Feasibility of Rainwater Harvesting on Scott Laboratory

Rainwater Harvesting at OSU

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Abstract – Water conservation has risen to be an important issue in today's society. We analyzed the applicability of a rainwater collection system on a major building in the north academic core of The Ohio State University. This was done by doing environmental and economic analyses on the tanks that would be placed at Scott Laboratory. The economic analysis determined the system's financial profile by comparing projected costs of utilizing varying tank sizes, while the environmental impacts were determined through use of Sustainable Minds' Life Cycle Assessment software. It was found that over the course of a year, over 1,700 lbs. of CO_2 would be prevented from being released into the atmosphere and that the tanks' initial cost would break-even in less than 2 years as a result of the building's reduced water usage.

Keywords – rainwater harvesting, water conservation, life-cycle analysis, energy reduction

I. Introduction

The Ohio State Engineers for a Sustainable World chapter developed a conceptual rainwater collection system that sought to reduce a campus laboratory building's domestic water usage and environmental impact. This project was carried out on Scott Laboratory because it was one of the largest consumers of energy and water among all Ohio State campus buildings. To understand the environmental impacts of building such a system, a life-cycle analysis was conducted. Sustainable Minds' software, a program that provides life cycle assessment tools for product concept evaluation, was utilized by the team to investigate the project's environmental impacts in conjunction with the team's research on the rainwater harvesting system's economic feasibility and potential energy reduction. The following sections describe the team's assumptions, the environmental impacts, the economic feasibility, and a conclusion detailing the implications of our findings and its impact on future work.

II. Assumptions

Specific assumptions were necessary in order for this project to proceed, and the team researched data on various components needed in rainwater harvesting systems so that an approximate analysis of its environmental impact could be produced.

In order to use the Sustainable Minds software, approximations were made regarding the amount of material needed for each component of the collection system and then were added to the System Bill of Materials (SBOM) for that particular concept. There were several SBOMs developed for a total of eight concepts which varied by the type of material used for piping and tanks as well as the tank size (2,500 gallons vs. 5,000 gallons). The input assumptions for all components to the SBOM were needed in order to produce results for analysis, so our team worked on identifying significant components that were assumed to be basic components required for a rainwater harvesting system.

A rough outline of the building was made to determine the approximate length of the pipes used to transport the water. We then utilized either polyvinylchloride (PVC) or cross-linked polyethylene (PEX) since both materials are conventionally used in water piping, and the approximated length of piping to be used was 230 meters with an assumed product lifetime of 35 to 50 years.[1] The mass per length was calculated by the group: the approximated weight of the PVC piping listed in the SBOM was 1,571.8 lbs., whereas the approximated weight of the PEX piping was listed in the SBOM as 1,912.9 lbs.

In consideration of the acidic nature of the rain collected by the system, the team made assumptions to ensure that collected rainwater would have minimal corrosive effects on the piping throughout Scott Laboratory. The team assumed that in order to increase the pH of 4.6 (average pH of rain in Ohio)[2] to a pH of 6.0, 220.2 lbs. of sodium carbonate would be needed in the manufacturing stage of each SBOM concept in order to bring the water quality to a pH level acceptable for usage within Scott Lab to minimize corrosion.

Latex-based paint was incorporated in the manufacturing stage of the SBOM as a standard in all rainwater harvesting system concepts since thermoplastic materials, PVC and PEX, are known to degrade over time due to UV radiation present in sunlight. Thus, the approximate amount of latex-based paint needed to cover the piping for each design concept was calculated to be 56.9 lbs. The paint's weight was calculated by determining the surface area one gallon of paint would cover and calculating the approximate weight of that gallon.

Next, assumptions needed to be made in order to calculate the CO_2 emissions from bringing in city water to the building.

