The Association des Arénas du Québec
presents

Within the framework of the Programme d'intervention en refrigération dans les arénas du Québec (PIRAQ)

Technical Fact Sheets on the Impacts of New Energy Efficiency Technologies and Measures in Ice Rinks

Developed and produced by

Ressources naturelles Canada Natural Resources Canada

Canada

Fact sheets on the impacts of energy efficiency new technologies and measures in arenas

An initiative of the Programme d'intervention en refrigeration dans les arénas of Québec (PIRAQ)

In collaboration with

Agence de l'efficacité énergétique
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Preface

The Association des Arénas du Québec (AAQ) is proud to present the charts on the impacts of energy efficiency new technologies and measures in arenas. Realized within the framework of the Programme d'intervention en réfrigération dans les arénas du Québec (PIRAQ), these fact sheets will be tools of choice for any expert in refrigeration and building, intervening in arenas and curling rinks.

I make a point of thanking the AAQ's partners in the realization of this document: Natural Resources Canada, of which the CANMET Energy Technology Centre – Varennes and the Office of Energy Efficiency for their expertise and their support, the Agence de l'efficacité énergétique du Québec, Hydro-Québec and the Federation of Canadian Municipalities for their support.

The president of the Association des Arénas du Québec,

Benoit Lazure

* We thank Mr. Daniel Giguère and Mrs. Ethel Mayrena Zelaya from CANMET Energy Technology Centre – Varennes and professor Radu Zmeureanu from Concordia University for their participation in the realization of the fact sheets.

CONTENTS

SYNOPSIS

This document comprises nine fact sheets intended to arenas stakeholders and more specifically to consultants and managers of arenas. These fact sheets aim to facilitate the estimation and compare the impacts of various energy efficiency measures and new technologies on the consumption of energy and the reduction of greenhouse gas emissions in arenas.

A fact sheet was prepared to represent the standard Québec arena[1]. It is used as reference to the other fact sheets, which deal with an energy efficiency measure in particular. This initiative lies within the scope of the Programme d'intervention en réfrigération dans les arénas of Québec (PIRAQ), which aims to promote energy efficiency in arenas.

1 To know the characteristics of the standard Québec arena, we refer the reader to the report: *Potential of energy saving in the arenas of Quebec*, CTEC-Varennes, October 2000. http://ctec-varennes.nrcan.gc.ca/fr/publication/r2000-96e.html

BACKGROUND

The Association des Arénas du Québec (AAQ), Agence de l'efficacité énergétique of Québec (AEE), CANMET Energy Technology Centre – Varennes (CETC-Varennes), the Office of Energy Efficiency (OEE), Hydro-Québec and Gaz Métropolitain (SCGM), joined their efforts for the realization of the Programme d'intervention en réfrigération dans les arénas du Québec (PIRAQ). The PIRAQ aims to introduce, promote and advance the idea of energy efficiency in order to influence behavior and decision making of energy consumers, operators, arena designers as well as equipment fitters through refrigeration knowledge transfer.

Within the framework of the PIRAQ, the study " Potential for energy savings in arenas of the province of Quebec " realized by CETC-Varennes showed that there is a natural energy efficiency potential of 270 GWh/year and a potential of reduction of greenhouse gas emissions of 81 kiloton-equivalents of CO_2/year in Québec's ice rinks by the implementation of energy effectiveness measures in the ice rinks' systems of heating, ventilation, air-conditioning and refrigeration (HVAC-R). At this time, this potential is almost completely untapped.

Investigations carried out in the arenas have revealed that the majority of them intend to upgrade their refrigeration systems in the next five years, it is significant to set up a program of intervention to facilitate the installation of energy efficiency measures suggested.

The fact sheets in this document are part of this program. They will be used as guides for arenas' stakeholders (managers of arenas, owners, consultants) to assess and compare the impacts of various energy efficiency measures and technologies on the consumption of energy, the energy expenditures and greenhouse gas emissions reduction in ice rinks. They will thus make it possible to choose in an enlightened ways, econergetic technologies and energy efficiency measures which will meet their needs best and this, in a sustainable development context.

MODELING - SIMULATION

Within the framework of the PIRAQ, CTEC-Varennes has developed, in collaboration with the University of Concordia, a computer-based tool to model ice rink energy consumption, based on the DOE-2.1E software.

This simulation tool has been developed to study the sensitivity of various econergetic technologies applied specifically to arenas. The results of simulations carried out made it possible to prepare the eight fact sheets in this document. The energy computation software DOE-2.1E was used to simulate heat exchange in the arena. This software allows the calculation of energy consumption for heating and refrigeration, to incorporate several types of HVAC-R equipment and to show various strategies of operation. To be able to take account of the effects of the ice inside a building that is at the same time heated and cooled, routines of calculations in the form of *Functionals Values* were added to DOE 2.1E's *Input file* software to take account of the specific technical characteristics of the arenas.

The basic model was validated with data from the monitoring of an arena whose design and operation correspond to the great majority of Québec arenas. The results of this model make it possible to compare energy savings generated by the establishment of various measures of energy efficiency. The building includes an interior ice sheet with stands for attendance, locker rooms and showers for players, and rooms for services and administrative support.

To calculate the hourly energy consumption of each zone and to make the energy balance of the building, the model addresses these following parameters:

- Climate;
- Characteristics of the envelope of the building such as thermal insulation;
- Lighting power and intensity;
- Temperature of the resurfacing water;
- Ice sheet temperature;
- Humidity level of the ice rink;
- Fresh air intake;
- Emissivity index of the ceiling above the ice sheet and walls;
- System of refrigeration's type, capacity, output and operation mode;
- Capacity, output and operation mode of the air heating system, including heat recovery from the refrigeration system;

- Capacity, output and operation mode of the domestic and resurfacing hot water heating system, including heat recovery from the refrigeration system.

DESCRIPTION OF THE FACT SHEETS

Each fact sheet is comprised of eight sections: the title of technology/measure, its technical description, its direct or indirect benefits, its energy-saving potentials, its environmental impacts, specific comments from specialists, as well as charts to facilitate comprehension. The consumption of energy is indicated in kWh-equivalent/year for the combined contribution of electricity and natural gas, for one 12 months period of use including only 9 months operating the ice sheet surface.

The greenhouse (GES) gas emissions reduction potential of each new measure/technology is presented in kilotons of CO_2 equivalents/year. This includes the environmental impacts resulting from the annual reductions in refrigerant leakages and in fossil and electricity consumption.

REFERENCE ARENA

GENERAL DESCRIPTION

Building area	3 000 m^2	Duration of operation	9 months
Ice surface dimensions	26 x 61 m	Hours of operation/week	93 h
Ice thickness	25 mm	Lighting hours/week	80
Number of ice sheets	1	Rink lighting	18 kW
Ceiling emissivity	0.85	Number of resurfacings/week	67
Year of construction	1974	Resurfacing water temperature	65°C

REFRIGERATION SYSTEM

Number of evaporators	2	Cooling capacity	280 kW
Type of evaporators	DX	Brine supply temperature	-10°C
Number of compressors	5	Compressor motors	110 kW
Number of condensers	2	Condenser motors	7.5 kW
Number of brine pumps	1	Brine pump motor	20 kW
Type of refrigerant	R-22	Brine flow rate	50 L/s

DESCRIPTION OF FEATURES

Overall thermal resistances

- Ceiling RSI-3.5
- Exterior walls (above grade) RSI-3.2
- Windows RSI-0.35

Lighting and air conditioning

Areas (Occupation)	Surface (%)	Lighting (W/m^2)	Temperatures (day/night)	Fresh Air Intake (L/s/m^2)
• Locker room	15	7.9	21°C/13°C	0.60
• Administration	10	10.5	21°C/13°C	0.52
• Ice rink	60	10.0	S/O	0.60
• Stands	10	4.4	18°C/13°C	0.60
• Mechanical room	5	N/A	N/A	N/A

- Heating under concrete slab is electric. The ground temperature set point is 5°C.
- Two 50 kW electrical coils provide space heating in the "Administration" and "Locker Room" areas. 60 kW of electric baseboards provide building perimeter heating.
- Heat recovered from the refrigeration system compressors provides heating through the ventilation system for the stands area. A 150 kW electric coil provides additional back-up heating.
- The ventilation system operates at a constant flow rate and is operational 24 hours a day.
- This study did not include the electrical or mechanical rooms due to the slight effect on the overall arena energy consumption. The surface area is however included in the building's total area.
- None of the areas have summer cooling.

