UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Evaluation and Implementation of Practical Energy Savings Measures for UBC's Indoor and Outdoor Swimming Pools

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CEEN 596

Dec 6, 2010

CEEN 596 Final Project Report

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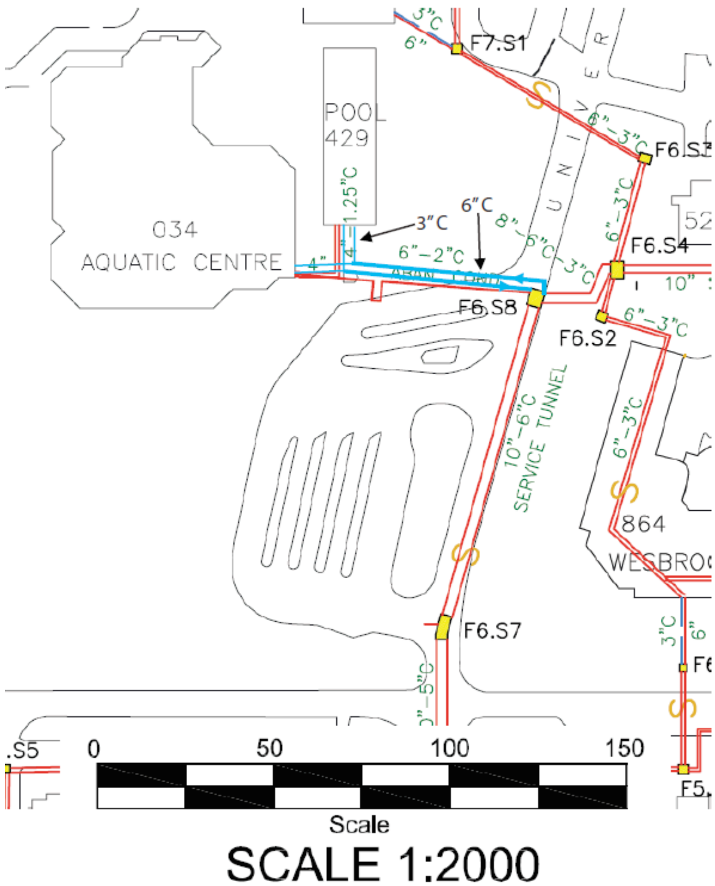


Executive Summary

The following is a proposal to modify the heating system of the Aquatic Center and Empire Pool such that both pools are heated with steam condensate collected from neighboring buildings. The proposed **Neighborhood Condensate Heat Recovery Project** will provide 100% of the heating requirements for UBC's indoor and outdoor swimming pools and generate immediate operational savings from reductions in water, energy, and greenhouse gas emissions.

The project will:

- Save an estimated 10,000m^3 of water per annum
- Reduce steam production by 13,000 KLBS/yr (1.7% of annual production)
- Reduce natural gas consumption through improved steam system efficiency of 9400 GJ/yr
- Reduce campus Greenhouse gas emissions by 468 tonnes/yr (0.75%)
- Provide compatible infrastructure for future hot water district energy system
- Cost an estimated $428,000 CAD
- Generate savings for UBC Utilities of $272,000 per annum
- Payback in 1.6 years

Table of Contents

Figures

Acknowledgments

I would like to thank the University of British Columbia for its the dedication to leadership in sustainability. Never before has a university so thoroughly embraced a role as an agent of change for the good of the planet.

I would also like to thank my beloved fiancée, Dr. Judith Maxwell Silverman, who challenges me to be my best.

Introduction

The University of British Columbia (UBC) aspires to become a world leader in sustainability education, research, and operationalization. To achieve this ambitious goal UBC has recently announced the following aggressive Greenhouse Gas (GHG) reduction targets.

33% below 2007 levels by 2015
67% below 2007 levels by 2020
100% below 2007 levels by 2050

The targets are based on Scope 1 and 2 GHG emissions eligible to be offset under the British Columbia Public Sector Carbon Neutrality Law - Bill 44. Scope 1 emissions are defined as direct fossil fuel consumption on campus while Scope 2 is indirect emissions from electricity consumption. UBC's 2007 GHG baseline is 61,090 tonnes of CO_2 equivalent[1].

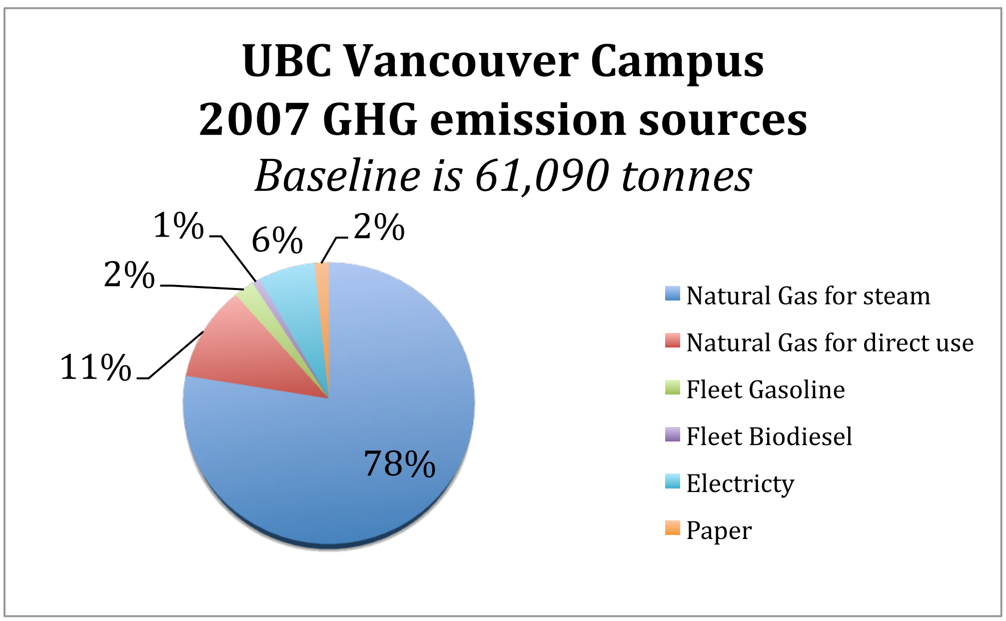


Figure 1. UBC 2007 GHG emission Sources[1]

To achieve the 2015 33% reduction target the following key initiatives have been proposed or committed.

1) Bioenergy Research and Demonstration project – Committed
2) Continuous Optimization of Building – Committed
3) Steam to Hot Water Conversion of District Heating System – Proposed

The Steam to Hot Water Conversion has received Executive Level 1 and 2 approvals and will be seeking Level 1 Board of Governors approval in February 2011.

In addition to the three initiatives listed above the University has begun to transform the campus in to a living laboratory for sustainability. This initiative involves leveraging the expertise of faculty (including researchers), students, staff, and industry to solve local and international problems.

Purpose

The purpose of this CEEN 596 project is to save money and greenhouse gas emissions for the University of British Columbia through reductions in energy and water consumption at the Aquatic Center swimming pools.

Project Objectives

This project has four main objectives:

1. To investigate and explain the revocation of the Public Sector Energy Conservation Agreement (PSECA) funding that was granted in 2008 for improvements to the Aquatic Center that were recommended by an energy audit performed by the consulting firm SES Inc.
2. To produce an improved energy audit of the Aquatic Center using previously unappreciated infrastructure and utility data.
3. To make recommendations for new energy saving upgrade options including an analysis of capital cost and net present value (NPV) estimates.
4. To deliver the project, which summarily includes securing the necessary funding, hiring of required personnel (project managers, mechanical designers and construction trades), measurement and verification of savings.

Background

Together UBC's Aquatic Center and Empire Pool are the highest energy **intensity** buildings on campus; together consuming 21 million LBS of steam annually (2.7% of the total steam produced). To provide this steam UBC's central steam plant burns 27,000 GJ of natural gas, which results in 1,350 tonnes of GHG emissions per year (2.2% of UBC's total Scope 1 and 2 emissions).

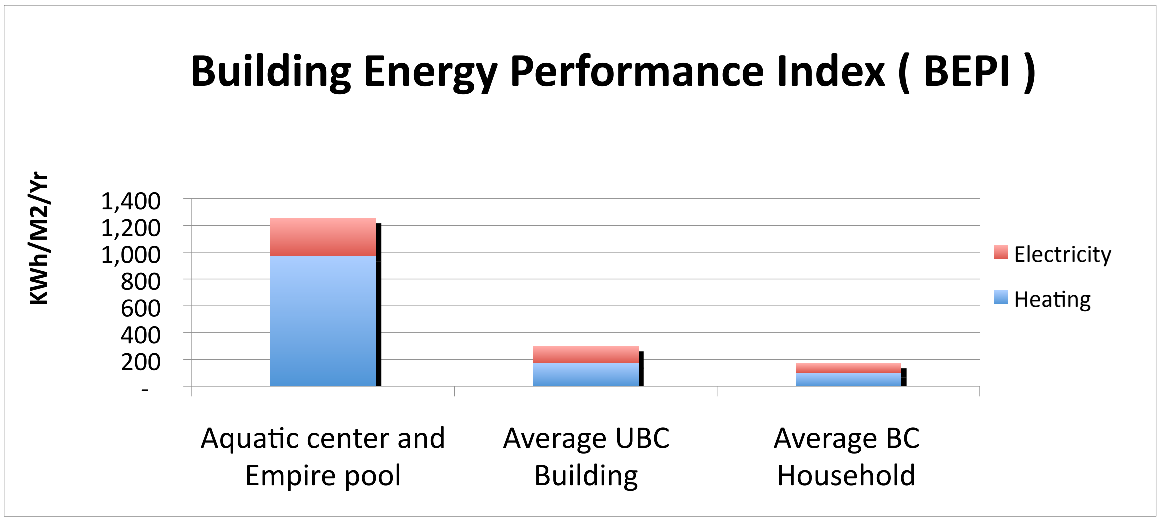


Figure 2. UBC Building Energy Performance Index BEPI[10]

As an ancillary department run by Athletics, the Aquatic Center and Empire Pool are "revenue" customers and are billed by UBC Utilities for steam, electricity, and water. Steam is billed at $21.63/KLBS, electricity is billed at $0.039/KWh plus $5.9/KW for peak demand charges, and water is billed $0.29/ft^3. Annual utility bills exceed $630,000/yr, and at $445,000/yr, **steam represents the lion's share and is the primary focus for this report**. Due partially to these high operational costs the Athletics Department is currently advocating for a new pool and Aquatic Center. The location, timing, and funding of this new building is uncertain and a best-case scenario for Athletics would see the existing Aquatic Center pools renewed or decommissioned in under 3 years.

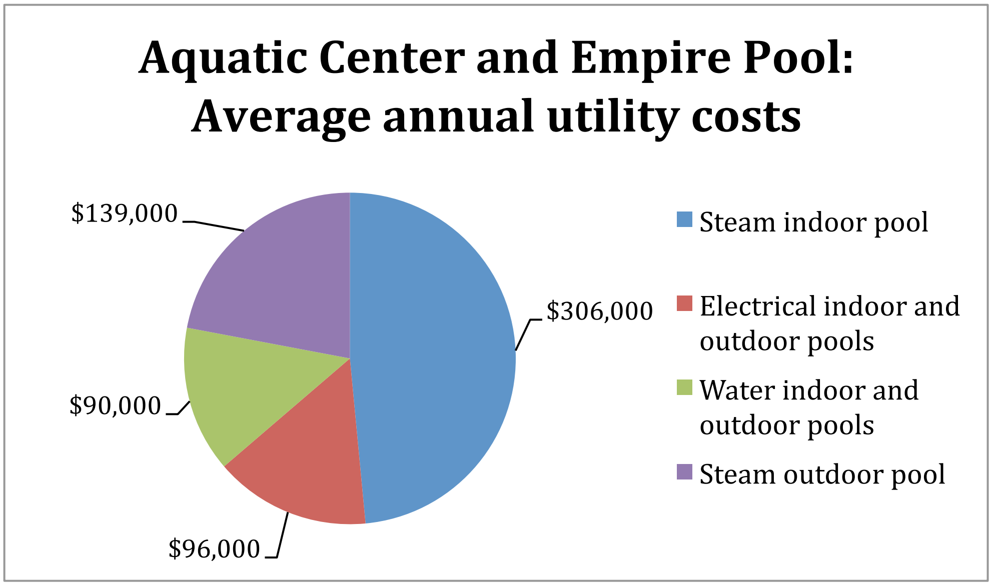


Figure 3. Aquatic Center and Empire Pool average annual utility costs

History of Swimming at UBC

UBC's 50 x 20 meter outdoor pool, the Empire Pool, was constructed in 1954 to provide an event platform for the British Empire Games. Excavation dirt was deposited in a pile, which has since become a sentimental campus staple know as the knoll. In 1978 the 5,300m^2 (57,000ft^2) Aquatic Center was completed providing an indoor 50 x 25 meter lap pool and a 20 X 10 meter baby pool. Currently both pools are heavily used. Furthermore, the pools are of significant importance to the UBC Athletics Department as over the past 12 years the UBC women's and men's swimming teams have won 11 CIS championships each.

Utility Bills Assessment

Historical utility data was obtained from UBC Utilities records[2]. The Aquatic Center and Empire Pool have separate steam meters but share an electrical and water meter. Variations in annual consumption are believed to be primarily due to meter reading issues.

