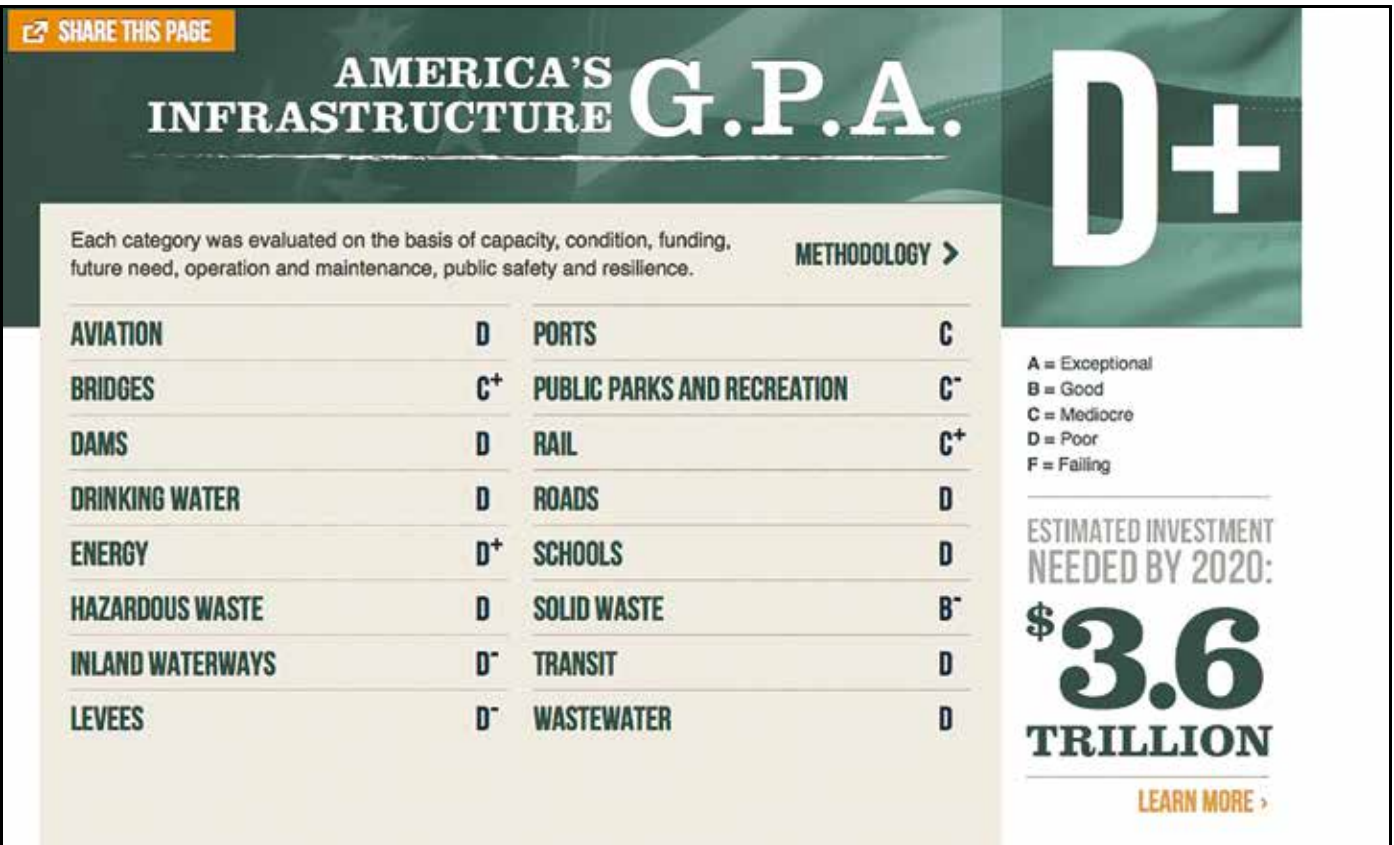


Declaring Independence

Our energy and water infrastructure is in crisis, but these projects have built in resiliency with systems that function in tandem with or independently of municipal treatment plants and electricity grids.

