerants, or utilization of packaged refrigeration systems with secondary loops, in order to reduce the synthetic refrigerant charges

Score scale

The scoring system is a fundamental aspect of the program. It is an attractive communication tool that contributes to the green communication strategy of the Ice Rinks – Supermarkets. It is above all an efficient tool to the owner of the infrastructure; it helps him to assess the value content of the project submitted by his architect / engineering consultant.

In buildings like supermarkets, ice and curling rinks, where the refrigeration process represents a significant part of the energy consumption, the common energy intensity index in kWh/m^2 is not the best indicator. The nominal refrigeration capacity should also be considered for the energy intensity index equation. The CoolSolution score has been developed to provide a simple way to rate a refrigeration facility based on the three basics criteria already listed.

The CoolSolution score is the weighted sum of three subscores: the heat recovery score plus the climate score plus the refrigerant score. The heat recovery score is proportional to the ratio of the heat recovery capacity and the heat rejection capacity of the refrigeration system. The climate score is proportional to the minimum design condensing temperature, the average environmental temperature and the heat recovery score. The refrigerant score is

[1] CoolSolution is an official mark of Natural Resources Canada

proportional to the reduction of the equivalent CO_2 emission of the actual refrigerant charge compared to the refrigerant reference charge of R-22. Ammonia will have a score of 100% because the equivalent CO_2 emission is negligible compared to a synthetic refrigerant.

Figure 2 presents an example of the labelling that has been developed for characterizing ice rink performance. A facility that gets a score higher than 50% is “CoolSolution” compliant.

Figure 2: CoolSolution Labelling for ice rinks

5.2 Partnerships

This initiative has been delivered across Canada in collaboration with provincial governments, utilities, and associations. The strong partnership put in place helped create synergies and leverage activities. The manufacturing industry was involved to provide the appropriate equipment and systems.

5.3 Capacity building

This activity has included the following: awareness and training workshops and material developed specifically for each category of stakeholders: decision-makers, engineering consultants and operators

- **Increase decision-makers’ awareness**

  The purpose was to ensure that persons such as corporate managers who take the decisions about new constructions and are instrumental in deciding the level of participation in environmental protection, are informed about these innovative technologies. Efforts were also targeted at appraisers who generally have a technical background and evaluate a project relevance. They strongly influence the decision to adopt or not the proposed technologies.

- **Build the capacity of designers, consulting engineers and system operators**

  It is important that the developer's consulting engineer or engineering department is offered technical support through design and analysis tools, accompanied by training courses. Equipment suppliers and installers are also part of this group.

5.4 Demonstration projects

Several demonstration projects have been performed across Canada, in both supermarket and ice rink applications. Many of them have been largely instrumented in order to carry out detailed performance analysis. The projects identified practical barriers to implementation. They showed that performance could be achieved in different provinces and localities where codes and standards, climate and building practices differ. Several case studies have been prepared and published. The benefits of the demonstration projects are huge in terms of visibility and credibility, and deployment of tools for the different stakeholders.

Figure 3 shows the performance obtained in a supermarket located in the Montreal area (Repentigny) (Giguère and al. 2005; NRCan Repentigny 2008). In this new store the following strategies have been implemented: secondary fluid on high and low side of the refrigeration system, space heating from heat recovery only, mechanical subcooling between medium and low temperature refrigeration systems.

Store	**TOTAL BUILDING ENERGY**				
	Energy Consumption	GHG from Electricity	Percent Diff. w. Repentigny	Energy Consumption per Unit Area	
	(kWh)	*(kT-eq. CO_2)*	*(kWh)*	*(kWh/m²)*	*(GJ/m²)*
Case 1: No Remediation	8,060,231	2.88	32.6%	826.3	3.0
Case 2: Some Remediation	7,078,402	2.53	16.5%	725.6	2.6
Case 3: Repentigny	6,078,751	2.17	0.0%	623.1	2.2
NOTES:		Repentigny Area:	9,755	m²	
		Combined Cycle Gas Turbine (CCGT):	3.575E-07	kT CO_2/kWh	
		Canada Average:	2.230E-07	kT CO_2/kWh	

Figure 3: Annual Total Building Energy Consumption

Figure 4 shows the performance obtained in an existing supermarket in the Ottawa area. The purpose of this demonstration project was to show the feasibility of implementing heat recovery in the case of an existing store. The retrofit has resulted in a 46% reduction of the supermarket's total natural gas consumption or a 61% reduction of the amount of natural gas used to provide space and water heating for the supermarket during the heating season