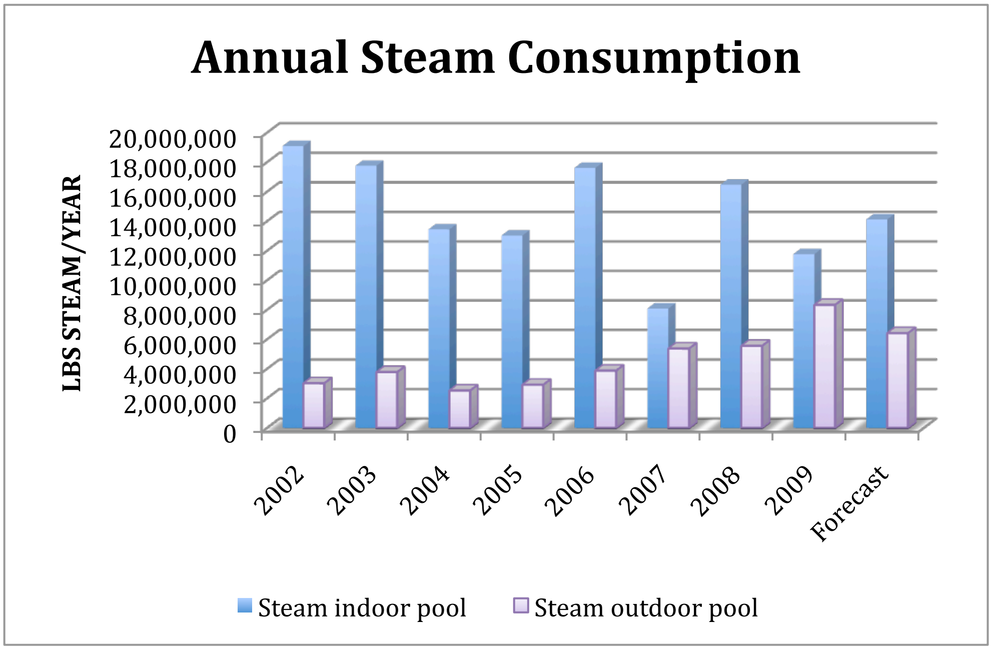


Figure 4. Aquatics Center and Empire Pool steam consumption history

In 2007 the indoor pool was closed for 1 month and meter data is missing for 2 months. Also the outdoor pool began year round operation which has double steam consumption[3].

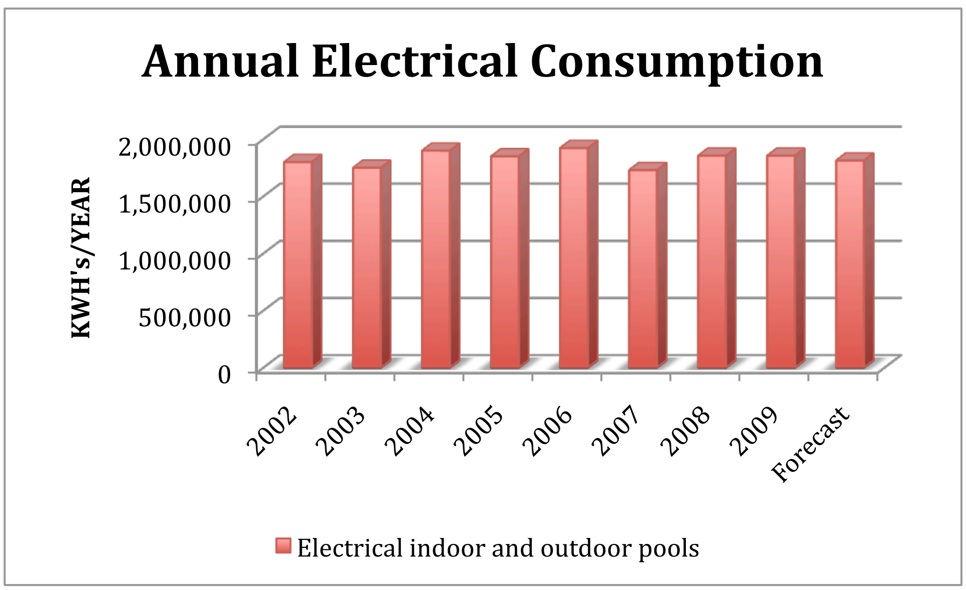


Figure 5. Aquatics Center and Empire Pool electrical consumption history

Electrical consumption is very consistent both hourly and annually which suggests fans and motors are running constantly day and night. This is not surprising as large motors for HVAC equipment and pool filtering are run continuously.

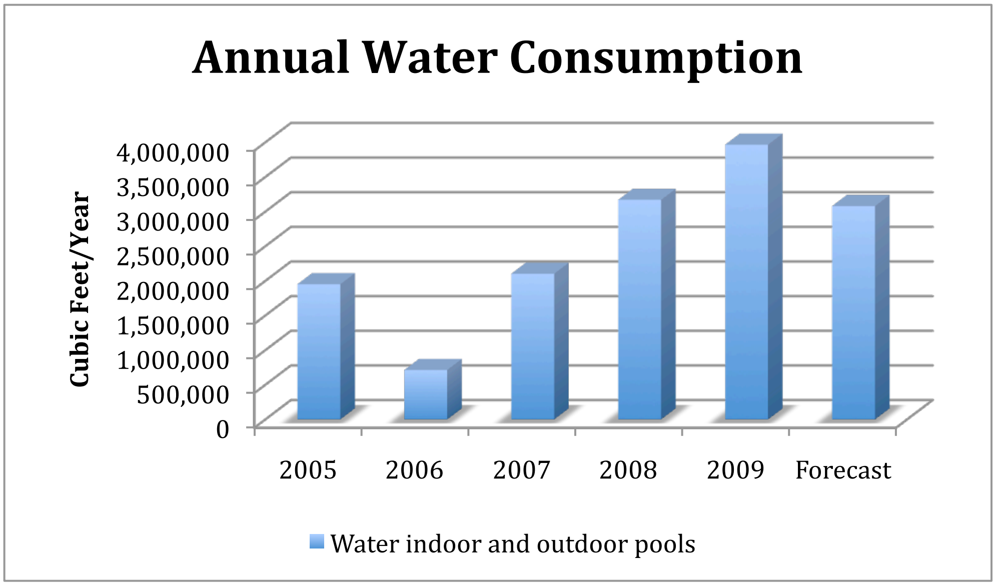


Figure 6. Aquatics Center and Empire Pool water consumption history

Water consumption has increased significantly in recent years. It is believed this is due to increased evaporation losses and leakage from both pools. The 2006 outlier is due to a broken water meter.

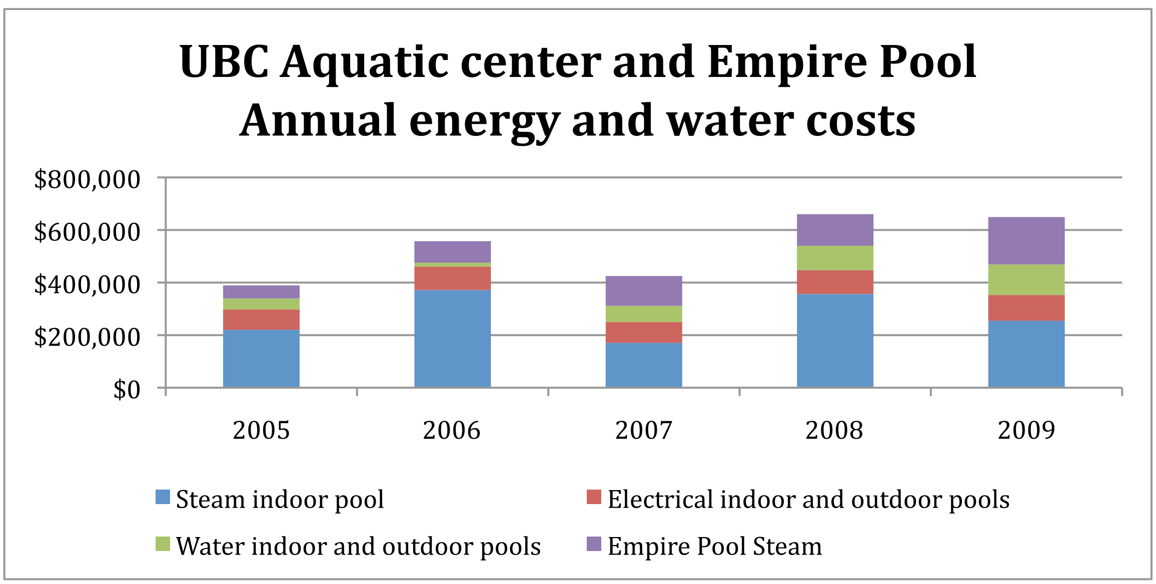


Figure 7. Aquatics Center and Empire Pool annual energy and water cost history

Comparison to the Vancouver Aquatic Center

The City of Vancouver Aquatic Center is similar in both size (6018m^2) and age to UBC's Aquatic Center. Data on energy use and cost was kindly provided by Ian Harvey[4] with the City of Vancouver. A Building Energy Performance Index (BEPI) was calculated for both the UBC and Vancouver Aquatic Center and these values were used to compare the energy intensity of the two facilities. Unfortunately water data for the Vancouver Aquatic Center is unavailable.

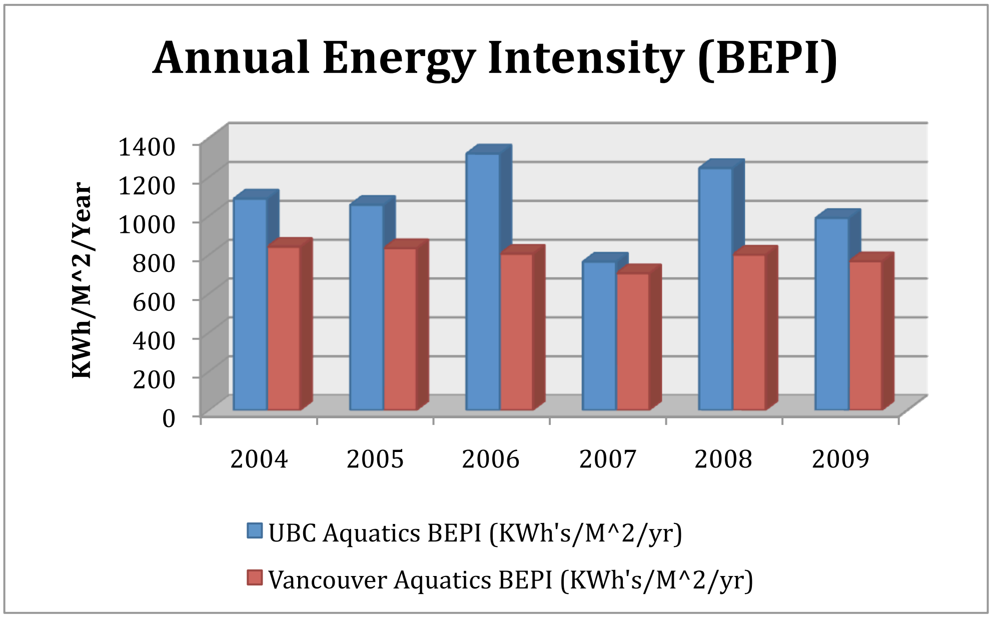


Figure 8. UBC and City of Vancouver Aquatic Center energy intensity

The comparison of energy intensity above shows that UBC's Aquatic Center consumes approximately 25% more energy per square meter than Vancouver's Aquatic Center.

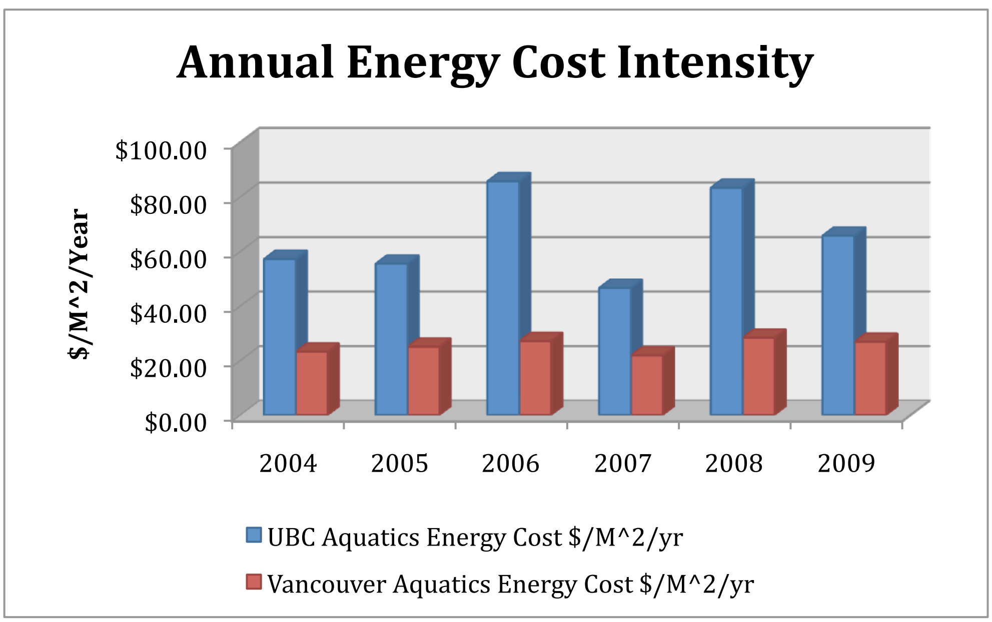


Figure 9. UBC and City of Vancouver Aquatic Center energy cost intensity.

On a per square meter basis UBC Athletics is paying 2.5 times more for energy than the City of Vancouver. There are 2 primary reasons for this large discrepancy:

1. Increased energy intensity (BEPI):
   UBC's facility consumes 25% more energy per square meter then the Vancouver Aquatic Center.

2. Price of energy:
   UBC Utilities currently charges the Aquatic Center $21.63/KLBS of steam. Steam is produced at the UBC central steam plant at a pressure of 165 PSIG with an energy content of 1,264 KJ/LBS. This translates into a cost of $17.11/GJ.
   However at the pool, the steam heat exchangers are only 83% efficient and the remaining energy, (now in the from of 80°C condensate water) is wasted because it is disposed of via the sewers. Due to this loss, UBC Athletics is effectively paying $20.50/GJ to heat the indoor pool. In contrast, the City of Vancouver Aquatic Center is paying $8.50/GJ for natural gas to heat its pool.

