An Investigation into a The Centre for Interactive Research on Sustainability (CIRS) style Solar Aquatic System at the UBC Farm

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Abstract

The purpose of this study was to evaluate the impacts of installing a Solar Aquatic System for water treatment similar to the one in use at the UBC Centre for Interactive Research on Sustainability. The system should purify water, making it suitable for irrigation, fertigation, aquaculture, and other purposes (not for drinking). We analyzed economic, environmental, and social factors to determine whether the construction of such a system would be in the best interest of the UBC Farm and UBC as a whole. We found that the SAS was a good solution when taking into account all economic factors. Although the short-term cost of capital investment and operation costs were high, the fact that the SAS could be expanded to filter a higher capacity as the population of the south campus increases in the future was one of the determining factors when determining the economics involved. We also found that it met the environmental requirements. The Fecal coliforms were reduced to less than 200 colonies/100mL, estrogen and endocrine disruptor levels were reduced by between 93-95%, nitrogen levels and phosphorus levels are reduced by 98.7% and 97% respectively, and heavy metals were found to be reduced to acceptable levels by being absorbed by certain kinds of plants. The remaining pollutant levels in the effluent of the system were low enough that it could be used for irrigation, fertigation, aquaculture, and other agricultural purposes, but not for human consumption, as the water does not meet the drinking water standards. The SAS system is good from a social point of view because it has a positive effect on education. It improves students' learning attitude and provides a better environment for students to learn. It also helps UBC to be agent of change, and as a leader of green in Canada. However, the construction may disturb people who are living near that area, and people are afraid of buying the crops that are irrigated by the treated wastewater. Overall, we recommend the installation of a CIRS style SAS system at the new UBC Farm building due to these benefits.

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Glossary

Greywater	Wastewater that does not contain human waste. It generally is less contaminated than blackwater. It is generated by activities such as handwashing.
Blackwater	Wastewater containing human waste. This comes from sources like toilets and urinals.
SAS	Solar Aquatic System
CIRS	Centre for Interactive Research on Sustainability
Effluent	The processed water exiting a natural or artificial system.

1.0 Introduction

In this report we have evaluated a Solar Aquatic System (SAS) similar to the one at the Centre for Interactive Research on Sustainability (CIRS) at UBC for implementation at the UBC Farm. We performed a triple bottom line assessment, examining environmental, economic, and social effects the installation of such a system would produce. In addition, we have also factored in the needs of the sponsor (Andrew Rushmere) when reviewing the solar aquatics system for implementation at the UBC Farm.

The requirements the system must meet include:

-An open system so that students or visitors at the UBC farm can view the ongoing operation

-$15-20 million total building cost

-Waste water system must be onsite

-A capacity for 75 to 100 full time occupants

-Must be expandable to a larger scale for a long term approach

-Possible integration with UBC farm hydroponics

-Must meets UBC and Government regulations on Wastewater treatment

-Should provide job creation for students or public?

-The system should take up less than 20 square meters in space

-Must be able to filter grey and black water and also common household chemicals

Current wastewater treatment system

Currently UBC utilities purchases more than 4 million Cubic Meters of water from metro Vancouver per year. Water is pumped from the Capilano Reserve to the Vancouver UBC campus. After being used it leaves as waste through a sanitary sewer where it is pumped to the Iona Island Wastewater Treatment Plant in Richmond (UBC sustainability, 2012). UBC pays $0.40 per cubic meter of wastewater to Iona Island (Levit, 2010).

There are benefits to a centralised system such as this; the wastewater treatment process is managed by another company therefore reducing much of the capital and operational costs needed to manage one's own wastewater treatment plant, water safety and knowledge of the processes is also an important factor involved and by outsourcing any risks are put onto the outsourced company (Metro Vancouver, 2011) . However a significant amount of resources is put into this system every year as the distribution system requires long piping and energy is required to pump to water to and from campus (Metro Vancouver, 2008).

UBCs wastewater treatment system is also highly ineffective. Wastewater leaving campus through the sanitary sewers consists of potable water, sewage water and rainwater runoff. A significant amount of resources is wasted through this system as grey water is mixed with black water. Wastewater treatment for black water requires more energy and resources to purify compared to grey water. Much of the potable water or rainwater runoff which enters the wastewater system undergoes many filtering processes which are unneeded. It is more economically and environmentally sound to treat greywater and blackwater separately (Lets go green, 2012).

