Proposed Renovations for Lansing Chapman Rink

Energy Efficiency Improvements

A Luce Foundation Grant Report
By Corey Benson '11

Executive Summary

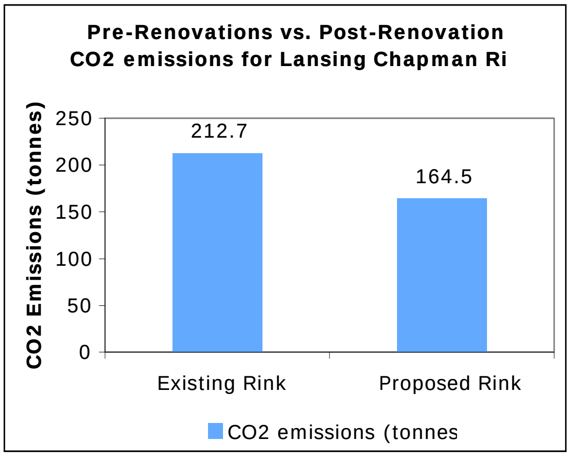
Lansing Chapman rink has been an integral part of Williams College campus since 1961, serving as home ice for the men's and women's Varsity hockey teams. While the rink's biggest aesthetic appeal is its classic voluminous design, it is this design that also creates unnecessary and wasteful energy use and carbon emissions. With these two considerations in mind, i.e. the historical appeal of the building and its decidedly inefficient design, I attempted to identify solutions that would maintain the rink's architectural character while drastically improving the rink's energy efficiency and ultimately saving the College thousands of dollars annually.

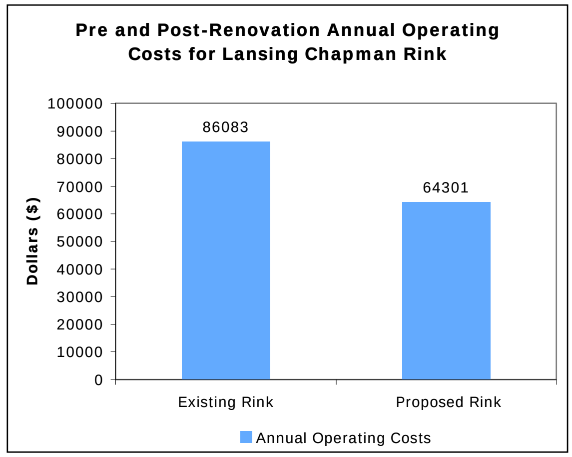
Here is a list of the recommended energy efficiency enhancements:

- The installation of an "Astro-Rink" low emissivity ceiling will drastically lower annual refrigeration costs by decreasing the heat load on the ice surface.
- Replacing the old metal halide lighting system with a new florescent lighting system will increase lighting levels, reduce kW demand, and eliminate wasted lighting time.
- The purchase of an electric Zamboni and ice edger will improve indoor air quality and reduce ventilation and heating loads.

Recommended Improvement	Project Cost	Annual Savings ($)	Emissions saved (tonnes of eCO2)
"Astro-Rink" Low Emissivity Ceiling	$35,712.50	$10,343.77	17.5
New T-5 Florescent Lighting System	$141,405.68	$4,004.80	6.8
Electric Zamboni and Edger	$118,700	$7,433.12	23.9
Sale of Existing Zamboni	-$10,000 (estimate)		
Total	**$285,818.18**	**$21,781.71**	**46.2 tonnes**

All together, the recommended renovations will decrease operating costs by 25.3%, energy used by 21.9%, and CO^2 emissions by 29.3%. The full renovation project has a net present value of $12,268.97 and an internal rate of return of 6.5%.





Introduction

Lansing Chapman rink has been an integral part of Williams College campus since 1961, serving as home ice for the men's and women's Varsity hockey teams. While the rink's biggest aesthetic appeal is its classic voluminous design, it is this design that also creates unnecessary and wasteful energy use and carbon emissions. With these two considerations in mind, i.e. the historical appeal of the building and its decidedly inefficient design, I attempted to identify solutions that would maintain the rink's architectural character while drastically improving the rink's energy efficiency and ultimately saving the College thousands of dollars annually. Williams College's goal to reduce emissions by 10% of 1990 levels by the year 2020, means that new solutions must be envisioned and implemented to make our buildings more energy efficient.

Different Energy Systems/Existing Emissions

In fiscal year 2008, Williams College used: 27,368,364 kilowatt hours of electricity and ~420,000 mmbtus of energy between electricity use, heavy fuel oil, natural gas, and B5 oil (a mixture of 95% natural gas and 5% biodiesel).[1]

Lansing Chapman Rink used 481,893-kilowatt hours in FY 2009 for refrigeration, ventilation, and lighting (~1.7% of the campus's total electricity use). Lansing Chapman Rink also uses steam produced at the heating plant using natural gas and number 6 oil which heat the building and produce hot water for showers and ice maintenance, and propane to operate the ice resurfacing Zamboni vehicle and edger. In total, Lansing Chapman rink used 3,036 mmbtus of energy in FY 2009, accounting for ~0.7% of total campus emissions.

Heating the campus produced ~50% of all greenhouse gas emissions in FY 2008. Lansing Chapman Rink used 47% of its emissions for hot water and heating in FY 2008. Because of concerns that lowering the temperature in the rink would cause the piping to freeze, there have been few efforts thus to decrease the heating load in Lansing Chapman rink.[2] As such, the majority of my work entailed a reduction in emissions from the other

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[1] "Sustainability at Williams: Energy Use". http://www.williams.edu/resources/sustainability/energy_use.php Accessed August 3, 2009.