   Note: For UBC Utilities the all-in cost to deliver energy through the steam system is approximately $16.50/GJ and represents one of the primary drivers behind the campus wide steam to hot water conversion.

Building Data

UBC Aquatic Center

The indoor pool has 2 mechanical rooms, 2 steam rooms, 2 saunas, a hot tub, office space, a fitness room, and a diatomaceous pool filter. The pool is maintained at 28°C year round and air temperatures range from 22-24°C[5]. Typically indoor pools maintain higher air temperatures in the range of 27-29°C, which minimizes evaporative heat losses, make-up water, and pool chemical use. There are several reasons UBC's Aquatics Center has lower air temperatures.

1. Only 1 out of 6 steam coils in the main air-handling unit (HV-1) servicing the pool area are functional, this means air temperatures can not keep up the set points[5].
2. Event spectators and lifeguard personnel become sleepy and uncomfortable at the higher air temperatures[4].

To prevent structural damage humidity levels are maintained below 60% via two large air-handling units running at all times (HV-1 and HV-2). This method of dehumidification is extremely energy costly. In contrast, most swimming pools use a heat pump based dehumidification system to capture latent heat and return it to the pool[4]. Due to potential health risks associated with build up of nitrogen trichloride, as well as other toxic gases produced when chlorine reacts with ammonia, ASHRAE recommends public swimming pools with spectator areas to be maintained at a minimum of 0.54 cfm, approximately 8 air changes per hour[6].

Air temperatures in the weight room and office space fluctuate from 18°C at night to 22°C during the day. A small amount of air conditioning is provided to the office space only.

Siemens DDC controls and pneumatic actuators control the majority of building systems including exterior lighting, air temperature set points and steam valves for heat exchangers. Several control nodes are connected to UBC's central building management system (BMS).

Empire Pool

The outdoor Empire Pool is adjacent to the Aquatic Center and has a separate mechanical room with a single steam heat exchanger, steam meter, pumps and sand filter. The pool is maintained at 27°C year round. In the fall of 2009 a tent was installed over the outdoor pool.

Due to a broken condensate return line presently all of the steam condensate generated after heating both the pools is directed to the sewers. This results in approximately 10,000 cubic meters of wasted 75°C water each year. To prevent damage to the sewer system steam condensate from the outdoor pool is quenched by mixing it with fresh water. The indoor pool steam condensate is not quenched.

Energy Balance and Calculations

Various methods exist to calculate evaporative heat losses for occupied swimming pools[7]. Based on literature reviews the following evaporative heat loss formula was used from M.M. Shal[8].

Step 1.

$$E = KA_p \rho_w (\rho_r - \rho_w)^{1/3} (W_w - W_r)$$

K = 290 constant
A_p = Area of pool (ft^2)
P_r = Density of air in room (LBS/ft3)
P_w = Density air at pool surface (LBS/ft3)
W_w = Humidity ratio at surface (LBS of moisture/LBS of dry air)
W_r = Humidity ratio in air (LBS of moisture/LBS of dry air)

When the data is analyzed
E = 290*15,608*0.07054*$(0.07339-0.07054)^{.333}$ * (0.02385-0.00991) = **632 LBS/hr**

Step 2.

To include the evaporative effect from pool use the following empirical formula was added[7].

E = Unoccupided Evaporation rate * (160*N/A_p+1)

N = Average number of pool occupants = 20

When the data is analyzed
E = 632 * (160*20/15608+1) = **761 LBS/hr**

Step 3.
Annual Energy consumption = LBS/HR evaporation * BTU/LBS * Hours/yr
Enthalpy of evaporation at surface of water = 1047.2 BTU/LBS

= 761 LBS/hr * 1047.2 BTU/LB * 8760 = **6,986 MMBTU/YR**

Literature reviews and the outdoor pool steam meter data confirm the calculation above is reasonably accurate.

Using the above calculation with metered data from the outdoor pool and previous energy audits a break-down of approximate steam use was generated. The results show that ~65% of the steam delivered is used to heat the pools (Fig. 10).

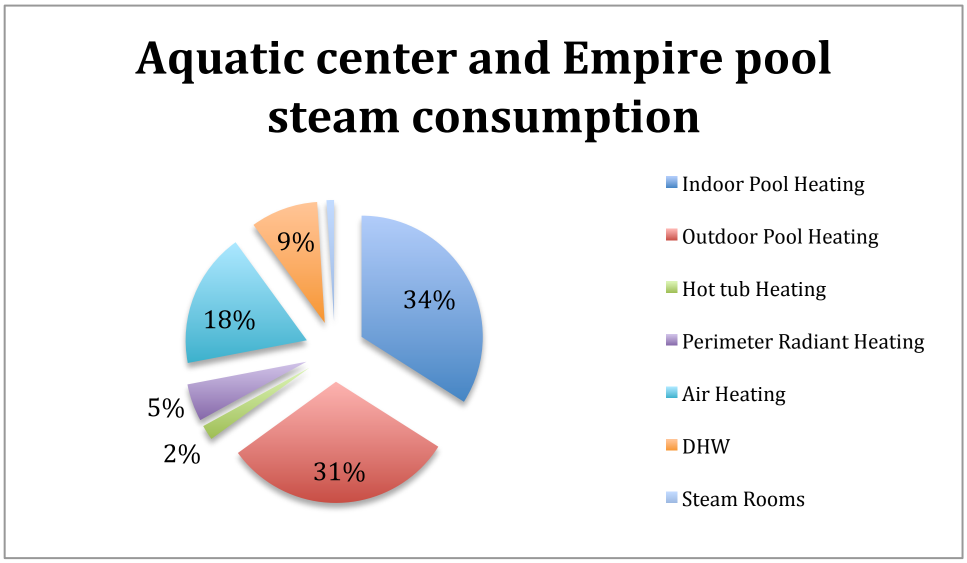


Figure 10. Steam consumption breakdown.

To summarize the building audit, and to aid the reader going forward, a schematic of the UBC Aquatic Center energy INPUTS and OUTPUTS was generated. Figure 11 depicts the approximate energy balance for both pools. Note: additional losses from the building envelope are assumed to account for the difference between INPUT and OUTPUT energy.

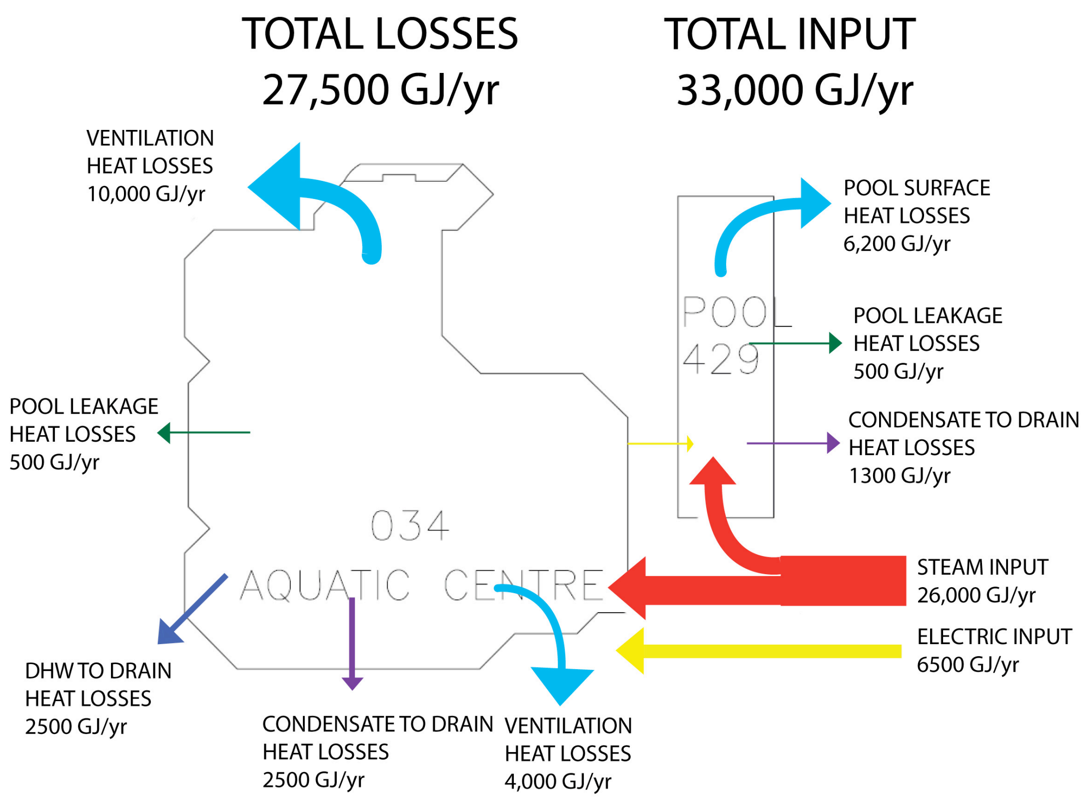


Figure 11. Aquatics Center Energy Balance

General Options for Swimming Pool Heating

High-energy consumption and low exergy heating requirements make swimming pools around the world excellent candidates for alternative heating methods. The following is short review of heating and energy saving options that should be considered first for all new indoor and outdoor swimming pools regardless of location.

1) Collocate swimming pools near to existing waste heat source. (e.g. UBC's Ice Arena has approximately 300 KW of 20°C waste heat from the ice refrigeration system)
2) Outdoor pools should have a pool cover. A cover can save up to 10% of the annual energy. [4]
3) Indoor pools should consider using a medium pressure UV light to destroy unwanted and potentially toxic chloramines. This will reduce the requirement for make-up air and significantly reduce energy consumption.[4]
4) A heat pump based dehumidification system should be required for all indoor pools and will pay for its self through tremendous energy, water and chemical savings.[4]
5) Air-to-Air heat recovery should also be considered to preheat cooler make-up air with warm exhaust air[4]. Potential systems are reviewed below:
    a. Glycol Loop – simple, low cost, low maintenance system ~40% efficient
    b. Heat Pipe – simple, higher costs, low maintenance system ~ 60% efficient
    c. Air-to-Air Plate Heat Exchanger – simple, higher costs, higher maintenance system ~ 80% efficient
    d. BKM Reverse Flow Heat Recovery – complex multiple plate system, higher costs, higher maintenance ~ 90% efficient

If heating is still required after implementing these options the following heating options should be considered. Note that the economic, social, and environmental benefit of each option will depend on the location in question. There is no prescriptive solution to heating a pool.

1) Solar thermal – Works exceptionally well on swimming pools in almost every region on earth and usually can pay for it's self in less than 5 years[4]. The only reason not to use solar thermal system is that something better exists, for example waste heat.
2) Geothermal (all types) – Functions well to heat pools, however the facilities must consider the price of electricity, GHG impacts and the conductivity of the ground before implementing.
3) Air-source heat pumps – Great for pools in temperate climates like Vancouver. COP will be less then geothermal but cost will also be less. Electricity price, GHG impacts, and noise are issues that need to be considered.
4) Biomass – Should be considered if abundantly available, easy to access, and cheap. Emissions and maintenance are issues that should be considered.
5) Condensing Natural Gas Boilers – Regardless of the primary heating system a natural gas boiler will likely still be required as back up. This boiler can be condensing or non-condensing, but with condensing boilers efficiencies of over 90% can be expected.

Previous Energy Studies

In October of 2008 SES Consulting Inc. was hired to conduct a thorough review of the UBC Aquatic Center and Empire Pool energy consumption and in doing delivered a long list of energy saving recommendations (Appendix 1). The most significant projects are listed below.

Table 1. SES Consulting Inc. energy audit recommendations summary

Rank	Short list recommended options	Costs	Payback	GJ/Saved
1	Pool Heat Reclaim	$630,000	3.2	8180
2	Domestic Water Heat Reclaim	$250,000	6.8	1580
3	Heat Pump Heating for Empire Pool	$150,000	3.3	2680
4	Hot Tub Heat Reclaim	$15,000	4.7	155
	Total Mechanical	**$1,045,000**	**3.7**	**12595**

In total SES Consulting Inc. recommended the release of $1.186 million to implement a wide range of energy savings options that would annually save UBC Athletics $320,000 through a fuel use reduction of 12,366 GJ, which equates to a reduction of 870 tonnes of GHG emissions. The study was later submitted as part of a grant application to the Public Sector Energy and Conservation Agreement (PSECA).

UBC Awarded a $1.186 million PSECA Grant

In March of 2009 UBC was awarded a **$1.186** million PSECA grant to implement the energy saving options presented in the SES Consulting Inc. energy audit. UBC immediately appointed a project manager and issued an RFP for a mechanical designer, which was won by Stantec Engineering.

Rising Cost Forced UBC to Return the Grant

In September 2009 UBC returned the PSECA grant. It's rare for a granting organization to award over $1 million for an energy retrofit project, it's even more unusual for the grantee to give the money back! To find out what went wrong I conducted numerous interviews with key UBC stakeholders including the Sustainability Office, Project Services, the Aquatic Center as well as Stantec personnel.

In short, unexpected and unexamined infrastructure issues drove the costs of each project up until they exceeded PSECA's allowable payback window. Below is detailed review of each project and the main reasons they were cancelled.

 # 1) Exhaust heat reclaim for the indoor pool

To prevent structural damage to the building, indoor humidity levels must be maintained <61%. Currently the indoor pool achieves this goal by exhausting large volumes of warm moist air and replacing it with cool dry outdoor air. The process wastes a tremendous amount of heat. SES Consulting Inc. recommended the installation of a dehumidification system and passive air to air heat recovery wheel.

