Green building with onsite wastewater treatment systems

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Study analyzes average per connection embodied energy, embodied carbon, and costs for 40 sewer extension projects.

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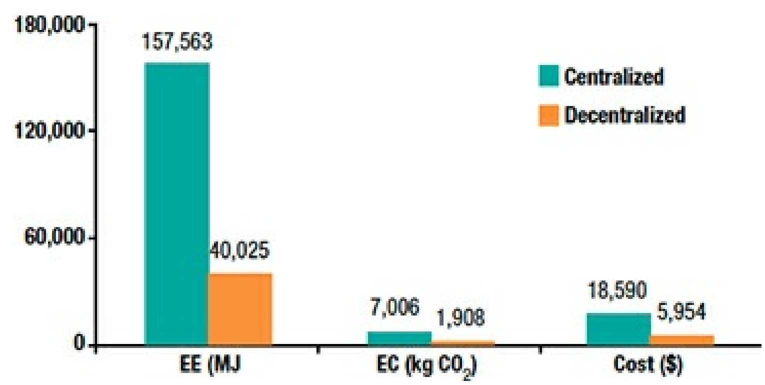

Figure 1: Comparison of average per connection resource consumption for centralized and decentralized wastewater management.

The environmental benefits of operating decentralized wastewater management have long been cited. Decentralized management is most often passive, allowing for groundwater recharge with little to no operational energy consumption. Decentralized systems require little maintenance and, with proper care and design, perform equally to centralized treatment processes.

Centralized systems, on the other hand, often require pumping stations to convey sewage to the wastewater treatment plant (WWTP), where it undergoes energy- and chemical-intensive treatment processes prior to discharging into local water bodies. In addition, gathering all the wastewater into one localized area is often disastrous during inclement weather. The U.S. Environmental Protection Agency has estimated that approximately 1.26 trillion gallons of untreated wastewater flows into surface waters nationwide each year due to combined sewer overflow discharges. In comparison, it is estimated that only 200,000 replacement onsite wastewater systems are installed each year in the U.S.

Despite these operational environmental benefits, centralized sewer replacement, expansion, and separation continue to be the focus of federal funding and new development. The funds distributed through the Clean Water Act State Revolving Fund are largely biased toward centralized wastewater management programs; a mere 0.2 percent of the allocations are used toward decentralized wastewater treatment, despite approximately 25 percent of all homes currently using decentralized wastewater management schemes.

While there are areas where decentralized wastewater treatment is not a viable option because of lot size or geologic conditions, the first reaction to sewage problems is usually to connect the area to an existing WWTP through centralized sewer line extensions. However, before reaching this conclusion, the environmental, economic, and cost impacts of each project should be more clearly assessed to ensure it is the best solution.

Studying the environmental impacts

The Southwest Virginia Regional Wastewater Study (SVRWS) was developed in 2005 as part of an attempt to manage wastewater in Southwest Virginia. The project focused largely on extending centralized sewer lines to areas with antiquated septic systems and considered some decentralized managed wastewater systems due to remote location, topographic situations, small size, or soil conditions. In all, over 136 sites were examined under the following criteria: degree of health hazard, severity of environmental problems, number of customers served, construction cost per connection, construction feasibility, as well as residential, commercial, and industrial growth potential. The top 44 centralized projects, 12 decentralized projects, and three hybrid projects were then recommended for implementation. Of the 44 centralized projects, 40 were sewer extensions to existing WWTPs.

Material consumption and construction of 40 sewer extension plans from the SVRWS were quantitatively analyzed to help determine the environmental and economic impacts per connection for centralized and decentralized projects.

	CENTRALIZED PER CONNECTION	DECENTRALIZED PER CONNECTION	DIFFERENCE	PERCENT DIFFERNCE
Embodied Energy (MJ)	157, 563	40,025	117,538	75%
Embodied Carbon (kg CO_2)	7,006	1,908	5,099	73%
Cost (USD)	$18,590	$5,954	$12,636	68%

Table 1: Comparison of average per connection resource consumption for centralized and decentralized wastewater management.