Domestic hot water

- Domestic hot water heating is provided partly by heat recovery from the desuperheater of two refrigeration system compressors and by an auxiliary natural gas water heater.

Ambient relative humidity

- The "Rink and Stands" area have two dehumidifiers to control ambient relative humidity at 50%. The refrigeration system load is calculated based on this humidity limit. There are no humidifier or dehumidifier in other parts of the arena.

Refrigeration

- The cooling system's energy efficiency ratio (EER) is 1.5 kW/ton or 7.85 BTU/h/W.
- The refrigeration system contains 750 kg of R-22 refrigerant and has an annual average loss of 10% of this total or 75 kg.

Exterior lighting

- Exterior lighting is not included in this study.

Climatic data

- Hourly climatic data for Montréal from 1996 was used to prepare the fact sheets.

REFRIGERATION SPECIALIST'S REMARKS

The main features of Reference Arena 'A', along with its operating modes, were derived from the study "Potential for Energy Savings in Arenas of the Province of Quebec" conducted by the CANMET Energy Technology Centre-Varennes in December 2000. Energy consumption calculated for the reference arena will be used as a baseline for calculating the future energy savings realized by the implementation of energy efficiency measures.

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

	Total emissions* *Tonnes CO_2-eq./yr*
Reference Arena	*278*

NOTE* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

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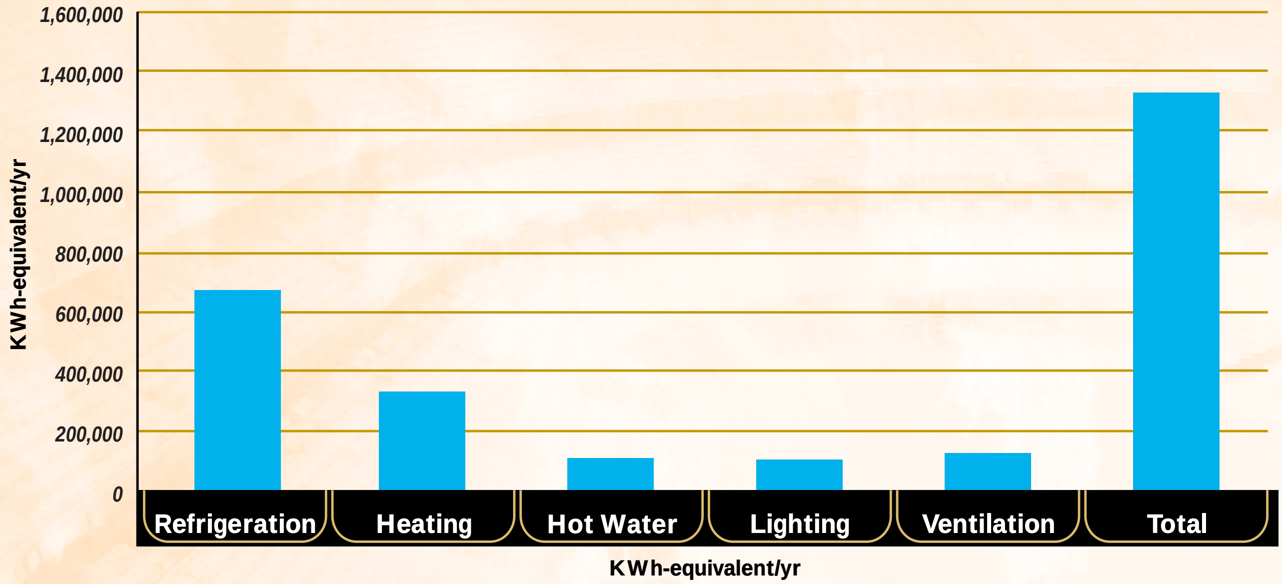
REFERENCE ARENA

Arena's Energy Consumption



	Refrigeration	Heating	Hot Water	Lighting	Ventilation	Total
Reference Arena	670,000 (50%)	330,000 (25%)	105,000 (8%)	102,000 (8%)	124,000 (9%)	1,331,000 (100%)

Figure 1

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INFLUENCE OF THE TYPE OF ICE RINK CEILING

BACKGROUND

Reference conditions

Infrared radiation from an ice rink ceiling represents up to 30% of the ice sheet refrigeration system load.

On sunny days, the arena roof surface can reach temperatures well above the ambient outdoor temperature. Heat is transmitted by conduction to the inside of the ice rink area ceiling. The temperature, colour and emissivity index of the inner surface of the ceiling are the main causes of the radiation thermal load to the ice rink.

Common materials used for ceilings (wood, steel, etc.), have an emissivity index (e) of between 0.85 <e< 0.95. These high emissivity indices promote radiation heat transfer from the ceiling to the ice surface; thus increasing the refrigeration load.

Proposed improvements

To reduce the cooling load due to ceiling radiation, at least four options could be considered:

- Install a suspended ceiling of low-emissivity aluminized cloth;
- Cover the ceiling directly with a aluminum-based low-emissivity (0.05) paint;
- Install a suspended ceiling made from an opaque cloth with an emissivity index of 0.85;
- Paint the ceiling with a low-emissivity (0.24) paint.

BENEFITS

Direct impacts

- Refrigeration system energy consumption is reduced by 93,000 kWh a year, or 14% of the total refrigeration system consumption and nearly a 7% saving of the total energy consumption.
- The refrigeration load due to ceiling radiation is reduced to 15% or 16% of the total refrigeration load, or a reduction of nearly 50% of the radiation load.

Indirect impact

- For same brightness, the reflectivity of low-emissivity ceilings allows for a reduction in the lighting power demand (the resulting reduction in electricity consumption is not considered in this fact sheet).
- Condensation of water vapour on the building structure above the suspended ceiling is reduced.
- Improved arena acoustics.

REFRIGERATION SPECIALIST'S REMARKS

Simply adding a canvas false ceiling between the ice rink and the arena roof will reduce electricity consumption by 77,000 kWh a year. This is more than 80% of the potential reduction in energy consumption calculated for a low-emissivity polished aluminum-foil-faced false ceiling. In addition to masking the ceiling, the canvas false ceiling creates a lower average temperature air space above the ice rink than a roof without any masking. The quantity of radiant heat exchanged between the canvas false ceiling and the ice surface is reduced considerably.

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

		Total emissions* Tonnes CO_2-eq./yr
Suspended Canvas False Ceiling;	*ε = 0.05*	*260 (- 6%)*
Integrated Canvas False Ceiling;	*ε = 0.05*	*263 (- 5%)*
Suspended Polished Aluminum-Foil-Faced False Ceiling;	*ε = 0.85*	*263 (- 5%)*
Aluminum-Based Painted Ceiling;	*ε = 0.24*	*266 (- 4%)*
Reference Ceiling;	*ε = 0.85*	*278 (Ref)*

* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

NOTE: Energy consumption and energy savings were estimated on the basis of Montréal's 1996 climatic profile. Readers may refer to the technical fact sheet "Reference Arena".