BY SUCHI RUDRA

PHOTO CREDIT: MATT GROCOFF



Troubling Trends. Consistently, the American Society of Civil Engineers has given drinking water and wastewater infrastructure poor marks. In its 2013 *Report Card for America's Infrastructure*, drinking water and wastewater infrastructure both earned a D, while energy infrastructure scored a D+.

THE CALIFORNIA WATER CRISIS may be on everyone's minds, but it's not just California whose water supply is in trouble.

In many U.S. cities, the water supply relies on a system of water treatment plants and pipes built as far back as the mid-to-late 1800s. Some systems still include pipes made of wood.

Bursting water mains are becoming more common (as in about 240,000 times a year), with some of the recent occurrences taking place in major cities, such as Boston and Los Angeles. The American Society of Civil Engineers' 2013 annual *Report Card for America's Infrastructure* recently rated the nation's drinking water and wastewater systems with a lowly grade of D.

Yet the issue goes deeper than the estimated \$16 billion *per year* that the National Resources Defense Council (NRDC) says would

be required for the total repair and replacement of decrepit water and sewage pipes. It goes deeper than the contamination of the water supply by chemicals leaked into lakes and rivers.

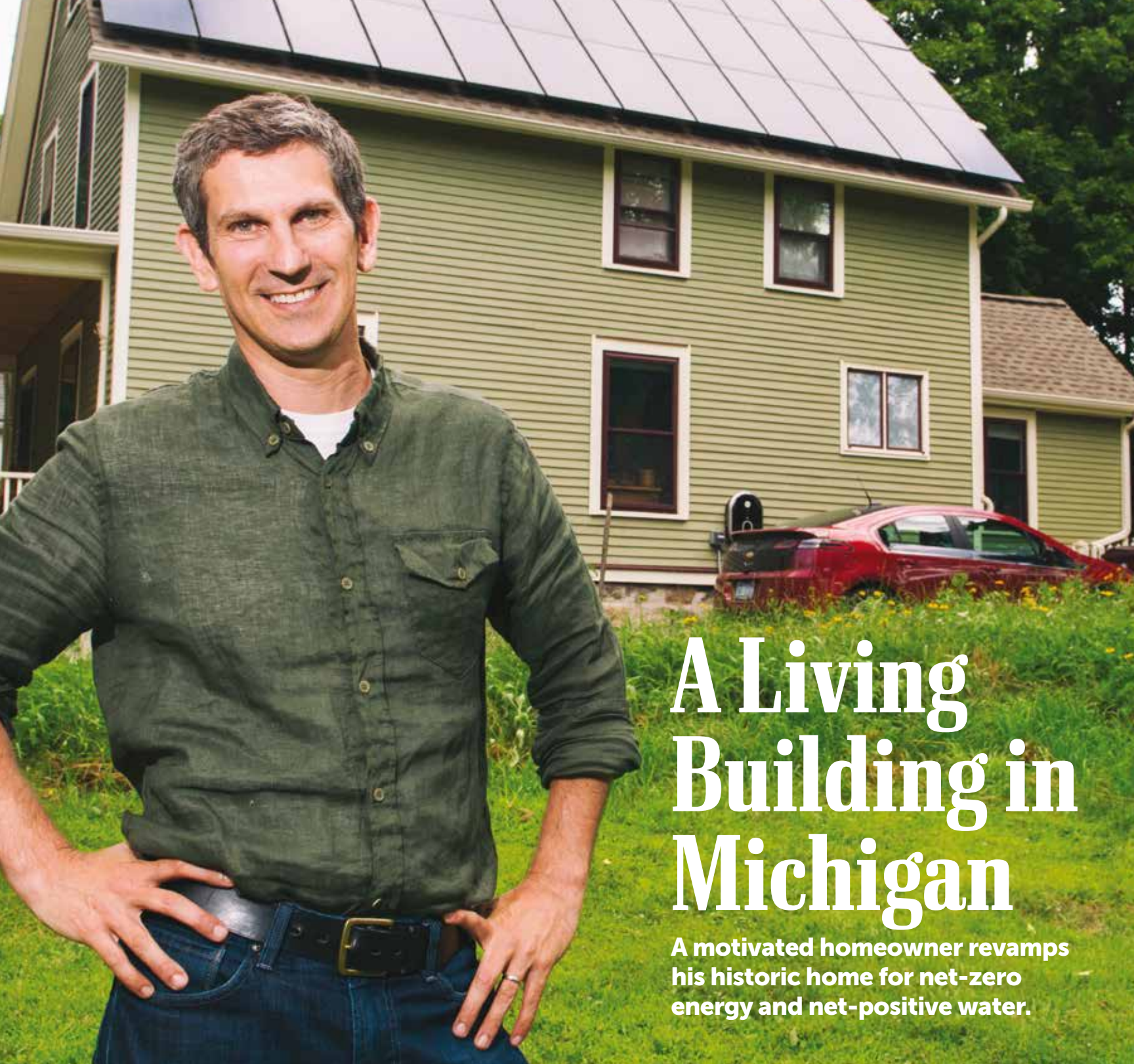
As environmentalist and THRIVE Collaborative founder Matt Grocoff sees it, it's the unnatural centralization of America's water infrastructure that is the true core of the problem.

