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Analysis of greywater use for toilet flushing in San Francisco

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Abstract

As human population continues to grow rapidly, demand for water quantity and quality is experienced worldwide. Recent technology has explored the idea of utilizing graywater as opposed to the low flush toilets in common households. Our objective is to determine if the cost-benefit-analysis proves that upgrading to toilets utilizing graywater will reduce money and water consumption. We expect our results to demonstrate significant water and cost savings when comparing the low flush toilet to toilets utilizing graywater.

Graywater is defined as wastewater created from human-induced activities such as showering, bathing, washing dishes, etc. The interesting aspect of using graywater for toilet flushing is due to it containing a minimal amount of human waste. Toilets water is purely mechanical in nature, as the water physically moves waste through the sewer. As such, this water does not need to be clean. Graywater toilets use water from showering or dish washing for flushing. Currently, low flush toilets use 1.8 gallons of pure water per flush. A typical efficient home could generate about 25,000 gallons of graywater per year. This equates to at least 15,000 flushes per year or 4,250 “free” flushes per person in a household of four. This paper investigates the monetary saving of switching to graywater for the entire city of San Francisco. The water savings of every household switching to a graywater toilet are compared to the costs of implementing such a plan.

This paper will primarily use a cost-benefit analysis for households switching from traditional flush toilets to graywater toilets. The onetime cost of implementing graywater technology, excluding any additional maintenance costs of operating a graywater system, will be compared to a yearly water savings. Our model of yearly water savings will also seek to capture the expected increase in water demand by forecasting future growth. Population growth combined with the water use of an average toilet will be counted as future water savings. Future monetary savings will be discounted with an r value of 0.046.

Introduction

Our project will investigate the cost efficiency of reducing urban water use through utilizing graywater for toilets. Typical households spend half of their water consumption on indoor water uses. Of this indoor water use between 15 to 30 percent, depending on the water efficiency of the toilet, is spent on flushing. Grey water utilizes recycled water from bathing or handing, allowing for the conservation of clean water.

For our case study, we specifically examine using greywater due to the major benefits that it provides. One benefit that deemed appropriate is the reduction in fresh water consumption. This means that San Francisco residents can save a significant amount on their water bills. In addition, the overall community can benefit through having less wastewater enter the sewer systems. This reduction directly results in wastewater treatments being able to last longer as they are now able to not function as rigorously in treatment. Overall, this reduction in cost of maintenance through upgrades at the wastewater treatment can be redirected towards other areas such as investing the extra money into public education or building infrastructures.

Objective

The main objective of this project is to address and then quantifying a reasonable amount for per capita use in San Francisco to determine cost effectiveness of greywater systems. A cost benefit analysis for the city of San Francisco will compare the benefits of water savings against the costs of implementing a greywater system. We are investigating potential water saving from toilets utilizing greywater in San Francisco and the cost of installing graywater. This involves estimating water use from typical household toilets in a given year, estimating current toilet efficacy, and monetizing water savings. We will finally determine if the net benefits, or the benefits minus the costs, are positive to determine if a widespread graywater system makes sense for the city of San Francisco.

Hypothesis

The topic of water conservation is prominent especially in times of drought and although the effects of implementing toilets utilizing greywater are not yet taken to large-scale in San Francisco, the long-term benefits projected by scientific models should be closely examined. Case studies around the world show that using greywater has the potential to reduce demand for up to 35% of water consumption. If utilizing greywater on a small scale in San Francisco, then there may potentially be worldwide application, where the water savings can significantly reduce water demands. We hypothesis replacing every household's traditional toilet with one utilizing greywater will produce net benefits for the city of San Francisco. The benefits from water savings will outweigh the installation costs, and thus the project should be undertaken.

Data Sources

Demographic data about the city of San Francisco comes from the most recent United States Census.

The water usage and cost of water comes from the San Francisco Public Utilities Commission. The price of water used is at the discharge rate for single family residential homes beyond the first 4 units of water.

The cost of installing graywater comes from the price charged by Reaqua Systems, a British company that specializes in graywater installation.

The discount rate r is from Yale Economist William Nordhaus and his research on discount rates for climate mitigation.

Additional material on graywater originates in academic papers are cited in the reference section of this paper.

Methods

A benefit cost analysis will be done on to determine the viability of installing a graywater system in every household in the city of San Francisco. The benefits are monetized the cost of water saved by the greywater technology. These benefits are then discounted to equal a present value for water savings over the lifespan of a graywater toilet. Costs are considered to be the cost of installing graywater, multiplied by the number of households. The net benefits will then be calucluated by subtracting the costs from the benefits. Any positive values reveals positive net benefits, and thus a worthwhile investment for the city of San Francisco.

