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The carbon footprint associated with water management policy options in the Las Vegas Valley, Nevada

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ABSTRACT

A system dynamics model was developed to estimate the carbon dioxide (CO₂) emissions associated with conveyance of water from the water source to the distribution laterals of the Las Vegas Valley. In addition, the impact of several water management policies, including water conservation, reuse, and population growth rate change was evaluated. The results show that, at present, nearly 0.53 million metric tons of CO₂ emissions per year are released due to energy use for water conveyance in distribution laterals of the Valley from Lake Mead, located 32.2 km (20 miles) southeast of the Las Vegas at an elevation of nearly 366 m (1200 ft) below the Valley. The results show that the reduction in per capita water demand to 753 lpcd by 2035 can lower the CO₂ emissions by approximately 16.5%. The increase in reuse of treated wastewater effluent within the valley to 77 million cubic meters by 2020 results in the decrease of CO₂ emissions by 3.6%. Similarly, change in population growth rate by $\pm 0.5\%$ can result in CO₂ emissions reduction of nearly 12.8% by 2035 when compared to the current status.

Keywords: Water conveyance; Energy; Carbon footprint

INTRODUCTION

Water production - which involves extraction, treatment, transmission, distribution, use, and disposal of water -- requires energy. Reduction in energy use is a major goal for sustainable development of water supply systems (Vieira and Ramos, 2009). The reduction in water's energy use has dual benefits: it reduces the cost of water production and it lessens greenhouse gases (GHGs) emissions.

The use of energy contributes to the carbon footprint, which is a measure of the total amount of greenhouse gases, expressed as carbon dioxide equivalents (CO₂e), that directly and indirectly result from an activity or are accumulated over the life stages of a product (Strutt and others, 2008; Wiedmann and Minx, 2008). The carbon footprint related to water production in the U.S. accounts for 5% of all U.S. carbon emissions (Griffiths-Sattenspiel and Wilson, 2009). However, the size of the carbon footprint varies depending on the source of energy used for electricity generation. In this research, a dynamic model is developed, using the water system in

the Las Vegas Valley as a basis that can evaluate the impact of different options for water management in terms of energy use and the associated carbon footprints. This model can assist policymakers in deciding which policies will reduce the carbon footprint of water systems, and therefore making more sustainable choices.

RESEARCH APPROACH

A dynamic simulation model for the Las Vegas Valley was developed using system dynamics (SD) modeling approach to facilitate the computation of energy use as well as the carbon footprint of water conveyance. The impacts of water conservation policies, water reuse, and change in population growth rate on the carbon footprint of water transport in the LVV were investigated.

Simulation models play an important role in understanding complex problems addressed in water resources management. In the past, SD simulation models have been used to address water resources management problems, some of which include: a water consumption model to understand the system behavior due to water saving, wastewater reuse, and water transfer (Zhang and others, 2009); a simulation model for municipal water conservation policy analysis (Ahmad and Prashar, 2010; Stave, 2003); a decision-support model for community-based water planning (Tidwell and others, 2004) as well as for investigating water trading/leasing and transfer schemes (Gastelum and others, 2010); a water balance model for irrigation management (Khan and others, 2009) and flood management (Ahmad and Simonovic, 2001, 2006; Simonovic and Ahmad, 2005); a reservoir operation model (Ahmad and Simonovic, 2000); and a spatial system dynamics model, developed by integrating system dynamics and a geographic information system (Ahmad and Simonovic, 2004); an object-oriented model for water resources policy analysis (Simonovic and Fahmy, 1999); and a dynamic model to evaluate the impacts of water reuse in terms of energy consumption and salinity control (Venkatesan and others, 2011).

