# Reducing CO2 Emissions with Decentralized Wastewater Systems

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## Introduction

Although water consumption in UC Berkeley accounts for approximately only 1% of CO2 emissions, water conservation and reuse should be one of the priorities of the university. Water conservation and reuse could translate in tangible CO2 emission reductions result of the energy intensive nature of water transportation and treatment processes. More importantly, incorporating decentralized wastewater systems in campus, will contribute to establish a model of sustainable water management practices.

Currently, one of the biggest challenges to promote investment in water reuse systems in the campus is the low price of water. Previous proposals prepared by UC students to implement decentralized wastewater systems have recognized that at current water rates, there is little incentive for investing this type of projects. However, water price does not reflect actual environmental and economic costs related to basin overdraft, wastewater pollution, and CO2 emissions produced by energy consumption.

In this report, I present an analysis of potential CO2 savings that could result from installing decentralized water systems in campus. Because the technology for these projects is in development, and the cost is determined on a case-by-case basis during the design process for specific projects, it is not possible at this time to present an economic feasibility analysis. One thing is certain; DWS would require significant investment for low returns in the short term. Nevertheless, incorporating pilot DWS projects on campus will help the university to transition to sustainable water practices and to achieve its water conservation and CO2 emissions reduction targets in the long term.

## Decentralized Wastewater Systems

Decentralized wastewater systems (DWS) are currently being developed as an alternative to current centralized systems. A decentralized system is a “close loop” system that treats wastewater onsite and provides treated water for some type of reuse ,such as irrigation, nd toilet flushing. Depending on the technology, DWS could also provide the opportunity of reusing the nutrients of wastewater. Conversely, centralized systems follow a “linear model” of energy intensive water use and discharge. Under this system, wastewater is transported through the sewage infrastructure, treated, and discharge into a body of water. Some of the problems associated with this model are the high cost of building and maintaining infrastructure, bypassing of sewage systems during storms resulting in direct discharge of sewage into the water bodies, and groundwater contamination due to pipe crack leaks. In Berkeley, specifically, ground movement and settling has caused cracks in pipes in the older areas, resulting in sewage leakage resulting in groundwater ( Elmer et al , 2007).

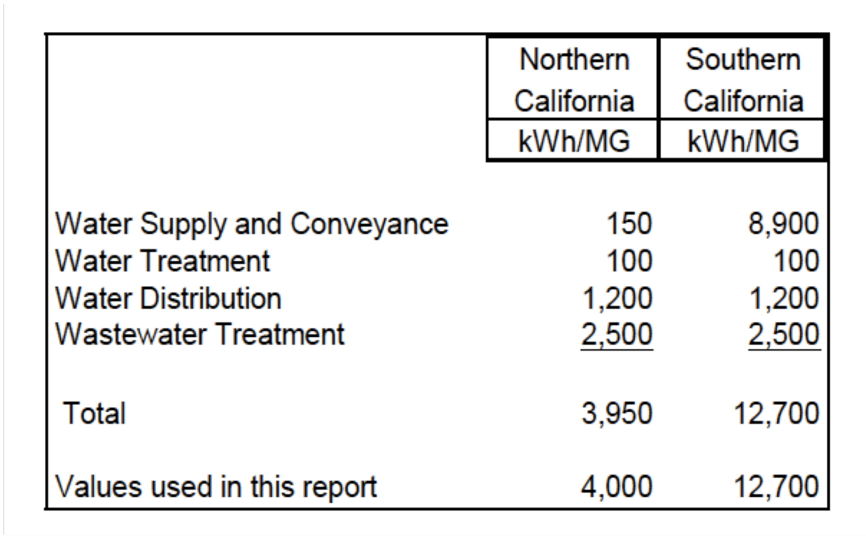
## Water Use and CO2 Emissions

Water supply and discharge are energy intensive. In terms of CO2 emissions, data at the state level indicates that water supply production and distribution uses 19% of the state’s electricity, 30 % of its natural gas, and 88 billion gallons of diesel fuel every year. The Department of Water Resources points out to the need of assessing and planning for the effects on climate change of the CO2 emissions resulting from water use.