Calculations

345,811 households in San Francisco x

$$* \frac{2.41 \text{ people}}{1 \text{ household}}$$

This converts the number of households in San Francisco to number of people (United States Census 2010).

$$* \frac{4 \text{ toilet flushes}}{1 \text{ person}}$$

This is the number of flushes per person

$$* \frac{1.8 \text{ gallons}}{1 \text{ flush a day}}$$

The number of flushes is converted to gallons of water used

$$* \frac{1 \text{ hundred cubic feet}}{748 \text{ gallons}}$$

Gallons of water are converted to hundred cubic feet of water

$$* \frac{\$11.25}{1 \text{ hundred cubic feet}}$$

This water is converted to monetary terms using the cost per hundred cubic feet the city of San Francisco charges for water (San Francisco Public Utilities Commission)

$$* \frac{30.41 \text{ days}}{1 \text{ month}} * \frac{12 \text{ months}}{1 \text{ year}}$$

This converts the water savings per day to water savings per year

= $ 32,940,094.12 a year

Discounting our benefits

$$= \frac{\overline{FV}}{r}\left(1 - \frac{1}{(1+r)^T}\right).$$

FV is the future value. This is equal to the $32,940,094.12 we calculated in the above equations.

r is the rate at which the future is discounted. This value is determined by factors such as the interest rate, the return on capital in the economy, social time preference, and the utility of future consumption. r is set equal to 0.043. This value is consistent with Yale economist William Nordhaus's discount rate in determining

T is the lifespan of grey water toilets. This value was estimated at 30 years, based on the lifespan of traditional toilets. A greywater toilet's lifespan is not considered to be shorter than a traditional toilet. Replacement costs after 56 year is smaller, as the infrastructure is already in place.

$$\frac{32{,}940{,}094.12}{0.043} * \left(1 - \frac{1}{(1+0.043)^{56}}\right)$$

= *$693,549,184.3*

This represents the present discounted value of future water savings.

Costs

Each greywater system costs $2,000 per household. This cost is from British company Reaqua Systems. This cost includes the physical material costs and labor costs of installing the greywater.

$$345{,}811 \text{ households} * \frac{\$2{,}000}{1 \text{ household}}$$

= *$691,762,000*

Net Benefits

Net benefits are the total benefits of water savings minus the total costs of implementing greywater in every household in San Francisco.

$$\$693{,}549{,}184.3 - \$691{,}762{,}000$$

$$=\$1{,}787{,}184.30$$

Error and uncertainty exists on both sides of our cost benefit analysis. The costs associated with maintenance of greywater systems were not included in this estimate. Greywater was not assumed to have any additional maintenance compared to regular flush toilets. This, however, may not necessarily be the case. The lifespan of graywater toilets were also considered to comparable to that of regular flush toilets. It is possible, however, that graywater systems have additional wear and tear which reduces the lifespan of the toilet. A shorter lifespan would reduce benefits. The building themselves are also assumed to last at least 56 years. Building which are demolished would have savings less than expected because the toilets within the buildings did not last for the full 56 years. Monetary beneifts in the future are need to be discounted. While we felt the 4.6 percent discount rate, taken from Yale Economist William Nordhaus was justifiable, strong logical arguments for either a higher or lower r value exist. A higher r value discounts the future more, which would lower our benefits, while a smaller r value values the future more and would raise our benefits.

The costs of implementing graywater may have been overstated by the economic principals of economies of scale and the learning by doing effect. Economies of scale refers to the price per unit of output falls as the amount of output increases. In this case, the cost of installing individual graywater systems falls as more are produced. The mass production of graywater allows for fixed factory costs to be spread over more units, or for a more standardized process to be employed. The learning by doing effect represents the cost of graywater being driven down as additional efficiency gains occur through investment in search and development. Producing so many graywater toilet systems would encourage companies to invest in graywater technological research, leading to effiency gains. Also, workers who install the thousands of graywater systems will also, by nature of repetition, learn to install them more efficiency. This too will drive down the cost in our Cost Benefit Analysis, which would increase our net benefits.

Conclusions

Our study on how San Francisco can significantly reduce its costs, then further research can be conducted on other ways of utilizing greywater. Grey water represents substantial portion of household water consumption in volume. Treated grey water to a level complying reuse rules and regulations can be reused for several purposes including agriculture, landscaping and toilet flush. Our research shows that there is potential for learning from this small scale application to utilizing more greywater in households and applying it to a larger scale.

Both the local government and individual households should be interested in the result of this report. Local governments and California Regional Water Boards, if switching to greywater shows net benefits on our cost benefit analysis, should incentivize greywater technology implementation. This could involve education plans, tax breaks for individuals that switch, or subsidies for low income households. Individual households would also

San Francisco Public Utilities Commission (SFPUC) informs the public that they are looking for innovative ways to conserve water, and a way to achieve this is through utilizing greywater. For instance, SFPUC designed a program that uses laundry water as greywater to water landscape. Although this laundry-to-landscape greywater program won’t officially launch until fall 2015, our research actually encourages similar programs to be implemented in the future.

Even though the concept of "Tragedy of the Commons" has been around for almost fifty years, the daunting side effects of uncooperative interactions amongst the common people are beginning to be apparent. In our case of the severe drought situation, farmers and other water users must begin to conserve water consumptions. Our report identifies the need to address prominent issues regarding our precious water supplies through investing into greywater technology. However, if there is not enough public demand for the implementation, then as a society we can fail to effectively plan water use sustainably for the future. Perhaps due to limited knowledge on the local geography around America, every situation may be different and not necessary need to implement a greywater-use system for toilet flushing. On the other hand, when decisions are left to local residents, then San Francisco water users succeeded in implementing their greywater-to-irrigation program, which is an impactful management technique to mitigate further abuse to the water supply. If there are more similar programs like this around the state of California, then there will slowly begin to be more acceptance of such technology. Ultimately, local governments should attempt to address the water shortage problem first with the local users, and decide if this is something that can be applied on a larger scale. In conclusion, from the research that we carried out, it shows that San Francisco can benefit from this implementation and that this will serve as a learning model for other states to follow. However, in order to succeed on a large scale, the degree of intervention between local governments and public should be properly outlined in order to ensure optimal results when solving and utilizing a relatively new technology in flushing toilets.

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