In order for UBC to achieve its long-term goals of a sustainable and net positive water system, UBC must start implementing localized wastewater treatment so that it can achieve many of its sustainability objectives(UBC sustainability, 2012).

2.0 SAS Process Overview

Collection and Surge Tank

Water is collected and inorganic particles are removed. Large particles are filtered out with screens (Eco-tek, 2009).

Blending Tank

Filtered water is then aerated and combined with sludge from the clarifier to introduce microorganisms into the mixture. The mixture is then pumped into the aerobic tanks.

Aerobic Tanks

Here the mixture is passed through a tank filled with aquatic and non aquatic plants, snails, fish and microorganisms designed to filter the water and remove contaminants. At this stage, the water is gently bubbled to improve the oxygen content of the water and increase the biological activity.

Clarifier

The water is then pumped out of the aerobic tanks into the clarifier. Here, the water is left to settle by gravity. Solids accumulate at the bottom of the tank and some are reintroduced into the blending tank to bring microorganisms back into the system.

Microscreen and Sand Filter

The water is then passed through a fine sand filter, filtering out any remaining particles and debris. This performs a similar task as the clarifier, and can act like a backup if the clarifier fails, so the constructed wetland is not overloaded with solids.

Constructed Wetland

The water is then passed through a constructed wetland. This consists of crushed stone and various wetland plants designed to soak up pollutants. The intake for the system is located below the surface of the water, and the flow is also beneath the surface, to limit the amount of oxygen at this stage. This is the last biological part of the system.

UV treatment

The water is then treated with UV light to eliminate bacteria still present in the water, which the rest of the system does not remove. With the UV treatment, the expected fecal coliform count should be less than 200 colonies/100 mL (Teal, 1993).

Worm Composting (Vermiculture)

Excess solids produced during in the Clarifier stage can be composted in a vermicomposter. This is a bed of sand and gravel beneath a layer of plants. Worms are introduced into the composter, and sludge is added. The worms then compost the sludge into material suitable for agricultural use.