What went wrong:

1. Asbestos was found in and around air handling unit #1 (HV-1).
2. 5 of 6 steam coils in the HV-1 were found to be leaking steam and needed to be decommissioned and replaced.
3. New VSD motors and DDC controls were required to realize the predicted savings.
4. Pool leakage was not properly accounted for in the original study.

 # 2) Domestic water heat reclaim

This was a very complicated measure that included the installation of air to water heat recovery coils in the exhaust of air-handling unit #2 (HV-2) and a solar hot water installation on the roof connected to domestic hot water and the swimming pool.

What went wrong:

1. The roof required significant structural upgrades to support the solar panels.
2. HV-2 required significant reconfigurations and upgrades.

 # 3) Empire pool heat pumps

This project would install 70 tons of air source heat pumps to heat the outdoor pool.

What went wrong

1. Noise from the heat pumps was too loud for competitive swim meets and the only suitable location for the heat pumps was on the pool deck.
2. To allow for swim team practices the outdoor pool is now run year-round which limits the effectiveness of air source heat pumps, as they would not perform well in the winter.
3. The additional electric load required by the heat pumps would have triggered significant upgrades to the buildings electrical systems.

Lessons Learned

In conclusion, through this re-examination of the UBC Aquatics Center energy use - and re-evaluation of the motives of all the interested parties - at least four salient lessons can be learned. These must be respected if future energy saving efforts regarding the UBC Aquatic Center are to be made. Those lessons are:

1. Be careful when dealing with granting organizations such as PSECA who are looking for short paybacks and can move projects elsewhere.

2. Make sure the beneficiary of the project is onboard and committed to the projects success.

3. Be weary of transferring loads from one energy source to another as it may trigger large and expensive upgrades.

4. Make sure to explore all options and look beyond the traditional boundaries of individual building energy use.

New Energy and Cost Saving Options

Guiding Principles

1. Review options not considered by SES Consulting Inc.
2. Recommend implementation if evaluation indicates
   a. Payback is less than 2 years
   b. Compatible with the campus Hot Water Conversion Project

Option 1: Reinstatement of Condensate Return System

Over the past decade UBC Utilities and the Campus Sustainability Office have worked hard to return steam condensate back to the powerhouse and presently over 70% of the steam that leaves the plant is returned and reheated. As mentioned, the condensate return piping from both the indoor and outdoor pools is currently decommissioned. This results in approximately 21 million LBS/yr (10,000M^2/yr) of wasted 75 degree Celsius water.

Restoring the condensate system would return 90% of the condensate, annually saving UBC Utilities $10,000 in water, $2,000 in steam chemicals, and $7,000 in energy and carbon liabilities.

To fully capture all of the condensate from both pools over 140 meters of 2 inch condensate piping will need to be restored. In addition 4 new condensate pumps must be installed as well as a new condensate receiver for the Empire pool. The cost of this restoration is expected to exceed $400,000, which will result in a payback of 21 years. As such this option violates the guiding principles.

Option 2: Condensate Heat Scavenging

A common practice with steam district energy systems is to install a second heat exchanger to recover the leftover heat in the steam condensate. Typically these are shell and tube style, however, recently plate and frame heat exchangers have become popular. The main advantage of plate and frame is their greater heat transfer efficiency and small size to surface area ratio, which allows them to fit into tight mechanical room spaces.

This project would install a small 28 KW (stainless-steel brazed plate heat exchanger, 2 circulation pumps and 200 feet of insulated PEX (cross-linked polyethylene) piping to exchange heat from the condensate tank to the pool filter tank (Fig. 12).

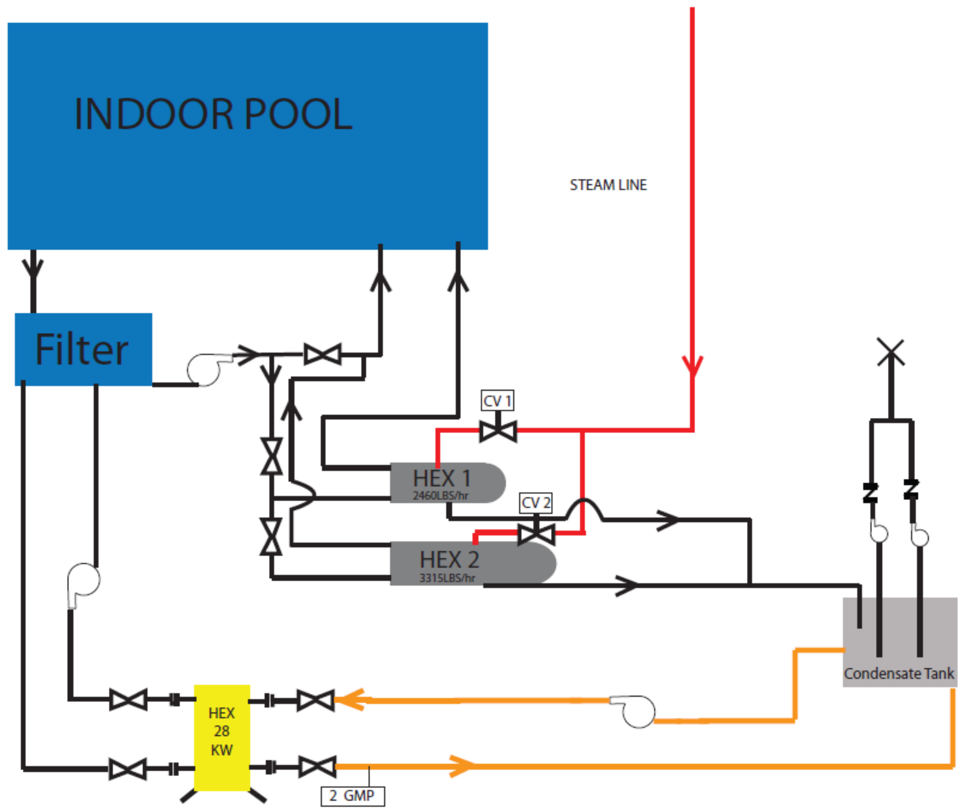


Figure 12. Small scale condensate heat recovery schematic.

It is anticipated that the project would reduce the average temperature of the condensate tank from 75°C to 33°C (167°F to 91.4°F) with just over 11,000 KLBS/yr condensate entering the receiving tank the annual energy savings for athletics are estimated 832 KLBS of steam and $18,000/yr. This translates into annual savings at the powerhouse of 1070 GJ and 53 tonnes of GHG emissions.

The preliminary capital cost for the project is estimated at $10,000, translating to a payback of 0.56 years.

Direct use of steam condensate into the pool as make-up water

Another option briefly considered by this report is to pump steam condensate directly into the pool for use as pool make-up water. However, the UBC steam plant uses two types of amines, Cyclohexamine and Morpholine, to inhibit corrosion in the condensate return piping. Although these products are found in concentrations of < 10 parts per million (ppm) they are toxic in higher concentrations. Options for removing the amine were reviewed but in the end the concept was abandoned due to safety concerns.

Option 3 - Neighborhood Condensate Heat Scavenging

This project has the potential to provide 100% of the heating requirements for both swimming pools. The project would install supply and return pipes, pumps and plate heat exchangers to divert returning condensate from neighboring buildings through plate heat exchangers located in each pools mechanical room (Fig. 13) and then back to the powerhouse. Once back at the powerhouse the reduced condensate temperatures will allow for greater flue gas heat recovery in the boiler economizers (Fig. 15) and improve the overall steam system efficiency. Additional benefits of the project include repairing the broken condensate return line and compatibility with planned future hot water heating infrastructure.

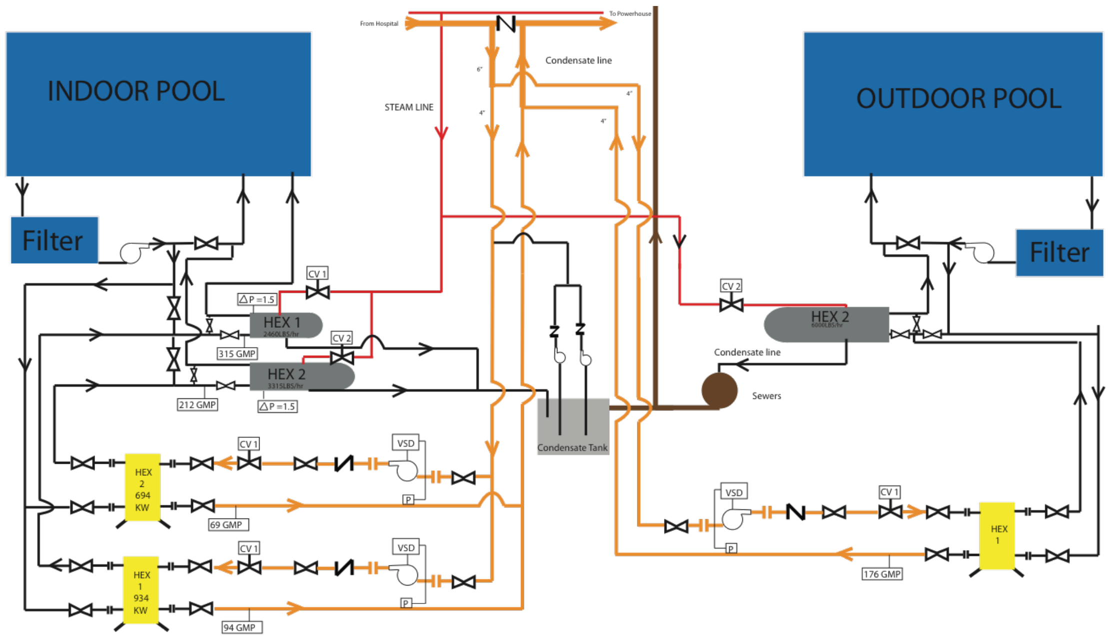


Figure 13. Neighborhood Condensate Heat Scavenging Schematic Diagram

To achieve the goal of heating both pools approximately 14,000 GJ/yr of annual energy will be required. With average condensate temperatures of 75°C and pool temperatures of 28°C a ΔT of 43°C (77°F) across the plate heat exchangers is achievable and approximately 175,000 KLBS/yr of condensate will be required. This large volume of condensate will come from the nearest 18 buildings listed below (Table 2).

Reduced steam production and increased efficiency in the boiler economizers will annually save 9400 GJ of natural gas, 468 tonnes of GHG emissions, 10,000 cubic meters of water and $272,000. A preliminary capital cost estimate for the project is $428,000 for a simple payback of 1.6 years (Table 5).

Note: The above simple payback assumes UBC Utilities continues to bill Athletics at the same $20.50/GJ rate until the project is paid off at which point a new rate will be negotiated (Table 5).

Table 2. Annual Condensate return flows of buildings neighboring the pools.

Option 3	KLBS/YR STEAM	ΔT °F	MMBTU/yr	GJ/yr
Neighborhood condensate heat recovery				
UBC hospital (Koerner, Detwiller, Purdy)	36010	77	2773	2925
~~War Memorial~~	~~5706~~	77	439	464
~~GSAB~~	~~2797~~	77	215	227
IRC	5128	77	395	417
Biomedical Research	2563	77	197	208
COPP, FRIEDMAN, MEDICAL SCIENCES BLOCK C	17266	77	1329	1403
J.B. MacDonald	7561	77	582	614
David Strangway	2264	77	174	184
WOODWARD BIOMEDICAL LIBRARY	4016	77	309	326
Line loss condensate	28400	77	2187	2307
Life Sciences Center	51035	77	3930	4146
CHBE	13074	77	1007	1062
Pulp and paper	2743	77	211	223
Aquatic Center + Empire Pool	6573	77	506	534
Wesbrook Building and Annex	8844	77	681	718
Cunningham building + Addition	6807	77	524	553
Total condensate available	**192283**	77	14806	15620

Note: Condensate line meters at the powerhouse confirm average annual returns for the southeast loop are over 300,000 KLBS/yr.

Option 3.1 - New Sub building

The new 24,000 m^2 Student Union Building (SUB) will be located adjacent to the Aquatic Center and completed in the spring of 2014. The building will be built to LEED Gold standards and partake in the living building challenge which requires low GHG forms of heating. As mentioned, the future of the Aquatic Center and Empire Pool is uncertain and both pools might be decommissioned in 3 years. If this happens significant heating capacity, pumps and plate heat exchangers will become available for the SUB.

It is anticipated that the new SUB building will have a building energy performance index (BEPI) for heating of 50 KWh/m^2/yr and annually require 4,300 GJ.

The new SUB will be built to UBC code using a low temperature hydronic heating system and if connected to the condensate return would require approximately 61,000 KLBS/yr. Assuming this displaces high efficiency natural gas boilers annual savings are expected of 2,600 GJ, 129 tonnes of GHG's and $24,000. It is assumed that any costs to hook up the system would be paid out of the new SUB project budget.

This option has been presented to the mechanical designers for the new SUB who are considering it in conjuncture with solar thermal panels. Backup heating will still be required as the condensate system is powered by electric pumps, which will cease to operate during power outages.

Recommendation of Preferred Options

Based on the evaluation criteria below the preferred option is to heat both pools with returning condensate from other buildings. The **Neighborhood Condensate Heat Recovery Project** will provide will provide 100% of the heating requirements for both of UBC's pools and generate immediate operational savings from reductions in water, energy, and greenhouse gas emissions.