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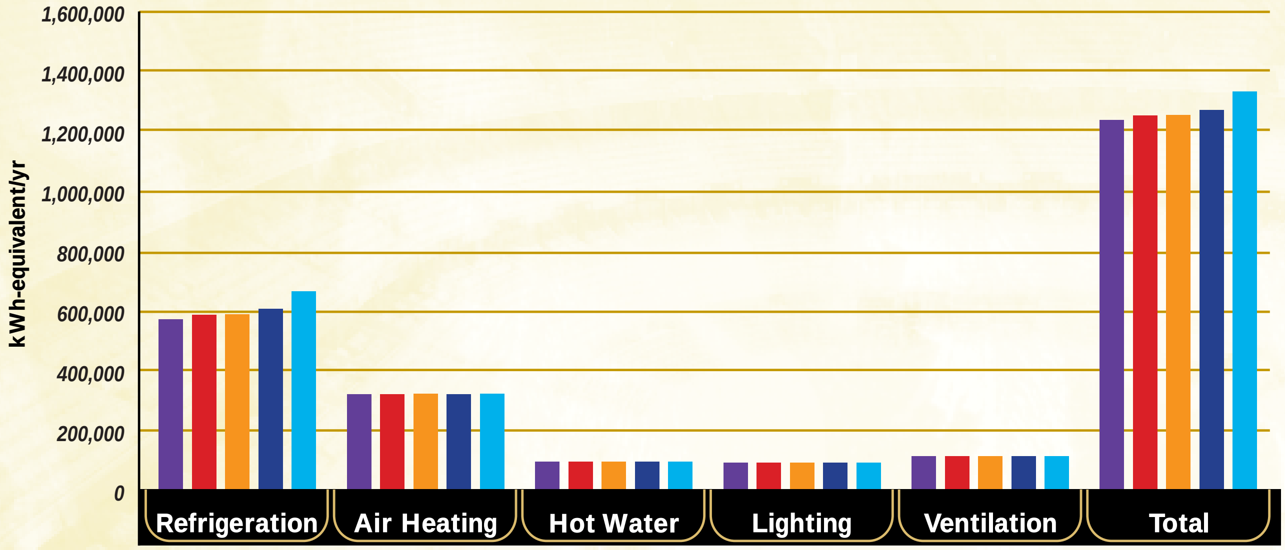
Arena's Energy Consumption



Ceiling	Refrigeration	Air Heating	Hot Water	Lighting	Ventilation	Total
Suspended Canvas False Ceiling; ε = 0.05	577,000 (-14,%)	329,000	105,000	102,000	124,000	1,237,000 (-7%)
Integrated Canvas False Ceiling; ε = 0.05	592,000 (-12,%)	329,000	105,000	102,000	124,000	1,252,000 (-6%)
Suspended Polished Alluminum-Foil-Faced False Ceiling; ε = 0.85	593,000 (-12,%)	329,000	105,000	102,000	124,000	1,253,000 (-6%)
Aluminum-Based Painted Ceiling; ε = 0.24	611,000 (-9,%)	329,000	105,000	102,000	124,000	1,271,000 (-5%)
Reference Ceiling; ε = 0.85	670,000 (Ref.)	330,000	105,000	102,000	124,000	1,331,000 (Ref.)

kWh-equivalent/yr

Figure 1

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THE SECONDARY COOLANT AND PUMPING POWER RELATION

BACKGROUND

Reference conditions

In most arenas, the rink ice is cooled by a brine (or secondary coolant) solution circulated in a network of pipes that are embedded in a concrete slab.

Generally, a constant-speed pump circulates the brine (coolant) through this network of pipes; making two passes through the slab before returning to the refrigeration evaporator to be cooled again.

The brine pump often uses over 15% of the refrigeration system's total energy consumption.

Proposed improvements

The energy consumed by the refrigeration system and the brine pump may be minimized by the use of:

- Two-speed motors running at full speed during the day and at low speed during unoccupied hours (night),
- Variable-speed motors controlled by the brine temperature differential change;
- Two or more pumps controlled by the brine temperature differential change or with an occupied-unoccupied (day-night) timer;
- Brine circuits that complete four or more passes through the slab.

BENEFITS

Direct impacts

These strategies reduce the total brine flow rate and therefore reduce the required pumping power:

- Energy consumption of the brine pump and the refrigeration system is reduced by as much as 93,000 kWh/yr or 14% of the total system consumption.

Indirect impact

- Multi-pass networks may affect the ice temperature uniformity.
- Any reduction in brine flow rate influences the performance of the refrigeration system.

REFRIGERATION SPECIALIST'S REMARKS

The brine pump motor's energy consumption increases directly the refrigeration loads. Consequently a double effect on the arena's energy consumption is realized and explains the large potential impact of the pumping strategies described. One of these strategies, multi-pass brine circuits, enables the flow rate necessary for cooling the ice surface to be reduced by half. However, the refrigeration system has to be designed or modified to provide the appropriate refrigeration operation for the new flow rate conditions.

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

Brine network / pumping regime	Total emissions* Tonnes CO_2-eq./yr
4-pass circuit / low speed at night	*260 (-6%)*
5-pass circuit / fixed speed	*262 (-6%)*
4-pass circuit / fixed speed	*264 (-5%)*
2-pass circuit / low speed at night	*271 (-3%)*
2-pass circuit / variable speed	*269 (-3%)*
2-pass circuit / fixed speed	*278 (Ref.)*

NOTE* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

NOTE: Energy consumption and energy savings were estimated on the basis of Montréal's 1996 climatic profile. Readers may refer to the technical fact sheet "Reference Arena".

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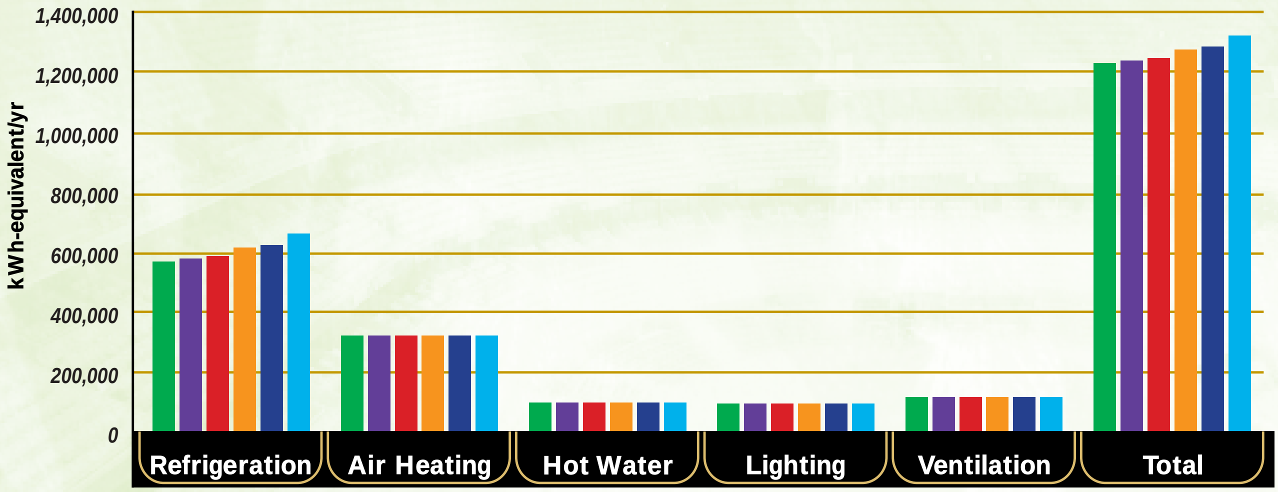
Arena's Energy Consumption



kWh-equivalents/yr

	Refrigeration	Air Heating	Hot Water	Lighting	Ventilation	Total
4 Pass/2 Speeds	577,000 (-14%)	330,000	105,000	102,000	124,000	1,238,000 (-7%)
5 Pass/Fixed Speed	586,000 (-13%)	330,000	105,000	102,000	124,000	1,247,000 (-6%)
4 Pass/Fixed Speed	595,000 (-11%)	330,000	105,000	102,000	124,000	1,256,000 (-6%)
2 Pass/Var. Speed	623,000 (-7%)	330,000	105,000	102,000	124,000	1,284,000 (-4%)
2 Pass/2 Speeds	632,000 (-6%)	330,000	105,000	102,000	124,000	1,293,000 (-3%)
2 Pass/Fixed Speed	670,000 (Ref.)	330,000	105,000	102,000	124,000	1,331,000 (Ref.)

