



## Decentralized Systems



### THE CHALLENGE

Nearly a quarter of U.S. households rely on decentralized wastewater treatment systems—capturing and treating wastewater on site or in small community clusters rather than tapping into the services of larger, centralized systems. Decentralized systems may be scattered across different geographical locations, and are not linked physically or managed under the umbrella of a centralized system. Distributed systems are also typically scattered across different geographical locations, but can be linked to a central system physically or managed under the umbrella of a centralized system. These approaches can offer a range of benefits. They can require less energy, help keep local water cycles in balance, and be more resilient to disasters than their larger, more traditional counterparts.

Many homes and communities are similarly applying a more localized approach to stormwater treatment, incorporating elements such as rain gardens and green roofs. These smaller-scale options work through engineered and natural processes to offer a host of benefits. Less infrastructure and shorter pipelines can equate to lower costs—in terms of both capital and operating expenses—and can also mean fewer breaks and leaks to keep up with. And many green infrastructure options can offer added community benefits, like ponds, parks, and gardens.

Applications are on the rise as utilities more frequently consider decentralized treatment systems when deciding how to service new communities, with many recognizing the

advantages of a joint approach, where independent decentralized treatment strategies work alongside conventional centralized systems. And as water demand increases, the adoption of decentralized systems that recycle water is also gaining ground. These options can be particularly attractive to companies and institutions, as escalating water costs push them to find ways to cut expenses.

### THE RESEARCH

Amid a shortfall in funding to build and upgrade wastewater facilities in the early 1990s, there was a national push to look beyond traditional treatment, and decentralized systems surfaced as one alternative. EPA's 1997 *Response to Congress on Use of Decentralized Wastewater Systems* outlined the viability of this option as a permanent part of our infrastructure, and shortly after, the agency increased funding in this area. The additional funds led to the formation of the Decentralized Water Resources Collaborative (DWRC), a partnership of water and power organizations focused on providing the science and education needed to bolster the safe and reliable use of decentralized systems.

As a member of DWRC, WRF played a primary role in this research. Between 1997 and 2010, WRF collaborated with DWRC on more than 70 research projects totaling \$16 million in EPA funding centered on environmental science, engineering, management, economics, policy, education, and training. WRF also provided managerial oversight for half of the two-phased research effort, administering more than 40 of the total projects.



Since then, WRF has continued to build on this science, producing a growing body of relevant research conducted with cross-sector partners. Affirming that this topic will remain a long-term priority, in 2020 WRF renewed a memorandum of understanding (MOU) to collaboratively work to advance decentralized performance and to protect water resources and public health. The MOU, originally signed in 2005, signals the commitment of EPA and 20 public and private organizations to promote proper management of decentralized systems and increase collaboration between key stakeholders.

### **Environmental Science and Engineering**

In order to expand the use of decentralized solutions in the field, the water sector first needs the science on the most effective solutions. While the septic tanks and drain fields that make up many decentralized systems are seemingly simplistic, the natural components involved can demand an understanding of disciplines beyond traditional wastewater practices—including influences like soil, vegetation, and underground water flow. Onsite systems that use advanced treatment, as well as the growing number of green infrastructure solutions, also call for deeper understanding.

In 2008, *Factors Affecting the Performance of Primary Treatment in Decentralized Wastewater Systems* ([1169](#)) took one of the first overarching looks at the modern septic tank process, which up until that point was largely based on research from the 1950s. The study pulled together what was known about design, installation, operation, monitoring, and maintenance, focusing on factors likely to affect primary treatment, including influent characteristics, sizing, hydraulic design, and seasonal effects. The resulting fact-sheets and Research Digest established a baseline of knowledge and helped launch the next generation of research.

The 2009 report, *Influent Constituent Characteristics of the Modern Waste Stream from Single Sources* ([1159](#)) focused on understanding the makeup of water that goes into decentralized systems. Waste streams have undergone significant changes in recent years due to the use of different personal care products, medications, and cleaning agents, as well as a shift in water use patterns. This research sheds light on the composition of raw wastewater and the influence on final effluent. Based on year-round monitoring of more than 15 residential sites in diverse U.S. regions, the study identifies trends that are linked to location, season, occupant age, and household water use—and draws lines between constituents in raw wastewater and final effluent.

This information can be used to help engineer onsite systems that adequately treat water on a consistent basis.

WRF research is also expanding the science behind the use of recycled water in onsite systems. The 2011 report, *Long-term Study on Landscape Irrigation Using Household Graywater* ([1196](#)), produced in partnership with the American Cleaning Institute, examined how water from clothes washers, bathtubs, showers, and sinks can be reused in landscape irrigation—and the potential impacts on soil, groundwater, plants, and human health. While findings suggested there were significant advantages to be gained from the use of household graywater, such as a reduction of up to 50% in household potable water use, the report uncovered major gaps in industry knowledge. This prompted the launch of several research projects and the release of a guidance manual for owners of homes and businesses that covers installing graywater reuse systems and separating graywater at the source.