"Centralization is not a model that works in nature," he says. "When we centralize, we disconnect from nature in so many ways. It's a recipe for disaster. But right now, money is dumped into this centralized system, and you can't shut down the grid—so, that cost-shifting and overcoming of regulatory barriers will have to happen over time."

The nation's energy supply isn't much more promising; ASCE's *Report Card* rated the Energy category with a D+. Across the country, aging power plants, substations and transmission lines exist in various states of repair.

So, it's not really surprising that homeowners like Steve Gold in Arizona and Grocoff in Michigan are turning their homes into wholly self-sufficient structures, or that community homebuilders like Brookfield Residential are experimenting with resilient home designs that will offer energy independence and superior water efficiency.

To do this—to turn toward a natural connectedness or "green infrastructure"—requires investing in natural systems such as wetlands, green roofs and open spaces. And in a more sustainable future, instead of going off-grid, everyone will be going on-network.



A Living Building in Michigan

A motivated homeowner revamps his historic home for net-zero energy and net-positive water.

PHOTO CREDIT: DOUG COOMBE

BEFORE HE MADE his energy bills disappear, Matt Grocoff was paying \$350 a month for heating in his historical, 2,600-square-foot home in Ann Arbor, Michigan. If all goes as planned—under the strict objectives of the Living Building Challenge that Grocoff is aiming for—his water bills may also soon disappear.

Grocoff, an environmentalist and founder of the THRIVE Collaborative, has always emphasized the importance of designing a net-zero-energy system, not just a net-zero-energy building. While it may be easy to blame the home's occupants for lacking

eco-friendly behavior, Grocoff believes that behavior change in the home is a difficult thing.

“Changing a shower head to higher efficiency will do more to save hot water than by telling someone to turn off water while shaving. We should still tell people to conserve water, but we should also put energy into systems, and not just focus on behavior changes. I can knock off several more kilowatts just by buying a \$1,500 appliance—I don’t need to spend \$10,000 insulating my basement. It’s a great point that people are missing in net-zero building,” Grocoff points out.

continued on page 40

In fact, plenty of people told Grocoff that net-zero energy wouldn't be achievable in such an old home, unless he installed triple-pane windows and a slew of other pricey features. But Grocoff and his team were able to keep the original single-pane windows by restoring and weather-stripping them and then adding storm windows.

Naturally, part of the net-zero strategy was adding insulation, including blown-in cellulose in the walls and spray foam in the attic.