Figure 1

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OPTIMIZING REFRIGERATION CONDENSING TEMPERATURE

BACKGROUND

Reference conditions

Air-cooled refrigeration systems use pressure controllers to maintain refrigeration-condensing temperature at or above 35°C regardless of the outside air temperature.

The main purpose of maintaining the condensing temperature higher than 35°C is to ensure that the refrigeration system will start-up reliably in cold weather and to ensure good heat recovery for space heating needs.

Proposed improvements

To reduce energy consumption:

- Install a cooling system that will vary the refrigeration condensing temperature according to outside temperature and space heating demand.
- Ensure that waste heat exchangers have high thermodynamic efficiency (at least 75%).

BENEFITS

Direct impacts

If the system is run at a 24°C condensation temperature:

- The refrigeration system capacity increases by more than 10%.
- Its energy consumption falls by 170,000 kWh/yr (-25%).
- However, lowering the condensation temperature does reduce the heat recovery performance.

Indirect impact

- A moderate refrigeration system condensing temperature will extend the refrigeration compressor life and reduce the opportunity for refrigerant leaks for open type refrigeration system.

REFRIGERATION SPECIALIST'S REMARKS

Figure 2 (over) indicates the effect of the refrigeration condensing temperature on the energy consumption for heating the stands, the refrigeration system and the combination of both applications. The refrigeration system's consumption increases with an increase of the condensing temperature; whereas energy consumption for heating decreases because of energy recovery. However, for condensing temperatures between 24° and 27°C, the total energy consumption of the two is minimized. This concludes that for the reference arena the maximum total energy efficiency is not necessarily achieved at conditions that produce the greatest heat recovery, or at the lowest condensing temperature. While the methods described appear simple, the services of a skilled refrigeration specialist are required to ensure that the refrigeration system performs well and reliably.

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

	Total emissions* Tonnes CO_2-eq./yr
Variable condensation temperature	*249 (-11%)*
Reference arena	*278 (Ref.)*

NOTE* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

NOTE: Energy consumption and energy savings were estimated on the basis of Montréal's 1996 climatic profile. Readers may refer to the technical fact sheet "Reference Arena".

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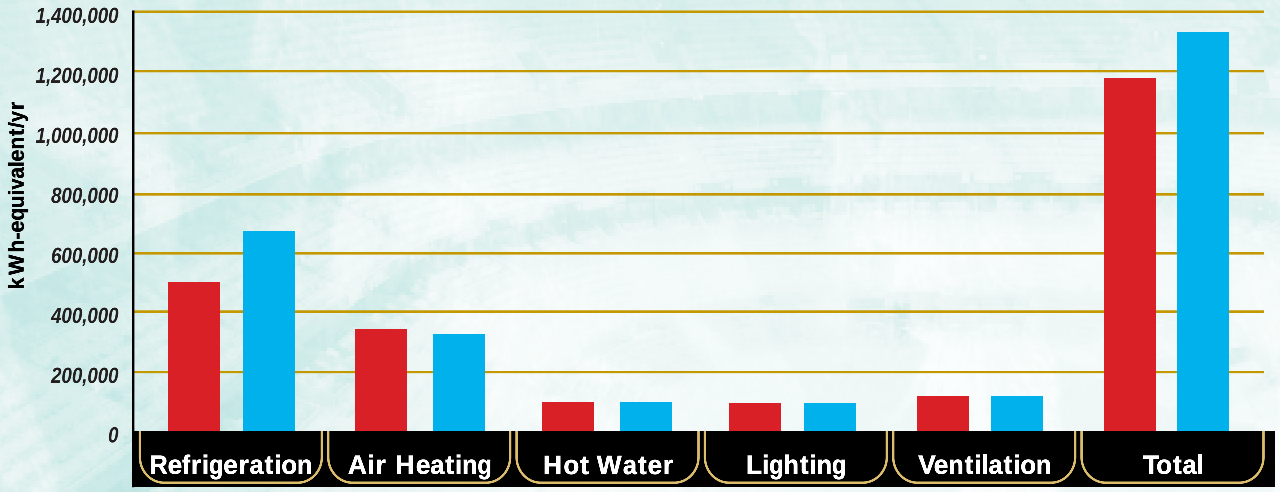
Arena's Energy Consumption



kWh-equivalent/yr

	Refrigeration	Air Heating	Hot Water	Lighting	Ventilation	Total
Condensation T°: 24°C	501,136 (-25%)	346,000 (5%)	105,000	102,000	124,000	1,178,136 (-11%)
Reference Arena	670,000 (Ref.)	330,000 (Ref.)	105,000	102,000	124,000	1,331,000 (Réf.)

Figure 1

Impact of the condensing temperature on the heating and refrigeration loads

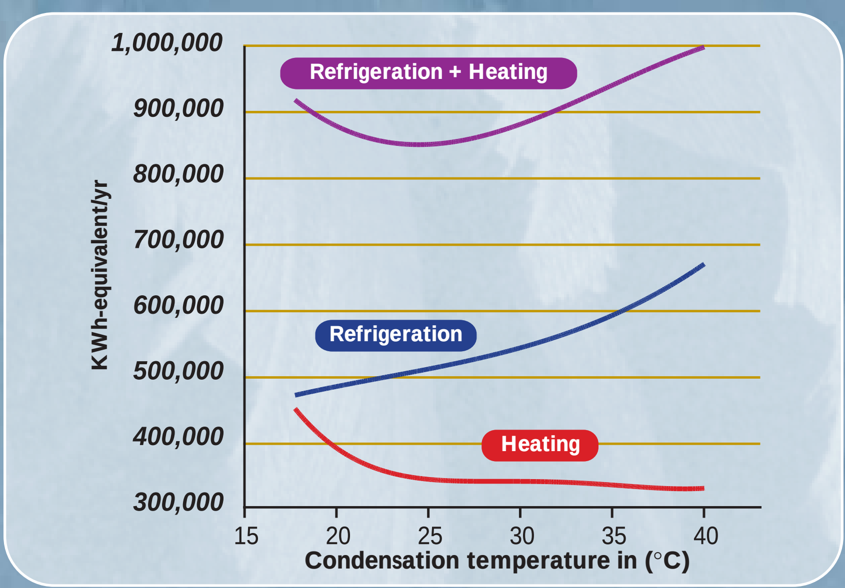


Figure 2

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REDUCTION OF LIGHTING INTENSITY IN THE ICE RINK

BACKGROUND

Reference conditions

The heat given off by the ice rink lighting simultaneously increases the rink's refrigeration load and reduces the heating load of the stands. However, the overall result is an increase in total energy consumption.

The installed lighting power directly influences the building's electricity demand.

The reference arena's lighting annual energy consumption is about 4,500 kWh/kW based on an average of 4,500 hours of operation per year.

Proposed improvements

The impact of lighting on the arena's energy consumption can be reduced by:

- Using lighting systems where the brightness (multi light level intensity) and the number of operating lamps can be adjusted according to the type of activity and the occupancy rate.
- Optimise the height of fixtures by considering the reflectance of walls and the low-emissivity ceiling, while ensuring the required clearance above the ice rink is maintained.

