RETScreen® ICE AND CURLING RINKS Model

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Abstract: The Refrigeration and RETScreen program teams at CETC-Varennes have collaborated to develop the new RETScreen model for assessing viability of energy efficient ice and curling rinks projects, with a focus on heat recovery from refrigeration systems. This software can be used to evaluate the energy savings, life-cycle costs, emission reductions, financial viability and risks for various types of energy efficient technologies. Also, the model aims to reduce the cost of pre-feasibility studies; disseminate knowledge to help people make better decisions; and by training people to better analyse the technical and financial viability of possible projects

This ice and curling rinks model is a unique decision support tool developed with the contribution of numerous experts, and seeks to build the capacity of planners, decision-makers and industry to implement renewable energy and energy efficiency projects. This tool has been 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.

Key Words: RETScreen, energy*, efficiency,* ice rinks, refrigeration model

1 INTRODUCTION

The CANMET Energy Technology Center–Varennes (CETC-Varennes) of Natural Resources Canada (NRCan) has developed, with the contribution of numerous experts from government, industry, and academia, a Clean Energy Project Analysis Software called RETScreen International [CETC–Varennes 2008]. The software can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies. The RETScreen Software [RETScreen International 2008], available free-of-charge, is now being used by more than 145,000 people in 222 countries and this is growing at more than 900 new users every week. RETScreen is quickly becoming the international standard for clean energy project analysis. In RETScreen Version 4, the software's capabilities have been expanded from renewable energy, cogeneration and district energy, to include a full array of financially viable clean power, heating and cooling technologies, and energy efficiency measures. The international appeal of this decision support tool has been improved through the expansion of climate data, required by the tool, covering the entire surface of the planet, including central-grid, isolated-grid and off-grid areas, as well as through the translation of the software into 25 languages that cover roughly 2/3 of the world's population.

The Refrigeration and RETScreen program teams at CETC-Varennes have collaborated to develop the new RETScreen model for assessing the viability of energy efficient arena projects (i.e. skating & curling rinks), with a focus on heat recovery from refrigeration systems. Since January 2007, the beta version of this decision-support tool is available on-line and can be downloaded from the RETScreen Website under the "Arenas & Supermarkets" heading in the download table: *http://www.retscreen.net* .

This tool has been 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. The tool aims at supporting decision makers, building owners, managers, and consultants of these sectors to evaluate different options for the implementation of new or retrofit heating, ventilation, air-conditioning and refrigeration (HVAC&R) systems.

2 ICE AND CURLING RINKS

There are roughly 2,600 arenas and 1,000 curling rinks in Canada, which consume around 4 terawatt-hours (15 petajoules) of energy annually. Refrigeration represents over 50% of the energy bill in these facilities. The intensive integration of new heating, ventilation, air-conditioning and refrigeration (HVAC&R) technologies in an ice rink facility can result in energy savings of up to 60% compared to a standard facility. Significant savings can be achieved through "process integration". The heating and refrigeration systems of the building are integrated such that the heat pulled out from the ice rink zone is pushed into the comfort zone, rather than being released to the environment.

Ice rinks release significant quantities of greenhouse gases. The total greenhouse gas (GHG) emissions from all these recreational facilities in Canada are estimated at more than one megatonne of Carbon Dioxide Equivalent (Mt) per year (one Mt = 1 x 10^6 tonnes). This arises not just from the production of the energy consumed by the rink, but also from synthetic refrigerant leaks. Conventional ice rink refrigeration systems contain very large refrigerant charges: an average skating rink will have 700 kg of refrigerant. Because synthetic refrigerants are potent greenhouses gases, with some having over 3,000 times the effect of carbon dioxide, these leaks result in serious greenhouse gas emissions. So the strategies for reducing energy consumption and greenhouse gases emissions for ice and curling rinks must necessarily result in a reduction of refrigerant charge.

3 CLEAN ENERGY PROJECT ANALYSIS SOFTWARE

RETScreen directly addresses the accuracy versus investment cost dilemma. It assists the user, at the very earliest stages of the project to quickly and simply assess whether the potential for a clean energy project is sufficiently promising to merit further investigation or even engineering and development work. It takes into consideration all the important factors and performs a life-cycle cost analysis, thus ensuring a just comparison between clean energy technologies and their conventional competitors. By streamlining the process, it encourages the widespread consideration of clean energy technologies, leading to a larger number of successful projects.