Thus, information from "U.S. Water Supply and Distribution Fact Sheet" from the University of Michigan were used, and even though power consumption for the treatment and transport of water varies from region to region, we assumed it was uniform and constant across the United States. Also, since the Columbus water treatment plant uses energy provided by American Electric Power (AEP), which generates the majority of their electricity from coal, it was assumed that for one kWh burned, 2.1 lbs. of CO_2 were released into the atmosphere.[1] In regards to the volume of water retained by the system, collection of rainwater was assumed to have a catchment rate of 100%. Additionally, it was assumed that all collected rainwater would be used by the building.

Assumptions for financial analysis of this project were also needed to determine savings by the team's potential rainwater harvesting system. According to Scott Laboratory's water bills from 2011-2013, the price of water was at $0.008 per gallon, and thus each gallon caught in the catchment system would save that much.

III. Environmental Impact

The environmental impact of the rainwater harvesting system was studied through a two pronged approach: the CO_2 produced in creating the components for the harvesting system was determined using the Sustainable Minds software, and the CO_2 saved from decreasing the amount of treated water transported to Scott Laboratory was also determined.

After an analysis was done on Sustainable Minds' software, it was found that the system concept that combined PVC piping and HDPE tanks produced the least impact per functional unit. Additionally, the choice of piping material seemed to be the leading factor in determining environmental impact, thus it was determined that there is a lot of freedom in the choice for tank size. If PVC piping is used with a 5,000 gallon HDPE tank, about 5,022.35 lbs. of CO_2 is produced, which is considerably more "green" when compared to the system concepts that combined stainless steel tanks and PEX piping. The environmental performance record for all concepts tested by the Sustainable Minds software shown in Fig. 1 compares all the concepts by their environmental performance based on the manufacturing stage of the SBOM.

After the initial environmental costs of building a rainwater harvesting system, the unit would begin to make a return on its environmental investment by off-setting the energy that would be required to bring treated water to Scott Laboratory. Scott Laboratory, in FY 2012, used 465,700 cubic feet of water; the monthly break down of water consumed and the cost per month can be seen in Table 1. We then calculated the optimum area available for capturing rainwater off Scott Laboratory's rooftops and determined that the area of the roof was approximately 24,638 square feet. The total collected rainwater from the rooftops was projected to be approximately 79,089 cubic feet per year when taking into consideration that the annual precipitation was 38.52 inches in Columbus according to www.findthedata.org. This equates to over half a million gallons of water that could potentially be saved every year. If all of the water that falls upon the roof were to be harvested, then the system could provide Scott Laboratory with 17% of its total water needs.

[1] Data collected from US Energy Information Administration, http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11

Table 1: Monthly consumption and cost of water in Scott Laboratory

FY 2012		
Start Date	**Consumption (ft^3)**	**Cost**
6/14/2011	40,300	$2,365.61
7/13/2011	18,000	$1,056.60
8/11/2011	18,000	$1,056.60
9/10/2011	19,200	$1,127.04
10/12/2011	114,200	$6,703.54
11/19/2011	37,900	$2,224.76
1/4/2012	65,500	$3,844.85
1/31/2012	35,200	$2,066.24
2/28/2012	25,700	$1,508.59
3/29/2012	15,400	$903.98
4/14/2012	31,500	$1,849.05
5/10/2012	44,800	$2,629.76
Total:	465,700	$27,336.62

According to energy consumption data reported by "U.S. Water Supply and distribution Fact Sheet,"[3] the total water needed by Scott Laboratory equates to nearly 5,000 kWh. The energy is obtained from AEP, as stated in the Assumptions section. This means that over 1,700 lbs. of CO_2 are prevented from being released into the atmosphere every year. Also, because water can be retained in the tanks, less water would be emptied into the storm water drainage system, which would help to mitigate demand on the city's treatment plant during peak times. This would help prevent erosion problems from occurring along the Olentangy River shore line. A collection system like this is also readily implementable to irrigation systems where natural rainwater is more beneficial to the landscape than treated city water. It would release fewer chemicals, like chlorine and fluoride, into the environment which is a direct benefit to the lawn surrounding Scott Laboratory.

