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A Cost Benefit Analysis of Improving Energy Efficiency of a Fitness Facility

Abstract

Abstract: Nearly 40% of the total U.S. energy consumption in 2012 was consumed in residential and commercial buildings, as recorded by U.S. Energy Information Administration. With the urgent need to reduce overall energy consumption in the U.S., many efforts are made to improve the energy efficiency of buildings. However, energy managers identify budget constraints as one of the main obstacles in improving the energy efficiency of buildings. Hence this study focuses on a cost benefit analysis of improving the energy efficiency, with a special focus on fitness facilities in college environments. As a case study, the author focuses on improving the energy efficiency of the fitness facility at Colby College, ME. The author first understands the energy consumption of the current facility, benchmarks energy consumption of the improved facility, evaluates the energy conservation measures for improved facility through life cycle costing; and depicts the effect of net present positive projects on energy baseline of existing and improved facilities. Retrofitting Heating, Ventilation, Air Condition (HVAC) and lighting systems, replacing the original appliances with energy efficient equipment and improving the building envelope are methods considered in improving energy efficiency. As economic costs, the author takes into account the installation costs, operating costs and payback periods of the methods. As economic benefits, the author accounts the cost savings from improved energy consumption and environmental benefits such as the reduction of green house gas emissions.

Keywords

Energy Efficiency, Building Energy, Sustainability, Cost Benefit Analysis

Cover Page Footnote

-Prof.Sahan Dassanayake, Professor of Economics for the guidance provided -Patricia Whitney, Physical Plant Department at Colby College, for the preliminary data provided -Kevin Bright, Sustainability Coordinator at Colby College, for the guidance provided

1. Introduction

This study is a cost benefit analysis of improving the energy efficiency of Harold Alfond Athletic Center and Swimming Pool, at Colby College. The facility accounts for 114,214 gross square feet space, built for the provision of athletic facilities including a swimming pool, weight and aerobic facility, a field house and office space for the Department of Athletic Administration. Approximately, 32 varsity sports teams that account for more than one third of the student body use this facility for training purposes throughout the year. Last major building envelope renovation of this building was in 1992/93 periods, and the building is identified as a relatively old facility with a potential for a major renovation in the near future [Kevin Bright]. From this study the researcher hopes to find cost effective methods to improve the energy efficiency of the current facility that will be useful for Colby College to take into consideration when renovating this facility.

The researcher aims to answer the following research questions:

1. What are significant sources of energy consumption of the current facility?
2. What are proven technologies that can be used to retrofit and improve the energy efficiency?
3. What are the most cost beneficial methods available to improve energy efficiency?

2. Background

Retrofitting with proven technologies and replacing heavy energy consuming components can improve the energy efficiency of buildings, and yield important financial returns. "In the United States alone, more than \$279 billion could be invested across the residential, commercial, and institutional market segments. This investment could yield more than one trillion dollars of energy savings over ten years, equivalent to savings of approximately 30 percent of the annual electricity spend in the United States"[9]. However, the net benefit of an energy efficiency improvement of a building is not fully realized by many investors. "Unfortunately, the implementation rate of Energy Efficiency Measures (EEM) is so far still very low, as shown by recent research from the industrial Assessment Center database, due to existence of various barriers, some of them, beside the economic ones, related to the information about the

EEM, to the organization in which the investment being made, to the effective implementation phase of an EEM” [13].

Nearly 40 percent of total U.S. energy consumption in 2012 was consumed in residential and commercial buildings, or about 40 quadrillion BTU (U.S. Energy Information Administration). Buildings consume 70percent of the electricity consumption in U.S. [11]. The commercial and residential building sector accounts for 39 percent of carbon dioxide emissions in the United States per year, more than any other sector (US Green Building Council). Most of these emissions come from the combustion of fossil fuels to provide heating, cooling and lighting, and to power appliances and electrical equipment [10]. By using proven technologies to retrofitting buildings, carbon emissions can be reduced, in addition to conserving energy.