The original stone walls of the basement, however, allow for energy loss during the winter—but in the summer, that same feature works as part of a mechanically assisted natural ventilation system, which was part of the house's original design. Warm air flows in through the windows of the basement, drawn in by an attic fan, and is cooled there. The main floor windows remain closed, and the attic windows are opened to release the hot air. The flip of a switch determines if the natural ventilation or the AC will cool the house, depending on the outdoor temperature and humidity levels.

"It's about making simple rules for local interactions, just the way nature does. And most people will choose natural ventilation most of the time," Grocoff says.

CREATING A NET-POSITIVE WATER SYSTEM

While awareness and actual construction of net-zero- and net-positive-energy homes are steadily growing, achieving net-positive water can't exactly be called an "emerging trend." And yet some homebuilders and individuals are experimenting with self-



Complementary Goals. In tandem with the net-zero-energy goal, Grocoff wanted to preserve the character of his historic house. This included repairing, rather than replacing the original wood windows.



Power House. An 8.1 kW photovoltaic array from SunPower and Enphase microinverters helps this 114-year-old Michigan home produce more energy than it consumes.

sufficient water systems that can be easily replicated.

Grocoff's idea is to encourage a self-sufficient water system that would be "infinitely scalable." To work on a system design that will get his house off the city's water supply, Grocoff has teamed up with engineering graduate students from the University of Michigan's Better Living Using Engineering Laboratory (BLUElab) group. The comprehensive system will feature rooftop rainwater collection, filtering and disinfection, a graywater treatment and storage system from Nexus eWater and an engineered wetland, which will treat some graywater, along with blackwater from the dishwasher and kitchen sink. A basement composting unit will treat waste from toilets. (For a full explanation of the proposed system, see diagram on pages 42 and 43.)

Such a system doesn't come cheaply, though. Luckily, Grocoff's project has \$40,000 in grants from Dow Chemical Company and Ford Motor Company, a portion of which will be used to purchase components for the system. These include the cisterns, a composting system and the Nexus eWater graywater system. Some materials were also donated or provided at reduced cost by industry partners. The grant money also goes toward research and educational outreach in Ann Arbor.

But the challenge, aside from the expensive set up, is not really a technical one. So far, the regulatory barriers presented by local officials have been the biggest problem.

"We have the know-how, but it's very difficult to change the centralized water system that is in place," Grocoff says.

Grocoff explains that the Living Building Challenge Net-Positive Water Imperative requires a building to harvest and use all water

onsite and to replenish it, and then to discharge it onto the site after treating it. “For this old home, achieving net-positive water is nothing new—it’s about connecting the water usage into the natural system of water that existed before the house was built in 1901. In the early 1900s, the family living in the house had a cistern for landscaping and a well for water to be used inside.”

With the modern version of such a system, ensuring safety and water quality is critical. After high levels of lead showed up from testing the rainwater coming off of the home’s original roof, a new metal roof had to be installed. But the BLUElab team has now specifically designed the purification system to remove the contaminants found in the new roof material and is also conducting lab testing of rainwater running through the purification system in the lab. The team will also submit third-party water quality test results and work with city and county health officials to approve the treated water quality before the system can be used in the house.

“Treatment of potable water and graywater actually represents a larger energy expenditure. We chose UV disinfection over, for example, ozone treatment, in order to consume less energy, but running a UV bulb 24/7 still requires close to 500 kWh per year, just for potable water treatment,” explains Christopher Wang, a graduate engineering student at BLUElab. While the home currently generates a small surplus of electricity, solar panels will be added to the kitchen roof to meet the water system’s energy demands.

A CONNECTED NETWORK

If the storage tanks were to run dry or the purification system needed repair, the system will automatically switch to a backup water supply. Initially, this backup supply would be the municipal water supply. But Grocoff and the BLUElab team envision a future network of localized water systems on a neighborhood scale, where a water shortage in one system could be compensated by a water surplus in a neighboring system.