[2] Personal communication, Ken Jensen, Mechanical Maintenance Supervisor. Williams College. June 26, 2009.

energy systems in Lansing Chapman: the Zamboni (which uses propane), refrigeration, lighting, and ventilation (all of which use electricity).

Table 1. Existing Emissions Profile

Source	Energy (mmbtu)	CO^2 Emissions (Kg)	% Emissions
Hot Water	694.43	54,165.85	26%
Heat	564.6	44,038.43	21%
Zamboni (Propane)	72.8	9,998.53	5%
Refrigeration	915	55,541.71	26%
Lighting	288	17,459	8%
Ventilation	501.44	30,437.48	14%
Total	3,036	211,641	

Figure 1. Percentage of Total Greenhouse Gas Emissions by Source, FY09, Lansing Chapman Rink

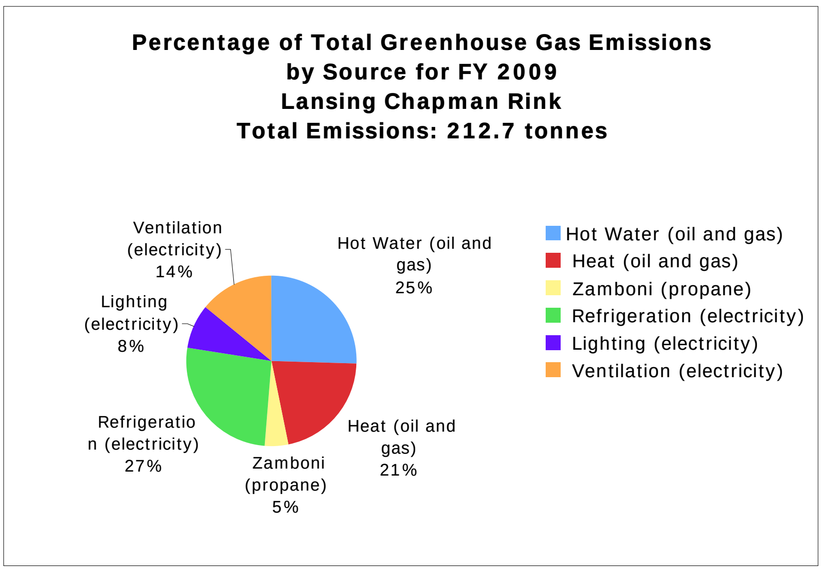
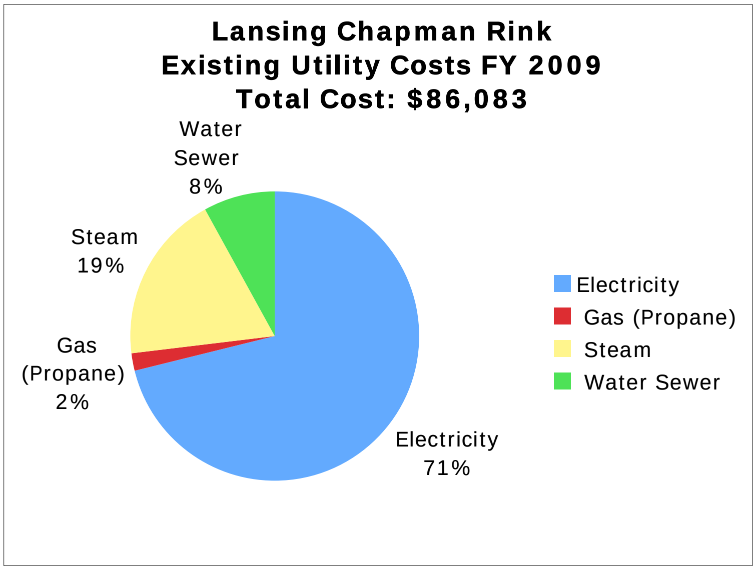


Table 2. Existing Cost of Utilities[3]

	Cost/Unit	Unit	Cost
Elec-.13	$0.13	kWh	$61,131.70
Gas- Propane 2.27	$2.27	Gallon	$1,816
Steam- $14.54	$0.01	mbtu	$1,6191
Water sewer- $9.32	$9.05	CCF	$6,943.83
Total/Yr			**$86,083**

Figure 2. Lansing Chapman Rink, Existing Utility Cost FY 2009

[3] Cost/unit information provided by Sam Tarnsaky ’09



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Lansing Chapman Rink Use

Lansing Chapman Rink is used primarily during hockey season. The men’s and women’s varsity hockey teams begin captain’s practices around October 15th and the season does ends around the first week of March. Factoring the time it takes to make the ice before the season and thaw it after the season, I estimate that the ice surface is maintained for approximately 24 weeks. During the winter months, the rink is used for a variety of activities: varsity free skating, varsity hockey practices, and games, figure skating, broomball, physical education skating, community skating and hockey, etc.

Outside of hockey season, Lansing Chapman Rink is used for indoor practices for both the men’s and women’s varsity tennis teams in the fall and the spring. Indoor tennis practices are held during inclement weather. In the summer, the rink is used for Nike Tennis Camp practices during bad weather.

