Heat Re-Circulation of the Columbia Icefields

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By:

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Introduction

According to the Oxford Dictionary the term feasible indicates possibility or practicality (Allen1989). The Greening the Campus project allows students to discover the meaning of the word feasible on many different levels. In the beginning, every idea on how to make the campus more sustainable is achievable in the student's eyes, but as the project goes on other things seem to get in the way of high hopes. Whether it is difficulty in obtaining quantitative data or financial barriers, many unforeseen obstacles can be expected. Nevertheless, Greening the Campus incorporated with WATgreen acknowledges that there are environmental problems on campus that can be changed. This allows students to creatively explore different research methods to move closer to a more sustainable campus and community. WATgreen is an organization that is in support of an environmentally aware campus; it offers significant new directions and opportunities for education and research (WATgreen 2003). WATgreen also promotes and supports sustainable activities making our campus at the University of Waterloo much more efficient (WATgreen 2003). To help WATgreen with its mandate our group decided to look at heat recycling and the benefits that could come from it. The Columbia Icefield Arena and its current cooling and heating systems were a suitable choice because in the process of cooling the ice the arena creates waste energy in the form of heat. When we started this project we predicted that the building could be heated by recirculating waste heat, thus saving the University of Waterloo energy and money. The initial goal of our project was to determine if a sustainable heat recirculation system would be feasible for the long term. The rationale behind this particular project was to determine if it is practical to harness the waste-heat energy. The recycling of heat is an initiative that will become more and more prominent with escalating energy costs and increasingly strict emission control standards (Staicovici 2002). Heat regeneration is a method of energy conservation, which many large companies throughout North America have adopted because it has managed to save millions of dollars a year (Chiras 2001).

The functions of ice have evolved due to the development of large scale refrigeration systems which can maintain ice rinks year round. Historically ice was a means of getting across small bodies of frozen water or coastal areas during the winter months (Ausley 2003). This is no longer the case. Ice has become more available year around which has served to increase the popularity of ice sports such as hockey. The first indoor ice rink was built by Lester and Joe Patrick in 1912. Underneath the ice was the world's then-largest refrigeration and ice-making system (Ausley 2003). The traditional size of an ice rink is normally 200’x85’, and an Olympic size ice rink is 200’x100’(McClean 1998). Indoor rinks require large refrigeration systems to make sure that the rink is not a small pond. Originally refrigerants were made of glycerin and water solutions; however, a lot has changed since then (Ausley 2003). Presently the refrigeration system of an arena can be created in a number of ways. There are a variety of cooling systems, from "environmentally friendly" energy efficient systems to wasteful ones. Some individual businesses provide excellent green benefits. An example of this is The Ice Kube system that was recently installed in the Port Elgin Arena in 1999, which will be discussed in detail under the Case Studies section (Renewable Energy 2001). Another important refrigeration company that has been creating ice rinks for 75 years is CIMCO. They have built over 4000 different facilities worldwide (CIMCO 2003). In fact, it was CIMCO that put in the Columbia Ice fields located in Waterloo in 1983 (Bill Kern, pers. comm. 2003).

Key Terms:

Feasibility: the capital costs of implementing a heat recirculation system must be paid back through energy savings resulting from its implementation within five years maximum. This project would have a higher chance of being installed if it paid for itself within three years (Rick Zalagenus, pers. comm).

Sustainability: Development that meets the needs of today without compromising the ability of future generations to meet their needs (Draper, 2002).

Methodology:

To legitimize our study, triangulation was achieved by gathering information from three sources: case studies of heat-recirculation systems at arenas, interviews with key informants, and measurements of cost and energy.

The approach taken to the case study review was exploratory. As Palys (2003) states, the exploratory approach allows researchers to achieve a better understanding of the phenomenon of interest to develop a better research question. This research was completed first to give the authors, who were admittedly unfamiliar with heating and cooling systems, a sense of what sort of recirculation system would be reasonable to propose. Academic journals, internet sources, and on-campus refrigerant systems were researched for relevant case studies of implemented heat recirculation systems.