To that end, BLUElab is working on a smart water valve to measure and gather a range of factors: water level in the household’s water storage tank, consumption rate of water by the household, local weather forecast (specifically precipitation) for the next few days and the historical weather forecast. An algorithm would then calculate the abundance or scarcity of water for the home, and this would be repeated for the household’s neighbors, including other homes, schools and parks, which would all have water tanks with smart valves. The tanks in this network could then share water, moving it from one tank to another, “not off-grid, but on network,” Grocoff says. “Nature does it on a scale where the river and the rainfall are connected in a single community, on an elegant, beautiful fractal scale. What we’ve done as a civilization is disconnect ourselves from nature.”

The BLUElab team believes that while this system isn’t necessarily replicable in just any region or climate, “part of the philosophy of the project is that the design should be tailored to the existing site, structure and available resources. But we would expect that this type of system is possible in much of the United States, given proper sizing of the rainwater catchment area and the storage tanks. Of course, rainwater harvesting might not be feasible in some drier climates, but a system designed on this small of a scale can still offer more versatility and efficiency than a centralized water supply and wastewater treatment system.”

Challenging Standards

MATT AND KELLY Grocoff’s home is a certified Net Zero Energy project under the International Living Future Institute’s Living Building Challenge program..

During the 12-month documentation (audit) period, which is part of the certification process, the house produced 8,939 kWh and consumed 8,676 kWh, for a net surplus of 295 kWh.

Once their water system is designed and built, the Grocoffs intend to pursue full certification under Living Building Challenge 3.0. This will require meeting 20 Imperatives under seven categories, or “Petals:” Place, Water, Energy, Health and Happiness, Materials, Equity and Beauty.

THE NET-POSITIVE WATER IMPERATIVE

The text of this Imperative states that 100 percent of the project’s water needs must be supplied by captured precipitation or other natural closed loop water systems, and/or by recycling used project water, and must be purified as needed without the use of chemicals.

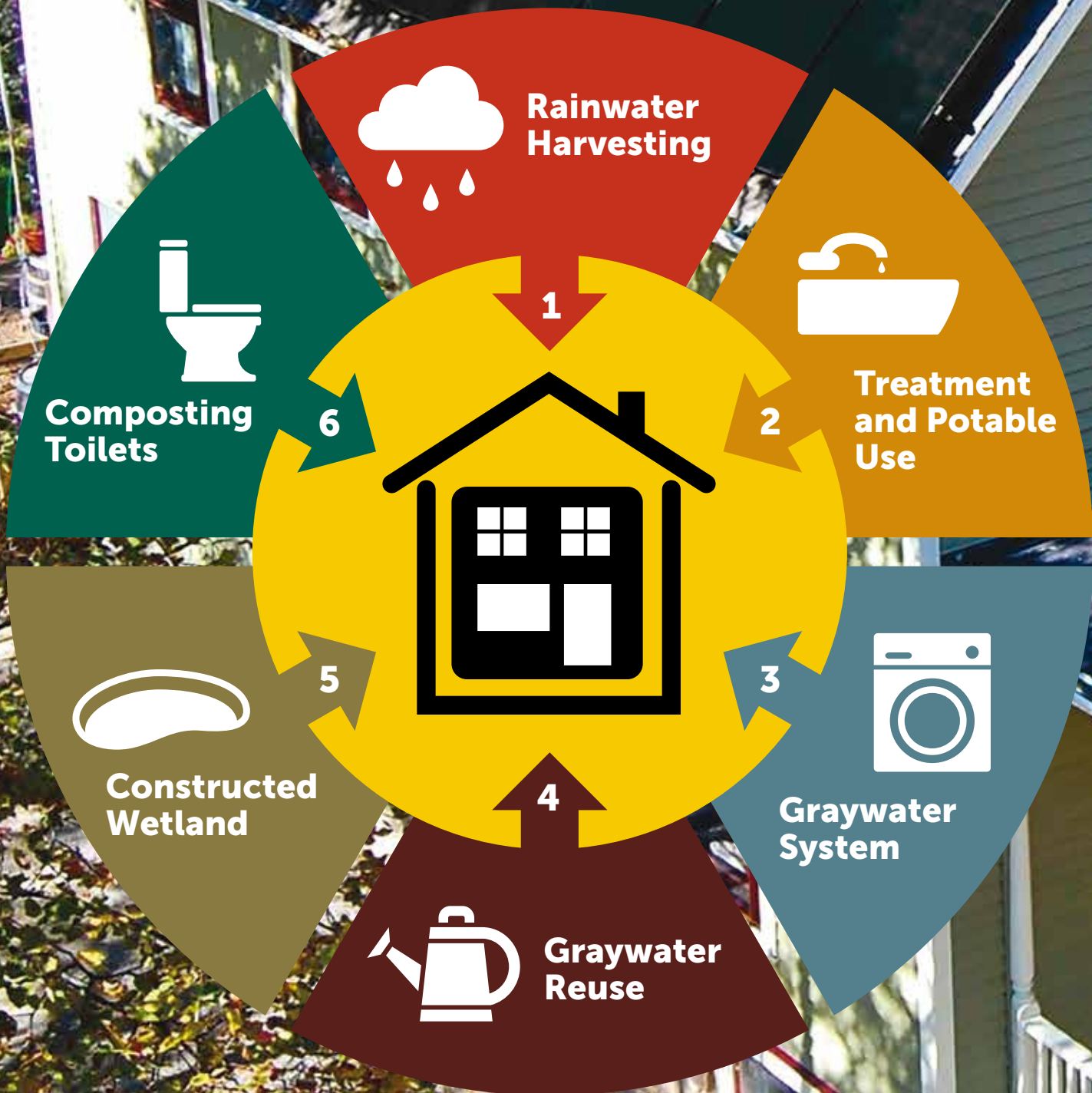
All stormwater and water discharge, including graywater and blackwater, must be treated onsite and managed either through re-use, a closed loop system, or infiltration.