More recently, a highly visible demonstration project sited at the San Francisco Public Utilities Commission Headquarters also explored decentralized water reuse, this time with a focus on drinking water. *PureWaterSF: Building-Scale Potable Water Reuse Demonstration Project* ([4691](#)), validated that building-scale wastewater can be successfully treated to potable water reuse standards, and pinpointed specific challenges facing small-scale systems; including differences in pathogen and chemical loads compared to large-scale systems, which may require different levels of treatment. This provided a unique opportunity to not only demonstrate the use of small-scale advanced treatment to remove chemical and microbiological constituents, but to educate the public on the importance and safety of potable reuse.

### **Management, Economics, and Policy**

While more communities are recognizing the benefits of decentralized systems, when it comes to implementation, the divergence in individual site needs and possible technology options can call into question issues of practicality and cost effectiveness. Once these systems are in place, even more questions can arise about how to manage them so they continue to perform effectively. WRF has been at the forefront of these issues, providing utilities and communities with guidance to ensure solutions reliably provide treatment to protect public health and surrounding water systems.

Released in 2009, *Guidance for Establishing Successful Responsible Management Entities (RMEs)* ([1369](#)) explores the

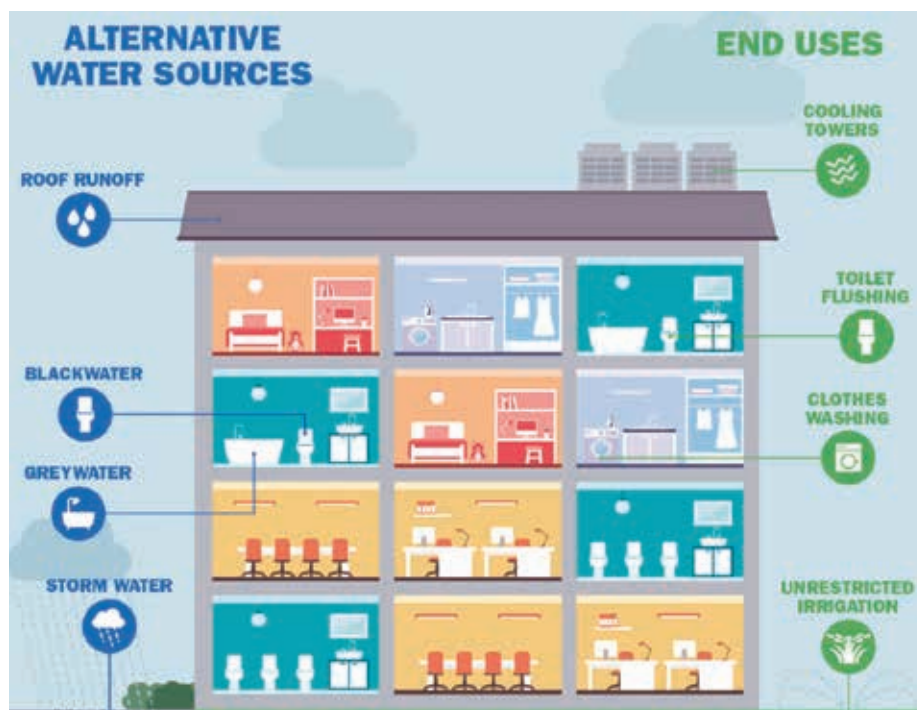


role of businesses and other organizations in providing the managerial oversight necessary for successful decentralized systems. The report maps out a step-by-step process for becoming an RME. A series of 10 accompanying factsheets covers central themes, including regulations at work in the sector, various business structures and models, management strategies, and common issues. The factsheets also provide insight into developing a business plan, projecting financial requirements, and marketing and maintaining positive public perception.

The 2010 guidebook, *Performance and Costs for Decentralized Unit Processes* (1364), dives into the economics and performance of onsite treatment, giving community leaders and planners a clearer picture of technologies and associated costs. Serving as a primer on decentralized treatment, the guide lays out fundamental information needed to work with other professionals, such as construction managers and financial personnel, to produce the best solutions for a community. A cost-estimation tool allows users to compare potential expenses involved with implementing common decentralized scenarios, and nearly 20 factsheets provide an overview of available collection, treatment, and dispersal technologies. Each factsheet provides a snapshot of use, installation, maintenance needs, and how the technology might fit into a community's vision, as well as a cost estimate.

WRF is also exploring situations where the integration of centralized and decentralized systems might be most appropriate. The 2010 study, *When to Consider Distributed Systems in an Urban and Suburban Context* (1366), analyzed 20 different scenarios where distributed approaches were used to provide integrated water services in communities using diverse management frameworks. The resulting guide helps decision makers determine whether to use a distributed approach in urban or suburban areas, or in areas that might normally be served by centralized systems alone. An accompanying model helps weigh the costs and benefits of various wastewater options taking into account economic value, environmental benefits, and community objectives.