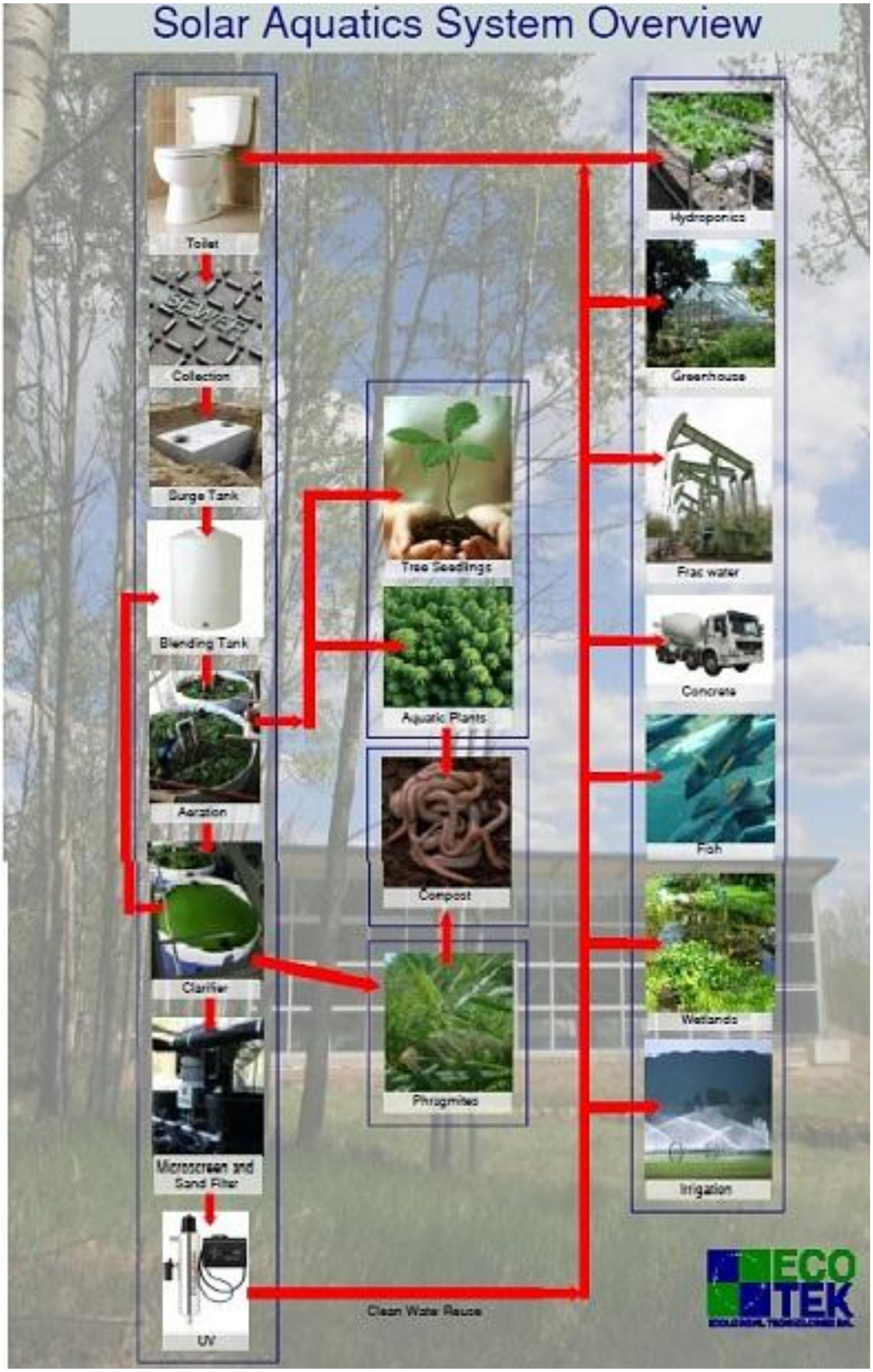

Figure 1: The SAS process. Source: http://www.ecotek.ca/ubccirs.html

3.0 Economic Impacts

The information on the Capital Investment is based off the solar aquatics system implemented in the CIRS building. We have chosen to use this as a comparison as the solar aquatics wastewater treatment in the CIRS is an example of a successful and operational localized wastewater treatment system which was also built by a local company (Ecotek, 2012). It can also be used as a comparison because of the scale at which it operates at and will be sufficient for any building close to the size of the CIRS building.

3.1 Capital investment

The cost of installing a solar aquatics system including base building costs will amount to a sum of $150,000. We can evaluate this amount by comparing the percentage value of the cost of the system to the budget of the UBC farm building and also the CIRS building. This will include the dual piping for the building itself and the solar aquatics system.

	Total Budget (Millions)	**Cost of SAS**	**Percentage Of Total Budget**
UBC Farm	**$15-20M**	**$150,000 (estimate)**	**7.5-10%**
CIRS Building	**$37M**	**$150,000**	**4.1%**

Assuming that the budget for the UBC farm building is 15-20 million and that the CIRS building is 37 million (Appendix 1) we can see that the SAS will take up almost 2 times the allocated resources in the budget for the UBC Farm than the CIRS building. Depending on the costs of other parts of the building the SAS may not be optimal for the

UBC Farm building. However we must also take into account that the flow of occupants in and out of the UBC Farm building could be much less than the CIRS building due to location and use. A cheaper option or a smaller scale of the SAS could be opted for instead.

3.2 Operating costs

The annual maintenance and operational costs of the CIRS system is around $20000-$30000. The costs include labour (operator wages, physical plant maintenance and yearly servicing), lab testing for water quality, and reporting (Appendix 1). However other locations which use similar eco-tek SAS have much lower operational costs which range from $5000-$15000.

The operating costs can be reduced by many of the goods created from the solar aquatics system. Services such as creating jobs or allowing UBC students opportunities to operate the system or using the system as an education tool for the public to view. Revenue can also be gained from aquaculture production, greenhouse production, and soil fertilizer which are all by-products of the system (Ecotek, 2012), and also by reducing costs by using reclaimed water for processes such as watering ecosystems or flushing the toilet.

3.3 Development

In order to evaluate the cost of the SAS we must also evaluate the long term costs and benefits of the system.

It is estimated that by 2030 housing space on the UBC vancouver campus will almost double what it was in 2009, from 349,370 to 645,070 square feet (UBC Vancouver, 2009). This will mean that the population of the south campus of UBC will greatly increase in the years to come.

In the early stages the SAS will be built according to existing flow of sewage. To accommodate the higher population of the south campus it can then be expanded in later stages when there is a need to treat more water. As the system is built in modules it is quite simple to expand the operation (Eco-tek, 2012).

As UBCs current wastewater treatment system phases out older building in the area can then be converted to use the SAS. This can be quite effective as buildings nearby can simply construct piping linking themselves to the wastewater system and ideally convert to a more sustainable way of treating water.