The project will:

- Save an estimated 10,000m^3 of water per annum
- Reduce steam production by 13,000 KLBS/yr (1.7% of annual production)
- Reduce natural gas consumption through improved steam system efficiency of 9400 GJ/yr
- Reduce campus Greenhouse gas emissions by 468 tonnes/yr (0.75%)
- Provide compatible infrastructure for future hot water district energy system
- Cost an estimated $428,000 CAD
- Generate savings for UBC Utilities of $272,000 per annum
- Payback in 1.6 years

Table 3. Evaluation Criteria

Decision Criteria	Option 1	Option 2	Option 3	Option 3.1
Under 2 year Payback	No	Yes	Yes	Yes
Compatibility with future energy sources	No	No	Yes	Yes
Compatibility with planned buildings (New Sub and New Student Residences)	No	No	Yes	Yes
Funding potential	No	Yes	Yes	Yes
Total Yes	0	1	4	4
Preferred option			√	√

Detailed Evaluation of the Neighborhood Condensate Heat Scavenging Project

Capital cost estimate

A capital cost estimate of $427,823 was calculated for the project with the assistance of the consultant Marian Lis, PEng.

Table 4 Neighborhood Condensate Heat Scavenging Capital Cost Estimate

Capital cost estimate	Meters/Quantity	$/Meter	Cost
Outside costs			
Paired condensate piping (schedule 80)**	100	$ 1,300	$ 130,000
Additional Landscape contingency	40	$ 500	$ 20,000
TOTAL			$ 150,000
Indoor costs			
Plate heat exchangers	3	$ 8,000	$ 24,000
Building piping	100	$ 500	$ 50,000
Pumps	3	$ 7,500	$ 22,500
6" Isolation valves	4	$ 750	$ 3,000
4" Isolation valves	4	$ 1,500	$ 6,000
Control valves	3	$ 3,000	$ 9,000
Energy Meter	1	$ 10,000	$ 10,000
Control panel (wiring and actuators)	1	$ 20,000	$ 20,000
Manhole	1	$ 10,000	$ 10,000
SUB TOTAL			$ 154,500
Mechanical contingency		10%	$ 30,450
Architectural contingency		10%	$ 30,450
Shutdowns		1%	$ 3,045
Design Fee		10%	$ 30,450
Project Management		9.5%	$ 28,928
Grand TOTAL			**$ 427,823**
** Includes, condensate tie in, trenching, expansion joints, valves and restoration			

Simple Payback and NPV Analysis

Despite the fact that the Aquatic Center may be decommissioned in the next three years, a simple payback analysis shows that the project will have paid for itself in savings after only 1.6 years (Table 5). Additionally I have calculated the Net Present Value of this project over a 10 year period using a discount rate of 5.75%. This demonstrates a present value of potential savings of $1.6 million for UBC Utilities in the event that the pools remain in existence.

Table 5. Simple Payback and NPV Analysis

AQUATIC CENTER POOL PROJECT SUMMARY		YEAR	2010	2011
1) POWERHOUSE BAU (2008 BASELINE)			$/YR	$/YR
NATURAL GAS CONSUMPTION/YR	1,000,000	GJ		
STEAM PRODUCTION/YR	770,000	KLBS/YR		
STEAM SOLD TO ATHLETICS FOR POOL USE	13,427	KLBS/YR	$ 290,426	$ 290,426
COST OF STEAM SOLD (UTILITIES)	13,427	KLBS/YR	$ 173,259	$ 173,259
NET PROFITS (LOSS) PER YEAR			$ 117,167	$ 117,167
2) POWERHOUSE POST POOL PROJECT				
STEAM REDUCTION/YR	13,427	KLBS/YR		
STEAM PRODUCTION/YR	756,573	KLBS/YR		
PERCENT REDUCTION	1.7%	%		
NATURAL GAS CONSUMPTION/YR	990,585	GJ		
PERCENT REDUCTION	0.94%	%		
ENERGY SAVED/YR	**9415**	GJ		$ 61,102
GHG EMISSIONS SAVED	468	tonnes		$ 25,796
WATER/CHEMICAL SAVED	10000	cubic meters		$ 12,000
CONDENSATE SOLD TO ATHLETICS FOR POOL USE	174377	KLBS/YR		$ 290,426
PROJECT COST	**$ 428,000**		$ 428,000	
SIMPLE PAYBACK	**1.6**			
NET PROFIT LOSS PER YEAR			$ (428,000)	$ 389,324
CASH FLOW COMPARED TO BAU			$ (428,000)	$ 272,157
10 YEAR NPV	**$1,599,039**			
Discount rate	**5.75%**			
3) POWERHOUSE POST POOL PROJECT AND NEW SUB BUILDING				
STEAM REDUCTION/YR	13427	KLBS/YR		
STEAM PRODUCTION/YR	756573	KLBS/YR		
PERCENT REDUCTION	1.7%	%		
NATURAL GAS CONSUMPTION/YR (GJ)	993184	GJ		
ENERGY SAVED/YR POOL + NEW SUB	**11616**	GJ		$ 75,386
GHG EMISSIONS SAVED	578	tonnes/yr		$ 31,827
WATER/CHEMICAL SAVED	10000	cubic meters		$ 12,000
CONDENSATE SOLD TO ATHLETICS FOR POOL USE	174377	KLBS/YR		$ 290,426
PROJECT COST	$ 428,000		$ 428,000	
SIMPLE PAYBACK	**1.5**			
NET PROFIT LOSS PER YEAR			$ (428,000)	$ 409,639
CASH FLOW COMPARED TO BAU			$ (428,000)	$ 292,472
10 YEAR NPV	**$1,750,344**			
Discount rate	**5.75%**			
New Sub GJ Energy Saved	**2599**			
New Sub Tonnes of GHG's Saved	**129**			
$ saved/YR	**$ 23,986**			

UBC Powerhouse Schematic Diagram and Energy Balance Before

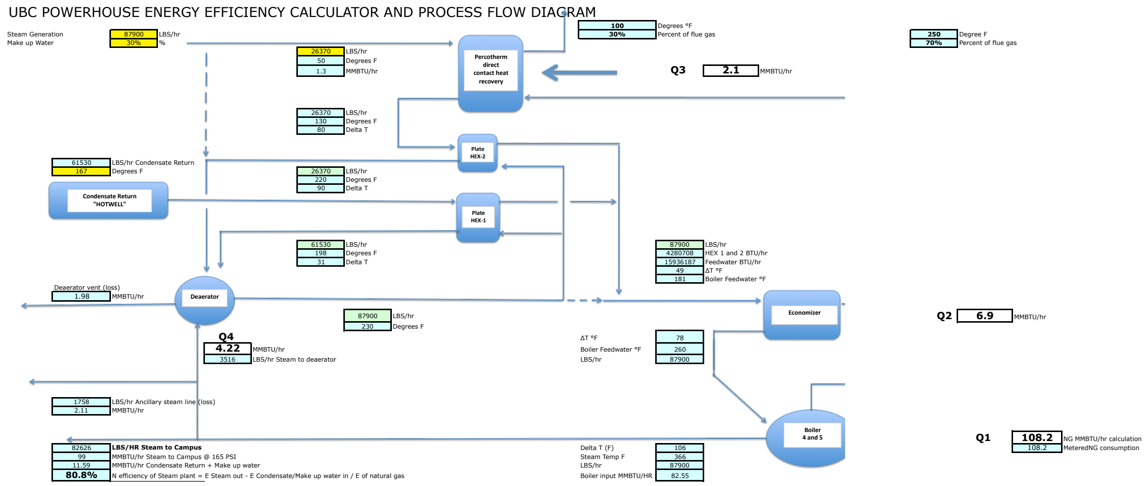


Figure 14. UBC Powerhouse Schematic Diagram and Energy Balance[9]

UBC Powerhouse Schematic Diagram and Energy Balance After Aquatic Center Upgrades

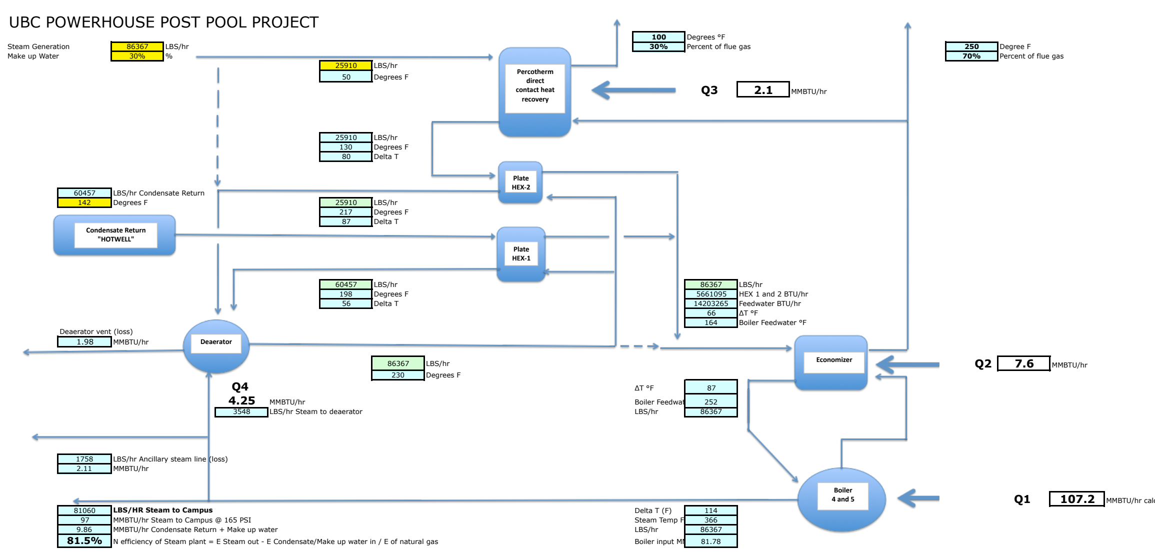
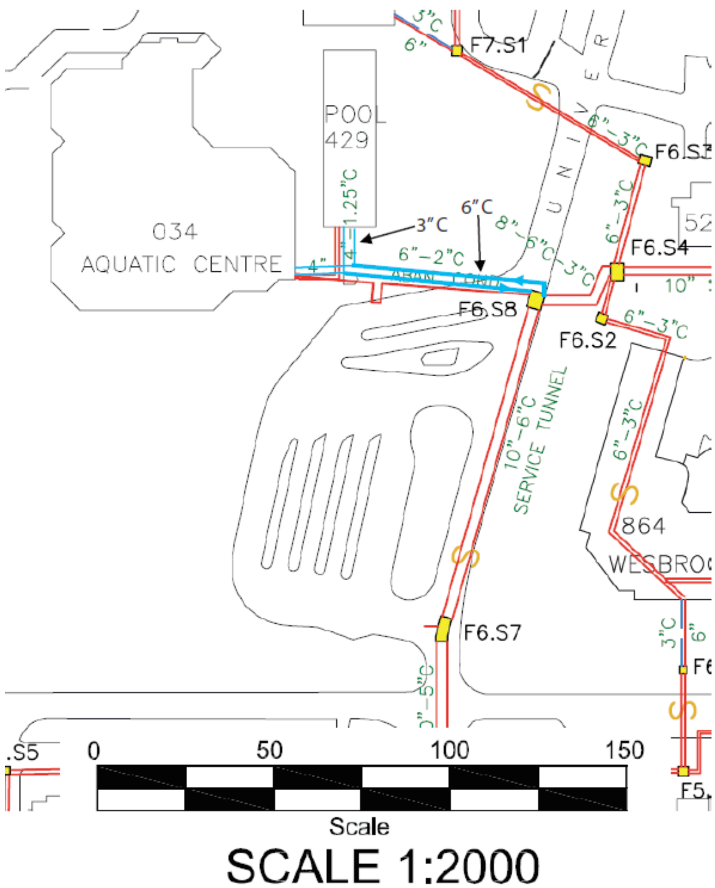


Figure 15. UBC Powerhouse Schematic Diagram and Energy Balance After Aquatic Center Upgrades [9]

Project Delivery

The proposed **Neighborhood Condensate Recovery Project** has received unanimous support form UBC Building Operations and Utilities personal and $50K in seed funding has been committed by them. A project manager has been appointed, a Request for Proposals has been issued to private sector engineering firms, and AME Consulting Inc. has been selected for detailed design and capital budgeting confirmation.

Additionally it has been confirmed that the Utilities steam fitter crew can install the outdoor piping and that the labor involved will be free to the project. However, this crew is only available from February to April 2011 and some equipment such as direct buried condensate piping requires at least two months lead-time. Thus there is a strong incentive to move quickly to order the piping and implement this project. The scheduled completion date for the project is April 1st 2011.



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1. UBC GHG emissions inventory 2007 http://www.sustain.ubc.ca/sites/default/files/uploads/pdfs/2007GHGInventorySummary.pdf

2. Personal communications - Anne-Marie Novak, Accounting Supervisor UBC Utilities

3. Personal communications – Lloyd Campbell, Manager UBC Aquatic center.

4. Personal communications - Sean Healy, Supervisor Aquatic Services and Ian Harvey, Manager of Major Maintenance for the City of Vancouver.

5. Personal communications – Mark Scott, Manager Building Management System

6. ASHRAE addendum n to ASHRAE standard 62-2001 http://www.ashrae.org/content/ASHRAE/ASHRAE/ArticleAltFormat/200418145036_347.pdf

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Appendix: SES Consulting Inc. Energy Study

UBC Aquatic Centre and Empire Pool
Energy Study

Alliance

Energy Study for:

UBC Aquatic Centre and Empire Pool

Attention:
Kavie Toor

Senior Business Development Manager

Prepared by:

SES Consulting Inc.

October 3, 2008

UBC Aquatic Centre– 6121 University Blvd, Vancouver, BC

- Energy Study -

TABLE OF CONTENTS

Appendices

1. Executive Summary

1.1 Background of the Project

SES Consulting Inc. was asked to provide an Energy Study to analyse the present operation of the UBC Aquatic Centre and Empire Pool (UBC AQC). The 5,300 m^2 (57,000 ft^2) single storey aquatic centre operates 50 meter indoor and outdoor pools with some office space and a fitness centre in the basement. The facility currently has a combination of linear fluorescent, high intensity discharge (HID), and compact florescent lighting. Heating, ventilation, and air conditioning (HVAC) is provided by five air handling units, of which only one of these units has DX air conditioning. The facility currently produces 1,203 Tonnes of Annual CO_2 Emissions based on the following energy consumption data.