The initial cost of installation and implementation are perceived as common constraints in improving energy efficiency. Instead of building new facilities, retrofits or upgrading the already available technology could bring higher returns at a relatively lower installation cost. Another challenge in implementing energy efficient technologies in buildings is the nature of financial returns to be incurred over a longer period of time. This leads to under investment in energy efficient technologies in buildings. However, certain available technology installations with longer estimated life relative to the estimated payback period are attractive to the investors. Also targeting high intensive areas of energy consumption in building could give higher returns from energy savings. HVAC, illumination, appliances and hot water are four major types of retrofits to improve energy efficiency identified by ASHRAE in buildings [12]. HVAC and illumination are regarded as high intensity energy uses as they generally consume over 80 percent [10] of the total energy consumption in a building, hence also two key potential areas to reduce energy consumption.

3. Literature Review

To understand the types of attributes and proven technology that could be taken into consideration in analyzing the cost effectiveness of improving the energy efficiency, a variety of literature were reviewed.

Andrea Trianni, Enrico Cigno and Alessio De Donatis, in their study *A Framework to characterize energy efficiency measures*, provide six categories of attributes to consider in evaluating energy efficiency measures: economic, energy, environmental, production-related, implementation-related and indirect attributes. In our study, we use the economic attributes the researchers identify: payback time, a factor that is found to significantly influence the implementation

of energy efficiency projects [15], and the implementation costs including the equipment purchases, adaptation costs, and engineering/contractor fees. Although, Trianni, Cgno and Donatis recommend using other attributes such environmental, production related, implementation related and indirect attributes, due to the lack of data and difficulty in valuating such attributes, they are not included in the research methods in the study on Colby's Athletic Facility. The researchers stress on how developing an innovative framework to characterize energy efficiency measures could benefit to effective sharing of knowledge both for decision makers and policy makers [14], and this further strengthened the researcher's motivation of the project to be useful for a future renovation of the building.

In understanding the distribution of the energy by end use in a fitness center with similar facilities, the researcher referred to the study, *Harnessing Human Power for Alternative Energy in Fitness Facilities: a Case Study*, by Maha N. Hji, Kimberly Lau and Alice M. Agogino. The study focused on the feasibility of capturing kinetic energy at the Recreational Sports Facility (RSF) at University of California, Berkley. The facility had an average energy consumption of 1.6 million kWh per year from the academic years 1986-2009.[The researcher used the following distribution of end use energy consumption of RSF as a baseline comparison of end use energy distribution for Harold Alford Athletic Center and Swimming Pool, at Colby College, to overcome the limitation of data. This study helps to understand that heating and ventilation and lighting account for more than 80 percent of the facility and hence is a potential area for improved energy efficiency. The case study conducts a cost-benefit analysis of retrofitting energy harnessing treadmills to replace the 28 treadmills available at the facility. Burrowing from Maha N. Hji, Kimberly Lau and Alice M. Agogino, the researcher also considers retrofitting the current traditional treadmills with EcoMills at Harold Alford Athletic Center and Swimming Pool, at Colby College.

Case study: Fun, Fitness, and Energy Savings! On Niles Family Fitness Center, Niles, Illinois funded by Cook County Energy Efficiency & Conservation Block Grant in Collaboration with U.S. Department of Energy studies improving the energy efficiency of a 70,000 square foot fitness facility available for families[16]. The researcher used this study in understanding potential technology and retrofits that could be used to improve energy efficiency of other fitness facilities. The case study recommended use of a range of low cost and capital intensive methods to reduce approximately 14 percent of the annual electricity usage, and 32 percent of the annual gas consumption of the facility. Low cost measures included installing occupancy sensors, updating halogen can lights, and using a cover on the whirlpool that yield 751,52kWh of an annual

electricity savings and 6998 therms of annual gas savings. The total initial cost of \$3,583 is expected to pay back in one and a half years with improved energy efficiency from the low cost measures. The study finds an overall incentive of \$3,450 for implementation of these low cost measures. The case study also focused on four methods of energy efficiency that would require relatively high capital investment. Downsizing the pool pumps, replacing the metal halide pool lighting with high efficiency T5s and gym lighting with high output T5 lighting, and installing a heat recovery option for the pool HVAC, that were considered as potential methods for improving energy efficiency even for Harold Alfond Athletic Center and Swimming Pool, at Colby College. The total initial capital necessary for these measures add up to \$111,900, and yield an annual cost saving of \$21,065. The expected payback period is five point three years, leaving a \$30,453 as the incentive to pursue such high capital incentive methods. The payback periods from this study were used as benchmark comparison for the calculation of energy savings from the retrofits for Harold Alfond Athletic Center and Swimming Pool, at Colby College.