The population of possible interviewees consisted of the core actors described above. Because of limited time, not all potential key informants could be interviewed. Thus it was necessary to sample. Intensity sampling, which involves choosing interviewees because of their experiential expertise in the area of interest (Palys 2003), was determined to be the most appropriate method because the information sought is specific and unknown even by some core actors. Strictly factual information was sought in the interviews. After reviewing the positions of the core actors, it was decided that one arena operator and one engineer from Plant Operations would be formally interviewed, and that construction and refrigeration companies would be consulted informally to supplement technical information.

Much of this technical information was applied in the quantitative calculation of feasibility. First, the maximum energy input of the arena's refrigeration system was determined. Next, the thermodynamic efficiency was estimated and used to calculate the amount of available "waste" energy. Efficiency of the proposed heat exchange was used to calculate the amount of waste energy that would be transferred to the new medium. Heat loss due to imperfect insulation as the new medium transports the captured heat to its destination was taken into account. The amount of time the cooling system runs, and that proportion of time it runs at capacity were incorporated into the calculations. Finally, the amount of energy potentially saved per hour was expanded to an amount of energy per month, then per season and finally per year. To determine what the equivalent cost of this total annual reused energy would be, the number of energy units was divided by the number of units of energy in one cubic meter of natural gas. Natural gas is the source of energy for the heating of the building (Bill Kern, pers. comm.. 2003). And finally this figure was multiplied by the number of dollars one cubic meter of natural gas costs. Capital costs were calculated by identifying and totaling operating, employment, and equipment costs. Feasibility was determined by comparing the total cost savings over five years and the capital cost. If the capital cost is larger, then the project is not feasible. Conversely if the savings are larger then the capital cost, it is feasible. Whenever there was ambiguity about a price or percent efficiency, conservative estimates were made. For example, a construction company employee estimated that installation of the heat-capturing system would take eight hours: we took that number up to twelve to ensure that our calculations would not claim to demonstrate feasibility unrealistically.

Systems Analysis

Core actors include the head engineer at Plant Operations, the manager of the arena, and the refrigeration company. Supporting actors include the University Board of Governors, Plant Operations administration, and maintenance staff. University of Waterloo students and other visitors to the arena are shadow actors.

Before exploring possible improvements to the Columbia Icefield cooling system, it is important to understand the mechanisms of the current system. Figure 1 maps the most significant inputs and outputs of the ice rink. Significant inputs include the refrigerant, which in this case is ammonia, water, operating funds, calcium chloride brine, and energy derived from natural gas. Significant outputs include water vapour, waste heat, captured heat, and exercise and improved student life. Improving student life is the reason the arena exists. Figure 2 is a more detailed description of the cooling system. The system was installed in 1983 and has not undergone significant changes since then (Bill Kern pers. comm. 2003). The cooling method for ice rinks is very similar to that of a household refrigerator, in which a fluid with a very low freezing point is circulated through the space or object to be cooled, absorbing that space or object’s heat and releasing it. Freon and Ammonium are the most commonly used working fluids in ice rinks. In the case of the Columbia Icefield, Ammonia is the working fluid. Ammonia is sent through a nozzle (See Expansion Valve, Figure 2), which expands the fluid into a gas, thereby cooling it to temperatures below zero degrees Celsius. It is to dangerous to use a volume of ammonia large enough to fill the approximate 12 miles of 1-inch piping that runs under the rink (Kern, pers. comm. 2003). Therefore, the under-rink pipes are filled with saltwater brine, cooled by heat exchange with the cold ammonia gas (See Brine Pipe under Rink, Figure 2). After passing through the heat exchange, the warmed ammonia gas enters the compressor (Compressor, Figure 2) where it is condensed into a very hot fluid (Kern, pers. comm. 2003). This runs up to condenser unit (Condenser, Figure 2) on the roof, where the pipe is in the form of a coil to increase surface area and therefore increase heat exchange with the air. A fan blows the warmed air out into the atmosphere. The still-hot ammonia fluid is further cooled by exchanging heat with another brine pipe that runs under the arena at a depth of four feet (Underground Brine Pipe, Figure 2). This warmed brine solution keeps the ground underneath the building from freezing, thus preventing structural problems from shifting ground (Kern, pers. comm. 2003). The lukewarm ammonia continues back to the nozzle and the cycle begins again. Complementing the ammonia cycle is a water cycle, in which water runs over the compressor to cool it. The warm water is stored in a holding tank (Water Holding Tank, Figure 2) and pumped up to the rooftop condenser, where it is sprinkled over the ammonia coil to increase cooling efficiency, and is blown off as water vapour (Kern, pers.comm.. 2003).