BENEFITS

Direct impacts

- For each kilowatt reduction of installed lighting power, a twofold reduction in the building's electricity demand occurs: 1 kW for the lighting itself and 0.25 kW for the refrigeration system to remove the heat given off by the lights.

Indirect impact

- Energy to heat the arena is reduced by 500 kWh/yr/kW of additional lighting.
- The use of natural lighting provides an ambience that might enhance daytime occupancy of the arena.

REFRIGERATION SPECIALIST'S REMARKS

The annual energy consumption of the reference arena's refrigeration system increases at the rate of 1,200 kWh/kW of additional lighting, or 0.2%. This value seems marginal when compared to the 500,000 kWh/yr that the refrigeration system compressors consumes; however, increasing lighting power from 10 to 50 kW, increases refrigeration system consumption by 10%.

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

	Total emissions* Tonnes CO_2-eq./yr
Lighting in stands 10 kW	*271 (-3%)*
Lighting in stands 18 kW	*278 (Ref.)*
Lighting in stands 24 kW	*284 (2%)*
Lighting in stands 48 kW	*307 (11%)*

NOTE* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

NOTE: Energy consumption and energy savings were estimated on the basis of Montréal's 1996 climatic profile. Readers may refer to the technical fact sheet "Reference Arena".

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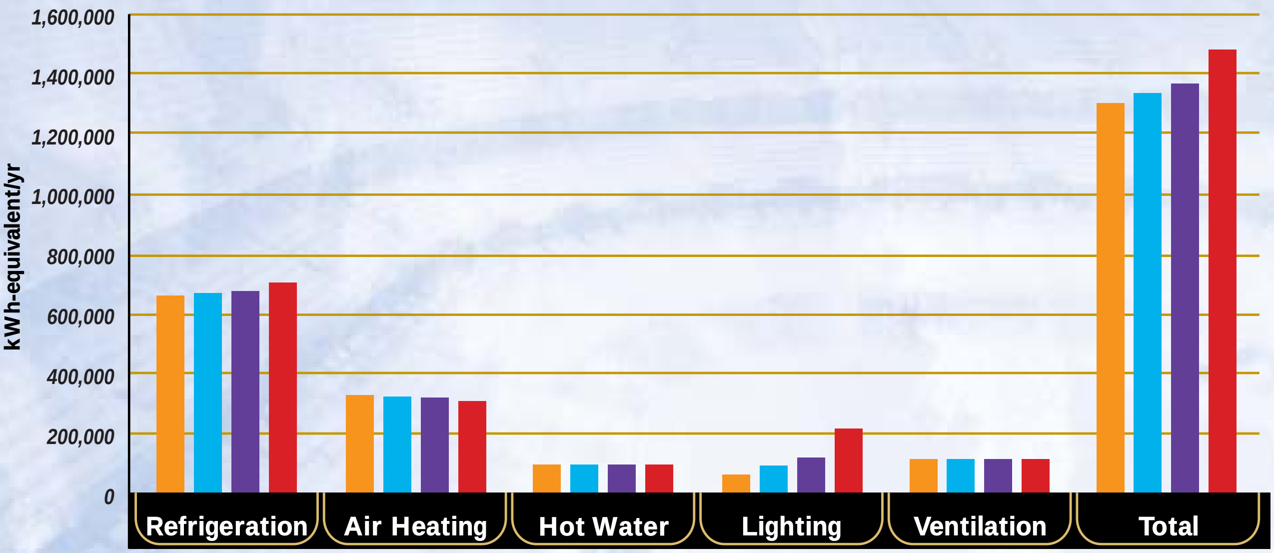
Arena's Energy Consumption



kWh-equivalent/yr

Lighting 10 kW	662,000 (-1%)	334,000 (1%)	105,000	72,000 (-29%)	124,000	1,297,000 (-3%)
Lighting 18 kW	670,000 (Ref.)	330,000 (Ref.)	105,000	102,000 (Ref.)	124,000	1,331,000 (Ref.)
Lighting 24 kW	678,000 (1%)	326,000 (-1%)	105,000	128,000 (25%)	124,000	1,361,000 (2%)
Lighting 48 kW	706,000 (5%)	315,000 (-5%)	105,000	224,000 (120%)	124,000	1,474,000 (11%)

Figure 1

Lighting energy consumption influenced by electricity power

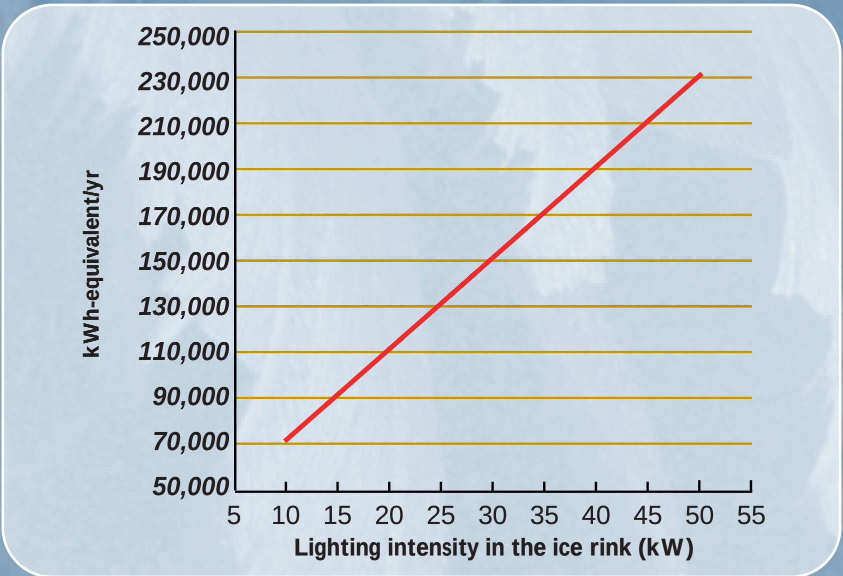


Figure 2

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TEMPERATURE OPTIMIZATION IN THE STANDS

BACKGROUND

Reference conditions

For spectator comfort, many arenas keep the temperature in the stands between 10°C and 15°C, some as high as 18°C while the building is occupied. In the case of the reference arena, space heating accounts for more than 30% of the refrigeration system's energy consumption.

Proposed improvements

To reduce energy consumption for heating and cooling:

- Lower the temperature in the stands, during both unoccupied and occupied periods.
- Heat the stands with a low-temperature (< 32°C) Radiant Flooring Heating (RFH) system. Heat recovered from the refrigeration system condenser is utilized to heat a fluid circulating in a tubing network embedded in the floor of the stands.

BENEFITS

Direct impacts

By reducing the set point temperature in the stands:

- The refrigeration system's energy consumption is reduced.
- The energy consumption for heating the stands is reduced.

Indirect impact

- The temperature in the stands affects spectators' comfort.

REFRIGERATION SPECIALIST'S REMARKS

As shown in Figure 2, increasing the temperature set point of the stands heating system has a double effect on the total facility energy consumption. According to the reference arena, a 1°C increase of the stands temperature set point results in a 13,000 kWh/yr increase in refrigeration system energy consumption and a 12,000 kWh/yr heating system increase. This 25,000 kWh/yr/°C energy consumption increase represents 2%/°C of the total facility consumption, still considering heat recovered from the refrigeration system.

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

	Total emissions* Tonnes CO_2-eq./yr
Temperature in stands = 10°C	*254 (-9%)*
Temperature in stands = 13°C	*262 (-6%)*
Temperature in stands = 15°C	*268 (-4%)*
Temperature in stands = 18°C	*278 (Ref.)*
Temperature in stands = 20°C	*286 (+3%)*

NOTE* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

NOTE: Energy consumption and energy savings were estimated on the basis of Montréal's 1996 climatic profile. Readers may refer to the technical fact sheet "Reference Arena".