Lisa Ryan and Nina Campbell in their study on Spreading the net: The multiple benefits of energy efficiency, identifies other benefits from improved energy efficiency at individual, national, and international level. These benefits include health and wellbeing impacts, poverty alleviation through energy affordability and access, increased asset values and job creation. At an international level, environmental benefits include reduced GHG emissions and better natural resource management. These benefits are evident for the impact of energy efficiency far beyond energy savings, leading to economic growth and social development. Though our study mainly focuses on the cost beneficial nature of the retrofits, the study by Ryan and Campbell help understand the areas in which further research is necessary to understand the net impact of improved energy efficiency of Harold Alfond Athletic Center and Swimming Pool, at Colby College.

4. Methods

a. Find the energy consumption of the existing facility

This study focuses on improving the energy efficiency of the field house, swimming pool, locker rooms and new weight room in the facility. The selection of site components was based on the design of the HVAC system of facility. Colby College currently does not monitor the energy levels by buildings or components

in the buildings, and hence following assumptions had to be made in calculating the energy consumption of the current facility:

- Floor space is a close approximate for the distribution of energy consumption by each component. The building floor space of Harold Alfond Athletic Center and Swimming Pool was calculated as a percentage of the total building space of the campus. The estimated energy consumption of HAAC was calculated as a proportion of the total energy consumption of the campus, relative to the building space.
- The estimated number of days of operation is 365 per year.
- Electricity cost is \$ 0.105 per kWh, \$0.0673 for the commodity, the remaining for its transmission to campus (Kevin).

The estimated total consumption of electricity of Harold Alfond Athletic Center and Swimming Pool is 1,888,499.49kWh/year at a total cost of \$198,292.45 per year [4].

Building Component	Space (GSF)	Percent of total building Space on campus	Electricity (KWh/yr)
Field House	7947two	0.05	765853.8
Pool	14768.0	0.01	142315.9
Training Room	3090.0	0.00	29777.6
New Locker Rooms	5964.0	0.00	57473.7
New Weight and Aerobic Rooms	10920.0	0.01	105233.6
Total Fitness Center	195968.0	0.12	1888499.5

Table 1: Distribution of Floor Space and Electricity consumption [4]

b. Find Methods to improve the energy efficiency of the buildings

This study focuses on four major areas of energy consumption in a building identified by ASRAE 90.1, including HVAC, illumination, water heating and appliances [5].

1. HVAC

Heating, Ventilation and Air Conditioning (HVAC) is important end use energy in buildings, as this system maintains the appropriate temperature, moisture and odor of air in a building. A properly maintained HVAC system helps to avoid mold and erosion of building envelope, and hence help reduce major repair costs of the building in the long run. An efficient system of HVAC is not only important for healthy operation of a building, but also for a healthy environment for the building users. Without a properly maintained level of air quality, the users of the building could be exposed to health risks. HVAC system of a building is a large system of hardware including boilers, heat pumps, fans, furnaces, ductwork and pipes. There are mainly two types of HVAC, cooling and heating. The energy consumed by the HVAC system heavily depends on the climatic conditions of the building site, as more energy is needed to help maintain the temperature, ventilation and damp conditions recommended. Approximately 30percent to 40percent of the total energy consumption of commercial building is used for space heating, ventilation and air conditioning. Hence, HVAC is an area in which large energy savings could be made through improved technology. However, HVAC is recommended to be the last option to reduce energy consumption in buildings by ASHRAE, as upgrading the HVAC would require relatively high capital costs than any other type of energy consumption in buildings.