Normalized **Annual Utility Costs (Inc taxes) and Consumption** for the UBC AQC for 2006 and 2007 are:

Historical Data	Energy Use (GJ)		BEPI (MJ/m2)		BEPI (kWh/ft2)		Cost ($)	
	2007	2006	2007	2006	2007	2006	2007	2006
Steam	17,090	22,406	3,240	4,248	84	110	$ 446,381	$ 585,241
Electricity	6,754	7,451	1,281	1,413	33	36	$ 85,042	$ 95,279
Total	**23,843**	**29,856**	**4,521**	**5,661**	**117**	**146**	**$ 531,424**	**$ 680,520**

The aim of the study was to analyse the existing operation of the building to try to seek out opportunities to reduce energy consumption, and to analyse the costs associated with these potential projects. Note that 2007 data was used as the baseline for analysing project savings as this data represents current consumption, though savings estimates will increase significantly if the normal energy usage is closer to 2006 levels.

1.2 Précis of Project

We have identified a number of excellent opportunities to cut the overall energy consumption for the facility in half. This accomplishment will require a large mechanical retrofit to the pool heating and ventilation systems, so that energy used to heat the pool, can be reclaimed before it is exhausted with the ventilation systems. In addition, we propose to heat the outdoor pool with air source heat pumps, and to add smaller heat reclaim systems to transfer heat to domestic hot water, and the hot tub. To supplement this heat reclaim, we propose to add solar water heating to the facility, and to tie all of these concepts together through DDC controls. After adding sensors, and intelligent programming, we can use DDC to monitor and verify the estimated energy savings, in addition to creating alarms if the system is not performing as planned. These projects represent a tremendous energy and greenhouse gas saving opportunity, and we highly recommend that the client pursue incentive opportunities from Eco Energy, BC Hydro, and the PSECA program to help implement these measures.

1.3 Summary Report Table

The costs associated with each of these projects are summarized below:

Project Summary		Annual Savings						
Measure Description	Capital Cost	Savings	Electricity (kWh)	Electricity (GJ_e)	Gas (GJ)	Payback	BEPI MJ / m²	GHG (Tonnes)
DDC Savings	$69,000	$23,200	377,000	1,357	308	3.0	316	29
Mechanical Savings	$1,045,000	$282,000	(724,810)	(2,609)	12,595	3.7	1,893	841
Lighting Savings	$72,300	$15,200	198,761	716		4.8	136	4
Total Savings	**$1,186,000**	**$320,000**	**(149,049)**	**(537)**	**12,903**	**3.7**	**2,350**	**874**

1.4 Allocation of Funds

These projects have the potential to reduce the **energy footprint** of the facility by **51.9%** resulting in a building energy performance index (BEPI) of **2,171 MJ/m^2**. If all of these projects meet with your approval, then we recommend that **$1,186,000** be budgeted for the implementation of capital projects. We estimate that these projects will increase the electrical load by **(149,049)** kWh, while saving **12,903** GJ of steam. The net result of this is **12,366** GJ of annual energy savings. When the UBC AQC achieves these savings, **870 Tonnes** of annual greenhouse gas (GHG) emissions (**72.6%** GHG reduction) will be eliminated while saving **$320,000** each year.

2. Customer Information

UBC Aquatic Centre	6121 University Blvd Vancouver, B.C. V6T 1Z1
Contact Information:	Kavie Toor, Senior Business Development Manager Phone: (604) 822 – 1688 Email: ktoor@interchange.ubc.ca

3. Background Description of Facility, Hardware and Systems

3.1 Overview

The UBC AQC, constructed in 1974, is a single storey building occupied seven days a week from approximately 7 am to 10 pm. The facility contains a large 50 m indoor pool, as well as a 55 m seasonal outdoor pool, some office space, a fitness centre and locker rooms.

UBC Utilities Customer Number - Aquatic Centre	**236**
UBC Utilities Customer Number - Empire Pool	**240**
Facility type	**Swimming Pool / Fitness Centre**
Facility age	**Constructed 1974**
Total floor area and number of floors	**5,274 m^2 / 1 storey + basement**

3.2 Mechanical Systems

Heating, ventilation and air conditioning (HVAC) for the UBC AQC is provided by five air handling units. The largest air handling unit (HV-1) has a 40 hp supply fan, and a 20 hp return fan serving the indoor pool natatorium. Other units serve the pool mezzanine viewing area, the fitness and locker rooms, and the lobby areas. All of these units have steam heating coils, and only MZ-1 serving the office area has mechanical cooling which is provided by a 20 ton DX air conditioning unit. The indoor pool area is also heated using a hot water radiant heating system.

Circulating and heating pool water uses a tremendous amount of energy in this complex. Each of the large 50 meter pools has a 50 hp pool pump, as well as a number of filter pumps. These pumps alone represent almost 700,000 kWh of electricity consumption. Each of the pools, as well as the hot tub have dedicated steam heat exchangers to heat pool water. Steam is provided to the facility through underground piping from a central UBC boiler plant that is located on campus.

Domestic hot water for the UBC AQC is provided by another dedicated steam heat exchanger, and is circulated with a domestic hot water recirculation pump.

The facility is equipped with a limited amount of building automation controls using a Siemens DDC system with pneumatic actuation of most devices. This DDC system provides complete control of most building systems including the exterior lighting, air handling units and steam valves for the heat exchangers. All major equipment is listed on pages A2-A3, indicating annual energy consumption, operating schedule, and area served.

3.3 Electrical System

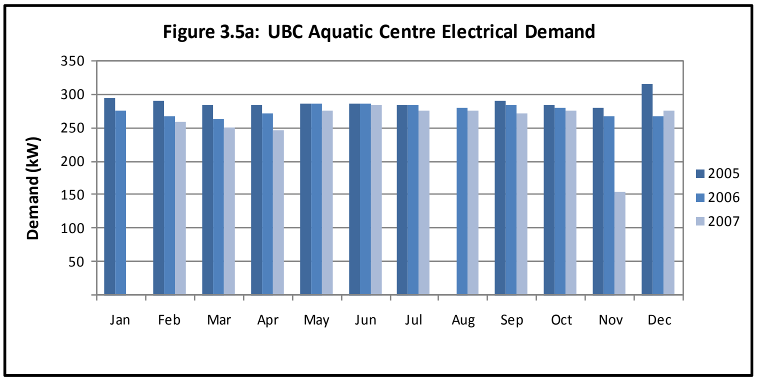
The facility has a 12.47 / 600 kVA electrical service. The peak monthly billing demand for this facility is approximately 250 kW in the winter, and rises up to 290 kW during the summer. Monthly demand and consumption profiles can be found in Section 3.5. Billing is according to BC Hydro rate schedule 1200.

3.4 Lighting System

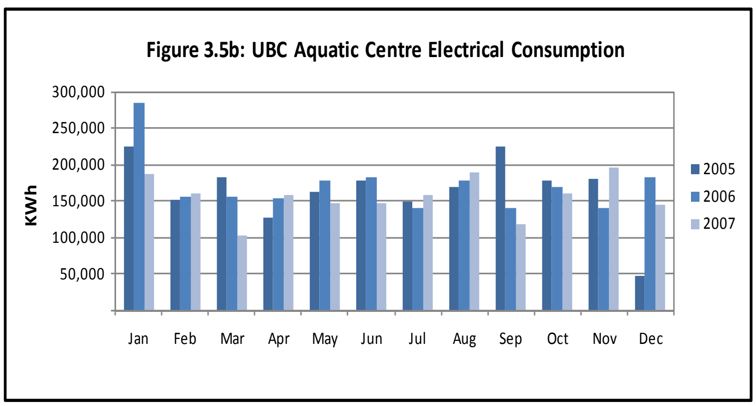
Please refer to the attached Quantum Lighting report (Appendix B) for a description of the lighting systems of this building. For the analysis of proportional energy use, we have assumed lighting density of 1.3 W/ft^2.

3.5 Energy Analysis

The main purpose of our study was to identify potential areas for conservation, and to analyze the feasibility of these projects. To understand the patterns of energy consumption, we have analyzed the electrical consumption for the building. The following energy analysis for the facility is based on UBC Utilities records. These graphs highlight trends in energy consumption that help us identify areas for potential conservation.

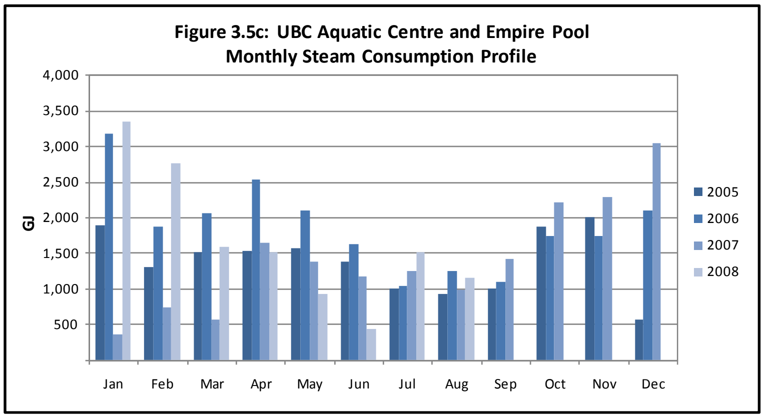


In Figure 3.5A we notice the facility demand has had a relatively consistent load profile for the last several years with a peak load of approximately 290 kW that drops down to 250 kW during the winter. This reflects the relatively constant use of the facility with additional pool pumps and some AC equipment contributing to a higher peak demand during the summer. The load factor for the facility is above 0.80, showing us that the majority of equipment in the building is running 24 hours a day.

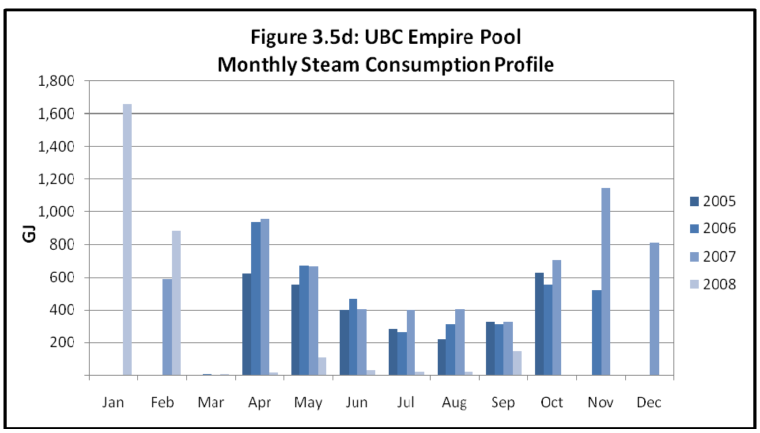


In Figure 3.5B we notice that monthly electrical consumption is quite unusual, with large variations for a given month from year to year. This trend results from two factors: changing facility loads as a result of seasonal activities, and the variations in the meter reading date from month to month. When we look at the daily consumption trend, it appears that the daily consumption is more consistent at around 5,000 kWh per day during the peak season, dropping down to 4,500 kWh per day during April.

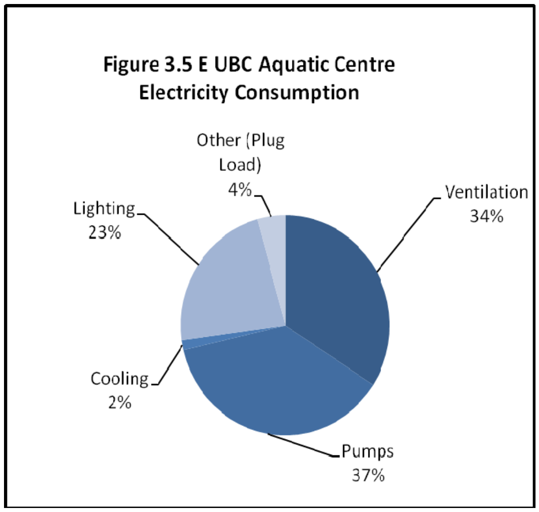
The monthly steam consumption data provided by UBC Utilities can be seen in Figure 3.5 C. Once again we see wide variation from year to year, with a generally obvious seasonal heating profile. This variation indicates an opportunity to reduce unnecessary consumption, for if it was possible one year, then it should be possible to repeat this behavior again. While annual steam consumption appears to vary dramatically from year to year, we have assumed an annual baseline of 17,000 GJ as we feel that the addition of monitoring and exception reporting technology will raise alarms and allow UBC plant operations to solve the problems causing this usage. We feel the 2006 consumption of 22,000 GJ could have been avoided through better management and control systems.



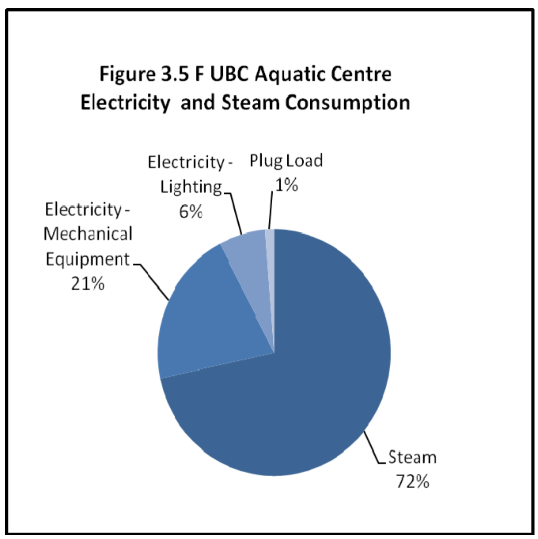
The monthly steam consumption data for the Outdoor Empire Pool can be seen in Figure 3.5 D. This trend shows us a few very important observations. First and foremost, it appears that the steam heating for the outdoor pool was left on during the past winter, using approximately 4,500 GJ (over $100,000 of steam at market rates) when the pool was not being used. Secondly steam consumption seems to have dropped to virtually nothing during the summer of 2008. We highly recommend investigation of the steam metering and consumption for this outdoor pool, as we conclude that either the billing data is incorrect, or the steam heating has recently been left on in the winter and turned off in the summer. If we assume that past trends are accurate, then the outdoor pool represents 4,000 GJ of annual steam consumption on average.