Fundamental to RETScreen's approach is a comparison of a conventional technology and a proposed clean energy technology. The absolute costs and benefits of the clean energy technology are not necessarily considered; rather, the incremental costs and benefits, compared to the conventional technology, are evaluated. The RETScreen financial analysis accounts for all the key factors affecting the financial viability of a project, including initial costs, annual savings, operation and maintenance costs, fuel costs, taxation, greenhouse gas (GHG) emission credits and renewable energy production credits. It automatically calculates important indicators of financial viability, permitting users to evaluate projects based on their own criteria. Then RETScreen can investigate the sensitivity of the key financial indicators to changes in the inputs. During this analysis, the user should keep in mind that indicators that consider profitability over the life of the project, such as the internal rate of return (IRR) and the net present value (NPV), are preferable to the simple payback.

As shown in Figure 1, RETScreen software is basically a five-step approach [RETScreen International 2008]. First an energy model is used to determine the energy benefits of the project under consideration, compared to a conventional alternative. Second, the additional costs of the clean energy project are evaluated. Third, an optional greenhouse gas analysis calculates the emissions reductions associated with the project. Fourth, a financial summary page indicates whether the project is financially attractive. And fifth, sensitivity and risk analysis sheets reveal how changes in inputs would affect the viability of the project.

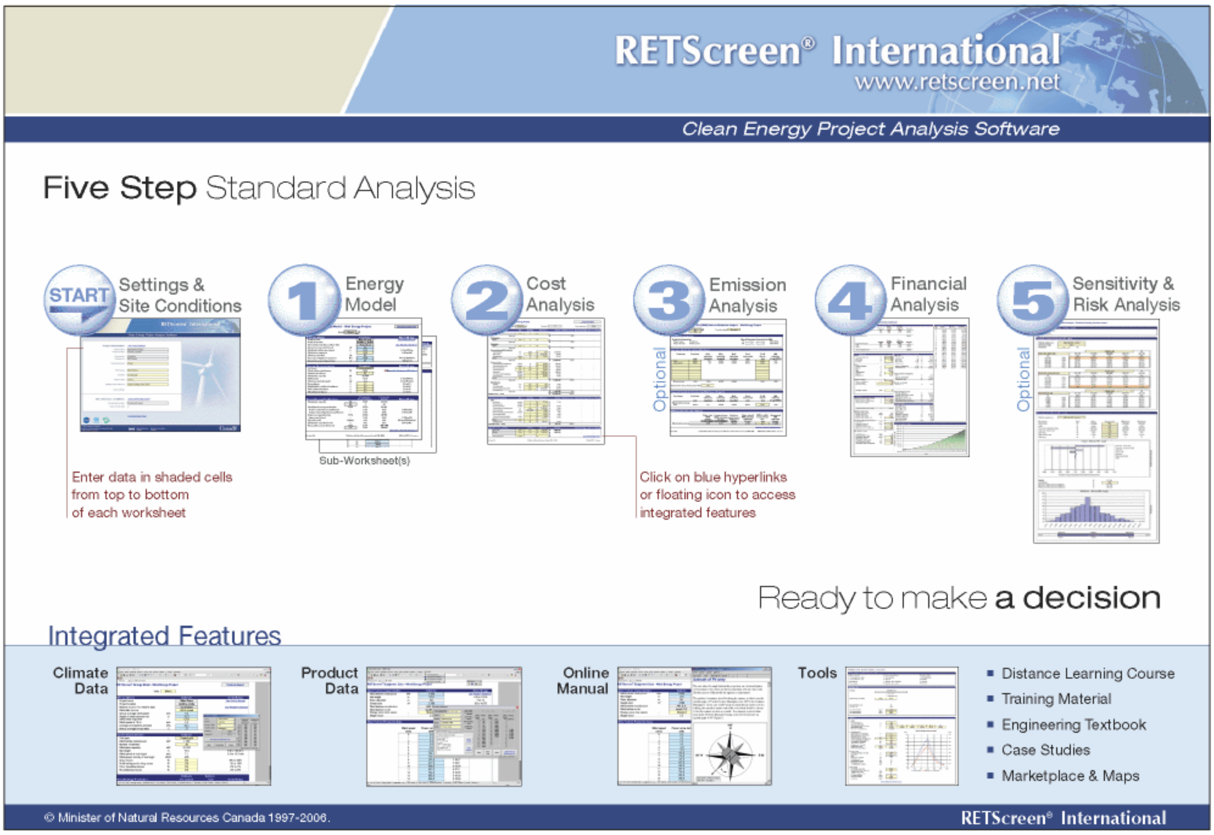

Figure 1: Five Step Standard Analysis

4 ARENA MODEL

The RETScreen Software estimates the energy savings, life-cycle costs, and greenhouse gas emissions reductions for ice rinks, permitting the user to investigate the impact of a wide range of advanced efficiency measures. These include the integration of the refrigeration and heating systems in order to achieve waste heat recovery, the use of secondary loops to distribute heat while reducing refrigerant leakage, lighting and ceiling improvements, floating head pressure, varying the thickness of the ice and layer of concrete above the embedded tubes, and other measures. The RETScreen Software permits the use of multiple currencies, operates in a choice of unit systems, and includes a number of useful auxiliary tools.

4.1 Settings Worksheet