It is important to understand that while the refrigeration and much of the ventilation system is shut off during the non-ice months of operation, Lansing Chapman Rink still uses 48.04 kW of electricity to run its lighting system. By analyzing recent electricity usage reports for the fall and spring, I estimate that the Men’s and Women’s Tennis teams use the rink for approximately 6 weeks per year (3 weeks in the fall, 3 weeks in the spring) for approximately 6 hours a week. The Tennis teams account for an additional 36 hours of full lighting use throughout the year. The rink is used during the summer months for the Nike Tennis Camp. The tennis camp lasts for four weeks. Factoring in an average of 10 hours of inclement weather per week, I estimate that the Nike Tennis Camp uses Lansing Chapman rink for approximately 40 hours annually.

Table 3. Energy Use by Season

Use	Annual Hours of Use	Energy Used (mmbtu)	Emissions (tonnes of eCO^2)
Varsity Hockey (October 15 -- Mar 7)	572.9	951.8	66.5
Non-Varsity Ice Use (October 15 – Mar 12)	983.85	1607.5	112.9

Wasted Ice Time (Lights on, No Activity)	287	458.5	32.0
Varsity Tennis (April 6 -- May 15)	36	5.90	0.35
P.E. Tennis (April 6 – May 15)	36	5.90	0.35
Nike Tennis Camp (June 15 – Aug 15)	40	6.55	0.39
Total	**1955.75 hours**	**3036.35 mmbtus**	**212.7 tonnes**

Estimating the rink required making some assumptions about use during non-scheduled hours. Upon examination of the Meeting Maker schedule for the rink,[4] I estimated 1,955 hours of annual lighting use of which 287 (~14.7%) hours occurred when the lights are likely on, but no one is using the ice. I assumed that the lights would be turned on for the first scheduled activity of the day and remain on throughout the day even if there were long breaks in between scheduled activities. For instance, on December 16, 2008, there is scheduled open ice for Varsity Hockey from 1:15-2:15pm and then again from 4:15-5:15pm. In the 2 hours between 2:15 and 4:15pm, there were no scheduled activities, but because of the long strike time for the metal halide bulbs, the rink's lighting system likely remained on. By examining the schedule throughout Hockey season, I was able to identify 287 hours of time where the lights likely remained illuminated, but no one was using the ice.

Table 4. Lansing Chapman Annual Use

Scheduled Ice Time	1,733.75 hours
Wasted Lighting Time	287 hours
Zamboni Time (Not scheduled)	146 hours
Varsity Tennis	36 hours
Nike Summer Tennis Camp	40 hours
Total	1,955.75 hours

Table 5. Varsity Hockey Use vs. Non-Varsity Hockey Use

Varsity Hockey Use	572.9 hours
Non-Varsity Hockey Use	1,095.85 hours
Wasted Lighting Time	287 hours
Total Use	1,955.75 hours

Refrigeration System

Maintaining the correct ice temperature is vital to the utility of the rink and the competitiveness of our hockey program. In order to assess the energy efficiency of our current refrigeration system, it is vital that we compare our rink's refrigeration system to standards set forth for competitive collegiate hockey.

Table 6. Annual Refrigeration Electricity Use

Year	kWh	Cost
FY 2007	237,696	$30,900.48

[4] The Meeting Maker schedule was provided by Gary Guerin, Associate Director for Operations/Athletics

FY 2008	226,688	$29,469.44
FY 2009	268,178	$34,863.14
3 year average	244,187	$31,744.35

Areas of Improvement within the Refrigeration System

The most significant energy issue in Lansing Chapman Rink is the radiation heat transfer that travels from the rink's ceiling to the ice surface. "Radiation heat transfer occurs between two surfaces that are not touching each other, independent of the temperature of the space between them".[5] Such radiative heating creates ice melting and ensures that additional energy must be used to continually re-cool the ice. While we did not measure the temperature of the rink ceiling during hockey season, we can be assured that it is significantly higher than the 18˚F ice surface. Not only does energy from skaters and lights build up on the ceiling, the central heating design blows hot air throughout the rink, and collects on the ceiling.

Possibly in an attempt to compensate for the extra heating load on the ice, the ice surface itself is kept colder than recommended by Brendan Lenko, P.E. of Custom Ice Inc. We could achieve energy savings with a higher brine temperature and a higher ice temperature. Currently, the ice temperature is kept at 18˚F and the brine temperature at 15˚F. According to Mr. Lenko, the ideal temperature for competitive adult ice hockey is 22˚F.[6] Raising the current ice temperature may be met with disapproval by the hockey coaches, but consideration should be given to experimenting with ice temperatures during the off-season in order to assess the feasibility of higher temperature ice or of letting ice temperatures rise during periods of inactivity.

Solutions to the Refrigeration System

The most important solution I propose for the refrigeration system is not directly tied to the refrigeration system itself, it is a retrofitting of the rink's ceiling with low-emissivity ceiling material. Produced by Energie Innovation Inc., the "Astro-Rink" low emissivity material has been used in rinks throughout the United States and Canada to drastically reduce refrigeration costs. Amherst College, one of Williams College's NESCAC rivals, uses a low-emissivity ceiling as well.[7] Energie Innovation Inc. and Custom Ice Inc. are two of the leading providers of the low-emissivity ceiling material. The ice in Lansing Chapman rink is difficult to maintain for a number of reasons. First, the central heating design allows heat to travel throughout the rink. In fact, spectators usually are spotted wearing t-shirts because of the high inside temperatures. Further research must be made into the possible installation of infrared space heaters, which heat the stands and player's benches only. Such a measure could potentially allow us to turn down the central heating in Lansing Chapman rink. In the present system, heat travels not just to the spectators, but throughout the air and above the ice. Second, the rink's

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[5] Brendan Lenko, P.E., "Low Emissivity Ceilings – Facts & Fictions". http://www.customicerinks.com/energyice/press1.htm Accessed July 29, 2009.
[6] Brendan Lenko, P.E., "Take Control of Your Ice". http://www.customicerinks.com/energyice/press4.htm Accessed July 29, 2009.
[7] Amherst College. Energy Conservation Projects. Orr Rink. https://www.amherst.edu/campuslife/greenamherst/energy_conservation#Orr%20Rink Accessed August 6, 2009.

cavernous design means that lots of hot air builds up over the ice surface. As hot air rises to the ceiling, the temperature differential between the ice surface and the ceiling increases substantially and the large volume of heated air heats the ice.