MODEL WATER SYSTEM

The major water source for the LVV is the Colorado River located in southern Nevada, passing through Lake Mead, which is located 32.2 km away from the LVV. To move water from Lake Mead to the LVV requires a lift of 365.8 m. Two major intake pumping stations and two booster pumping stations lift Colorado River water from Lake Mead to water treatment plants. At present (2009), the treated water is conveyed through five major laterals in the LVV using more than two dozen pumping stations. The water supplied in the Valley is used indoors and outdoors. The water used outdoor for landscape or in golf courses irrigation, is lost to the atmosphere through evaporation and evapotranspiration due to the arid environment, and contributes to shallow subsurface soil moisture, or flows to the Las Vegas Wash as urban runoff (Stave, 2003). The indoor used water is sent to one of the three wastewater treatment plants. The treated effluent from the wastewater treatment plants is returned back to Lake Mead through the Las Vegas Wash. Depending upon the amount of treated wastewater discharge, Nevada can withdraw more water than it is apportioned (300,000 afy) because credits are given for water returned to the Colorado River. This additional amount is known as “return flow credits”.

MODEL COMPONENTS

The SD model was developed using the SD software Stella® (www.hps-inc.com). The model is comprised of three major sectors, the water demand sector; the water supply and energy use sector; and the carbon footprint sector. The water demand sector computes the total water demand and demand fulfilled by Colorado River water based on the population and per capita water demand for a simulation period spanning from 2003 to 2035. The water supply and energy use sector is the main sector and incorporates all the major pumping stations and computes the energy requirements. The carbon footprint sector calculates the associated carbon footprint of moving water in the system based on the energy source used in pumping water. The total carbon footprint is calculated using the CO₂ emission rates summarized based on literature review.

The model is based on various assumptions: (i) 43% of the total water supplied is used indoors (SWAC, 2009); (ii) there is unlimited supply of water; (iii) the Lake level does not fluctuate; and (iv) there is no variation in the state's fuel source for electricity generation.

The following water management scenarios were examined by the model:

1. **Status quo scenario:** Evaluates the carbon footprint of water conveyance in the Las Vegas Valley with increasing population, without implementing water conservation measures.
2. **Water conservation scenario:** Explores the impact of reducing water consumption from the current 240 gpcd to 199 gpcd by year 2035, on the carbon footprint of the system.
3. **Water reuse increase scenario:** Investigates the impact on system's carbon footprint if water reuse is increased from the current 22 MGD (million gallons per day) to 56 MGD.
4. **Change in estimated population growth rate scenario:** Evaluates the effect of change in estimated population growth rate by $\pm 0.5\%$ on the carbon footprint of the system.

RESULTS

Status quo scenario

For the status quo scenario, the total CO₂ emissions, during conveyance of water from the source to the conveyance system in the LVV, in the year 2009 is calculated to be approximately 0.53 million metric tons per year and it is estimated to increase to 0.84 million metric tons per year by the year 2035 (Figure 1).

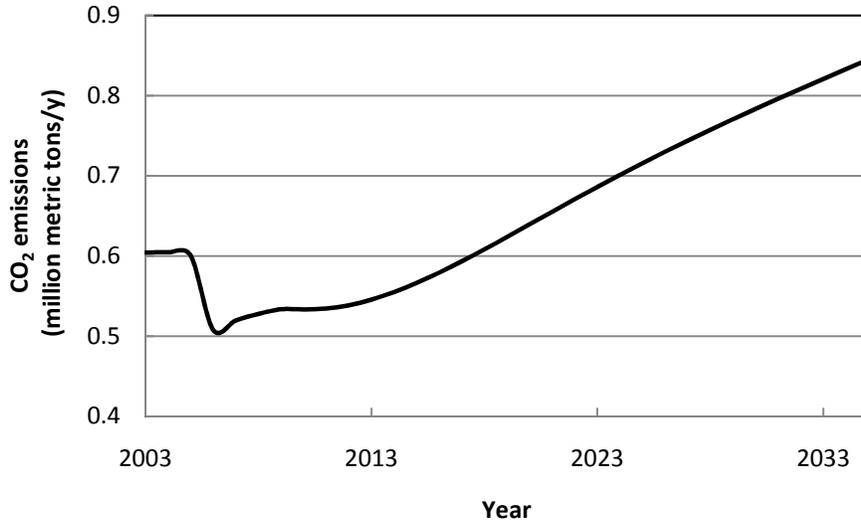


Figure 1. Total CO₂ emissions associated with moving water from Lake Mead to conveyance system in the LVV