Full Circle. The Grocoffs’ historic home did not originally depend on centralized water and sewer infrastructure.

Water Works

The University of Michigan's BLUElab is working with the Grocoffs to design systems for harvesting and treating rainwater and for recovering and treating graywater, blackwater and solid waste. The purification system is currently installed on the University of Michigan campus for testing, while the design of the wastewater treatment system is ongoing. Installation of the underground storage tanks and piping outside the house will take place this summer.





1. Rainwater Harvesting

Rainwater harvested from the metal roof and gutters passes through a vortex pre-filter. Filtered rainwater is stored underground in two 2,500-gallon polyethylene storage tanks.

About half a day's supply of water is stored in a pressure tank in the home's basement, filled by an above-ground jet pump.



2. Treatment and Potable Use

Pressurized water is supplied on demand to fixtures in the house through a purification system, which consists of three cartridge filters, a UV disinfection unit and a granular activated carbon filter.

The wastewater from the bath, shower and bathroom sinks is treated by the Nexus eWater graywater treatment system. The water from the kitchen sink and dishwasher is classified as blackwater due to the high level of organic compounds, nitrogen and phosphorous. This wastewater is first treated by a grease trap, then routed to the constructed wetland.



3. Graywater System

The graywater first goes through the *eWater Collector*. The *NEXtreater* treats graywater to the NSF 350 standard, rendering it appropriate for a variety of non-potable applications. Treated graywater is stored in the *NEXservoir* for future use.



4. Graywater Reuse

Treated wastewater from the *NEXservoir* is reused in the washing machine, the toilets and outdoor spigots, pending approval by local regulatory officials. Used water from the washing machine is routed to the constructed wetland.



5. Constructed Wetland

An engineered wetland treats wastewater from the washing machine, dishwasher and kitchen sink. Contaminants are removed from the wastewater as it drains through layers of plants and soil before re-entry into the environment.