While changing the height and shape of the rink's ceiling would be both economically and technically infeasible as well as detrimental to the rink's historic appeal, the low-emissivity "Astro-Rink" material is a good alternative that drastically lowers the temperature differential between the ice surface and the ceiling. Low-emissivity ceilings radiate drastically less heat (.05 emissivity factor) than the old wood ceiling material (.80 emissivity factor) and reduce the amount of heat that the ice absorbs. Milan and Robert Baljak of Energie Innovation Inc., estimate that the installation of the "Astro-Rink" low-emissivity ceiling material would save the College 84,508 kWh (~31.5%) of the 268,178 kWh of existing annual use in FY 2009, and $10,986 annually. The total cost for the new ceiling is estimated at $71,425, including installation. However, National Grid, one of the College's energy providers will likely give up to a 50% rebate for this energy efficiency project, cutting the cost to $35,712.50 (3.25 year simple payback). It is important to note that these savings estimates were made by Energie Innovation Inc., and as such, should be verified by an independent energy consultant.

Savings within the operation of the refrigeration system itself could potentially come from an increase in the temperature of the brine and ice in an effort to use less electricity while maintaining optimal conditions for the rink's many uses.

Additionally, ice temperature is kept stable throughout the day and night. I suggest that the Facilities staff experiment with allowing the temperature to rise in the evening when the ice is not being used. Such a measure would save refrigeration energy that is wasted when the ice is not in use.

Lighting System

The current lighting system has two settings, one for full lighting and one for half lighting. The full lighting setting uses 26, 400-Watt and 44, 750-Watt metal halide lamps, creating 48-foot candles of illumination and using 48.04 kW of electricity. The half lighting setting uses 13, 400-Watt and 22, 750-Watt metal halide lamps, creating 24-foot candles of illumination and using 24.02 kW of electricity. The existing metal halide bulbs take approximately 15 minutes to warm up. Once the lights are turned on in the morning, it is unlikely for them to be turned off at any point during the day. Additionally, the metal halide bulbs have degraded in light quality. The color has degraded from white to yellow and the number of foot-candles produced has decreased over time. Currently, there is no monitoring system to control when the lights are on and off; the lights must be turned on and off manually.

Areas of Improvement within the Lighting System

The long warm-up time for the metal halide bulbs creates an issue of wasted energy use. The problem of leaving lights on, especially at full 48-foot candle output, throughout the day when the rink is not in use is not only a problem of the warm-up time for the metal halide bulbs, it is also a behavioral problem. There are sometimes 4 hour blocks of time during the day where the lights are left on despite no ice activities. As such, any new improvements to the lighting system itself must be accompanied by a lighting control system that can be programmed to shut off the lights in non-use times.

Not only do the existing lights ensure that energy is wasted, they provide an inadequate amount of light for the varsity hockey teams. Every year players and coaches alike complain about the low light levels in the rink. The maximum 48-foot candle output is well below the lighting levels in the majority of collegiate rinks. For comparison, the NCAA requires 100-foot candles for televised Division I games.[8] There is no separate standard for Division III hockey, but without televised games, the 100-foot candle standard is not applicable.

Solutions for the Lighting System

The proposed system by Naomi Miller Lighting Design (Troy, NY) calls for the installation of 130 type F1 fixtures. Just like the old lighting system, the new system can operate at 2 distinct light levels. At full output (46.02 kw), the proposed system produces an average of 89-foot candles and at 1/2 output (23.01 kw), the proposed system produces an average of 45-foot candles. The maximum illumination over the ice will be in excess of 100-foot candles, with an average of 89-foot candles. The new “Astro-Rink” low-emissivity ceiling will be responsible for 10-12% of the lighting increase.[9] The different light levels can help the College manage its energy use according to the kind of ice activity required. It is our plan that the full output level will be only used for Varsity hockey activities. All other activities can use the 1/2 lighting setting. At the 1/2 setting, maximum lighting levels will be in the range of 45-foot candles. The proposed lighting system, including all installation costs, will cost $141,405.71.

Currently, we estimate that the lights are used for ~1560 hours at full lighting and ~390 hours at half lighting each year. This calculation was based on a thorough review of all scheduled rink activities throughout the year in a Meeting Maker document provided by Gary Guerin, Associate Director for Operations/Athletics. The schedule for Lansing Chapman rink did not include information on lighting levels, but I estimated that only the half lighting was used only 20% of the time. The majority of this half-lighting time came during ice-resurfacing. It is clear that not all Zamboni use is conducted in half-lighting, i.e. ice resurfacing during hockey games. As such, the estimate of ~657 hours of Zamboni use and the ~390 hours of half-lighting are not contradictory; much of the Zamboni use is during full-lighting periods.