Water conservation scenario

The per capita water demand has decreased from 1,113 lpcd (294 gpcd) in 2003 to 908 lpcd (240 gpcd) in 2009. The goal is to further decrease it to 753 lpcd (199 gpcd) by 2035. Figure 2 shows CO₂ emissions, assuming that the conservation goal of 753 lpcd (199 gpcd) water demand is fulfilled by the year 2035. The figure illustrates that the water conservation decreases the energy requirements by 16.5%, as compared to the status quo scenario. This corresponds to as much as 0.14 million metric tons of CO₂ emissions per year.

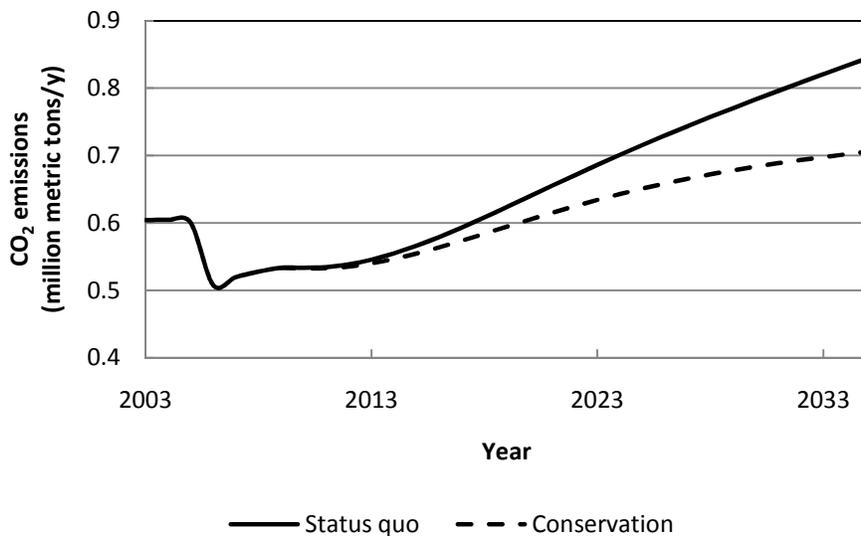


Figure 2. CO₂ emissions for conservation scenario

Water reuse increase scenario

On average, 10% of the treated effluent from wastewater treatment is reused. However, the reuse of treated effluent has increased from 25 MCM (~18 mgd) in 2003 to approx. 30 MCM (~22 mgd) in 2008; and it is expected to reach 77 MCM (56 mgd) by 2020 (CCN, 2000). Figure 3 shows the CO₂ emissions for the cases due to change in reuse rates. In 77 MCM reuse scenario, it is assumed that the reuse rate will increase gradually from 30 MCM (22 mgd) in 2009 to 77 MCM (56 mgd) by 2020 and remain constant onwards. This results in decrease of CO₂ emissions by nearly 3.6% (~0.03 million metric tons/y) by 2035. The other scenarios involve reusing treated effluent in addition to the status quo reuse amount at the reuse rate of 40%, 80% and 100%.