In order to identify the potential CO2 savings from DWS, I identified CO2 emissions from the different processes involved in water supply and treatment. The California Energy Commission (CEC) conducted a study to analyze the relationship between water use and energy use (CEC, 2005. According to this analysis, there are four steps involved in the process: water supply and conveyance, water treatment, distribution, and wastewater treatment. Diverting wastewater form the sewage system would reflect clear energy savings from the wastewater and treatment steps. Treating wastewater would also result in real energy savings from the supply, treatment and distribution steps, as a result of decrease in potable water consumption, but which would be harder to quantify without studying the specific consumption patterns in a real scenario. For this analysis I would only consider the potential CO2 savings associated with the elimination of wastewater treatment.

In California, electricity use associated with water supply and conveyance water varies greatly depending on the region, while water treatment, distribution, and wastewater treatment are similar throughout the state. Figure 1 shows electricity use in the four steps of water supply and discharge. As shown, water supply and conveyance require significantly more electricity in Southern California.

**Figure 1: Electricity Use in Typical Urban Water Systems**



| | Northern California kWh/MG | Southern California kWh/MG |
|---|---|---|
| Water Supply and Conveyance | 150 | 8,900 |
| Water Treatment | 100 | 100 |
| Water Distribution | 1,200 | 1,200 |
| Wastewater Treatment | 2,500 | 2,500 |
| Total | 3,950 | 12,700 |
| Values used in this report | 4,000 | 12,700 |

Source: California Energy-Water Relationship. Staff Report Prepared in Support of the 2005 Integrated Energy Policy Report Proceeding (04-IEPR-01E). November 2005

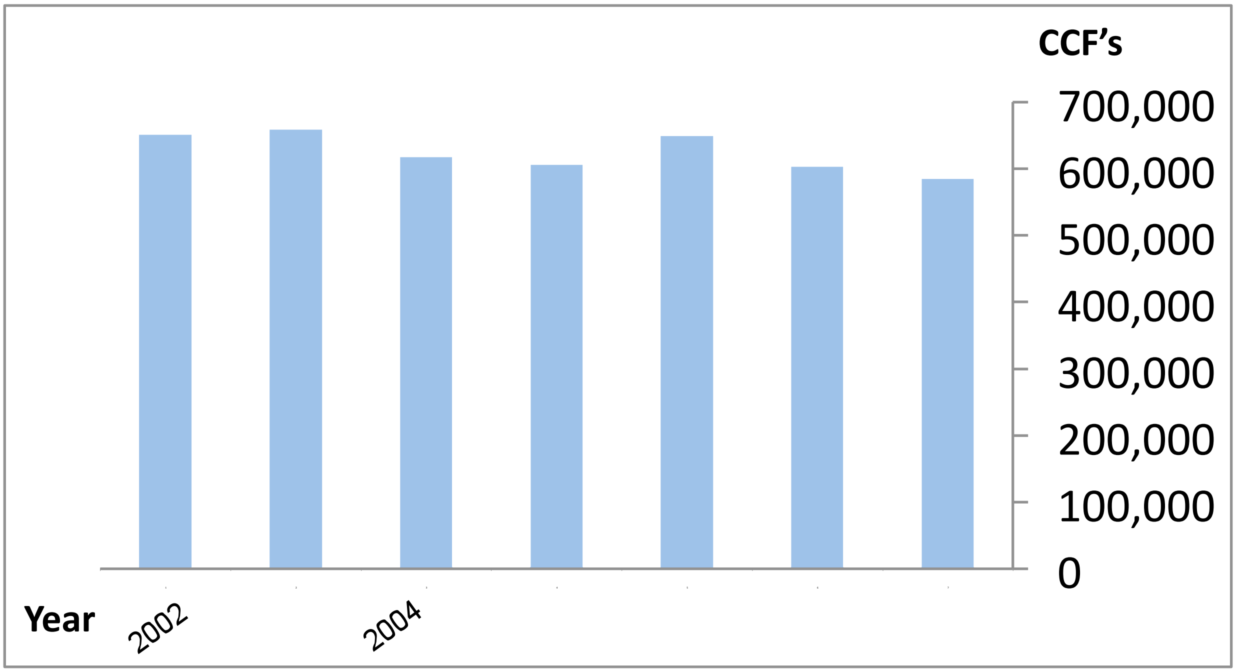
Wastewater treatment requires approximately 2,500 KWh per million gallons (MG) in both areas. These numbers suggest that in Northern California wastewater treatment accounts for approximately 62% of the total electricity used in the water supply and discharge process.