Results

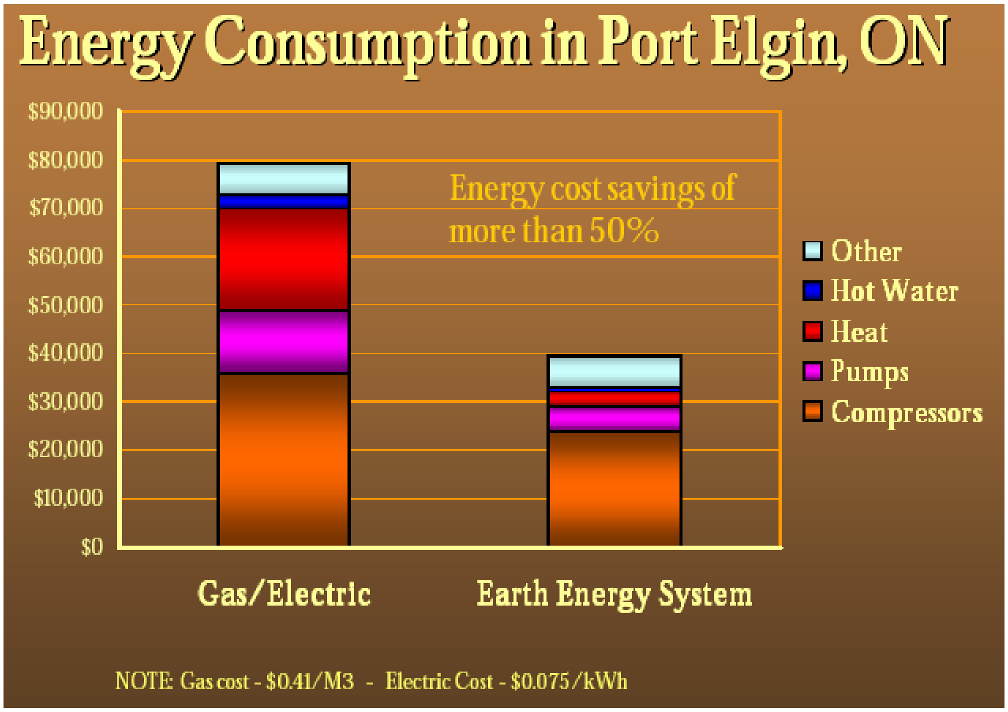
Originally, our proposal had been to build a duct around the hot ammonia pipe to capture the warm air and direct it back into the building. However, Rick Zalagenus informed us that this recirculation technique is impossible because it conflicts with the B52 Refrigeration Code. This code is meant to ensure that refrigeration systems are safe. Any systems with refrigerants which are dangerous to human health are required to have limited access and careful construction to avoid leakage (Canadian Standards Ass. 2002). In this case, vapours from a leak in the ammonia pipe would be sent straight into the air breathed by visitors to the arena. This is directly in conflict with the B52 Code.

Thus, another heat recirculation technique was researched. Instead of heating the air with captured waste heat, we chose to study the feasibility of using the waste heat to warm water for the building. The GFX Power Pipe system was determined to be suitable for this application. An 80 inch section of the warm ammonia pipe would be replaced with a copper GFX pipe. This pipe is wrapped with a thinner pipe through which flows cold city water. After absorbing the heat from the ammonia, the warmed water flows through insolated piping to the hot water heater, thereby reducing the amount of work the heater has to do (Renewable Energy Inc. 2002). Cross-contamination from the ammonia pipe is unlikely since the GFX pipes are carefully designed to prevent leakage of greywater to drinking supply (Renewable Energy Inc. 2002).