The greatest savings for the lighting system must be realized through behavioral changes. The current lighting system, besides producing only 48-foot candles, is inefficient because of its slow warm-up time. By replacing the metal halide lamps with fluorescent technology, Facilities staff will have the opportunity to turn off the lights when the rink is not in use, instead of their current practice of leaving the lights on between events for fear of the slow warm-up time. The installation of fluorescent technology and an effort to use the lights only during scheduled ice time will decrease the number of hours that the lights are used during the week. With this data in hand, we

[8] National Collegiate Athletic Association. Best Lighting Practice – Ice Hockey. http://www.ncaa.org/wps/wcm/connect/ncaa/ncaa/media+and+events/broadcasting/broadcasting+manual/sect2/light/hockey/01+hockey Accessed July 5, 2009.
[9] Personal communication, Naomi Miller. Naomi Miller Lighting Design. July 16, 2009.

could compare our current lighting usage assumptions to the actual lighting usage after the lighting renovations are complete.

With behavioral changes, i.e. only allowing Varsity hockey to use the full lighting output, total hours of full lighting use will drop from ~1,560 hours to ~573 hours and the half lighting will increase from ~390 hours to ~1096 hours, resulting in a decrease in energy demand from ~84,209 kWh to ~51,580 kWh, a decrease of 32,629 kWh and $4,004.80 annually.

Ventilation System

The ventilation system is used for two reasons. The players' locker rooms are ventilated 24 hours a day during the season to reduce humidity, provide fresh air for the team, and to reduce the likelihood of occurrence of bacterial infections such as MRSA. (locker room ventilation uses ~11kW of electricity) (note how you know this). In the rink itself, larger HVAC units (~17kW of electricity) are used to provide fresh air to players, staff and spectators. A considerable amount of outside air is required to ensure that air pollutants levels are kept at a minimum. The combustion of propane gas in the Zamboni and gasoline in the ice edger creates carbon dioxide and carbon monoxide, environmental pollutants that must be removed for the players' and fans' safety. During winter heated air is vented outside and make-up air taken from outside is brought into the building. The cold, fresh air introduced to the building is heated to the desired indoor temperature. In FY 2009, Lansing Chapman rink used 59,364 kWh of electricity (44,352 kWh for locker room ventilation and 15,012 from the large HVAC units).

There is an additional 87,600 kWh of unexplained energy use. This 87,600 kWh of unexplained electricity use (18.2% of total reported annual electricity use) could potentially be due to estimating error or metering error. Further investigation is required to determine the source of this error.

Solutions for the Ventilation System

The greatest potential for saving energy and associated costs in the ventilation system come from a reducing in the use of the large-scale HVAC units. The large-scale ventilation system must be used any time that the propane-powered Zamboni machine is used (approximately 4.5 hours per day). Consideration can be given to using a demand controlled ventilation system tied to CO monitors in the building. Careful assessment, design, installation and management of this type of system would be required to ensure that safety standards are met.

An alternative approach is to consider reducing the CO in the atmosphere through the purchase of an electric-powered Zamboni. The Zamboni Model 552 (~$105,000) operates with a 17.5 hp GE electric motor instead of a propane-powered motor. The purchase of an electric edger (~$3,700)[10], along with the electric Zamboni would eliminate carbon dioxide or carbon monoxide emissions in Lansing Chapman rink. As such, the large scale HVAC ventilation units could be used significantly less. For the purposes of this report, I assume that the elimination of carbon dioxide and carbon monoxide emissions would allow Facilities to shut off the large-scale ventilation system

[10] Personal communication. Joe Moran, Manager of Safety and Environmental Compliance. Williams College. July 29, 2009.

altogether, saving 15,012 kWh, $1,951.56, and ~50 mmbtus of energy annually. It is unclear whether the purchase of an electric Zamboni and edger would allow for a complete shutdown of the ventilation system, but regardless, it would significantly reduce its use. This approach has many benefits: reduction in electricity for fan energy, reduction in heat energy since the introduction of outside air will be minimized, a potential reduction of ~25% of steam heating demand. This reduction in heating demand would save $4,047.75 and ~141 mmbtus annually.

Table 7. Propane Zamboni vs. Electric Zamboni

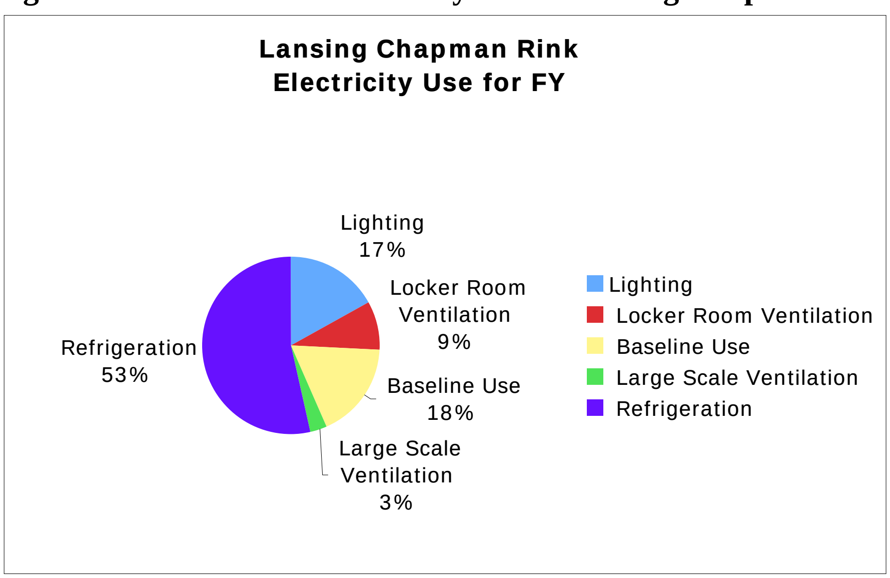
Type	Energy Demand (mmbtu)	Emissions (tonnes of eCO^2)	Annual Operating Cost
Propane Zamboni	72.8	9.99	$1,816
Electric Zamboni	7.5	0.45	$284.74