CEC establishes that total electricity used associated with water use is: 0.004 kWh Gallon. Each kWh is associated with and average of 0.301 kg of CO2 emissions in for UC Berkeley (Stoll, 2010) . Based on these assumptions I identified the following potential CO2 savings related to DWS systems.

## Potential CO2 and Economic Savings from Decentralized Wastewater Systems in UC Berkeley

As shown in figure 2, water consumption in campus has decreased in the last years. 2008, UC Berkeley consumed 585,052 ccf's. (Escobar, 2010)

**Figure 2: UC Berkeley Campus Water Consumption 2002-2008**

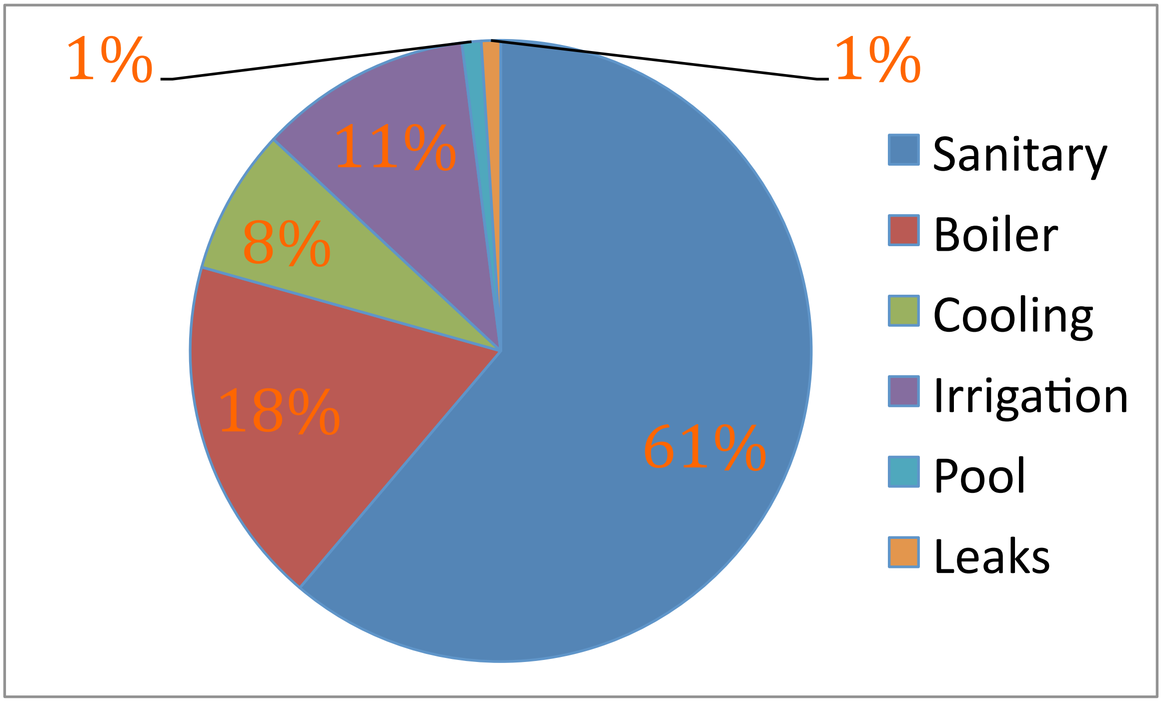


Source: table of own elaboration

For 2009, I will follow the assumption that water consumption has increased by 1.13% , at the same rate as enrollment increase (Stoll, 2010). Under this assumption water consumption for 2009 was 591,563 ccf's, approximately.