4.0 Environmental Impacts

4.1 Overview and Goals

The Solar Aquatic System (SAS) filters and purifies water through mostly natural means such as bacteria, plants, and snails (Eco-Tek, 2009). The main goal of the design of this type of system is to provide a natural means of water treatment that is effective without using toxic chemical additives such as chlorine. The advantages of this type of system include less sludge than conventional means, minimal odours, the filtration of heavy metals, reduction of estrogen and other endocrine inhibitor levels, and reduction of fecal coliform levels. The system also excels at decreasing ammonia and salt levels.

The goal of the SAS system will be to take in wastewater and rainwater and output purified water suitable for purposes such as irrigation, fertigation, and fish based aquaponics. The water should have low levels of fecal coliforms, estrogen and endocrine disruptor levels, salts, heavy metals, presence of antibiotics, phosphorus, and nitrates. The goal is to reduce and possibly eliminate the UBC Farm's dependence on the municipal water supply, and to treat all wastewater on site rather than pipe it out to an off campus location for treatment.

4.2 Fecal Coliforms

The SAS system by itself does not effectively eliminate fecal coliforms (Teal, 1993). Therefore, a UV light at the final stage of the process is recommended. With the UV treatment, final fecal coliform levels can be expected to be less than 200 colonies per 100mL.

4.3 Estrogen and Endocrine inhibitors

Estrogen and other endocrine inhibitors can also be expected to be severely reduced. A study showed that both natural and synthetic estrogens were reduced by 93-95% in a similar system using plants submerged in water to absorb them. These plants are still able to function when the contaminants are mixed with other sewage (Kumar et al, 2011).

4.4 Heavy Metals

The Solar Aquatic System can remove heavy metals from influent if certain types of plants are used in the aeration tanks (Kamal et al, 2004). A study of an SAS showed that three plants: parrot feather (Myriophylhum aquaticum), creeping primrose (Ludwigina palustris), and water mint (Mentha aquatic) were quite effective at absorbing heavy metals from polluted water. On average, they removed Mercury at a rate of 99.8%, Iron at 76.7%, Copper at 41.62%, and Zinc at 33.9%.

4.5 Nitrogen, Phosphorus, and Salts

SAS is effective at removing both nitrogen and phosphorus, and salts. The bacteria in the aeration tanks of the SAS are responsible for the majority of the nitrogen and phosphorus removal in the process (Teal, 1996). At an SAS treatment system in Massachusetts, USA, the total nitrogen removed by the system was 98.7%, and the total phosphorus removal rate was 97.0%. The levels remaining in the effluent were 6.1 mg/L and 1.5mg/L respectively (Hamersley, 2001).

4.6 Sludge

SAS produces 50% less sludge than conventional means. This sludge is mostly organic, and can be composted and eventually used for fertilizer (Eco-Tek, 2009). This can be done by worm composting for the sludge and the harvested plants from the tanks.

4.7 Environmental Impact

We have found that the Solar Aquatic System is environmentally suitable for the new UBC Farm building. It eliminates most fecal coliforms, estrogen and endocrine disruptors, salts, heavy metals, presence of antibiotics, phosphorus, and nitrates from contaminated water. The remaining levels of these contaminants are low enough that the water is safe to use for irrigation, fertigation, or for fish tanks. In addition, the treated water will not contain any chemical additives such as chlorine used in conventional treatment processes. The system is also relatively resilient, and can withstand relatively high concentrations of pollutants (Gulf-Main Times, 1997). However, the water is not suitable for human consumption, due to fecal coliform levels in the treated water not meeting drinking water standards.

5.0 Social Impacts

For the social impacts of the triple bottom line assessments, we looked at the advantages and disadvantages that the new building may have towards our society, mainly UBC. The social impacts of the new building were investigated based on online peer surveys and previous studies.

5.1 Advantages

We asked 10 students who are studying in Applied Science at the University of British Columbia by sending the survey link online. One of the survey questions is “If it is possible, would you like to get involved the project? Explain.” 7 students answered yes. Most students answered yes because they wanted to learn outside of classrooms and learning by getting involved the project. Since most of the students only learn about the theory in class, they don’t have a chance to see what actually is happening. In addition, they are all engineering students, and they think it is good to be more concerned about suitability. One of the students answered, “As engineers, we cannot just inventing the technology, but also caring about our environment and society.” As we can see from the responses, we can tell that the new building is a good way for education. It can help students, not just engineering students, to think about our environment. This building, particularly, has an aspect on how to consume water wisely. At the end, students will treasure every single drop of water, and will not waste it.