The worksheet settings, represented in Figure 2, is the first step to be completed for the data entry in the model. We define the type of facility here “Arena (hockey & skating)”, the language, the currency and the units of measurement desired. The user must choose between "Higher heating value (HHV)" or "Lower heating value (LHV)" base for fuel energy calculation. Finallly, the user enters the climate data location with the most representative climate conditions for the project. In this example the site is Montreal in Canada. The software engine for calculating energy consumption uses climate data monthly averages and design conditions as shown in the table.

RETScreen Settings & Site Conditions - Arena (hockey & skating) project

Project information

Project name	Arena (hockey & skating)
Project location	Quebec, Canada
Prepared for	Refrigeration Action Program for Buildings (RAPB)
Prepared by	Name - Organisation
Facility type	Arena (hockey & skating)

Settings

Language - Langue	English - Anglais
Online manual	English - Anglais
Currency	$
Units	Metric
Heating value reference	Higher heating value (HHV)

Site reference conditions

Select climate data location

Climate data location	Montreal Int'l. Airport
Show information	☑

	Air temperature	Daily solar radiation
Monthly average	**°C**	**kWh/m²/d**
January	-10.3	1.53
February	-8.8	2.39
March	-2.4	3.56
April	5.7	4.31
May	12.9	5.14
June	18.0	5.72
July	20.8	5.81
August	19.4	4.78
September	14.5	3.75
October	8.3	2.31
November	1.6	1.28
December	-6.9	1.06
Annual average	6.1	3.47

Heating design temperature	°C	-21.5
Cooling design temperature	°C	28.2
Annual average wind speed	m/s	3.6

Complete Energy Model sheet

Figure 2: Settings worksheet –Climate Data

4.2 Energy Model Worksheet

This worksheet is divided into two parts: the Facility Characteristics section and the Energy Efficiency Measures section. The Facility Characteristics section is a detailed description of the rink and hours of operations that significantly affect energy consumption. Figure 3 shows this section where the user enters the important dimensions of the facility, the operating schedule, number of spectators and the number of ice rink surfacing per week. For this example the ice rink dimensions correspond to the national Hockey Ligue are typical for
As per the National Hockey League Official Rules 2007-2008, the official size of the rink shall be 61 meters (two hundred feet 200') long and 26 meters (eighty-five feet 85') wide. The corners shall be rounded in the arc of a circle with a radius of 8.5 meters (twenty-eight feet 28') [The National Hockey League 2008]. The operating schedule is typical for municipal ice rinks, 86 hours per week, nine months per year of intensive rink operation, from August to May. The seventy ice surfacing per week yield to two energy consumption impacts: for process water heating and for the refrigeration load resulting from the hot process water solidification.