Table 8. Annual Electricity Use for FY 2009

Total	481,893 kWh
Refrigeration	268,178 kWh
Lighting + Ventilation	213,715 kWh

Lighting	84,299 kWh
Ventilation + Unexplained	129,416 kWh
Locker Room Ventilation	44,352 kWh
Unexplained Electricity Use	87,600 kWh
Large Scale Ventilation	15,012 kWh
Refrigeration	268,178 kWh
Total	**481,893 kWh**

Figure 3. Breakdown of Electricity Use in Lansing Chapman FY 2009



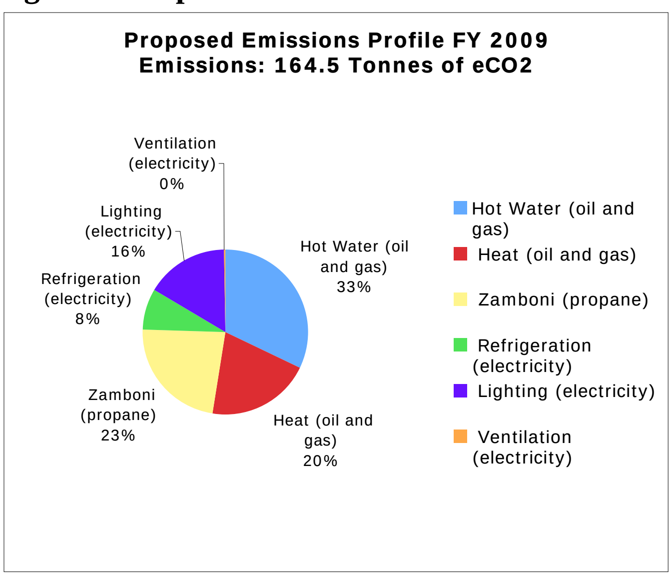
Importance of the Electric Powered Zamboni

Not only does the combustion of propane create carbon dioxide and carbon monoxide, it also creates nitrogen dioxide. Among these three environmental contaminants, carbon monoxide and nitrogen dioxide have been shown to endanger both hockey players and spectators. Massachusetts, along with Minnesota and Rhode Island, is one of only three states to regulate air quality at indoor ice rinks. Over the past year, hundreds have become sick and had to be hospitalized due to dangerous levels of carbon monoxide and nitrogen dioxide. In March 2009, exhaust from a "poorly maintained ice resurfacer sent 100 people to the hospital and forced four teams to withdraw from a college tournament outside Cleveland".[11]

While the existence of the 105 CMR 675.000 "Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI) requires indoor ice rink operators to conduct air sampling for carbon monoxide and nitrogen dioxide that use propane-powered ice resurfacers, electric ice resurfacers are superior for two major reasons. First, "they do an excellent job and keep the air drier than propane- or gas-powered machines, which helps the ice to remain hard, which pleases hockey players".[12] Second, electric resurfacers ensure that carbon monoxide and nitrogen dioxide levels remain at a rating similar to that "expected in a typical indoor office environment".[13]

Summary of Energy Efficiency Enhancements

Figure 4. Proposed Emissions Profile

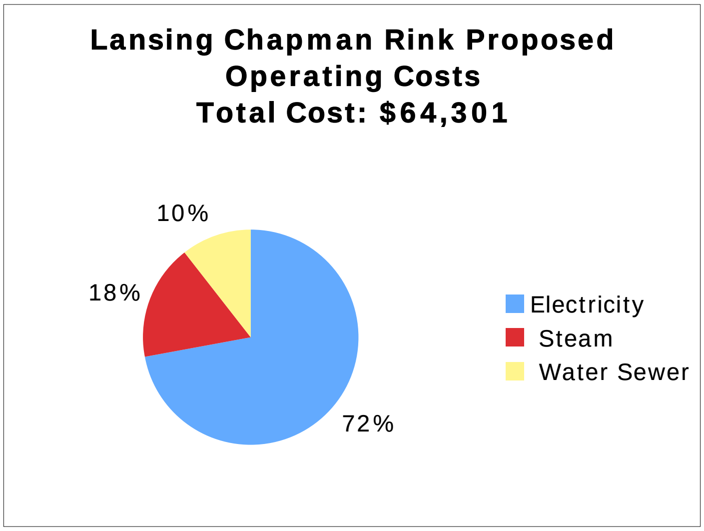


11 "Study Finds Health Hazards at Rinks". http://sports.espn.go.com/espn/e60/news/story?id=4068448 Accessed August 4, 2009.

12 "Electric resurfacers improve arena air quality, state finds" http://www.cbc.ca/canada/manitoba/story/2007/03/14/resurfacer-switch.html Accessed August 4, 2009.

13 "Electric resurfacers improve arena air quality, state finds" http://www.cbc.ca/canada/manitoba/story/2007/03/14/resurfacer-switch.html Accessed August 4, 2009.