Case Studies

In order to create and sustain an ice rink a lot of energy is used. There is a substantial amount of heat created when cooling the ice down to a freezing. Like the Colombia Icefields, this heat normally is carried through a series of pipes and released into the atmosphere. In Port Elgin, Ontario contractors set to build the rink realized this problem and decided to recirculate the heat and use it to keep the building warm. A ground loop of piping was built below the frost line, which stores the excess heat at a constant temperature. (Renewable Energy 2001). The reaming building is heated from the floor. There is a series of piping that runs along the floor of the building. This piping has a direct link to the underground loop (Renewable Energy 2001). A geothermal unit along with a dry fluid cooler unit act as the thermostat of the building, when the temperature is too low the geothermal unit draws more heat to increase temperature. While if the temperature is too high the dry fluid cooler unit decreases the temperature (Renewable Energy, 2001). In order to build the geothermal ice system there is a much larger initial layout but as shown here in the graph the return is more than a fifty percent annual savings in energy. These savings are based on energy costs of 1999; these savings will become larger the more energy costs increase.

Figure 3: Energy Savings at the Port Elgin Arena from Heat Recirculation.



Ice Kube, the company that built the Port Elgin arena, has approximately 3,000 arenas' that are going to be constructed in the next five years. 3,000 geothermal ice rinks will reduce green house gas emissions by about 420,000 tonnes. That is equivalent to 45,000 cars off the road (Renewable Energy, 2001). There are also lots of energy incentives for retrofitting and constructing new projects to comply with new energy management requirements. Enbridge Gas offers up to $30,000 rebate for complying with their new energy management program Multi*CHOICE* (Enbridge Gas, 2003). Enbridge measures gas usage on a cubic metres scale. This one-time incentive is calculated on the basis of the projected first-year natural gas savings and is given out on project completion. A portion of eligible incentive funds may be advanced to help defray the costs of feasibility or engineering studies (Enbridge Gas, 2003).

Heat recirculation from cooling systems is not a new phenomenon on the University of Waterloo's campus either. Recirculation systems have been installed in several locations in the Science buildings (Patti Cook pers. comm.2003.). A description of the system in room 371B of Chemistry 2 was provided by the Chemistry Department Manager Scott Nicoll. This small room, approximately 10 by 12 feet, is kept at four degrees Celsius. The refrigerant is Freon. This small cooling system generated so much waste heat that a section of the roof above the hot Freon pipes had to be opened up to the air (Scott Nicoll, pers. comm. 2003) A few years ago a heat recirculation system was added in which cool city water runs over the hot pipes and through a radiator at the building's air intake, raising the temperature of incoming air by ten degrees Celsius before it is heated the rest of the way by the furnace-powered radiator (Scott Nicoll, pers. comm 2003). This is an example of a feasible heat-recirculation renovation. However, the temperature of the hot Freon, 119 degrees Celsius, was higher than the temperature of the hot ammonia, about 45 degrees Celsius, used at the Icefields (Scott Nicoll, pers. comm.. 2003).

Interviews

The findings from our interviews were mostly qualitative; the information compiled came from interviews of key informants. Our group interviewed Mr. Bill Kearn who is head of maintenance of Columbia Icefields as well as interviewing Mr. Rick Zalagenus, the head engineer at plant operations. The information obtained from Mr. Kearn was completely qualitative, he explained the current process for heating the building and how the cooling system of the arena works. The Columbia Icefeild was built in 1983 and to this day is still using the same cooling system. The building is heated by natural gas but the arena itself is not heated at all. However, ice is cooled by an ammonia system with a calcium chloride solution. The ammonia is cooled and sent through piping underneath the ice surface. The piping underneath the ice is one inch in diameter running under the entire surface. The total length of the pipe is twelve miles long. The cooling system is run by a computer that monitors and regulates the temperature acting as a thermostat. When the ammonia reaches the correct temperature the computer shuts the system off just as a thermostat would. Also, the ammonia is extremely hot once it has entered the coil, and it is highly recommended that one does not touch the piping at this time. Once the ammonia is heated, it is cooled and stored in a holding tank before moving on to the condenser. The condenser unit is located on the roof of the Columbia Icefield complex where a fan then cools the ammonia by pushing air over it, and water is sprinkled to chill the ammonia pipe further. Furthermore, the compressor uses water to cool itself, or else the system would entirely over heat. In fact there is no one particular temperature the compressor is it kept at because it is regulated by the amount of water it uses at any given time. Kern also mentioned that it is more common to have a lot of little compressors running instead of two larger ones because using smaller compressors is more efficient in the long run. However, in the fall and winter the Icefeild only needs to use one compressor because it is much warmer in the summer thus needed the extra compressor.