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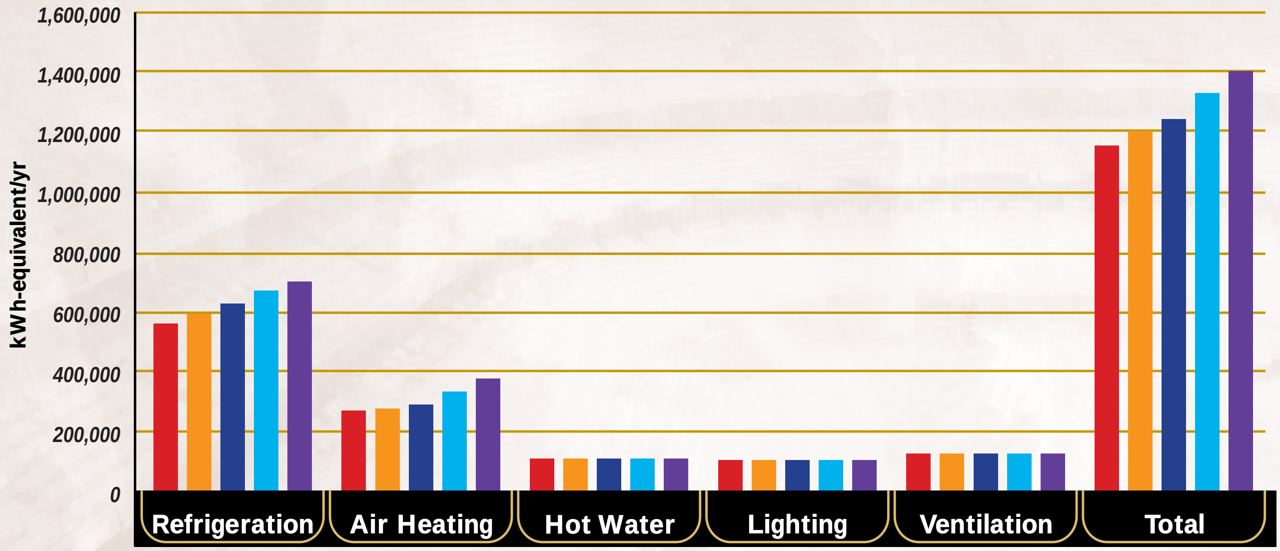
Arena's Energy Consumption



kWh-equivalent/yr

	Refrigeration	Air Heating	Hot Water	Lighting	Ventilation	Total
Stands T=10°C	558,000 (-17%)	266,000 (-19%)	105,000	102,000	124,000	1,155,000 (-13%)
Stands T=13°C	598,000 (-11%)	277,000 (-16%)	105,000	102,000	124,000	1,206,000 (-9%)
Stands T=15°C	625,000 (-7%)	289,000 (-12%)	105,000	102,000	124,000	1,245,000 (-6%)
Stands T=18°C	670,000 (Ref.)	330,000 (Ref.)	105,000	102,000	124,000	1,331,000 (Ref.)
Stands T=20°C	702,000 (5%)	375,000 (14%)	105,000	102,000	124,000	1,408,000 (6%)

Figure 1

Impact of the air temperature setpoint on the energy consumption for heating the stands and on the compressors

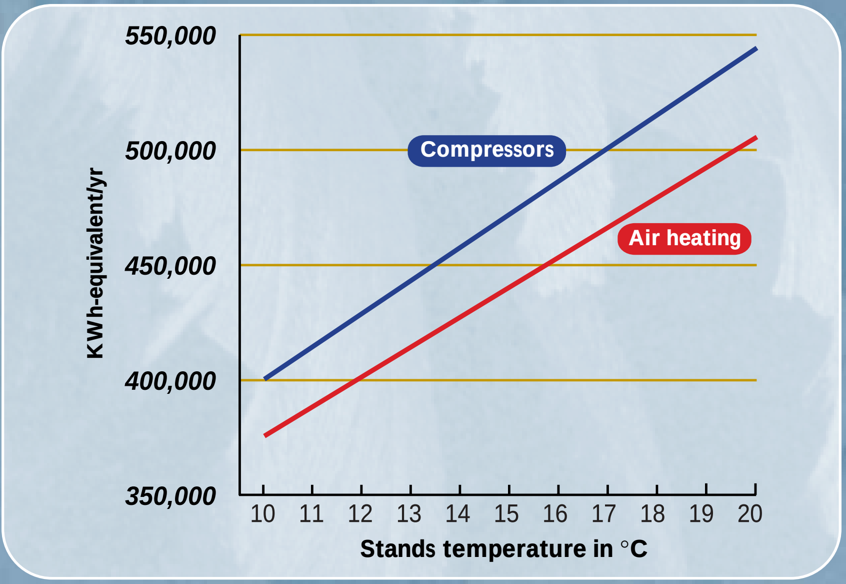


Figure 2

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MANAGEMENT OF ICE TEMPERATURE

BACKGROUND

Reference conditions

Most arenas keep the ice temperature constant throughout the season. A few vary the ice temperature set point for different activities or during the unoccupied (night) periods.

Proposed improvements

It is possible to reduce the refrigeration system's energy consumption as follows:

- Adjusting the ice temperature set point according to the season and the type of activities:

Hockey:	-6°C to -5°C
Figure skating:	-4°C to -3°C
Free skating:	-3°C to -2°C
No activity:	-2°C to -1°C

- Stop the brine pump and the refrigeration system during unoccupied periods. By measuring the ice temperature with an infrared sensor, the refrigeration system can be restarted if the ice temperature should increase to a preset maximum set point.

BENEFITS

Direct impacts

If ice temperature is allowed to rise during the night:

- The refrigeration system energy consumption decreases.
- The refrigeration system capacity increases.

Indirect impact

- Energy consumption for heating the stands area falls slightly when the cooling system and brine pump are stopped.
- Maintenance costs are reduced.
- Extends the equipments and components life.

REFRIGERATION SPECIALIST'S REMARKS

Figure 1 shows that merely allowing ice temperature to rise during the night will save 18,000 kWh (1%) per year. This figure does not include the lower energy consumption that would result from stopping the refrigeration system and brine pump. Figure 2 on the reverse indicates that energy consumption varies by 21,000 kWh/yr/°C of ice temperature change.

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

		Total emissions* Tonnes CO_2-eq./yr
T°ice constant day/night	*(T°DAY = -5°C)*	*278 (Ref.)*
T°ice variable during the night	*(T°DAY = -5°C and T°NIGHT = -1°C)*	*275 (-1%)*
T°ice variable day/night	*(T°DAY = -5°C and T°NIGHT = -3°C)*	*274 (-1%)*

NOTE* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

NOTE: Energy consumption and energy savings were estimated on the basis of Montréal's 1996 climatic profile. Readers may refer to the technical fact sheet "Reference Arena".