IV. Economic Analysis

The first analysis was done using the website http://www.ntotank.com/grwata.html (National Tank Outlet), where there are a variety of different tank sizes. The tank sizes of 3,000, 5,000, 7,000, 10,000, and 12,500 gallons were tested for economic viability.

Table 2 shows different tank sizes from National Tank Outlet, the cost associated with those sizes, the savings per

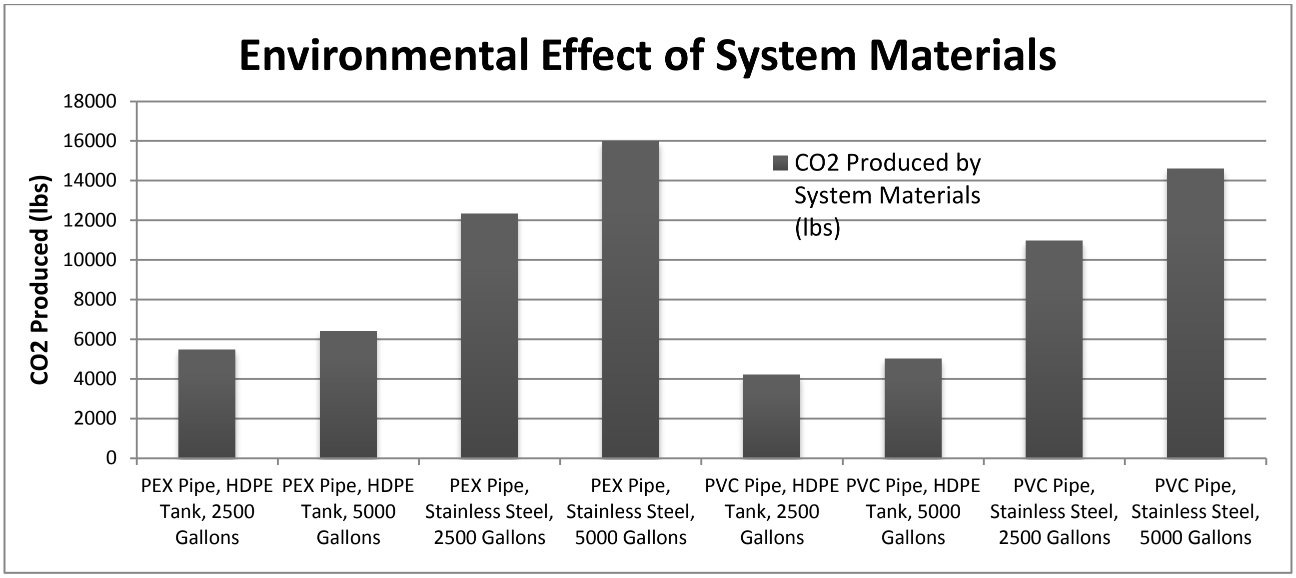

Fig. 1. The comparative environmental impact of tanks of various sizes and materials. It can be seen that the PEX Piping with a 5000 gallon tank constructed out of HDPE would be the most environmentally sound.

empty tank, and the number of months it would take for the tanks to pay for themselves. All calculations were based on the assumption that each gallon will save $0.008/gallon. Table 3 depicts the same information as Table 2, but with tank options from Rain Brothers, LLC. The "Goal Seek" tool in Microsoft Excel was used for this analysis. Rain Brothers LLC does not seem to offer as large of tanks, and they seem more expensive than National Tank Outlet, but the locality will reduce transportation distances, and thus will reduce an added environmental impact. Fig. 2 shows the comparison of the costs without shipping.