We have also analyzed the breakdown of energy consumption by building system in order to estimate the percentage of load each system represents. In Figure 3.5 E, the electricity consumption profile shows us that the lighting, ventilation, and pool pumps are the most significant electrical consumers in the building. These areas will be a focus of our energy savings measures.



In Figure 3.5 F, the overall energy consumption chart shows our estimate of the energy consumption breakdown associated with electrical usage and building heating. We see that estimated steam usage accounts for 72% of the total energy consumption for this facility, so this will be a focus for our study. These charts help us identify that we need to have a hard look at mechanical systems in addition to lighting opportunities to identify the areas with major potential for conservation.



4. Energy Conservation Opportunities

The primary purpose of this study was to identify energy conservation opportunities at the UBC AQC. We have identified and analyzed many potential opportunities to save energy and cost by modifying and upgrading mechanical systems at this facility, and we will explain these ideas in detail in this section. For financial savings estimates, we have used a base rate of $22.00/GJ for steam plus an average cost of the BC Carbon Tax of $25 / tonne. For electricity, current BC Hydro electricity rates of $7.23 / kW for demand and $0.0354 / kWh for consumption have been used, plus an additional 0.5% in rate riders.

For Greenhouse Gas estimates, we have used emissions factors of 0.022 kg CO_2e / kWh of electricity in BC. For steam use, we have used the natural gas emissions factor of 51.0 kg CO_2e / GJ and assumed an overall system efficiency of 75% to account for combustion and transmission losses resulting in a final steam emission factor of 68.0 kg CO_2e / GJ. Once again we note for emphasis, that we are assuming a baseline steam consumption of roughly 17,000 GJ per year for all of these savings estimates. Savings potential may be much higher than those described below if annual steam consumption is normally at 22,000 GJ as it was in 2006.

4.1 Mechanical Upgrades

The following measures describe a major upgrade to most of the pool water heating and ventilation systems. The changes we propose will significantly improve the efficiency of the water and air heating, as well as providing better overall control of the ventilation and humidity in the facility.

4.1.1 Pool Heat Reclaim

This project involves a retrofit of the main pool ventilation unit (HV-1) to add a large air to air heat exchanger, and a heat pump to be used as a dehumidification reclaim device. In addition to this equipment a new heating loop will be required to transfer heat to the water for the indoor lap pool. The essential concept with this measure is to reclaim the heat in the very moist air that is normally exhausted from the pool (using a very efficient heat pump in cooling mode that rejects heat into the pool), and then to run the dehumidified return air through a passive air to air heat exchanger (with an efficiency of 80%) to significantly reduce the heating of outside air. In addition, using this strategy, it will be possible to reduce ventilation rates as outdoor air will no longer be required for dehumidification purposes. This measure is a very complicated upgrade, and will require additional piping, ductwork, equipment, controls and electrical wiring that we estimate will cost $630,000 including design fees. According to our analysis, this will result in savings of 8,177 GJ of steam, while adding and 366,200 kWh (1,318 GJ_e) for a net energy savings of 6,858 GJ. This translates into a net savings of $197,000 per year for a simple payback of 3.2 years. Estimated GHG savings from this item alone are 548 tonnes per year.

Note: All measures that propose reduced ventilation rates will still remain well above ASHRAE recommended levels for pool applications.

4.1.2 Domestic Water Heat Reclaim

This project involves a retrofit of the pool mezzanine ventilation unit (HV-2) to add a heat pump used as a dehumidification reclaim device. This unit will be connected to the pool water heating loop, and will also have a small secondary pump that will pre-heat domestic water when there is demand. The essential concept with this measure is similar to above, but we will also add a solar water heating component to this design. By adding solar panels to this same water heating loop, we will allow the sun to preheat domestic hot water whenever it is possible, and will use control valves to re-direct water flow to the main pool if excess heat is available. When both the main pool and the domestic water heating system are not calling for heat, both dehumidification heat pumps will shut down. Once again, this measure is a very complicated upgrade, and will require additional ductwork, equipment, controls and electrical wiring that we estimate will cost $250,000. According to our analysis, this will result in savings of 1,580 GJ of steam, while adding 94,100 kWh (339 GJ_e) of electricity for a net energy savings of 1,241 GJ. This translates into an overall savings of $37,000 per year for a simple payback of 6.8 years. Of particular note, this project will qualify for an Eco Energy Incentive from the federal government because of the solar water heating component, though this funding has not been included in our analysis. Estimated GHG savings from this item are 105 tonnes per year.

4.1.3 Empire Pool Heat Pumps

The empire pool is currently heated with steam from April through October, for 7 months per year. This system is particularly well suited to the installation of air to water heat pumps, as the heat is required for the pool when outdoor temperatures are generally above 10°C. This measure involves the recommended installation of 70 tons of modular air source heat pumps for heating the empire pool, using the existing steam heating system as a back-up. Assuming an average coefficient of performance of 3.0 on these heat pumps, we will add 248,100 kWh (893 GJ_e) of electricity, while saving at least 75% of the current steam consumption for the Empire Pool, for a net energy savings of 1,786 GJ. Once again, this measure is a very complicated upgrade, and will require additional piping, equipment, controls and electrical wiring that we estimate will cost $150,000. According to our analysis, this will result in savings of $45,000 per year for a simple payback of 3.3 years. Estimated GHG savings from this item are 177 tonnes per year.

4.1.4 Hot Tub Heat Reclaim

A smaller project worth considering is the installation of an air source heat pump in the pool pump room in the basement to be used instead of steam to heat the hot tub. Assuming a coefficient of performance of 3.0, we will add 16,400 kWh (59 GJ_e), while saving 100% of the current steam consumption for the hot tub heat exchanger, for a net energy savings of 96 GJ. This measure will require additional piping, equipment, controls and electrical wiring that we estimate will cost $15,000. According to our analysis, this will result in savings of $3,200 per year for a simple payback of 4.7 years. Estimated GHG savings from this item are 10 tonnes per year.

4.1.5 Mechanical Opportunity Summary

We have summarized the DDC energy conservation measures below.

4.1	**Mechanical Measure Summary**			Savings			
Item	Description	Cost	Payback	$	GJ	kWh	GHG
4.1.1	Pool Heat Reclaim	$ 630,000	3.2	$ 197,000	8,180	(366,237)	548
4.1.2	Domestic Water Heat Reclaim	$ 250,000	6.8	$ 37,000	1,580	(94,111)	105
4.1.3	Heat Pump Heating of the Empire Pool	$ 150,000	3.3	$ 45,200	2,680	(248,089)	177
4.1.4	Hot Tub Heat Reclaim	$ 15,000	4.7	$ 3,210	155	(16,373)	10
4.1	**Total Mechanical**	**$ 1,045,000**	**3.7**	**$ 282,000**	**12,595**	**(724,810)**	**840**

4.1.6 Investigation of Alternative Technologies

We investigated a number of other technology solutions for the facility that have not been presented under our recommended measures, as longer paybacks made these solutions less attractive.

First we looked into ground source heat pump technology as a potential solution to heating pool water and ventilation air. We quickly came to the conclusion that it would be less cost effective to use geo-exchange than dehumidification reclaim. Estimated ground source heat pump capital costs are in the ballpark of $2,500,000 for a system sized to handle the current energy use for the UBC AQC, as we would require approximately 400 boreholes, and a major mechanical equipment upgrade for the facility. According to our brief analysis, this system would have a very rough payback of over 6 years, and would achieve a net energy savings of 12,800 GJ per year. In addition, if the site does not have a large aquifer present to provide a continuous source of heat, there is a risk of freezing the ground with extended use of the system without switching to air conditioning in the summer. The combination of higher capital costs, longer payback and increased risk have caused us to reject this option.

Finally we investigated micro steam turbines for electricity generation. The main heating distribution system at UBC is a high pressure steam, distributed to the various facilities at between 80 and 100 psi. At each building the steam is routed through a pressure reducing valve (PRV) and this wasted energy can be used to generate electricity. Once again we have rejected this idea due to very large capital costs and long payback periods.

4.2 DDC Controls

The existing Siemens DDC system at the facility provides some relatively low capital cost opportunities to implement a number of new energy savings features that we recommend to customize the controls based on our review of building operations. While these projects are relatively small in comparison to the proposed mechanical upgrades, we feel that these projects remain good opportunities, and will be important tools to monitor and verify the overall savings from section 4.1. These features are described below with an estimate of cost and energy savings provided for each measure.

4.2.1 HV Scheduling

Currently only one of the five air handling units is scheduled, and the others operate 24/7. The challenge with scheduling this equipment in a pool environment is that humidity levels build up and can cause mouldy damp conditions to fester. This said, we believe it will be possible to schedule off the pool mezzanine, and the locker / fitness air handling units when the space is unoccupied and humidity levels are below 70% relative humidity. This project will require the addition of new humidity sensors in the critical areas served by these units. This will result in savings of 40,800 kWh of electricity and $1,450 per year in energy expenses. The estimated cost of adding these sensors is $6,000, resulting in a simple payback of 4.1 years.

4.2.2 Pool turnover night mode

Currently each of the main 50 hp pool pumps operates 24/7 to maintain design turnover rates as required to maintain health standards. In addition, the outdoor Empire Pool pump remains on all winter even though the pool is not used for swimming. According to our brief analysis, turnover rates for the pool are far higher than required by health standards. We recommend slightly reduced (10%) circulation during operating hours and larger reductions after hours or when not in use (50% lap pool and 50% empire pool). Reductions still meet or exceed BC Health Act standards. This project will require the addition of new variable speed drives for the equipment the two pool pumps, and that this equipment be added to DDC control to implement this strategy. This will result in savings of 309,000 kWh of electricity and $11,000 per year in energy expenses. The estimated cost of adding this upgrade is $35,000, resulting in a simple payback of 3.2 years. This addition also has the added bonus of allowing us to implement automated load shedding on these pumps.

4.2.3 Outdoor Air Lockout

While there is an existing Outside Air Temperature (OAT) strategy in place it is currently configured at a set point of 18ºC, and it is not turning off the heating pumps. Especially with the implementation of the proposed heat reclaim and air source heat pump systems, we feel it will be very important to re-program the steam heat exchanger control valves to ensure steam is not being used while the other systems are operating. This will result in pump savings of 26,800 kWh of electricity, 101 GJ of steam and $3,600 per year in energy expenses. The estimated cost of adding this upgrade is $10,000, resulting in a simple payback of 2.8 years.

4.2.4 Domestic Water Night Setback

This project would schedule the domestic hot water recirculation pump off while the facility is unoccupied. While we estimate this will save a very small amount of electrical pump energy (131 kWh), it will be much more important to stop sending hot water through the building all night long to lose heat. We estimate that this will save at least 5% of the remaining steam used to heat DHW, representing savings of approximately 14 GJ per year. This represents a total of $360 per year in energy savings. We estimate the addition of this pump to DDC will cost $1,000 to implement, giving this project a payback of 2.8 years.

4.2.5 Load Shedding and Energy Monitoring

This project would add dashboard energy monitoring links for both steam and electricity to the DDC system, and would implement real time energy alarms when daily consumption rises above setpoint. Campus electricity peak demand would be linked to this system in a program to implement electrical load shedding when instantaneous demand rises above the current monthly peak. This facility has a number of non critical loads such as the pool pumps and de-humidification heat pumps that could be added to a load shedding program that would empower the facility to response to campus wide peaks, and to begin to manage overall campus peak demand. In addition, we have noted that huge surges in steam consumption have occurred in this facility in the past couple of years that may have been mitigated if DDC alarms had notified plant operations of the exceptional energy use. We highly recommend installing additional controls to the existing DDC system to enable these monitoring and load shedding features. We estimate that this could save 10% of the annual steam consumption remaining in the facility or 193 GJ per year, and could easily reduce campus peak demand by 20 kW per month or more representing $6,800 annually. The expected cost of this measure is $17,000, resulting in a simple payback of 2.5 years.

4.2.6 DDC Opportunity Summary

We have summarized the DDC energy conservation measures below.

4.2	**DDC Measure Summary**			Savings			
Item	Description	Cost	Payback	$	GJ	kWh	GHG
4.2.1	HV Scheduling	$ 6,000	4.1	$ 1,450		40,800	0.9
4.2.2	Pool turnover night mode	$ 35,000	3.2	$ 11,000		309,000	6.8
4.2.3	Outdoor Air Lockout	$ 10,000	2.8	$ 3,600	101	26,800	7.5
4.2.4	Domestic Hot Water Night Setback	$ 1,000	2.8	$ 357	13.5	131	0.9
4.2.5	Energy Monitoring and Load Shedding	$ 17,000	2.5	$ 6,780	193	20.0	13.1
4.2	**Total DDC**	**$ 69,000**	**3.0**	**$ 23,200**	**308**	**377,000**	**29**

4.3 Lighting Opportunities

Please refer to the attached Quantum Lighting report (Appendix B) for a description of the lighting opportunities in this building.