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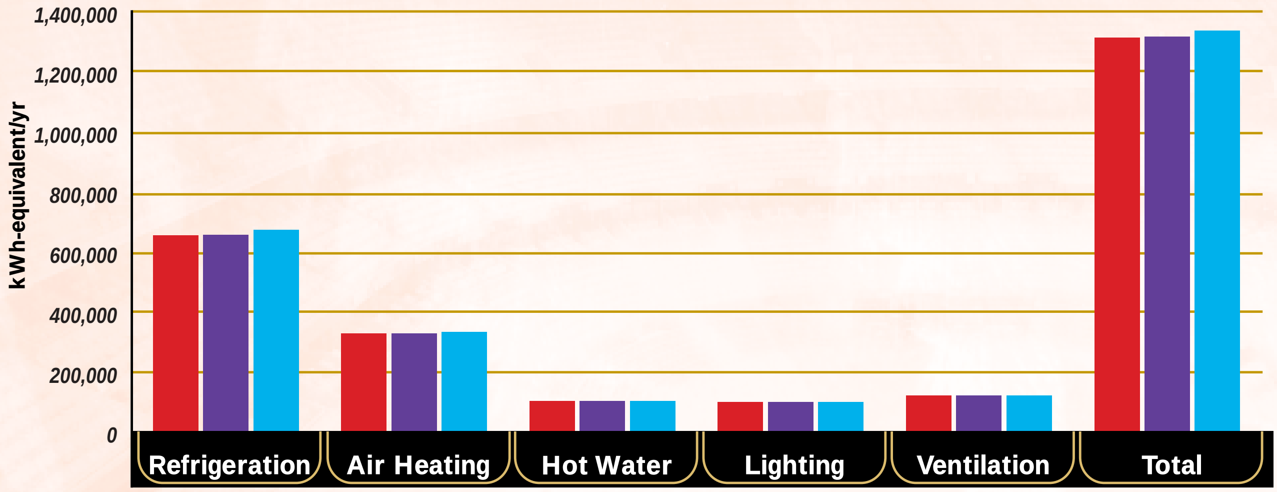
Arena's Energy Consumption



kWh-equivalent/yr

	Refrigeration	Air Heating	Hot Water	Lighting	Ventilation	Total
T°Ice Variable	652,000 (-3%)	328,000	105,000	102,000	124,000	1,311,000 (-2%)
T°Ice Variable Night	655,000 (-2%)	328,000	105,000	102,000	124,000	1,314,000 (-1%)
T°Ice Constant	670,000 (Ref.)	330,000	105,000	102,000	124,000	1,331,000 (Ref.)

Figure 1

Impact of the ice temperature on the total energy consumption of the arena

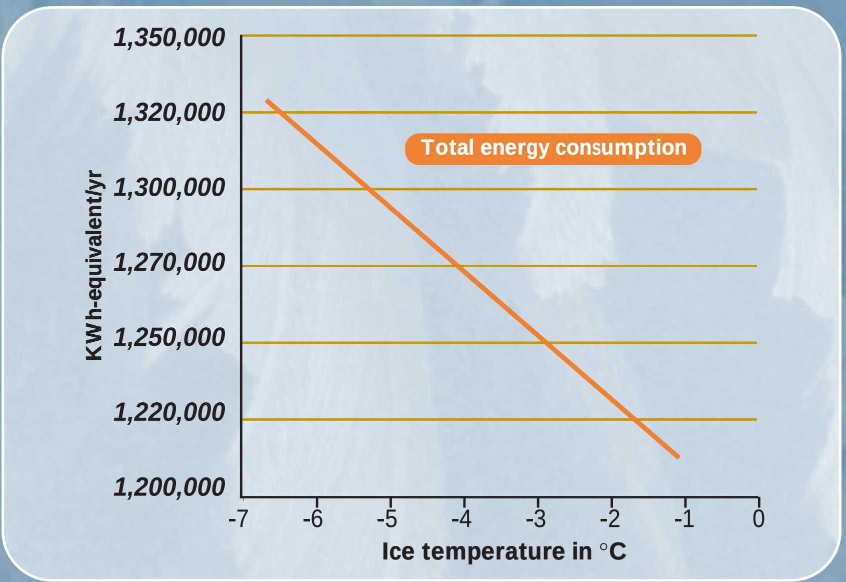


Figure 2

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USING A NETWORK OF HEAT PUMPS

BACKGROUND

Reference conditions

The current reference arena does not use heat pumps. A portion of the heat energy contained in the refrigeration compressor discharge superheated gas is recovered to produce domestic hot water and for space heating in the stands. To maximize heat recovery, the refrigeration condensing temperature is maintained above 40°C, which reduces the refrigeration system capacity and increases its energy consumption. This condensing temperature is maintained even when heating demand decreases. The areas around the rink, such as the main entrance, offices and locker rooms, do not use any recovered heat from the refrigeration system.

Proposed improvements

To reduce energy consumption:

- Use a refrigeration condensing system that utilizes a secondary coolant, which is utilized as a heat supply for a network of heat pumps. This will provide thermal energy for space heating of the stands, offices, locker rooms and other areas; preheating domestic hot water, and preheating the water for the ice resurfacing machine.

BENEFITS

Direct impacts

- Heat pumps allow refrigeration system operation at 24°C condensing temperature, thereby increasing the system capacity by more than 10%.
- The refrigeration system energy consumption falls by 170,000 kWh/yr (-25%).
- The network of heat pumps will satisfy the heating demand of all arena spaces, when the refrigeration system is in operation.
- The heat provided by using an electricity driven network of heating pumps replaces all other types of energy supply for space heating.
- The total energy consumption of the arena is reduced by 360,000 kWh (-27%).

Indirect impact

- The lower refrigeration system condensing temperature will extend the life of the compressors.
- The use of heat pumps may increase the arena's electricity demand.

REFRIGERATION SPECIALIST'S REMARKS

Integration of the refrigeration system with a heat pump network reduces total energy consumption by more than 27 % compared to the reference arena. This major reduction in energy consumption results from the recovery of refrigeration heat from condensation to meet the heating needs of the stands and other arena spaces. The use of an evaporative fluid cooler for rejection of excess energy can further reduce the refrigeration system energy consumption while maintaining heat recovery.

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

	Total emissions* Tonnes CO_2-eq./yr
Arena with a heat pump network	*166 (-40%)*
Reference arena	*278 (Ref.)*

NOTE* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

NOTE: Energy consumption and energy savings were estimated on the basis of Montréal's 1996 climatic profile. Readers may refer to the technical fact sheet "Reference Arena".

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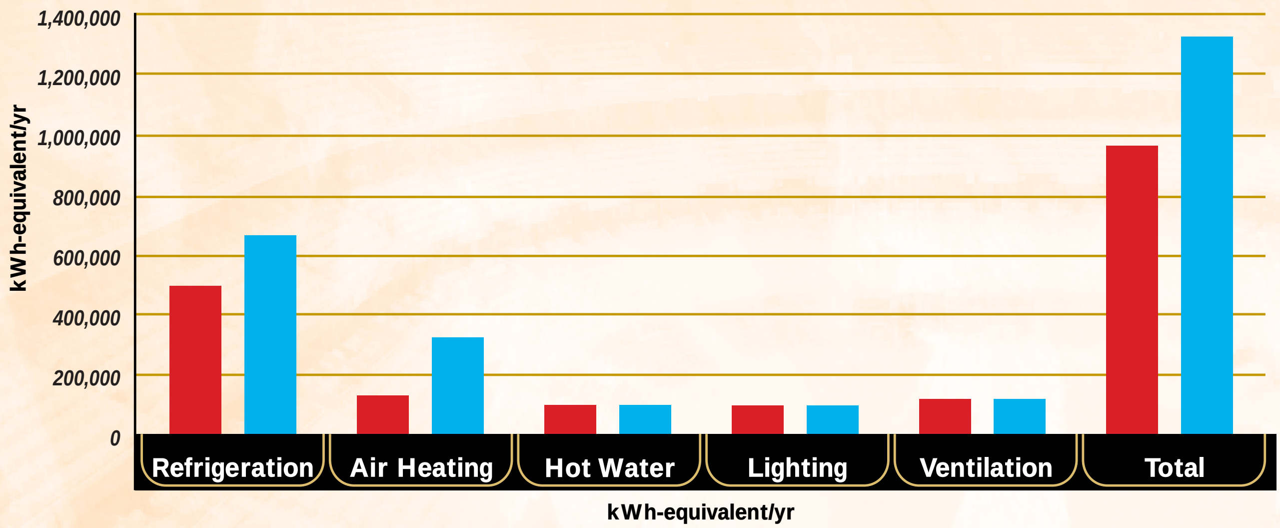
Arena's Energy Consumption



	Refrigeration	Air Heating	Hot Water	Lighting	Ventilation	Total
Heat Pump Network	501,000 (-25%)	136,000 (-25%)	105,000	102,000	124,000	968,000 (-27%)
Reference Arena	670,000 (Ref.)	330,000 (Ref.)	105,000	102,000	124,000	1,331,000 (Ref.)