The facility at Colby College, situated in an environment, where the natural temperature is below the threshold building temperature for about five-nine months of the year, uses a heating HVAC system. Also part of the athletic facility studied in this paper, uses steam and air as the mediums of load distribution. In estimating the energy consumed by the HVAC system for the facility, I calculated the energy consumption by the individual heat pumps and fans for the pool facility, locker rooms, field house and the offices of administration in the facility. All these components of the building had separate schedules for the operation of the HVAC system, depending on the average damp in air, and operation hours, and accounted for approximately 30percent of the total energy consumption.

A heat recovery system can help reduce up to 40 to 75 percent of the energy used for heating [16]. One main challenge in using an air to air heat recovery system is the corrosive nature of the moisture in the pool and spa area. High concentrations of chlorine can corrode the copper coils.

2. Appliances

Appliances accounted for 10 to 12 percent of the total energy consumption in our baseline study. Two major appliances with proven and energy efficient retrofits, are the fitness equipment and sauna in the locker room.

The weight room consists of eight treadmills, one stair master machine and seven cyclical machines. Of these fitness equipments, the electrical treadmill is the most energy consuming component. On average treadmills require 400-800W, and an elliptical machine uses 10-20W on average per a 15 to 20 minute workout. This adds up to approximately 69,000kWh for the treadmills and 12,00kWh for elliptical machines per year.

Energy harnessing workout machines could be an energy efficient alternative to electrical working out machines. Replacing a treadmill with an Eco-Mill, a self powered treadmill, can yield up to a 120 kWh per year. Replacing the eight elliptical machines with Rev-Rev, self powered cross trainer elliptical machines will yield an energy generation of 1,800 kWh per year. Both the Eco-Mill and Rev-Rev have meters that display the energy generated during the work-out, which will create an additional interactive sensation to increase the level of enjoyment from the work-out. Also this feature is identified as a method to increase the energy consciousness of the users. However, a disadvantage of this novel technology is the high cost of implementation. As most users are unfamiliar with this novel technology, training the users will require an additional initial cost. Installation of an Eco Mill costs \$7,000 per unit, when a traditional treadmill would cost only \$2,000. However, Eco Mills have negligible operational costs as there will be no need to replace electric motors or belts.

The sauna is another appliance at the athletic facility that has the potential to be retrofitted with proven energy efficient technology. The current sauna in the shower rooms has been non-operational, but the facility is looking into replacing this appliance with a new appliance. The baseline at the athletic facility is a six to eight user steam sauna available from six a.m. to ten p.m., and maintains temperature at 40 to 100 degree Celsius. In calculating the energy consumption, an approximate average use of three hours per day over 365 days

was used. The 30kW steam sauna uses water sprayed on hot stone, and requires 32,400kWh of energy per year. A more energy efficient retrofit available is a nine kW infrared sauna that requires approximately 10,800kWh per year. The infrared sauna would not require any water, where as the steam sauna would also require 1,500 gallons per year. The infrared saunas will also have a relatively lower installation cost, due to the relatively high availability of the product in the market. As there will no water used, any additional costs due to erosion or mold could also be avoided.

3. Illumination

Illumination accounts for a significant part of the energy consumption of a building, and there is no exception for an athletic facility. ASHREA finds that lighting accounts for about 40 percent of the energy consumption of an average of commercial buildings [1].

The lighting fixtures in the Field House and Training room meet the standard of ASHRAE 91. 9. Field house has eighty nine 6-lamp 50W T8 fixtures, and the training room has forty nine 32W T5 lamps. These lamps meet the ASHRAE minimum requirement of T8 lamps in commercial buildings.

One other way ASHRAE encourages energy efficiency in illumination is to install occupancy sensors. Up to 30 to 40percent of the energy for illumination could be reduced by using occupancy sensors in frequently used spaces. "Results of a 6-month test period, comparing energy consumption and lighting "on-time" (amount of time that lights are on) before and after occupancy sensor installation indicated energy use reductions of 30 percent in individual offices, 65 percent in restrooms, 60 percent in conference areas, 19 percent in classrooms, and 14 percent in group offices"[20]. The price of an occupancy sensor ranges from \$25 to \$100[13]. Use of occupancy sensors in spaces of the building that more frequently but not for long periods of time is proven to be energy efficient.