5. Energy Consulting and Project Management

As these projects are very complicated, we have included design scope for each item in our analysis. These estimated capital costs in this report all include design costs, and project management time to help direct the implementation of the projects described. If management is interested in following through with the installation of these projects, we highly recommend that these projects proceed on a design build basis to ensure that the engineering team remains involved from conceptual vision through to commissioning. We feel this is the best way to ensure that these projects are implemented in a way that will achieve the energy savings described in this study.

Appendix A:

Inventory Summary

UBC Aquatic Centre

Project Summary

Building Area

5,274 m^2 56,750 sqft

Energy Consumption	GJ	kWh
Steam	17,090	
Electricity - Mechanical E	4,920	1,366,781
Electricity - Lighting	1,542	428,262
Plug Load	291	80,956
Electricity	6,754	1,876,000
Sum Total	23,843	1,876,000

Historical Data	Energy Use (GJ) 2007	Energy Use (GJ) 2006	BEPI (MJ/m2) 2007	BEPI (MJ/m2) 2006	BEPI (kWh/ft2) 2007	BEPI (kWh/ft2) 2006	Cost ($) 2007	Cost ($) 2006
Steam	17,090	22,406	3,240	4,248	84	110	$ 446,381	$ 585,241
Electricity	6,754	7,451	1,281	1,413	33	36	$ 85,042	$ 95,279
Total	**23,843**	**29,856**	**4,521**	**5,661**	**117**	**146**	**$ 531,424**	**$ 680,520**

Actual Electrical Inventory Breakdown

System	kWh	kW	Ave. Hours
Ventilation	639,593	83	7,730
Pumps	699,827	112	6,259
Cooling	27,362	16	1,667
	-	-	
Lighting	428,262	74	5,800
Other (Plug Load)	80,956	9	8,760 (estimated hrs)
Total	**1,876,000**	**294**	6,380

Existing Systems

	W/ sq m	W/ sq ft
Lighting	14.0	1.32
Mechanical:	40.0	3.7
Plug Load	1.8	0.2

Energy Study Project Savings

Project Summary		Annual Savings						
Measure Description	**Capital Cost**	**Savings**	**Electricity (kWh)**	**Electricity (GJ_e)**	**Gas (GJ)**	**Payback**	**BEPI MJ / m²**	**GHG (Tonnes)**
DDC Savings	$69,000	$17,000	205,000	738	308	4.1	198	25
Mechanical Savings	$1,045,000	$282,000	(724,810)	(2,609)	12,595	3.7	1,893	841
Lighting Savings								
Total Savings	**$1,114,000**	**$299,000**	**(519,810)**	**(1,871)**	**12,903**	**3.7**	**2,090**	**866**
Projected Future Usage*			**2,395,810**	**4,187**		**2,431**	**337**	

Energy Savings	**46.3%**
Net Energy Savings	**11,032**

	Electricity	Steam	Total	GHG Savings
Current GHG (t CO2e)*	41	1,162	1,203	
GHG Savings (t CO2e)*	(11)	877	866	72.0%

*Note: Emission factors of 68.0 kg CO2/GJ for steam and 0.022 kg CO2 / kWh for electricity in BC

A1

Appendix A - Mechanical and Motor Inventory

Mechanical System Electricity Use

ENERGY INVENTORY FORM - Mech Systems

BUILDING NAME: **UBC Aquatic Centre** **Inventory By:** Jim Groenewoud

Syste Type	System Name	Equipment Number	Location	Area Served	Monthy Profile	hp	Load kW	Load Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Hrs	Annual kWh	% of Total	Schedule	hours / day
									Check Month Op. Hours Apply																
V	Pool Air Handler	HV-1	Fan room	Natatorium	A	40	29.8	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	261,398	19.1	24/7	24
V	Mezzanine Air handler	HV-2	Fan room	Natatorium	A	10	7.5	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	65,350	4.8	24/7	24
V	Weight Area	HV-3	Filter room	Weight room	A	15	11.2	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	98,024	7.2	24/7	24
V	Filter room	HV-4	Filter room	Filter room	A	1	0.7	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	6,535	0.5	24/7	24
V	Administration	MZ-1	Mechanical room	Offices and lobby	A	5	3.7	100%	496	448	496	480	496	480	496	496	480	496	480	496	5,840	21,783	1.6	24/7	16
V	Pool Return Fan	RF-1	Fan room	Nataorium	A	20	14.9	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	130,699	9.5	24/7	24
AC	MZ-1 DX cooling	CU-1	Roof	Administration	C	22	16.4	100%	0	0	0	48	149	240	397	397	288	149	0	0	1,667	27,362	2.0	on demand	16
P	Main Pool Pump	P-1	Filter room	Main Pool	A	50	37.3	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	326,748	23.9	24/7	24
P	Hydro Air	P-2	Filter room	Main Pool	F	7.5	5.6	100%	2.17	1.96	2.17	1.5	0.31	0	0	0	0	0.62	1.8	2.17	13	71	0.0	24/7	0.1
P	Heating pump	P-2D	Filter room	Radiation	E	1.5	1.1	100%	372	336	446	504	595	648	744	744	648	521	432	372	6,362	7,120	0.5		24
P	Filter Pump	P-3	Filter room	Hot Tub filter	E	0.8	0.6	100%	372	336	446	504	595	648	744	744	648	521	432	372	6,362	3,797	0.3		24
P	Heating pump	P-4E	Filter room		A	7.5	5.6	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	49,012	3.6		24
P	Heating Pump	P-4D	Filter room		A	5	3.7	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	32,675	2.4		24
P	Heating Pump	P-5	Filter room		A	1	0.7	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	6,535	0.5		24
P	Heating Pump	P-6	Filter room		A	0.3	0.2	100%	372	336	372	360	372	360	372	372	360	372	360	372	4,380	980	0.1		12
P	Condensate pump main	P-7	Filter room	Facility	A	3	2.2	100%	372	336	372	360	372	360	372	372	360	372	360	372	4,380	9,802	0.7		12
P	Condensate pump main	P-8	Filter room	Facility	A	3	2.2	100%	372	336	372	360	372	360	372	372	360	372	360	372	4,380	9,802	0.7		12
P	Sump Pump	P-9	Filter room	Aquatic center	A	2	1.5	100%	31	28	31	30	31	30	31	31	30	31	30	31	365	545	0.0		1
P	Sump Pump	P-10	Filter room	Aquatic center	A	2	1.5	100%	31	28	31	30	31	30	31	31	30	31	30	31	365	545	0.0		1
P	Sanitary pump main	P-11	Filter room	Facility	A	7.5	5.6	100%	186	168	186	180	186	180	186	186	180	186	180	186	2,190	12,253	0.9		6
P	Sanitary pump main	P-12	Filter room	Facility	A	7.5	5.6	100%	186	168	186	180	186	180	186	186	180	186	180	186	2,190	12,253	0.9		6
P	Pool pump	P-1	Empire Filter Rm	Empire Filter Rm	I	50	37.3	100%	0	0	744	720	744	720	744	744	720	744	0	0	5,880	219,324	16.0	24/7	24
P	Ozone Injection Pump	P-14	Ozone Room	Main Pool	A	1	0.7	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	6,535	0.5		24
P	DHW recirc pump	P-15	Filter rm	Facility	A	0.08	0.1	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	523	0.0		24
P	Chemical pumps	P-16-25	Filter Rooms	Pools	A	0.2	0.1	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	1,307	0.1	24/7	24
	Sump pump	P-26	Empire pool mec	Empire pool	A	3	2.2	100%	31	28	31	30	31	30	31	31	30	31	30	31	365	817	0.1		1
	Sump pump	P-27	Empire pool mec	Empire pool	A	3	2.2	100%	62	56	62	60	62	60	62	62	60	62	60	62	730	1,634	0.1		2
V	Air Compressor	CA-1	Filter room	Aquatic center	A	3	2.2	100%	372	336	372	360	372	360	372	372	360	372	360	372	4,380	9,802	0.7		12
V	Air Compressor	CA-2	Ozone Room	Ozone Room	A	1	0.7	100%	62	56	62	60	62	60	62	62	60	62	60	62	730	545	0.0		2
V	Air Compressor	CA-3	Empire Filter Rm	Empire Filter Rm	A	3	2.2	100%	124	112	124	120	124	120	124	124	120	124	120	124	1,460	3,267	0.2	24/7	4
V	Ozone Generator	OZ-1	Ozone Room		A	0.3	1.0	100%	124	112	124	120	124	120	124	124	120	124	120	124	1,460	1,460	0.1	24/7	4
V	Chlorine Exhaust fan	EF-1	Chlorine Room	Chlorine room	A	0.5	0.4	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	3,267	0.2		24
V	Storage Exh	EF-2	Storage room	Storage room	A	0.33	0.2	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	2,157	0.2		24
V	Electrical Rm Exh.	EF-3	Electric Vault	Electric vault	A	0.75	0.6	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	4,901	0.4		24
V	Male Dryer	EF-4	Change room	Change room	A	1	0.7	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	6,535	0.5		24
V	Washroom Exhaust	EF-5	Change room	Change room	A	1	0.7	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	6,535	0.5		24
V	Womens dryer exhaust	EF-6	Change room	Change room	A	1	0.7	100%	744	672	744	720	744	720	744	744	720	744	720	744	8,760	6,535	0.5		24
V	Empire Filter Room	EF-7	Empire filter roon	Emire Filter rm	I	0.75	0.6	100%	0	0	744	720	744	720	744	744	720	744	0	0	5,880	3,290	0.2	24/7	24
V	Generator Room Exh.	EF-8	Gen set room	Gen set room	A	0.75	0.6	100%	3.1	2.8	3.1	3	3.1	3	3.1	3.1	3	3.1	3	3.1	37	20	0.0	24/7	0.1
V	Elevator Exhaust fan	EF-9	Elevator Mech R	Elevator Mechanical Room	A	0.5	0.4	100%	155	140	155	150	155	150	155	155	150	155	150	155	1,825	681	0.0	24/7	5
V	Elevator	EL-1	Aquatic Center	Aquatic Center	A	5	3.7	100%	155	140	155	150	155	150	155	155	150	155	150	155	1,825	6,807	0.5	24/7	5
				Totals			215.4															1,369,232			

Appendix A - Steam Devices **Steam Consumption**

ENERGY INVENTORY FORM - Steam Devices
BUILDING NAME: **UBC Aquatic Centre**

System Name	Equipment Number	Service Areas	BTU/h	ComB Eff	% LF	Monthy Profile	Daily Hours	Monthly Hours J	F	M	A	M	J	J	A	S	O	N	D
Lap Pool Heat Exchanger	HX-1,2	Indoor Pool	4,482,500	100	11	a	24	744	672	744	720	744	720	744	744	720	744	720	744
Hot Tub Heat exchanger	HX-3	Hot Tub	84,000	100	20	a	24	744	672	744	720	744	720	744	744	720	744	720	744
HV-1 Heating Coil		Natatorium	2,796,000	100	38	h	24	744	605	595	504	298	144	0	0	144	446	576	744
HV-2 Heating Coil		Natatorium Mezzanine	808,000	100	33	h	24	744	605	595	504	298	144	0	0	144	446	576	744
HV-3 Heating Coil		Change rooms	1,614,000	100	6	h	24	744	605	595	504	298	144	0	0	144	446	576	744
HV-4 heating Coil		Filter room	0	100		h	24	744	605	595	504	298	144	0	0	144	446	576	744
MZ-1 Heating Coil		Administration and Lobby	172,000	100	10	h	16	496	403	397	336	198	96	0	0	96	298	384	496
DHW Heat Exchanger	HX-4	Domestic Hot Water	600,000	100	50	a	16	496	448	496	480	496	480	496	496	480	496	480	496
Empire Pool Heat Exchan	HX-5	Outdoor Pool	1,200,000	100	48	i	24	0	0	744	720	744	720	744	744	720	744	0	0
Totals			11,756,500					5,456	4,614	5,506	4,992	4,117	3,312	2,728	2,728	3,312	4,811	4,608	5,456

System Name	Monthy GJ J	F	M	A	M	J	J	A	S	O	N	D	Annual Hrs	Annual GJ	% of Total	Comments
Lap Pool Heat Exchanger	387	350	387	374	387	374	387	387	374	387	374	387	8,760	4,556	26.2	on demand
Hot Tub Heat exchanger	13	12	13	13	13	13	13	13	13	13	13	13	8,760	155	0.9	on demand
HV-1 Heating Coil	834	678	667	565	334	161	0	0	161	500	646	834	4,800	5,379	30.9	on demand
HV-2 Heating Coil	209	170	167	142	84	41	0	0	41	126	162	209	4,800	1,350	7.8	on demand
HV-3 Heating Coil	76	62	61	51	30	15	0	0	15	46	59	76	4,800	490	2.8	on demand
HV-4 heating Coil	0	0	0	0	0	0	0	0	0	0	0	0	4,800	0	0.0	on demand
MZ-1 Heating Coil	9	7	7	6	3	2	0	0	2	5	7	9	3,200	55	0.3	on demand
DHW Heat Exchanger	157	142	157	152	157	152	157	157	152	157	152	157	5,840	1,848	10.6	on demand
Empire Pool Heat Exchan	0	0	452	437	452	437	452	452	437	452	0	0	5,880	3,572	20.5	on demand
Totals	1,685	1,420	1,911	1,740	1,460	1,195	1,009	1,009	1,195	1,686	1,412	1,685	51,640	17,407		

	J	F	M	A	M	J	J	A	S	O	N	D		Total
Actual Consumption 2007	360	737	573	1642	1382	1169	1250	994	1413	2217	2301	3052		17,090
Actual Consumption 2006	3193	1882	2070	2531	2101	1639	1044	1245	1109	1741	1745	2106		22,406
Actual Consumption 2005	1901	1309	1513	1537	1573	1392	1006	921.7	1011	1882	2009	576.1		16,630
Baseline	1901	1309	1385	1537	1573	1392	1006	922	1178	1947	2018	1000		17,167