Figure 1

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OPTIMIZATION OF ICE AND CONCRETE SLAB THICKNESS

BACKGROUND

Reference conditions

In most arenas, ice thickness varies from 20 to 40 mm with 25 mm of concrete slab above the embedded brine-tube network.

Proposed improvements

To reduce the refrigeration system energy consumption:

- Keep the ice at an optimal thickness, generally 25 mm.
- On a new arena or when replacing the concrete rink floor, ensure that the concrete thickness above the embedded coolant pipes is not in excess of 25 mm.

BENEFITS

Direct impacts

The refrigeration system energy consumption and performance are directly affected by the thickness of the ice and the concrete. The thicker these are, the more electricity it takes for the refrigeration system to maintain the top surface of the ice at the desired temperature: i.e. 10,000 kWh/yr/inch of ice and 3,000 kWh/yr/inch of concrete.

Indirect impact

With increased ice or concrete thickness, the additional electrical consumption of the refrigeration system provides more recoverable energy to meet space-heating needs in the arena.

REFRIGERATION SPECIALIST'S REMARKS

Figure 2 indicates that reduced ice or concrete thickness has a significant effect on the refrigeration system consumption. However, total energy consumption is merely unaffected, as the cooling system's increased energy consumption is offset by the quantity of heat recovered. We nevertheless recommend reducing ice and concrete thickness for two reasons: the refrigeration system provides more capacity with better performance with a reduction in mechanical work, therefore life expectancy is extended. A network of heat pumps to recover refrigeration system heat rejection will significantly reduce energy consumption for space heating (see fact sheet No. 7: Using a Network of Heat Pumps).

ARENA'S ANNUAL GREENHOUSE GAS (GHG) EMISSIONS

	Total emissions* Tonnes CO_2-eq./yr
Ice thickness 20 mm; concrete thickness 25 mm	*266 (-1%)*
Ice thickness 20 mm; concrete thickness 50 mm	*267 (-0.5%)*
Ice thickness 25 mm; concrete thickness 25 mm	*267 (-0.5%)*
Ice thickness 50 mm; concrete thickness 50 mm	*268 (Ref.)*
Ice thickness 50 mm; concrete thickness 25 mm	*268 (-)*

NOTE* Calculations of GHG emissions include electricity, fossil-fuel energy and refrigerant leaks.

NOTE: Energy consumption and energy savings were estimated on the basis of Montréal's 1996 climatic profile. Readers may refer to the technical fact sheet "Reference Arena".

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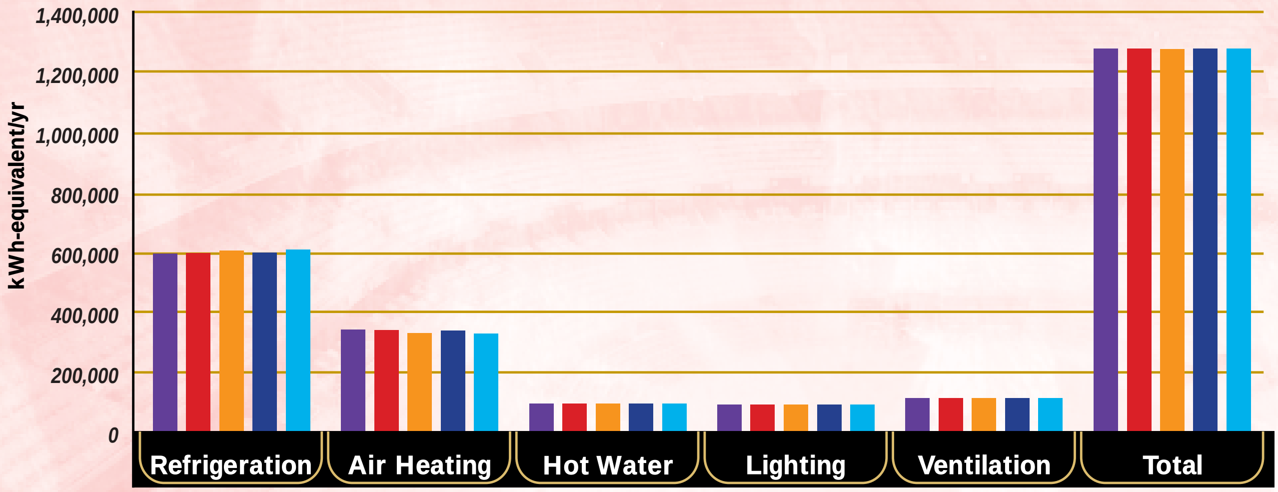
Arena's Energy Consumption



	Refrigeration	Air Heating	Hot Water	Lighting	Ventilation	Total
Ice 20mm/Concrete 25mm	605,000 (-2%)	352,000 (4%)	105,000	102,000	124,000	1,288,000 (-)
Ice 25mm/Concrete 25mm	607,000 (-2%)	350,000 (3%)	105,000	102,000	124,000	1,288,000 (-)
Ice 50mm/Concrete 25mm	616,000 (-1%)	340,000 (1%)	105,000	102,000	124,000	1,287,000 (-)
Ice 20mm/Concrete 50mm	608,000 (-2%)	349,000 (3%)	105,000	102,000	124,000	1,288,000 (-)
Ice 50mm/Concrete 50mm	619,000 (Ref.)	338,000 (Ref.)	105,000	102,000	124,000	1,288,000 (Ref.)

Figure 1

Impact of the refrigeration system's energy consumption in terms of ice and concrete thickness

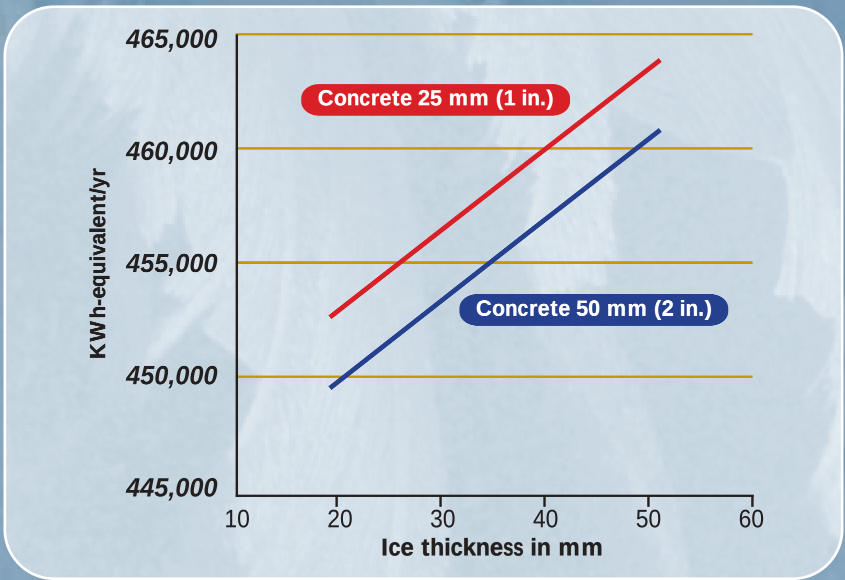


Figure 2

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