It is important to consider the breakdown of water uses on campus, given that some water uses do no divert water to the sewage system and already translate in CO2 savings. Figure 3 shows a breakdown of water uses by type.

**Figure 3: UC Berkeley Water Use by Type of Use**



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An agreement between EBMUD and UC Berkeley, allows the university to calculate a "discharge rate" based on the percentage of water diverted to the sewer system, and to avoid the payment of .63 cents per ccf discharged. The no discharge categories are cooling tower, irrigation, pool evaporation, and leaks. The estimated discharge ratio is 69.5% (Escobar, 2010). The remaining 30.5% represents the percentage of water that does go into the sewer system. Based on CEC estimates of energy intensity for the water consumption cycle, the campus already saves 62% on CO2 emissions from the portion of water consumed, but not discharged (approximately, 180, 426 ccf's in 2009), The 2009 UC Berkeley Greenhouse Gas Inventory indicates that there were 1970 metric tons of CO2 emissions associated with water use in that year. However, considering the 30.5 not discharge rate, approximately 372 metric tons of CO2 were saved on wastewater treatment for this water units. These current savings so far are not incorporated into greenhouse gas emissions inventories, but because they can be quantified, they should be incorporated into current inventories.

In terms of economic savings, UC Berkeley saved approximately $113,800 on no discharge water consumption. The opportunity is then in expanding the economic and CO2 savings through alternative water disposal projects.

Given the high cost associated with DWS infrastructure, the implementation of DWS would be a long process that would require education and research, but there are real potential CO2 emissions and economic savings associated with this kind of projects. The following are two of the most promising DWS technologies that could be implemented for future projects in campus.