Figure 5. Proposed Operating Costs After Renovation



The Economics of the Proposed Lansing Chapman Energy Efficiency Enhancements

The Net Present Value figure represents the College's financial incentive for executing the renovations rather than simply placing the money in an interest earning bank account. Put simply, at the end of a 20-year period, the College will have $12,268.97 more if it invests in rink renovations as opposed to investing the same amount of money at 6%. With no increase in utility costs over the 20-year period, the net present value falls to -$35,983.64. The College does not expect stagnation in utility costs over the next 20 years.

Table 8. Net Present Value

Net Present Value (20 years)	$12,268.97
Internal Rate of Return	6.5%
Cost of Renovations	$285,818.18
Annual Savings	$21,781.70
Simple Payback	13.12 years

Note: The Net Present Value assumes 2% inflation in electricity prices and a 6% interest rate.

Table 9. Renovation Costs

New Renovation	Cost
"Astro Rink" Low-E ceiling	$35,712.50
New Fluorescent T-5 Lighting (incl. installation)	$141,405.68
Electric Zamboni + Electric Edger	$118,700
Sale of Zamboni	-$10,000
Total Cost	**$285,818.18**

Table 10. The Economic and Environmental Impact of Recommended Improvements

Recommended Improvement	Cost	Energy Saved (mmbtu)	Emissions saved (tonnes of eCO^2)
"Astro-Rink" Low Emissivity Ceiling	$35,712.50	288.3	17.5
New T-5 Florescent Lighting System	$141,405.68	112.0	6.8

Electric Zamboni and Edger	$118,700	272.6	23.9
Sale of Existing Zamboni	-$10,000 (estimate)		
Total	**$285,818.18**	**672.9**	**46.2**

Figure 7. Pre-Renovation vs. Post-Renovation Annual Operating Costs

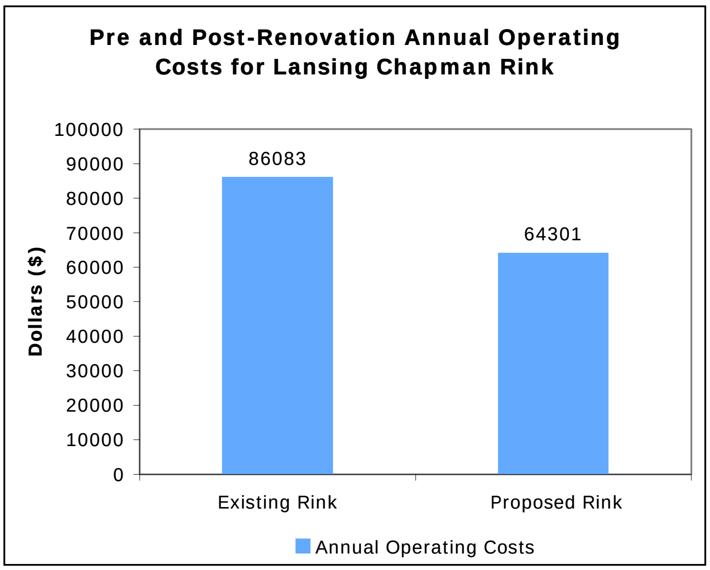


Figure 8. Pre-Renovation vs. Post-Renovation CO^2 Emissions

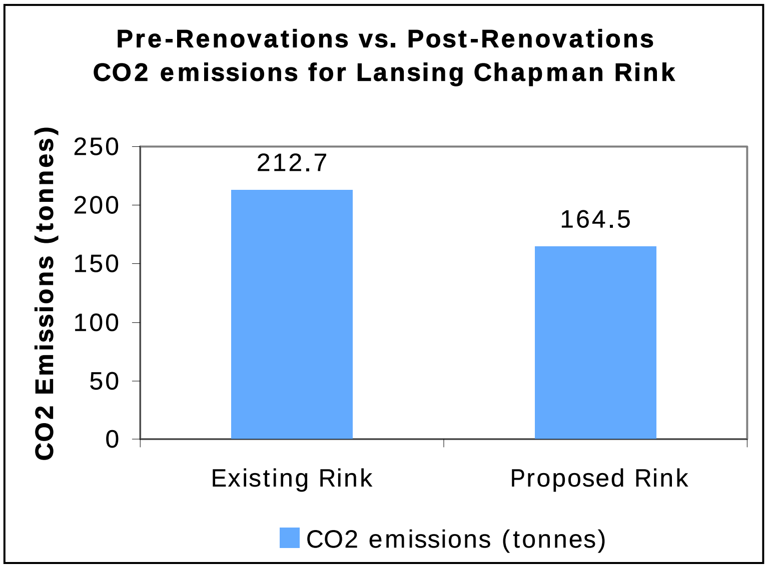
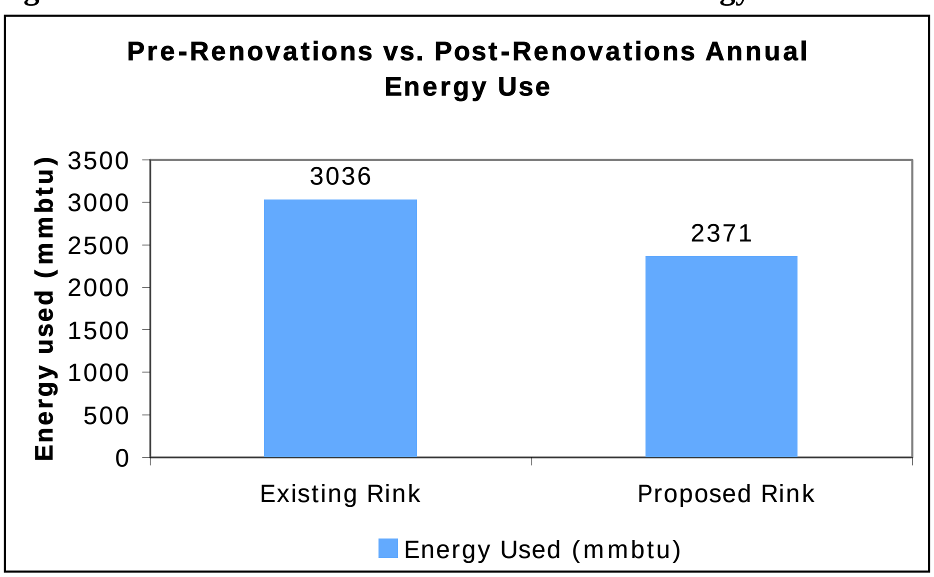