RETScreen Energy Model - Arena (hockey & skating) project

Facility characteristics	Unit			%
Dimensions				
Ice rink length	m	61		
Ice rink width	m	26		
Number of ice rinks		1		
Total ice rink(s) area	m²	1,580		52.5%
Spectator area	m²	350		11.6%
Administrative area	m²	400		13.3%
Dressing room area	m²	500		16.6%
Unconditioned area	m²	180		6.0%
Total building floor area	m²	3,010		100.0%
Ice rink ceiling height	m	8.0		
Other area ceiling height	m	3.4		
Operating schedule				
Operating season - start	mmm-dd	August		01
Operating season - end	mmm-dd	May		01
Operating hours per day - weekday	h/d	12		
Operating hours per day - weekend	h/d	18		
Peak number of spectators		500		100.0%
Average number of spectators		100		20.0%
Number of ice resurfacings per week		67		

Figure 3: Energy Model Sheet – Facility Characteristics

The fundamental RETScreen's approach compare a base case and a proposed case. The absolute costs and benefits of the clean energy technology are not necessarily considered; rather, the incremental costs and benefits, compared to the conventional technology, are evaluated.

As shown in Figure 4, the Energy Efficiency Measures Section is divided into 5 columns: the name of the measure, the measurement units, the base case, the proposed case and the estimated incremental cost of the measure. This method of data entry compare instantaneously the energy impact of an energy efficiency measure. The list of measures considered are:

- The thermal insulation of the building envelope;

- The type of ceiling above the ice and the influence of the ceiling radiation emissivity;
- The air makeup of the building as well as the set points for the temperature and humidity for the bleachers;
- The hot water consumption for showers;
- The intensity and the schedule of lighting for the ice rink and the building;
- The brine piping circuiting type embedded into the concrete slab, the thickness of ice, the control method and the temperature of the ice, the temperature and the amount of surfacing hot water;
- Finally, measures that allow the recovery of the heat rejected by the refrigeration system or by the superheated gases from the compressors discharge or from the condensation heat. The floating head pressure control is also considered, it is either fixed or variable to take benefit of the cold climate.

Energy efficiency measures	Unit	Base case	Proposed case	Incremental cost (credit)
		Copy base to proposed	See Energy consumption graph	
Building envelope				
Exterior walls insulation level		Medium	Medium	$ -
RSI-value of exterior walls	m² - ºC/W	2.40	2.40	
Roof insulation level		Medium	Medium	$ -
RSI-value of roof	m² - ºC/W	4.80	4.80	
Ceiling type		High-e ceiling	Low-e aluminised covering	$ 35,000
Ceiling emissivity		0.85	0.05	
Building controls & ventilation				
Ice rink design airflow rate	L/s - m²	1.50	1.50	
Ventilation operating strategy		According to the occupancy	According to the occupancy	$ 27,000
Stands temperature operating strategy		Heating / No cooling	Heating / No cooling	$ -
Stands temperature	°C	15.0	15.0	
Stands & ice rink relative humidity	%	50%	50%	$ 25,000
Domestic hot water				
Number of showers per week		670	670	
Miscellaneous hot water use	L/d	200	200	
Lighting				
Ice rink lighting load	kW	24.0	12.0	$ -
Ice rink lighting load per unit area	W/m²	15.2	7.6	
Other lighting load per unit area	W/m²	8.0	8.0	$ -
Other lighting load	kW	11.4	11.4	
Total lighting load	kW	35.4	23.4	
Lighting schedule		User-defined	User-defined	$ -
Hours of lighting per week	h/w	80	80	
Ice rink				
Rink secondary fluid circuit		2-pass circuit	2-pass circuit	$ -
Rink secondary fluid flow rate	L/s	50.00	50.00	
Ice thickness	mm	30.00	30.00	
Ice temperature	°C	-7.0	-7.0	
Ice temperature control		Constant	Constant	$ -
Ice resurfacer hot water use	L	430	430	
Ice resurfacer water temperature	°C	65	65	
Refrigeration system				
Superheat recovery		No heat recovered	Heat recovered for water heating	$ -
Superheat recovery rate	%		50%	
Condensing heat recovery		No heat recovered	Heat recovered for space heating	$ -
Condenser head pressure control		Fixed	Floating	
Heating capacity - heat pump	kW		100.00	See product database
Manufacturer				
Model				1 unit(s)
Heating design COP - heat pump			4.0	
Total incremental costs (credits)				$ **87,000**
		Complete Equipment Selection sheet		