Using a snowball methodology for our interviews we took the information that Mr. Kearn gave us and formed appropriate questions for Mr. Zalagenus,. Mr. Zalagenus, was pleased with the idea we proposed, however, at this time it was not practical as the temperature of the ammonia being released is not hot enough to use for recirculation back into the building. The temperature of the ammonia gas is variable at best ranging from approximately ninety to a hundred and five Fahrenheit. Monthly heating bills are hard to determine as the water and air are both heated by natural gas. There is a large amount of water consumption in the building. Showers are constantly being used as well as the bathroom, which adds to a large part of the natural gas bill. There is only one natural gas meter that reads total monthly consumption and it does not differentiate between water and hot air. The proposed method for re-circulating the heat into the building is through a duct that captures the hot air that is released into the atmosphere. However, Mr. Zalagenus, informed us that the logistics of that method is not possible because the air containing ammonia cannot be released into the building. The proposed idea needs some minor alterations to the plan. A second duct would have to be installed that would separate the ammonia and hot air. Also the construction would have to follow the proper building codes. The B52 refrigeration code prohibits construction that could allow the ammonia to escape into the building (Canada Standards Ass. 2002) . Mr. Zalagenus, is the person who has the ability to approve the construction of the new system. He has the authority to grant the funds to any small projects under $100 000, which our study would be classified under this type of renovation. However at this stage the feasibility is not possible as there are limitations that have to be addressed.

Calculations

$33 491 /year

33 491 $/year * 0.7 = 23 444 $/year

The average cost of natural gas used by the arena for heating both air and water is $33 491 for the year 2000. The majority of energy costs are for heating water (Rick Zalagenus pers. comm.. 2003) (See Appendix 1). Thus it was estimated that 70% of the total natural gas expenditures per year went to heating water.

Therefore, savings cannot exceed 23 444 4/year.

130 horsepower/hr * 0.6 = 78 horsepower/hr

78 horsepower/hr * 2547 = 198 666 BTU/hr

198 666 BTU/hr * 0.62 = 123 173 BTU/hr

123 173 BTU/hr * 0.9 = 110 856 BTU/hr

Summer:

30 day/month * 24 hr/day = 720 hr/month

720hr/month * 110 856 BTU/hr = 79 816 052 BTU/month

79 816 052 BTU/month * 0.75 = 59 862 039 BTU/month

59 862 039 BTU/hr * 6 months = 359 172 235 BTU/half year

Winter:

720 hr/month / 2 = 460hr/month

360 hr/month * 110 856 BTU/hr = 39 908 160 BTU/month

39 908 160 BTU/month * 0.75 = 29 931 120 BTU/month

29 931 120 BTU/month * 6 months = 179 586 720 BTU/half year

179 586 720 BTU/half year + 359 172 235 BTU/half year = 538 758 955 BTU/year

538 758 955 BTU/year / 35 500 BTU/m3 = 15 176 m3/year

15 176 m3/year * 0.39 $/m3 = 5919 $/year

The maximum temperature of the ammonia pipe is about 95 degrees Fahrenheit (Cimco employee pers. comm.2003). However, because of the wide variety of influences on temperatures, waste energy is calculated in British Thermal Units, or BTU. The refrigeration system, when running at maximum capacity, is 130 horsepower per hour (Bill Kern pers. comm.2003.). Assume that the thermodynamic efficiency of the system is 40%. This means 60% of total energy input is waste energy. Assume that all waste energy is in the form of heat. Thus 78 horsepower/hr is available for recirculation. This figure is converted to BTU/hr, where 1 horsepower/hr (electric) equals 2457 BTU/hr. The 80-inch model of the GFX system is 62% efficient (GFX Heat Recovery Systems 2003). Polyurethane insulation which would envelope the hot water pipe is extremely effective; a conservative estimate of its insulation efficiency is 90% (Reitzal Insulation Co. employee, pers. comm.. Nov 19, 2003). The compressor runs during winter months approximately half of the time, and all the time in the summer (Bill Kern. Pers. comm.. 2003). However, the system does not function at capacity during all the periods when it is running (Bill Kern, pers. comm.. 2003). This is taken into consideration in the calculations by estimating that during half of the time the compressor is on, it is only running at half of capacity, thereby generating a total of 75% of the maximum energy load. Thus the number of hours the system is running in both winter and summer is multiplied by 0.75. For the sake of simplicity, winter and summer are each counted as six months long. According to Natural Resources Canada (2003), there are 35 500 British Thermal Units (BTU) of energy within one cubic meter of natural gas. Currently, the price of natural gas in Southwestern Ontario for small industrial uses is 39.7 cents per cubic meter (Union Gas 2003). After accounting for all of these factors, the savings per year equal $5 919.