Table 2: Time needed to make a net-zero return on investment for varying tank sizes from NTO

Tank Size (gallons)	Cost	Savings/Empty tank	Number of Months Until Breakeven
3,000	$ 1,180.00	$ 24.00	6
5,000	$ 2,429.00	$ 40.00	12.3
7,000	$ 4,650.00	$ 56.00	23.6
10,000	$ 5,190.00	$ 80.00	26.3
12,500	$ 8,998.00	$ 100.00	45.6

Table 3: Time needed to make a net-zero return on investment for varying tank sizes from Rain Brothers, LLC

Tank Size (gallons)	Cost	Savings/Empty Tank	Number of Months Until Breakeven
500	$ 651.68	$ 4.00	3.3
1,000	$ 995.16	$ 8.00	5
2,500	$ 1,596.65	$ 20.00	8.1
3,000	$ 1,962.67	$ 24.00	10
5,000	$ 4,432.19	$ 40.00	22.5
6,100	$ 4,980.91	$ 48.80	25.3

V. Conclusion

Based off of our results, implementing a system such as this would be beneficial to both Ohio State and the environment. The rainwater harvesting system would reduce

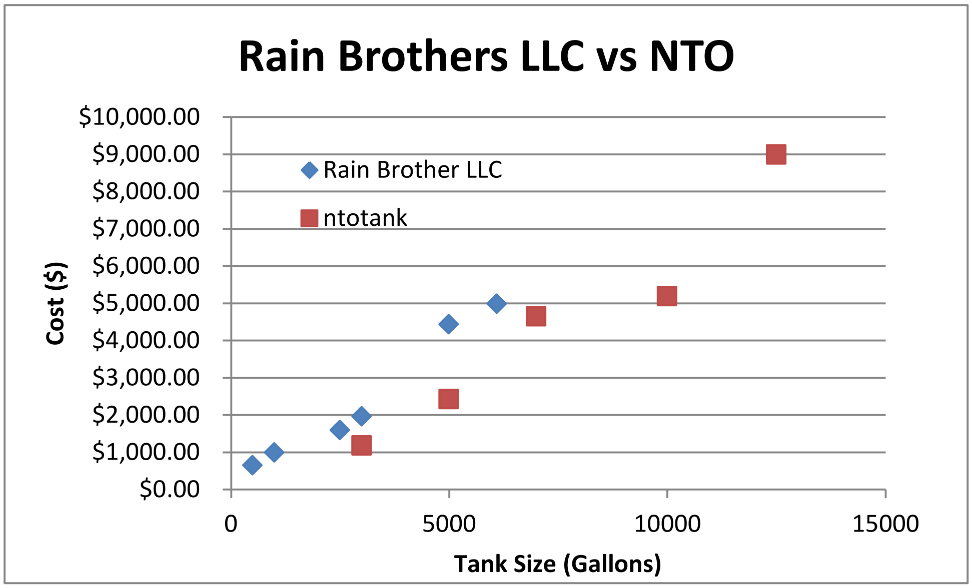

Fig. 2. Price comparison between Rain Brothers, LLC and National Tank Outlet

the amount of water needed by Scott Laboratory as well as its expenditures on energy. Use of the Sustainable Minds software was beneficial for analyzing the project's impact on the environment from a manufacturing standpoint. The installation of such a system would prevent over 1,700 lbs. of CO_2 from being released each year, thus, a rainwater harvesting system would be environmentally sound. In addition, a 5,000 gallon tank purchased from Rain Brothers, LLC would take only 22.5 months to break even. To help pay for this system, there are multiple grant opportunities Ohio State can take advantage of, and Franklin County offers tax breaks for mitigating storm water runoff. As our results show, the installation of this kind of system would be beneficial in all meanings of the word. Also, the system could be placed in multiple different buildings on campus, and similar results would be seen.

REFERENCES

[1] Institute of Materials, Wavin Industrial Product Ltd. 1996. "Old PVC-U Water Pressure Pipes: Investigation into Design and Durability."

[2]National Atmospheric Deposition Program, University of Illinois at Urbana-Champaign. 2010. "Hydrogen ion Concentration as pH from measurements made at the Central Analytical Laboratory, 2010."

[3] Center for Sustainable Systems, University of Michigan. 2012. "U.S. Water Supply and Distribution Fact Sheet." Pub No. CSS05-17