Figure 4: Energy Model Sheet - Energy Efficiency Measures

4.3 Equipment Selection Worksheet

This worksheet contains the same 5 columns already identified (Figure 5). Entries for this sheet describes in detail the equipment for the base case and the proposed case by defining the following parameters: the types of equipment, capacity, efficiencies, coefficient of performance, the types of energy source, the energy rates and the incremental costs if applicable. The Equipment selection worksheet calculates the peak demand and the annual energy consumption for the two cases to be compared. Moreover, the user can activate a floating graph, shown in Figure 6, that represents in real-time the comparative results of equipment energy consumption for the equipments listed in the Equipment Selection worksheet: refrigeration systems, space heating, domestic water heating, process water heating (hot water for ice surfacing), air-conditioning system and finally the lighting system. The user can see at a glance the impacts of simultaneous measures on one simple graph.

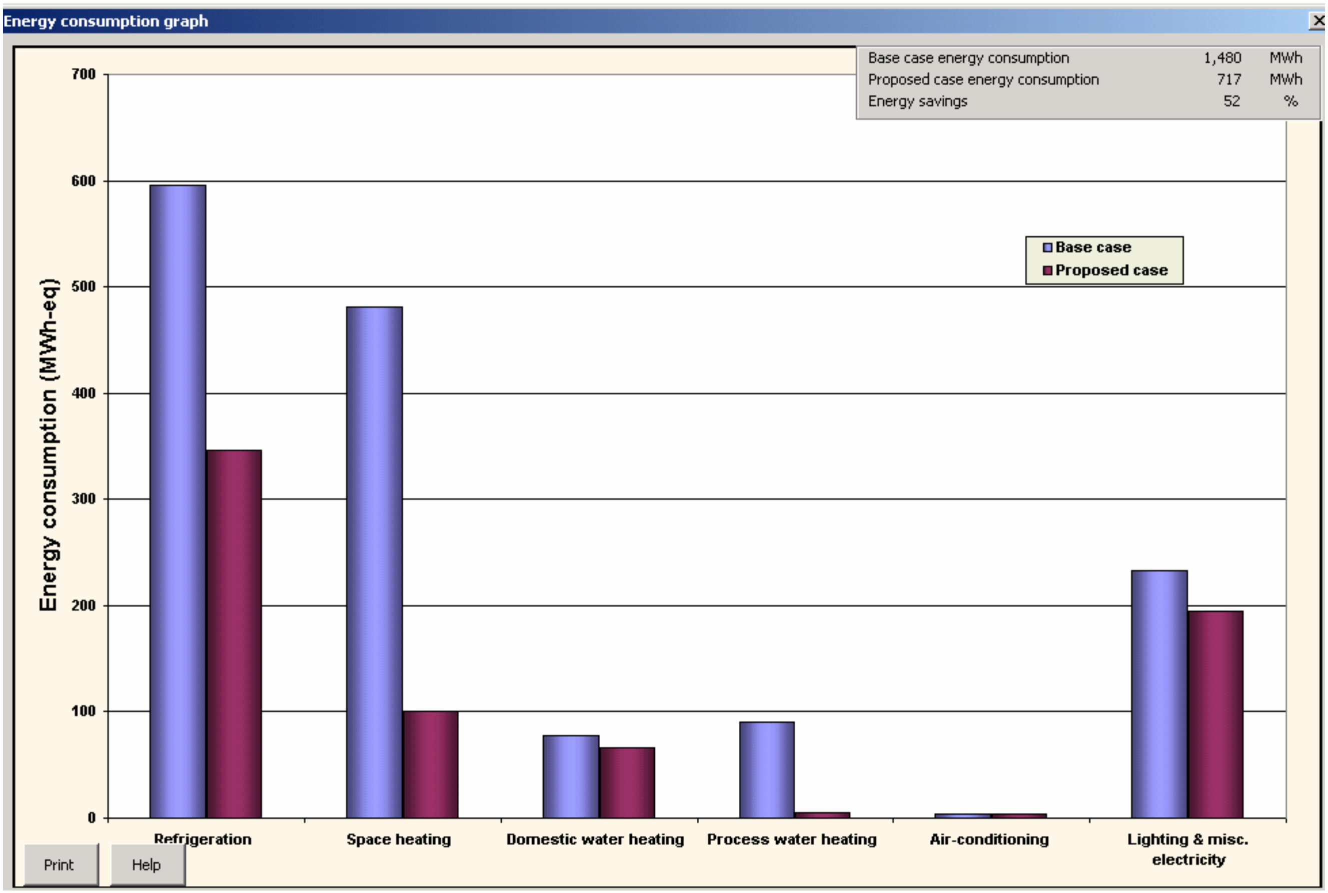

Figure 5: Energy Consumption Graph

RETScreen Equipment Selection - Arena (hockey & skating) project

System characteristics	Unit	Base case	Proposed case	Unit	Incremental cost (credit)
		Copy base to proposed	See Energy consumption graph		
Refrigeration system					
Demand	MWh	941	630	MWh	
Equipment type		Compressor	Compressor		
Peak load	kW	727.35	624.34	kW	
Suggested capacity	kW	363.68	312.17		
Equipment design conditions					
Capacity	kW	280.00	280.00	kW	$ 45,000
Manufacturer					
Model	1 unit(s)			1 unit(s)	See product database
Coefficient of performance - design		2.1	2.1		
Refrigerant condensing temperature	°C	40.6	40.6	°C	
Refrigerant condensing temperature - minimum	°C	35.0	20.0	°C	
Entering air temperature - condenser	°C	32.2	32.2	°C	
Refrigerant evaporating temperature	°C	-15.0	-15.0	°C	
Leaving secondary fluid temperature - evaporator	°C	-11.0	-11.0	°C	
Coefficient of performance - seasonal		2.0	2.8		
Electricity consumption - compressor	MWh	473	224	MWh	