The lights in the field house left on whenever there is a user, as there are no windows in the field house that lets sun light in. However, there are many times in the day, when the lights in the field house are left on even when there is no occupant, even though the events are scheduled and the desk worker can override. The field house is a space open for general users, when there is no scheduled practice. However, as the lights are to be switched on whenever a user walks into the field, the lights are left on for scheduled events, even when there is no occupant in the room. Hence, the field is a potential break room in which a motion sensor would have potential to reduce the energy consumption.

4. Hot Water Consumption

Heating water accounts for about eight to ten percent of the total energy consumption [1]. Efficient use of hot water can help reduce the energy consumption. Hot water is required for faucets, shower rooms, and for pool. Faucets at of the facility meet the ASHRAE standards of two point two gallons per minute. This helps to reduce water consumption by about 30 percent from the standard faucets [3].

Replacing the four gallons per minute showerheads with two point five gallons per minute showerhead is a method recommended by ASHREA for better hot water management. Average energy used at a shower is 3308 BTU (3.490 MJ). Energy wasted is from shower is 1361 BTU (1.436 MJ), 41.1 percent of the total energy [3]. The average volume of wasted water from showers is closer to 30 percent [6]. The average waste of energy in the hot water is about 40 percent [6]. On average 12.3 gal is the total water flow of a shower event [6]. Water used for a shower is nine point gal [6]. Approximately about two point nine gal (10.8 L), of 30.2 percent of water is wasted [6]. A relatively more water efficient showerhead such as two gallons per minute showerhead will help reduce the water wasted by approximately 50 percent.

One other efficient method to reduce the wasted energy from hot water is to use a drain recovery system, as recommended by ASHREA. A drain water heat recovery system collects the drain water and runs it along a pipe system to transfer the heat from drain water to unused water. This is also known as grey water heat recovery. An efficient drain water heat recovery system can help recover 15 to 40percent [12] of the heat loss. In this study we use the lower bound of heat recovery, a 15 percent heat recovery for the system. A hot water heat recovery system could cost up to \$20,000 as upfront costs. Prices for drain-water heat recovery system for a range from \$300 to \$500[12]. Energy.gov states that paybacks range from two point five to seven years, depending on how often the system is used [12].

5. Results

The highest energy savings were from the eco-mills with their ability to not only reduce energy consumption but also generate energy. However, due to the relatively new technology used, the Eco-Mills had an exceptionally high appliance cost involved. There are only a handful of companies that sell Eco-Mills and hence seem to dominate the market with exceptionally high prices. Hence, the Eco-Mills had the highest initial cost of installation. The payback period of

the Eco-Mills was three times larger than the life span of the Eco-Mills. This makes the Eco-mills a non cost effective retrofit. However, the installation of energy generating work out machine as an Eco Mill will be one of the most attractive methods to increase the energy consciousness of the students using the athletic facility.

Replacing the steam sauna with an infrared sauna could yield an energy saving of 21,600 kWh per year. This accounts for \$ 2268 per year. The initial cost of the infrared technology is \$2,600[10]. This initial cost can be covered with savings from energy costs within a payback period of two years, while an infrared sauna is expected to last for a total of five years.

The ongoing replacement of the old showerheads with one point five gallons per minute showerheads will reduce the waste of hot water from showers by 75 percent. There are approximately 14 showers in each male and female shower rooms. A one point five gallons per minute shower head costs \$30 per unit. Hence replacing a total of 28 shower heads will cost \$840 in total and will yield a total of 30,963 kWh per year. The initial cost will be recovered within a payback period of one year, when the shower heads are expected to have a life span of 10 years in total.

There are approximately 14 showers in each male and female shower rooms. The two main advantages of installing drain heat recovery systems in the shower room is the ability to benefit from the higher frequency of shower use, and the ability to reduce the cost of installation by using a heat recovery system from a larger amount of water collected from a row of showers installed in the same area. This enables to reduce the cost of installation per kWh of energy recovered. On average I used two drain water recovery systems for each shower room, to meet the design of showers in the locker rooms, totaling up to \$ 1,500 for each shower room. An additional \$1,000 was estimated for installation of the system in the already available plumbing system. The estimated annual savings from the heat recovered from the two shower rooms will be \$2438 per year. The annual energy savings are estimated to pay back the installation cost by four point four years, when the drain water system is predicted to have a span of ten years.

