The powerful potential of microgrids for livable cities

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Machines in the Wisconsin Energy Institute high-bay lab provide insight into how microgrid systems will interact with the grid. Credit: Matt Wisniewski/WEI

A majority of the world's population now lives in cities, which consume 75 percent of the world's resources and emit most of its greenhouse gases. The United Nations estimates that by 2050, an additional three billion people will move into these dense, resource-intense urban environments.

"Projecting from current trends, you realize that we should have a plan for how this change unfolds," says Mike Corradini, director of the

Wisconsin Energy Institute and professor of engineering physics.

As urban growth increases stress on global systems, Corradini is among a team of UW-Madison researchers working to develop solutions that contribute to the livability of future cities. When it comes to urban energy— and its ever-increasing consumption—Corradini believes resiliency, reliability and accessibility will be critical factors in ensuring a sustainable supply.

"When you're talking about a livable city, you're not just talking about energy or energy use," he says. "It's a combination of how we use water, create food, construct buildings, and transport people or goods. These are all largely connected and interdependent."

Of course, different cities have different energy needs, which means that livable city solutions tend to vary according to local need.

In the United States, for example, where infrastructure and utility support have made access to electricity nearly ubiquitous, plans for the future tend to focus on creating energy systems with greater efficiency and reliability. The focus in cities like New York or New Orleans is on building infrastructure to make cities more resilient when faced with extreme weather or natural disasters—by providing backup power during outages, as well as helping to ease systems back online as outages end.

In developing countries, however, electrification systems are often weak or nonexistent and the focus tends to lie elsewhere. In Uganda, where less than nine percent of the population has access to electricity, communities prioritize the development of individual off-grid solutions that have the flexibility to grow and meet future needs.

What's certain is that worldwide growth of urban centers will continue to pose energy challenges. And these challenges carry with them an opportunity to amplify the impact of livable-solutions planning and policy. By improving the places people already reside and preparing early for where they will live in the future, we can improve how we interact with the environment on a very large scale.

Microgrid researchers in the UW-Madison College of Engineering and the Wisconsin Energy Institute are taking up this challenge by developing an energy solution with the potential to strengthen all three critical factors of energy in a livable city: resiliency, reliability and accessibility. The microgrid, in other words, may offer a powerful, versatile and wide-ranging solution to a variety of energy challenges at different scales and under a range of conditions.

Resiliency

A microgrid is a small, self-contained electric-power system with the capability to seamlessly connect to and disconnect from the traditional grid, the network of power lines that move electricity from generating stations to users. It includes all of the components of the traditional energy infrastructure (generation, distribution and consumption) consolidated to accommodate smaller consumer base loads such as individual buildings, hospitals or campuses.

Many cities consume their energy predominantly from fossil fuel sources distributed through centralized generation systems. But this type of expansive infrastructure also comes with some risk.

"It's unlikely that, particularly in the United States, we'll completely replace the bulk power system," says Paul Meier, a Wisconsin Energy Institute scientist. "It's a vast infrastructure and, right now, there is little in the way of incentives to change it."

"But, there are opportunities to improve how the system operates or where our energy comes from that could benefit cities," adds Meier, whose research focuses on the economic feasibility and impacts of resource planning models.

The U.S. Department of Energy estimates that power outages and grid failures cost American businesses $100 billion annually. But when these interruptions occur, microgrid consumers can switch to electricity generated or stored locally, creating a more resilient and stable energy supply. In the case of hospitals, where the system can be designed to be even more robust and self-sustaining, key health services can be maintained throughout an outage.

Microgrids also create the flexibility to integrate energy from rooftop solar installations, nearby wind turbines or other distributed sources. These small-scale renewables have struggled to become cost-competitive with energy-dense fossil fuels at a utility scale. The microgrid can thus serve as a more immediate conduit between alternative energy resources and consumers.

Reliability

In India, rolling blackouts—an intentional shutdown of electricity distribution in certain areas to avoid overstressing the grid and creating a total system blackout—affect both rural and urban populations. In 2012, India experienced a massive electricity outage that affected more than 600 million people for many days. The outage crippled much of the country, bringing trains to a halt and leaving hospitals in the dark.

"At night you might see the factories shut down, so that power plants can divert electricity to people's homes. They're trying to be as equitable as possible," says Giri Venkataramanan, a UW-Madison professor of electrical and computer engineering. "For example, during irrigation season, more power will be transmitted to rural regions for pumping water out of the ground for the crops. At those times cities suffer, but people have adapted."

In many Indian cities where households or businesses have grid access but are forced to live "off-grid" throughout the day, a home energy system combining their own generation and storage capacity fills in for the prescheduled gaps. This system is essentially an incomplete microgrid, and provides a particularly possibility-rich opportunity for improvement in the future.

"Currently there is no interconnectivity among these makeshift microgrids," Venkataramanan says. "We know it can be done. The challenge is in figuring out how to use the assets that people have already invested in to help the grid during peak demand times."

Accessibility

Microgrids can complement a grid system by providing backup power for planned or unplanned outages. But in rural communi-ties throughout the developing world, where there is neither a grid system nor a backup plan, microgrids provide an opportunity for people to develop energy systems structured to their own needs.

In Uganda, a team of UW–Madison researchers hopes to help curb reliance on traditional energy sources that can be harmful to human health and the environment by developing a system that Venkataramanan describes as a wireless microgrid.

The project brings together collaborators from the Nelson Institute for Environmental Studies and the College of Engineering to expand from existing biogas systems and create electricity in a way that is accessible and useful for community members. Their system captures and uses biogas from an anaerobic digester to fuel a generator that charges batteries. The batteries can then be used to power lights and charge cellphones in homes throughout the community, without a grid.

The problems associated with growing cities will challenge how we build, plan, support and improve this uniquely human environment. The study of microgrids and other micro-scale energy systems is just one part of a broadening spectrum of UW-Madison research meant to help urban populations adjust and react with solutions right for them.

Provided by University of Wisconsin-Madison

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