Electricity consumption - secondary fluid pumps	MWh	122	122	MWh	
Electricity rate	$/kWh	0.081	0.081	$/kWh	
Electricity cost	$	48,198	28,025	$	
☑ **Refrigerant**					
Refrigerant type		R-22 (HCFC)	R-22 (HCFC)		$ -
Global warming potential	kgCO2/kg	1,700	1,700	kgCO2/kg	
Refrigerant amount	kg	750	750	kg	
Annual refrigerant losses	%	10%	10%	%	
Refrigerant rate	$/kg	12.5	12.5	$/kg	
Initial cost	$	9,375	9,375	$	$ -
Annual cost	$	938	938	$	
Space heating system					
Demand	MWh	385	4	MWh	
Equipment type		Boiler	Boiler		
Fuel type		Natural gas - m³	Natural gas - m³		
Peak load	kW	152.84	52.95	kW	
Capacity	kW	250.00	250.00	kW	$ -
Manufacturer					
Model	1 unit(s)			1 unit(s)	See product database
Seasonal efficiency	%	80%	80%	%	
Fuel consumption	m³	46,189	436	m³	
Fuel rate	$/m³	0.550	0.550	$/m³	
Fuel cost	$	25,404	240	$	
Electricity consumption - heat pump			95	MWh	
Electricity rate - heat pump			0.050	$/kWh	
Electricity cost - heat pump			4,772	$	
Total fuel cost			5,012	$	
Domestic water heating system					
Demand	MWh	62	53	MWh	
Equipment type		Boiler	Boiler		
Fuel type		Natural gas - m³	Natural gas - m³		
Peak load	kW	23.69	0.00	kW	
Capacity	kW	36.00	36.00	kW	$ -
Manufacturer					
Model	1 unit(s)			1 unit(s)	See product database
Seasonal efficiency	%	80%	80%	%	
Fuel consumption	m³	7,399	6,413	m³	
Fuel rate	$/m³	0.550	0.550	$/m³	
Fuel cost	$	4,069	3,527	$	
Process water heating system					
Demand	MWh	73	5	MWh	
Equipment type		Boiler	Boiler		
Fuel type		Natural gas - m³	Natural gas - m³		
Peak load	kW	28.99	0.00	kW	
Capacity	kW	36.00	36.00	kW	$ -
Manufacturer					
Model	1 unit(s)			1 unit(s)	See product database
Seasonal efficiency	%	80%	80%	%	

Figure 6: Equipment Selection Sheet

5 CONCLUSIONS

RETScreen calculates the energy savings and greenhouse gas emissions reductions associated with a wide range of energy efficiency measures and refrigeration system improvements for ice and curling rinks. In so doing, RETScreen provides significant preliminary feasibility study cost savings and consequently induce more energy efficient projects for ice and curling rinks.

6 REFERENCES

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