Key	Retrofit	Baseline	Annual Energy Savings (kWh)	Annual Savings (\$)	Initial Cost (\$)	Payback (Yr)	Life (Yr)
HR-Field	Heat recovery in Field House	No	20,796	2,184	20,000	9.2	20
1.5 g.p.m.	Install 1.5 gallons per minute showerheads	4.0 g.p.m.	30,963	3,251	840	0.3	10
DWHR	Drain water heat recovery	No	23,222	2,438	4,000	1.6	10
MSL-Field	Motion sensor lighting in Field House	No	25,632	2,691	4,450	1.7	10
MSL-Tr	Motion sensor lighting in Training Room	No	2,534	266	500	1.9	10
IR Sauna	Install an Infrared Sauna	Steam	21,600	2,268	2,600	1.1	5
EcoMills	EcoMills	Treadmills	69,120	7,258	64,000	8.8	5

Table 2: Comparison of Retrofit and Baseline

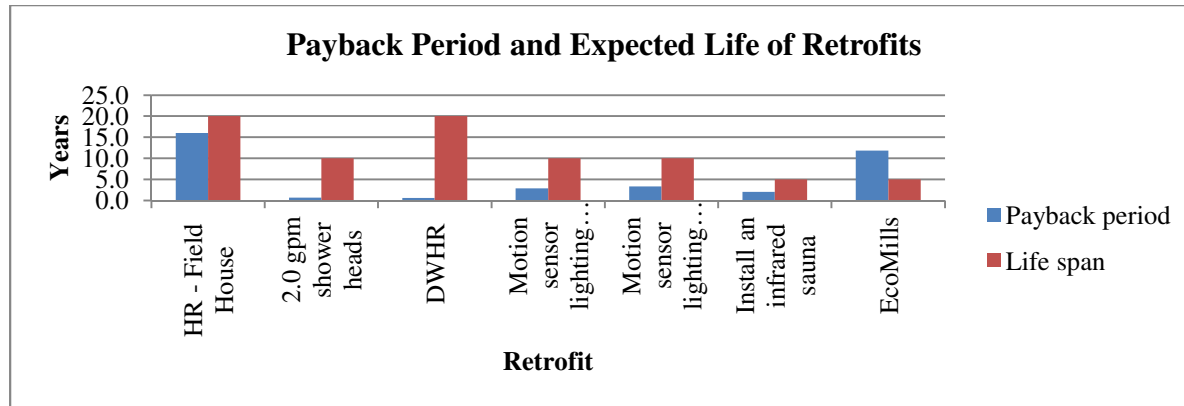


Figure 1: Payback Period and Expected Life of Retrofits

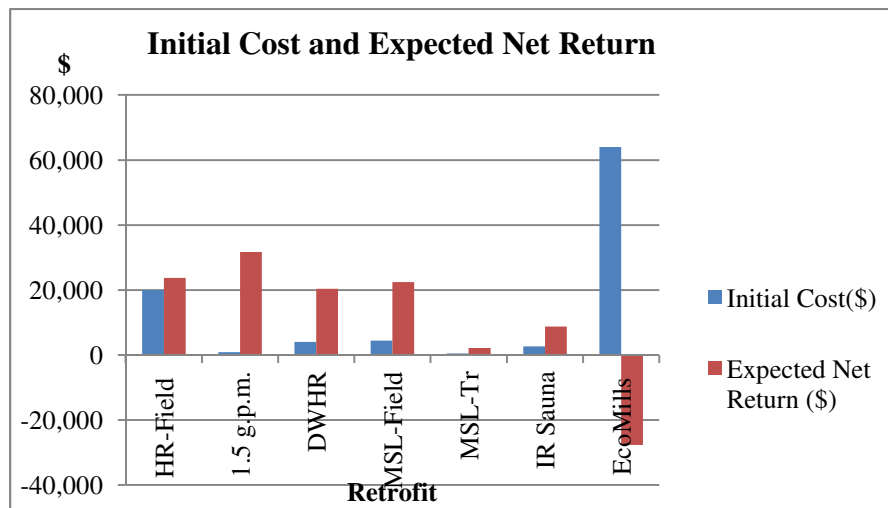


Figure 2: Initial Cost

6. Discussion

In general the pay back periods were less than five years for solutions except for the Heat Recovery system and Eco Mills. This is a promising result for investors. Eco mills seem to be a non cost effective solution as the energy generated is minimal and the cost of installation is relatively high as of the present market prices. However, the Heat Recovery system in the field house and equipment room is a promising long term capital investment that has net positive benefits over a longer life span of 20 years. All methods except the Eco Mill have net benefits as the payback period is relatively shorter than the expected life of each retrofit.

Other benefits commonly identified and not captured in this study are the environmental and health benefits, increase productivity of users. An energy efficient fitness facility at a college campus in which more than one third of the student body are athletes could yield further returns beyond monetary or energy savings. The college could draw attention to energy consciousness and sustainability of the overall campus through this initiative. Out of the methods considered the Eco mills had a potential for better attraction through the interactive experience provided for users. This indicates a possible need for development in design for better energy efficiency and low cost methods of working out machines.

The assumptions made in calculating the energy savings from the retrofits were based on the literature available and standards used by current the building energy sector. However, there could be facilities available in the future and making very long term high capital investments in the immediate future could be a waste of finances on this regards. With improved focus on energy efficiency in building there is a rapid development in the energy efficient technologies that the information used for this study could also have had a time lag involved. Certain energy efficient technologies such as improving the insulation of the envelope, energy efficient laundry equipment, using ultra efficient lighting systems or methods of orientation of the building to capture the maximum heat load are a few other methods already available but not discussed in this study. The energy savings and life span are based on the lowest value of the industry, due to the lack of detailed data on the already available technologies in the facility. The energy savings from heating could subject to change due to the specific climatic and geographical conditions.

