Spatial analysis and environmental effects of decentralized water reuse systems

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Abstract

This work utilizes a life-cycle assessment methodology as a framework for assessing the energy use and greenhouse gas (GHG) emissions of residential water reuse. To create a functionally equivalent comparison, the study compares decentralized systems implemented over a range of different scales with centralized water reuse, for different spatial conditions (e.g. topography and population density). The framework described here can be used as a planning support tool so that energy and GHG impacts are included in decision-making when integrating decentralized infrastructure for water reuse into an urban setting with existing centralized sewerage and wastewater treatment.

Keywords

Decentralized treatment, water reuse, spatial analysis, energy, greenhouse gases, life-cycle assessment

INTRODUCTION

Growing population and uncertain water availability threaten many cities in California and across the U.S. Treated wastewater has been recognized as an alternative water source through water reuse applications. Water and wastewater are inherently resource-intensive services. In the U.S., water services are responsible for 13% of the annual energy consumption (Sanders & Webber 2012). Decentralized water reuse is a promising option for increasing the sustainability of water infrastructure as it spatially merges supply and demand with tailored water quality, depending on the type of reuse (Gikas & Tchobanoglous 2009). However, decentralized systems lack treatment economies of scale which must be balanced against distribution efficiency gains of water reuse. Due to these efficiency tradeoffs, planning tools and frameworks for holistically assessing decentralized systems for water reuse have to be developed.

METHODS

This work identifies optimal locations and scales for decentralized wastewater treatment and reuse based on the spatial characteristics and existing conditions of an area. It utilizes a life-cycle assessment (LCA) framework to account for the environmental impacts of the water infrastructure (Baresel et al. 2015; Shehabi et al. 2012). By incorporating environmental indicators and metrics in a technical fashion, we have created a planning support framework to identify feasible locations where decentralization may be less resource intensive than the alternative.

We created an algorithmic process that integrates the spatial design of a water reuse treatment and distribution network with a life-cycle assessment (LCA) methodology of the infrastructure components to assess the energy intensity and greenhouse gas (GHG) emissions of water reuse systems for all life cycle stages- material production and delivery, system construction, operation and maintenance. It utilizes spatial algorithms and geostatistics combined with the environmental impacts of the life-cycle of the system components. We apply this methodology to assess decentralized water reuse with respect to the system scale compared to the hypothetical, but realistic, centralized alternative and to identify synergies between wastewater generation and urban water use.

RESULTS

We applied this framework to an urban area in the U.S. to assess the environmental implications of water reuse systems. We estimated the spatial and demographic parameters for the specific area and the corresponding GHG emissions for recycling water under a decentralized and a centralized scenario. By comparing the two scenarios for different facility sizes serving between 100 and 10,000 residential customers, we identify areas and scales where decentralization is the more efficient option. Figure 1 presents the comparative preliminary results for a particular area in the case study and shows GHG emissions for the conveyance and treatment phases of the two water reuse scenarios.

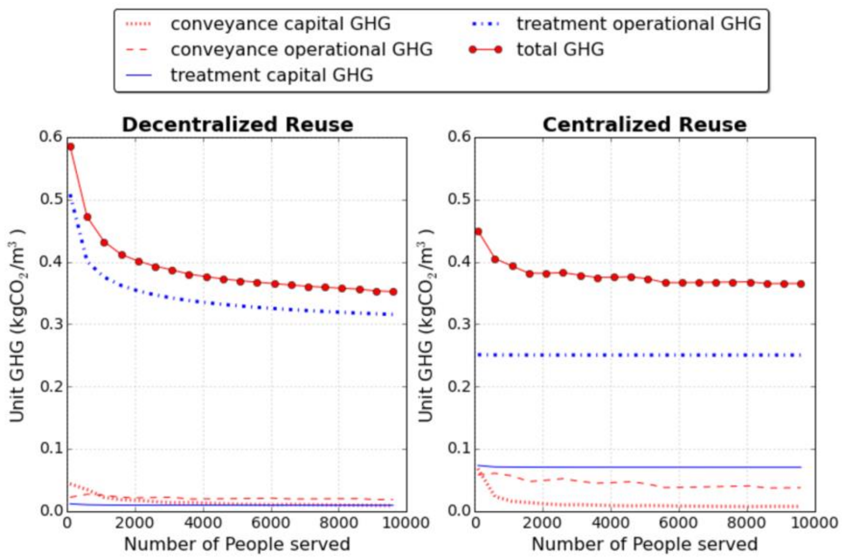

Figure 1: GHG emissions comparison plot for both scenarios of centralized and decentralized water reuse

CONCLUSIONS

To create a functionally equivalent comparison, the study assesses decentralized systems in a range of scales in comparison to centralized water reuse scenarios, for different spatial conditions. The results reveal optimal scales and locations for implementation of decentralized systems which achieve energy and GHG emissions advantages compared to centralized reuse alternatives. The methodology described here can be used as a planning support tool for integrating decentralized infrastructure for water reuse in an urban setting with existing centralized sewerage and wastewater treatment.

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