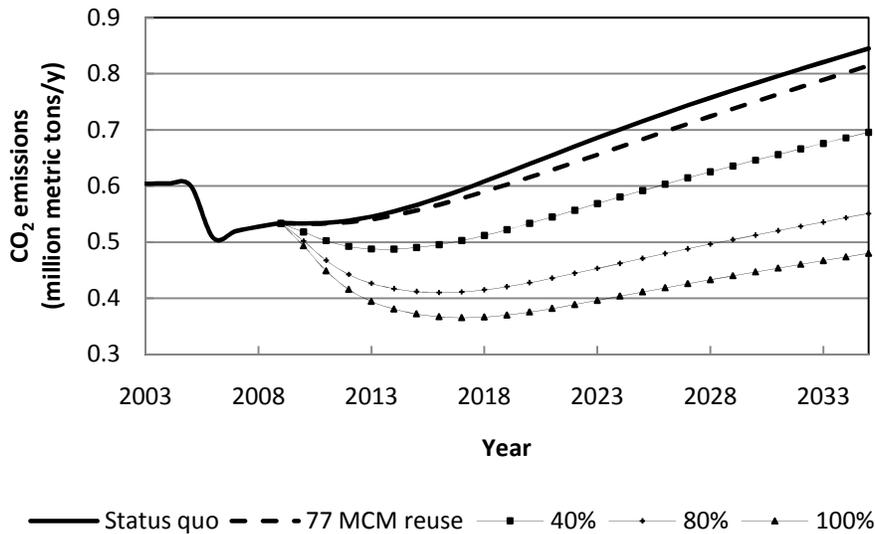


Figure 3. CO₂ emissions for varying reuse rates

Change in estimated population growth rate scenario

If the population grows as predicted by Centre for Business and Economic Research (CBER, 2009), then by 2035, nearly 0.84 million metric tons of CO₂ per year will be released (Figure 4). If the predicted population growth rate is varied by $\pm 0.5\%$, the CO₂ emissions will vary by 12.8% on average. A 0.5% change in the estimated population growth rate will result in a change in population by 0.41 million, as compared to the 3.2 million status quo population in the year 2035.

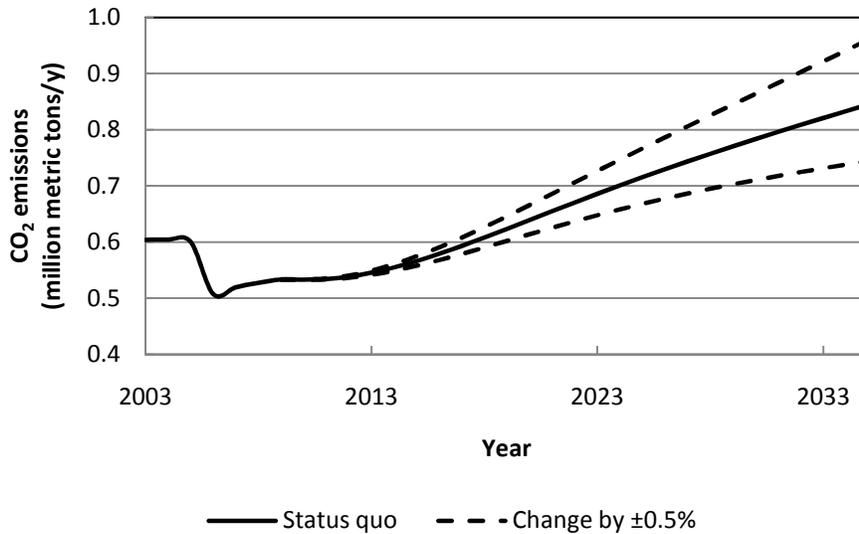


Figure 4. CO₂ emissions when annual population change rate is increased or decreased by 0.5% in the Las Vegas Valley

CONCLUSION

The model simulations revealed that the energy used to satisfy water needs of the LVV results in considerable amount of CO₂ emissions and it will increase substantially (nearly 58%) by the year 2035, if no water conservation measures are implemented. The model further reveals that water conservation and increase of the water reuse results in reduction in CO₂ emissions. Population growth rate change scenario indicated that the change in population growth rate by even 0.5% (± 0.41 million) can vary CO₂ emissions by 12.8% as compared to the status quo.

The conveyance of treated water in the distribution laterals dominates the energy use for water provision in the LVV as compared to lifting water from Lake Mead. Conserving water can be an excellent way to save energy and reduce CO₂ emissions. Conservation eliminates the energy required to pump, move, and treat fresh water from the source. It also eliminates the energy required to collect wastewater, treat and dispose or reuse it. In addition, the reuse of treated wastewater effluent within the Valley is an energy efficient water source because it eliminates the water transport energy requirements from source to the reuse points.

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