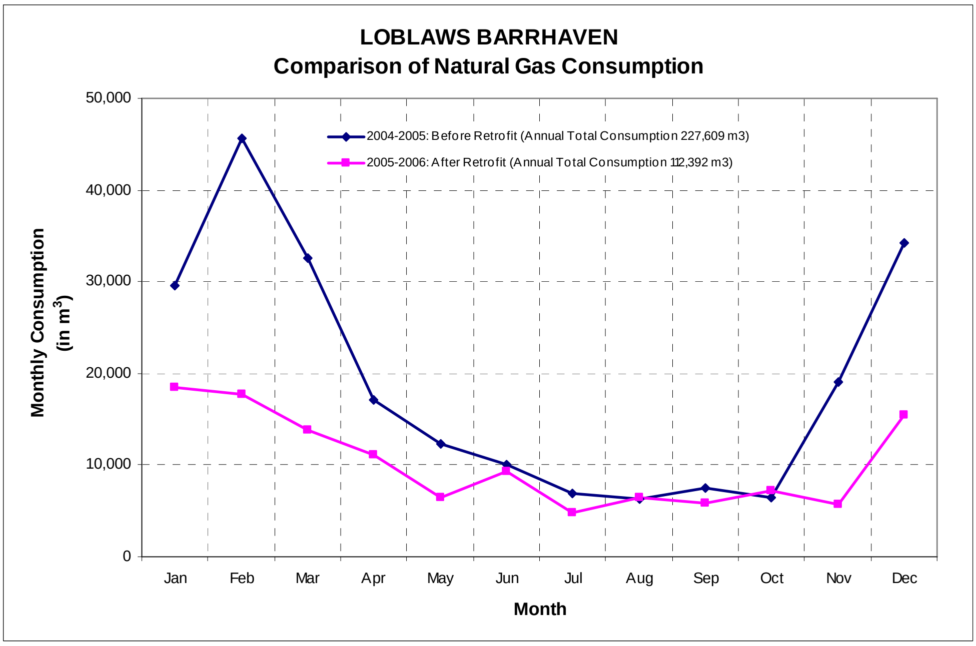

Figure 4: Monthly Natural Gas Consumption

- Figure 5 shows the annual energy performance of a new ice rink located in the province of Québec, in comparison with conventional ice rinks. The energy consumption is reduced by more than 50% compared to the average performance of these conventional ice rinks. (NRCan Val-des-Monts 2008)

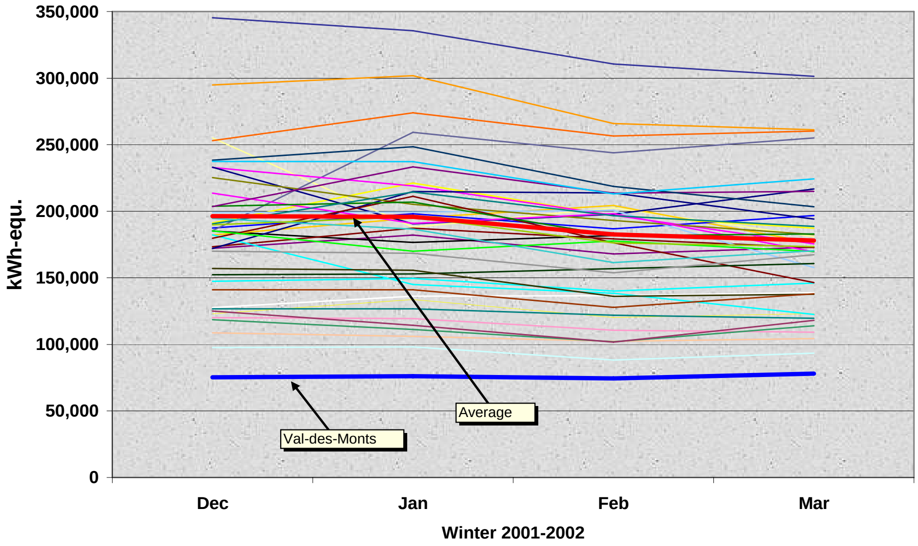

Figure 5: Monthly Energy Consumption of 44 ice rinks

5.5 Financial incentives

In order the remove the first cost barrier, an incentive was available for a four-month period for feasibility studies and implementation of CoolSolution in ice and curling rinks. This was well received. More than 25 feasibility studies and 20 implementations have been funded. The financial contribution was calculated using a direct correlation from the CoolSolution score. A minimum score of 50% was required for eligibility. The incentive was proportional to the ice surface. The incentive was between $ 25,000 and $ 60,000 for a standard single-pad and up to $ 95,000 for a multi-pad rink.

5.6 Technical support

Technical expertise was available during the program to provide support for the first projects at the different steps: prefeasibility study up to the system commissioning and operation. Too often, projects are abandoned because of some failures during this long process or because the final results do not meet the expectancies. This often results in jeopardizing and eventually killing the technologies proposed, at least for some period of time.

6 CONCLUSION

A market transformation in refrigeration has been initiated in Canada. Initially targeted at supermarkets, and ice and curling rinks, this transformation was the result of a program carried out by Natural Resources Canada. The program, built on strong partnerships with provincial organizations, associations, and utilities has been successful in bringing together the different stakeholders in order to implement the technologies and practices designed by CoolSolution. The manufacturing industry has also been involved. The energy savings obtained are in the range of 25 to 50% for ice rinks and 20 to 25% for supermarkets.These are quite impressive numbers. However, the first cost of CoolSolution is in many cases still too high, therefore financial incentives are still required. It is expected that with the increasing number of applications the costs will be reduced making it economically viable and therefore becoming the “standard” technology. One of the lessons learned is that innovative technologies and practices requiring high technical skills cannot be transferred without strong technical support. Therefore capacity building activities and access to expertise are key elements to success.

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