Moreover, the UBC farm wants this building to be open for other people to visit, and learn something from it. It creates a very good educational environment to people.

In addition, UBC intends to be a leader of green technologies in Canada. The CIRS building has been certified LEED (Leadership in Energy and Environmental Design) platinum. If an SAS system is built at the UBC farm, it will reinforce UBC’s image as a leader in green technologies and sustainability. The new building that is going to be built in the UBC farm will help UBC become greener. The new building captures the waste water and treats it, and uses them again for other purposes, such as irrigations. Therefore, UBC can produce a net-zero or even a net-positive amount of water consumption. UBC is an agent of change. It is a testing ground for new technologies, and if they work, others will follow. It provides a good example for other universities, not just in Canada, but in the rest of the world, to follow.

Last but not least, building a new building requires a lot of workers, which thus creates more job opportunities. UBC farm can also employ students and promote educational values by raising awareness of the functions of the building. The new building could also possibly create job for students or volunteering opportunities for its maintenance.

5.2 Disadvantages

We asked the students about “Although the treated wastewater is drinkable, will you still consume the crops that are irrigated by the treated wastewater? Explain.” 75% of students answered no. The main reason is they are afraid of the treated wastewater although it is clean. It may due to their feelings since the wastewater is from toilet, and the wastewater contains excrement which people may be disgusted at.

Furthermore, the construction may disturb people who are living near that area. The construction will create lots of noise and dust. Students may not concentrate on their study or work. Traffic may also be another problem for the neighbours.

Conclusion

Based on our triple bottom line assessment, we have concluded that the implementation of a CIRS style Solar Aquatic System at the UBC Farm would be beneficial to both the UBC Farm and UBC as a whole. Environmentally, the system will adequately filter out pollutants and bacteria for use for irrigation, aquaponics, and other purposes. Economically, the system's cost fits with the proposed budget of the new building, and will also save the Farm money in the long run, as water does not have to be dealt with offsite. Socially, it will reinforce UBC's image as a leader of sustainable technologies and will create job and volunteer opportunities. We can see that the new building has a positive effect on students' learning attitude and environment. The new building will let students not to only think of the technology but also the sustainability. It also helps UBC to be an agent of change. However, the construction may disturb some people who are living near there.

Appendix 1

E-mail to Dr. Alberto Cayuela

How much wastewater can the CIRS system process per day?
10,000L

What is the cost of installing such a system?
$150,000 including base building costs.

Are there any bad smells produced by the system?
Yes, but because the system is kept aerobic and contained in the enclosure, the effect is minimal.

How does the wastewater system work?
It's an activated sludge process with reinjection of sludge into the blending tanks so that sludge disposal is not required.
The plants in the tanks in the constructed wetland help harbour bacteria and remove excess nutrients such as nitrogen and phosphorous.

How much does UBC pay for clean water per unit (litre)?
I don't have that number. Aleks might be able to answer that.

How much does UBC pay to treat water per unit (litre)?
Ditto

What is the fee annually to maintain the water treatment system?
The annual M&O cost will be between $20,000-$30,000 per year, including labour, lab testing, reporting, etc.

What processes are involved to maintain the water treatment system? ie. technicians or regular checkup by ecotek?
Kim may be better suited to answer that.

Are there any tax cuts or grants that the government provide for implementing this type of water treatment system?
No tax cuts that I know of. We got several grants to build the facility.

What extra infrastructure and cost (compared to a normal building) is needed in the building in order to allow the water treatment system to be used? ie. Special piping to transport the waste water or regulatory systems within the building?
You need a dual piping system as the potable water and reclaimed water cannot be distributed using the same pipes.

If possible, maybe we could get a copy a spreadsheet which includes all the costs of the building?

Soft Costs	$8,579,132
Construction Costs	$23,516,820
Financial and Sunk Costs	$3,914,785
HST	$872,263

Total Project Cost $36,883,000

What sorts of contaminant levels (bacteria, particles, etc) are present in the water after it has gone through the SAS process?
Almost nothing. The water can be reclaimed to flush toilets and irrigate gardens and is chlorinated.

Figure 2: Part of the UBC CIRS Solar Aquatic System. Source: http://www.ecotek.ca/ubccirs.html

Figure 3: An aeration tank of the Solar Aquatic System. Source: http://www.ecotek.ca/ubccirs.html

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