Figure 9. Pre-Renovations vs. Post-Renovations Energy Use



System Maintenance

The expected life of a propane-powered Zamboni is 10-12 years.[14] Further research is needed to ascertain the expected life of the electric Zamboni model 552. This research must recognize that Williams College uses it Zamboni less than the average ice rink because of its non-ice uses outside of hockey season.

According to the "Astro-Rink" Owner's Manual, the "Astro-Rink" low-emissivity ceiling does not require any maintenance. Energie Innovation Inc. (the company that produces the "Astro-Rink") describes their product as "a permanently installed product, which will not stretch, sag, shrink, decay or deteriorate in any fashion, it may be removed for access to roof structures by simply removing the tape and screws, then refastening when access is complete…the Astro-Rink low-e ceiling is impervious to puck damage".[15]

The new T-5 florescent lighting system has been rated for 25,000 hours of use. Given the expected annual lighting use of 1,688.75 hours, the new florescent lights will last for ~15 years. I have not added the cost of replacing the lights to the project cost because the new T-5 florescent lights have a longer expected lifetime than the current metal halide bulbs. As such, any costs incurred by replacing the new florescent lights would be similar to those in replacing the existing metal halide lights.

There are some final recommendations I would like to leave the team that will hopefully oversee the renovations of Lansing Chapman rink. First, broomball must be played with clean shoes to: reduce the refrigeration costs associated with cooling the ice after it must be power cleaned with hot water, and reduce lighting and Zamboni use.

Conclusion

Lansing Chapman Rink stands as a vital part of Williams College's campus, and with a wise investment in energy efficient renovations; it will become a symbol of the College's commitment to sustainability.

In the proposed emissions profile, ~56% of total emissions for Lansing Chapman rink come from hot water and heat. To further reduce emissions, an overhaul of the heating system will be necessary. The major heating problem is structural; the entire rink is heated, instead of just the stands. Many other rinks utilize infrared heaters for the stands and player's benches and leave the rest of the rink unheated. This allows for a tremendous reduction in energy costs from heating and further reductions in refrigeration costs. One of the major problems with Lansing Chapman rink is that a great deal of heat is released to heat the rink, putting additional pressure on the refrigeration system because the heat continually melts the ice. Spectators are often seen wearing short sleeve shirts because of the high temperature in the building. There are some concerns with decreasing the temperature in the rink, i.e. freezing pipes, but I recommend further investigation of alternatives to the current system. By insulating the water pipes, we could see a dramatic reduction in steam heating costs.

Part of the problem with targeting heating, is that its economic costs and its environmental costs are not the same. While hot water and heating make up only ~25.9%

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[14] Agenda. Champlin City Council. http://74.125.95.132/search?q=cache:KIOGw7bjhWUJ:ci.champlin.mn.us/documents/AG-112408.pdf+expected+life+of+Zamboni+552&cd=7&hl=en&ct=clnk&gl=us&client=firefox-a Accessed Aug 4, 2009.

[15] "Astro-Rink" Reflective Insulating Material Owner's Manual. Energie Innovation Inc. http://74.125.95.132/search?q=cache:PMb-LKw-18oJ:www.energie innovation.com/media files/Owners%2520Manual%2520Generic.pdf+astro+rink+maintenance+costs&cd=1&h =en&ct=clnk&gl=us&client=firefox-a Accessed Aug 7, 2009.

of the operating costs of the rink, they account for ~47% of emissions in the existing emissions profile. On the other hand, lighting, refrigeration, and ventilation make up ~72% of operating costs, but only ~48% of emissions in the existing emissions profile. As such, lighting, refrigeration, and ventilation improvements will save the college more money, but are not the most important in terms of reducing emissions. There is hope that there will be improvements in the heating system, however. After the installation of a new lighting system, the low emissivity ceiling "Astro-Rink" material, and the purchase of an electric Zamboni and electric edger, the most dramatic improvements will have to be made in the reduction of heating costs. Even if these changes may appear to be a poor economic investment on their own, added into the total renovations project, they may still yield a positive net present value, while going a long way to further reduce emissions.

The proposed renovations will not only be a savvy investment; it will also save ~45 tonnes of eCO_2 annually, or 21.25% of Lansing Chapman rink's carbon emissions. The renovations to Lansing Chapman rink are an important step for the College to achieve its campus-wide goal of reducing emissions by 10% below 1990 levels by the year 2020.

Appendix 1 – Zamboni Model 552 Calculations

Annual operating hours: ~657 hours
Horsepower: 17.5 hp

- To estimate operating costs for a Zamboni Model 552, we use the fact that the engine is a 17.5 hp GE electric motor and multiply it by the time the Zamboni is used annually.
- 1 horsepower over one hour is equal to .745 kilowatt-hours

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