Capital costs

1$/ft * 250ft = 250$

9 $/12 ft * 250 ft = 187.5 $

70 $/hr * 16 hrs = 1 120 $

$ 615 + $187.5 + $250 + $1 120 = $ 2172.5

Polyurethane insulation costs about one dollar per foot (Reitzal Insulation Co. employee, pers. comm.. 2003). Approximately 250 feet of piping would be needed. Copper piping costs approximately nine dollars per twelve feet, and 250 feet would be needed. A construction company estimated a rate of 70$/hr for the plumber, and eight hours to complete. Because projects often run overtime, this number of hours was doubled in out calculations. Maintenance costs are negligible (Renewable Energy Inc. 2002). The total capital cost of the GFX system would be $2 172.5.

The GFX systems would saving $3746.5 in the first year, after accounting for capitol costs, and $5 919/yr in the years after.

Discussion

When conducting a feasibility study, it is important to have general knowledge in the area of study (Palys 2003). Researchers should have a basic understanding of the system of interest as well as the key actors and their biases. Our inexperience as researchers was apparent in our assumption that the technical system and the motivations of the actors could be thoroughly understood in the span of a few short months.

First, there were physical limitations in our measurements. For example, access to the refrigeration room was denied. This prevented the measurement of the temperature of the hot ammonia pipe. Instead, the temperature was discovered through CIMCO, a secondary source. Fortunately this proved to be more accurate than a physical measurement; the system is set to run at a certain maximum temperature that CIMCO provided for us, which avoided the need to take several temperatures and estimate maximum temperature range.

There is room for error in the calculation of the price of installation as well. From calling a reputable company, they were able to tell us how much the pipe would cost. This price might vary from one company to another. Construction companies estimated the costs of equipment such as insulation and copper piping. These estimates were very rough. To minimize wishful thinking, these costs were rounded up. The rate per hour for the plumber and number of hours necessary estimated by Rietzel Construction were also rounded up.

Another possible source of error was the actual layout of the building. In order for the energy to be re-used, the heat traveling in the pipe would have to go from the refrigeration room on one side of the arena all the way to the other side where the hot water heat is (See Figure 4). If these two locations were closer together, it would have been much easier to implement.

Along with the physical limitations of the project, there were also many administrative limitations. Within Plant Operation's budget is a specific amount of money being used for maintaining the buildings on campus. This includes paying for building repairs, heat, electricity, and staff. There would be also money set aside in case of emergency, like a leaky roof, or in the case of Columbia Icefields, an issue relating to the maintenance of the rink such as a flooding problem (Rick Zalagenus, pers. comm.. 2003). Unfortunately, there is not much money left over for retrofitting projects. The priority of Plant Operations is ensure that the buildings and systems are running smoothly; improvements are secondary.

One impediment to feasibility was the low price of natural gas. Union Gas describes how the price of natural gas is selected, and the company maintains that they are keeping the costs low for the convenience of the consumer. However, some environmentalists believe that consumers are not being charged the correct price that take into account the environmental and social impacts of exploiting unrenewable resources (McKenzie 2003). Union gas assures customers that “There is an abundant supply of natural gas. Our current reserves are thirty times greater than annual consumption” (Union Gas 2003). People need to be better educated and made more aware of the actual facts involving the over-consumption of not just fossil fuels, but all nonrenewable resources. The larger oil and gas companies need to take effective measures in implementing change and hopefully this would influence smaller companies to see the advantages to energy conservation.

According to our calculations, installing an 80 inch GFX system on the warm section of the ammonia pipe of the Columbia Icefields arena is feasible. The literature review revealed several examples of feasible heat recirculation systems, however only one example of feasible retrofitting was found. Interviewees did not think that the project would be feasible. This discrepancy between the results of the interviews and the calculations might be caused by flaws within the calculations, or preconceptions of the interviewees. A more detailed study of energy flow within the arena’s refrigeration and heating systems should be undertaken to solve this inconsistency.