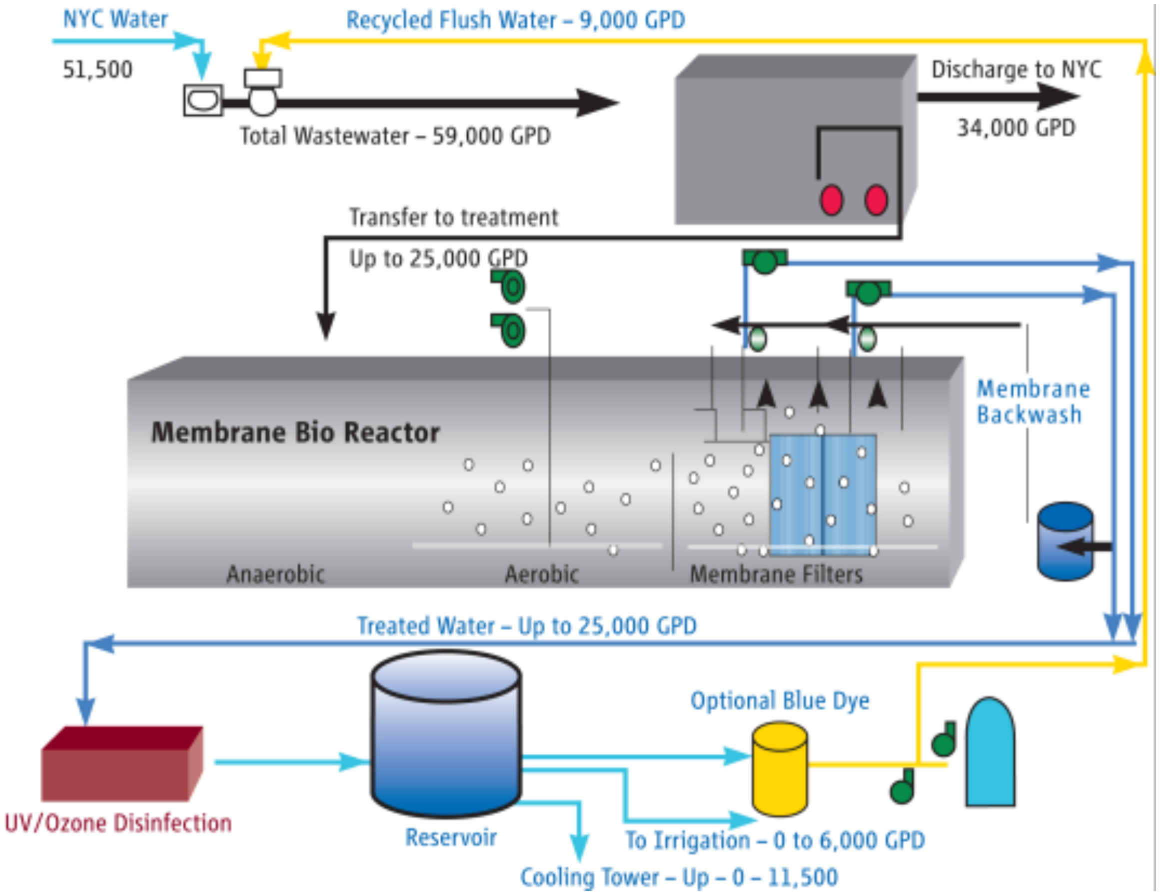
## DWS Technologies

### Membrane Bio-Reactors

Membrane Bio-Reactors (MBR) is an appropriate water reuse technology for an urban setting. One of the best examples of the application of this technology in the US is the Solaire building in New York. This 231 unit residential building counts with an MBR with a 25,000 gallons/day treatment capacity. The MBR , which uses Zenon© technology, and is operated by a third party: American Water. The system uses a double purple piping system and the treated water is reused for irrigation, cooling tower, and toilet flushing purposes.  The MBR system reduces potable water consumption by 50%, which is a good indication of potential water savings.

MBR's combine ultrafilter membranes in a tank with a biological treatment process, UV rays for disinfection, and ozone. Wastewater enters the tank and is pumped through the filters; air is also pumped in to build up the bacteria for digesting. "Ozone provides final oxidation and color removal. Solids empty into the sewer, and the treated water exits to a storage tank. Flow-through control is largely automated too.  Reclaimed water drawn from the storage reservoir is continually replaced with newly processed gray water, minimizing the need for makeup water from the city pipe"  (Engel, 2006).  Figure 4 shows the basic structure of an MBR.

**Figure 4: Solaris Building MBR Diagram**



1. Source: American Water. Available at: www.water.rutgers.edu/.../NJOWRA%20**CLERICO**%209-23-04%20v3.pdf

This process is sophisticated, but highly automated, reducing the costs associated with on-site operation. Standard maintenance consists of periodically removing filter membranes for cleaning and soaking.

This MBR model is design for each specific location. There are economies of scale and the capital cost of an MBR package varies between $50/GPD at 10,000 and GPD $15/GPD at 500,000 GPD. Operating costs range between $0.013/Gallon at 25,000 GPD and 0.009/Gallon at 400,000 GPD[1]

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[1] Overview of Water Reuse Technology - National Association of Regulatory Utility Commissioners. Available at:

**Advantages**

Based on the Solaire bulding experience these are the advantages of an onsite MBR unit:

- High volume wastewater treatment capacity.
- 35% less overall energy consumption
- 65% less energy at peak demand
- 50% less potable water used than other high-rise buildings of same size

**Disadvantages:**

- High capital cost
- Even at the low range of $0.009/Gallon operating cost, it is higher tan the $0.005/Gallon for UC Berkeley

**Living Machine**

Living machines are DWS that mimic natural process to treat wastewater. A Living Machine uses mainly bacteria, but also employs other living organisms such as plants and nails to aid in the mineralization and removal of contaminants from water.