	DECENTRALIZED SAVINGS PER CONNECTION	NUMBER OF DECENTRALIZED CONNECTIONS	TOTAL DECENTRALIZED SAVINGS
Embodied Energy (MJ)	117, 538	226,025	31,267,931,402
Embodied Carbon (kg CO_2)	5,099	266,025	1,356,336,964
Cost (USD)	$12,636	266,025	$3,361,360,285

Table 2: Summary of resource savings through current use of decentralized wastewater management.

The construction cost of each project was delineated within the report by a breakdown of material and construction costs. The breakdown of materials was used to determine the embodied carbon and embodied energy of the materials and construction for each project. These values were then used to determine the average resource consumption per connection and compare it to the average resource consumption of a typical decentralized wastewater treatment system.

A three-bedroom septic system was used as the model for the decentralized systems, as it is the most common form of decentralized wastewater treatment in Southwest Virginia. The septic tank and drainfield were designed using the State of Virginia's Regulations. The drainfield size and construction equipment typically used were chosen based on industry knowledge and a brief survey of designers and installers in Southwest Virginia.

Unit values for embodied carbon and energy were taken from the Inventory of Carbon and Energy (ICE) compiled by the University of Bath. This is a highly cited source of information and has been used in many life cycle and carbon footprint analyses. This document defines embodied energy (carbon) as, "…the total primary energy consumed (carbon released) over its life cycle… includ[ing] extraction, manufacturing and transportation." Fuel efficiencies and production rates were based on literature review.

Results and discussion

Average per connection embodied energy, embodied carbon, and costs for the 40 sewer extension projects and correlating decentralized wastewater system are shown in Table 1 and Figure 1. As shown, there is a 75 percent savings in embodied energy, 73 percent savings in embodied carbon, and 68 percent cost savings on average through the construction of decentralized wastewater systems compared with the centralized sewer extensions.

The savings associated with each decentralized system is significant; the energy savings of 117,538 megajoules (MJ) is equivalent to the energy content of 969 gallons of gasoline — enough to take 2,093 cars off the road in Washington, D.C., for a day.

When multiplied by a mere percentage of the homes being installed each year, the savings have the potential to be astronomical. The U.S. Census Bureau's 30-year average for single-family starts is 1,064,000 homes. Of these, approximately 25 percent (266,025) of the permits were for decentralized systems. The resource savings from this 25 percent of homes is estimated in Table 2.

As shown, the total energy savings are nearly 31 billion MJ each year; this equates to the equivalent amount of energy in motor gasoline consumed in Washington, D.C., Maryland, Delaware, and Virginia combined for nearly two weeks (4 percent of the yearly motor gasoline consumed in these states).

The embodied carbon savings of 1.4 billion kgCO2 each year equates to 351,019 people (56 percent of Washington, D.C.'s population) with an average commuting distance of 50 miles round trip choosing to carpool to work every day for an entire year.

Conclusion

Decentralized wastewater management provides both environmental and economic benefits for new communities and those looking to update their current wastewater management systems. They are often passive systems, requiring little to no operational costs, and can provide similar treatment levels to centralized systems when properly designed, sited, and maintained.

Where individual onsite wastewater systems are not always feasible due to lot size, soil conditions, or limiting subsurface layers, community decentralized systems can usually be designed. These projects often consist of a septic tank at each connection that leads to an offsite recirculating sand filter and can provide a low-cost, low-maintenance alternative to centralized sewer extensions.

With this in mind, greater efforts should be made toward designing sustainable wastewater management systems. With more balanced funding from the EPA, this could become reality. For every 1 percent of new homes permitted that switch to using a decentralized wastewater treatment approach, an additional 54 million kg CO2, 1.3 billion MJ, and $134 billion could be saved each year. If the percentage of homes served by decentralized systems increased to 50 percent, the total energy savings alone would be equivalent to 5.25 years of Washington, D.C.'s motor gasoline supply.

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