## WHAT IS ONSITE NON-POTABLE REUSE?



### Training and Education

Even with the best science, broad implementation of decentralized systems cannot be successful without professionals who understand how to properly site, design, operate, and maintain these systems. A weak link in any one of these areas can trigger negative impacts down the line—either to the environment or people living nearby. WRF has been a leader in providing the education and training the water sector needs to support decentralized solutions, helping to cement their role as a permanent, safe, and sustainable part of our wastewater infrastructure.

Released in 2005, *Model Decentralized Wastewater Practitioner Curriculum* (WU-HT-01-05) offers some of the first nationally accepted, streamlined training materials on decentralized treatment for field practitioners. The series of short courses builds on each other, covering everything from planning to trouble-shooting and repair. Four fully developed training modules focus on the high-priority topics of soil and site evaluation, water movement and treatment in soil, available technologies, and septic tanks. These modules contain in-depth information, as well as trainer's guides and audio-visual educational materials, helping to form the foundation of a basic curriculum.

That same year, *Decentralized Wastewater Treatment O&M Service Provider Training Program* (04-DEC-3SG) was pub-



lished, serving as a training manual for providers who operate and maintain single-family residential onsite treatment systems. The manual helps familiarize professionals with terminology and procedures and promotes communication between providers and customers. It also helps establish a benchmark for competency, enhancing the overall status of the onsite wastewater treatment profession.

*University Curriculum Development for Decentralized Wastewater Management* ([WU-HT-01-06](#)) further breaks down knowledge barriers in the area of decentralized treatment, providing information that can be integrated into four-year engineering and environmental science programs.

The *Installer Training Program* ([1355](#)), launched in 2010, focuses on installation—providing guidance that moves the water sector toward the goal of uniform practices for small-scale wastewater systems. Produced by the Consortium of Institutes for Decentralized Wastewater Treatment through DWRC funding administered by WRF, the program highlights critical steps in the installation process, covering key aspects of planning, material and equipment selection, and soil and site concepts, as well as installation inspection procedures. A set of accompanying checklists helps industry professionals verify correct installation, clear systems for operation, and troubleshoot for repairs.

Recently, WRF's decentralized research has also focused on guidance and training for systems that reuse water. *Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems* ([4632](#)), released in 2017, offers recommendations for setting appropriate performance criteria, management structure, monitoring, and permitting of on-site non-potable systems. A key consideration was flexibility of approach, enabling practical design and operation of onsite reuse systems that reliably deliver water and protect public health.

Building on this risk-based framework, the 2020 guidebook, *Onsite Non-Potable Water System: Guidance Manual and Training Modules* ([4909](#)), details how to implement an onsite non-potable water system based on public health regulations. In line with an expert panel's approach recommended by the National Blue Ribbon Commission on Onsite Non-Potable Water Systems, the guidance reinforces the safe design, operation, and permitting of onsite non-potable systems. A series of 10 training modules covers topics such as public health goals and multiple barrier treatment.

## WHAT'S NEXT

As communities and water utilities look toward decentralized solutions to fill a fundamental role in a holistic approach that diversifies water supplies and promotes smart community growth, WRF will continue to provide the science to support these approaches. WRF will invest in research to better integrate decentralized systems and to realize the full potential of their treatment capabilities and untapped benefits.

Two new projects are already making decentralized stormwater systems a more viable option. *Assessing the Microbial Risk and Impacts from Stormwater Collection and Use to Establish Best Management Practices* ([5034](#)) is developing practical guidance for the design and operation of stormwater use systems, including monitoring approaches that ensure safe, reliable water. *State of Knowledge and Research Needs for Stormwater Harvesting* ([4841](#)) will improve understanding of systems that capture stormwater for eventual use or reuse, evaluate drivers for implementing improved stormwater management, and develop recommendations for harvesting practices including those for onsite systems.

*Successful Implementation of Decentralized Reuse and Treatment Systems* ([5040](#)) is further expanding research into the application of water reuse in decentralized systems. The study is developing a web-based dashboard to capture the experiences of decentralized water reuse projects at utilities, pooling information on everything from drivers and regulatory issues to costs and outcomes. This information will allow interested utilities to learn from the practices of existing, successfully operating systems, and strengthen future implementation efforts.

Another project on the horizon will explore additional benefits utilities can gain from integrating decentralized systems, such as energy generation. *Integrating Sewage Thermal Energy Use and Other Emerging Water-Energy-Waste Technologies into Decentralized Systems* ([4843](#)) looks at how technologies that are already on the market can be incorporated into existing and new decentralized solutions to maximize energy production, paving the way for utilities to meet net-zero or net-positive energy goals and creating opportunities for new partnerships and applications—ultimately making decentralized systems a more attractive option and broadening the use of these small-scale solutions.