The basic Living Machine includes three stages. The first stage is an anaerobic septic tank, in which anaerobic bacteria break down organic matter. The second stage is a closed aerobic reactor. In this tank aerobic bacteria convert ammonia to nitrates in the process of nitrification and plants capture aerobic gases that may escape. The third stage is made up of one or more open aerobic tanks. Plants, bacteria, fish, snails and other aquatic organisms are present in the third stage to help clean the water. (Melnvik et al, 2004) These are the three basic stages, but ultraviolet disinfection is commonly also part of the treatment process. In some cases, an anoxic tank is installed between the anaerobic and aerobic tank.

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www.narucmeetings.org/.../LeChevallier%20NARUC%20Reuse%20Presentation.ppt

Depending on climate, living machines may need the installation of a greenhouse to keep adequate temperature for the last stage. The construction of a greenhouse increases the cost of building the system.

Figure 5 shows the approximate cost of installing a living machine. Silmilar to MBR systems, each living machine is designed and priced according to specific projects.

**Figure 5: Comparison of Living Machines ® and Conventional Systems.**

| **Process** | **40,000 gpd** | **80,000 gpd** | **1 million gpd** |
|---|---|---|---|
| "Living Machine" with<br>greenhouse | $1,077,7771 | $1,710,2801 | $10,457,5422 |
| "Living Machine" without<br>greenhouse | $985,391 | $1,570,246 | $9,232,257 |
| Conventional System | $1,207,0361 | $1,903,7511 | $8,579,9782 |

Source: U.S. EPA, 2001.

According to these estimated costs, a pilot living machine on campus would be more feasible at 40,000 gpd. At this range, the cost difference between a living machine and a conventional system is more than 20%. A living machine with this capacity would serve a UC Berkeley building such as Wurster Hall, where students and management have expressed interest in the installation of a DWS. Wurster Hall water use from toilets and urinals is up to 23,707 gallons/day (Chang et al, 2009), thus such a system would have enough capacity for serving building users.

A good example of the living machine application can be found at the Center for Environmental Studies building in Oberlin College. This system combines the living machine with a small wetland system and has a capacity of 7500 gpd. Besides providing treated water for irrigation, the living machine at Oberlin College serves an educational purpose and students are involved in the maintenance and management of the system.

**Advantages:**

- Capable of achieving tertiary treatment;
- Costs less to operate than conventional systems
- Chemical free
- Solar powered

**Disadvantages:**

- Increased cost in cold climates
- Wastewater deficit during school breaks

## Conclusion:

Investing in DWS projects will not only bring CO2 emissions and economic savings to UC Berkeley to help it to accomplish its Cal-Cap greenhouse gas reductions goals in the future; it will also serve an educational purpose and will provide campus with a more reliable and sustainable water management system.

At this point, considering low water rates, DWS have a low rate of return. However, water prices have consistently increased in the US in the last year, and are expected to increase two to four times by 2028. [2] It is in the interest of the university to invest and to create research around DWS before such expected price increases occur.

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[2] Nation's Mayors Report on Past and Projected Cost of
Public Water and Wastewater Services and Infrastructure. The United States Conference of Mayors Press Release. March 15, 2010. Available at :

One of the challenges of implementing DWS in campus, are the cost associated with modifying plumbing infrastructure on existing buildings to install required dual plumbing. For this reason, is recommended to implement pilot projects in new developments preferably. However, another option is to support existing efforts at the College of Environmental Design to install a DWS. In this case the economic investment could be also be managed as an educational investment which would open the door to seek for alternative funding.

Design of DWS projects presented in this report will require initial investments to conduct feasibility reports. Thus, the first step would be to fund initial feasibility studies for pilot projects.

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