The fluctuations in the price of electricity could also affect the estimated savings of energy cost. With the possible switch to less costly energy sources

over time due to increased research in renewable energy sources, could to longer payback periods than expected. The methods considered in this study do not have significant operation costs in addition to energy costs that are included in the calculations. However it is important to leave a margin for potential repair costs and wages for employers in installation.

Inspection of the existing building condition may be necessary before installation of the retrofits. The building has to have an expected life that exceeds the life of the installations. The energy savings from the retrofits are calculated on the baseline level of energy consumption. Hence the amount of savings could be objected to the assumptions made on the distribution of energy use by buildings on campus, and components of the building.

7. Conclusion

The study analyzed the costs and benefits of improving the energy efficiency a fitness facility, Harold Alfond Athletic Center and Swimming Pool, at Colby College. The results found indicated that improving the energy efficiency by using proven technologies can bring benefits within less than one to four years that could compensate the high initial costs. Complying with the background research, the improvement of energy efficiency of the facility will not only provide environmental benefits, but also a potential investment opportunity. The main challenge of reaping the benefits would be the relatively high installation costs, which indicates the need for financing support for building energy management industry. An institution such as Colby College could potentially consider a financing option such as a loan to overcome the initial financing needs. Hence a further study on the potential for financing would be beneficial for the institutions and policy makers.

Higher profile of energy efficiency could be achieved by targeting the energy intensive end uses such as HVAC and illumination. The estimated savings of energy and the payback periods fall within the ball parks provided by the literature. A portfolio of energy efficiency methods could be used to reduce the risk of unanticipated costs in the retrofits and initial financing needs. The improved energy efficiency could harness other non-economic benefits such as better energy consciousness among students. Better energy efficiency practices will also add to the sustainability related profile of the campus, improving the reputation of Colby College among other schools. A further study to understand benefits to students, college community and the college at a larger scale would strengthen the argument for improving the energy efficiency of the Harold Alfond Athletic Center and Swimming Pool, at Colby College.

8. Acknowledgements

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