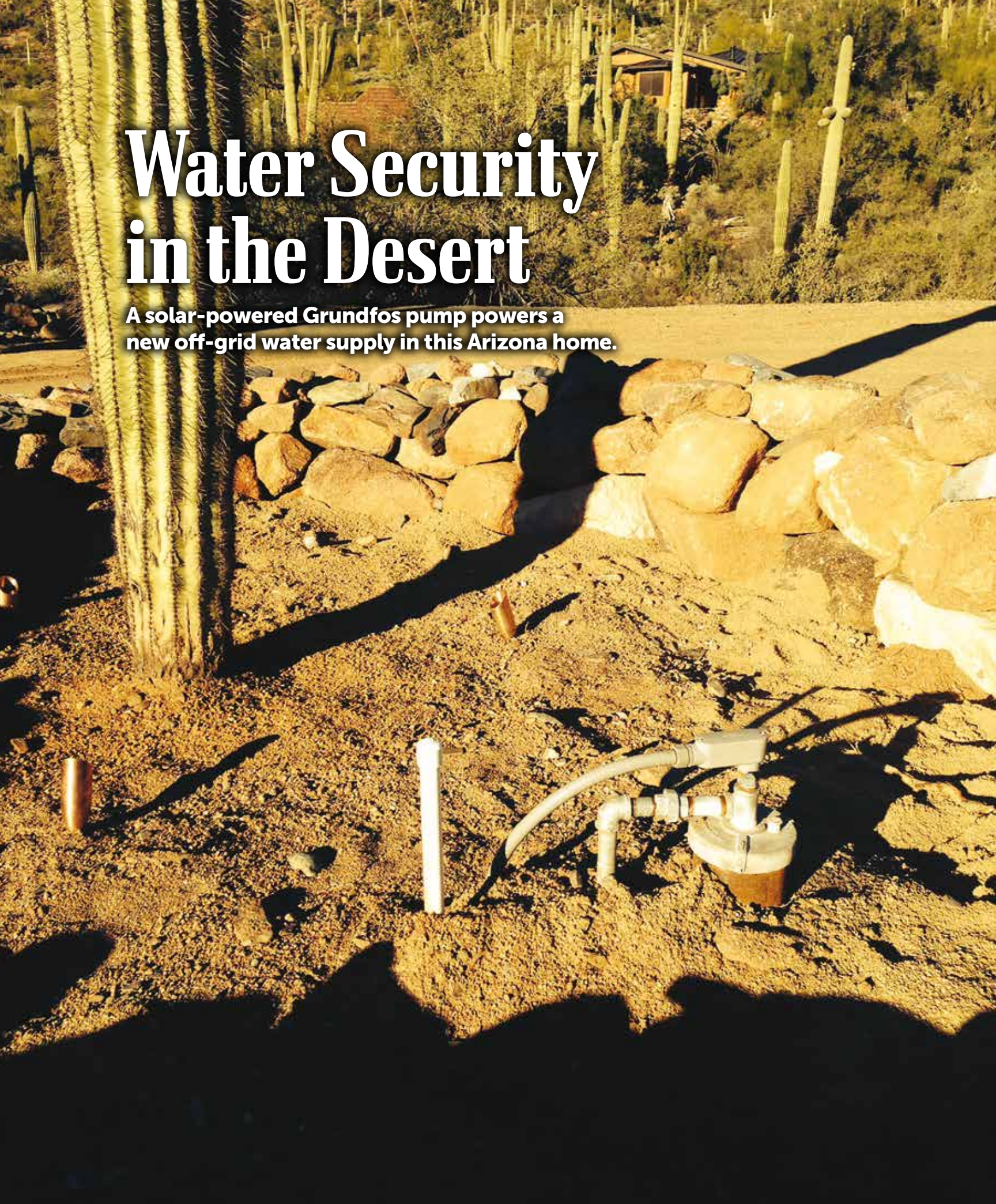


6. Composting Toilets

The toilet system is separate from the rest of the water cycle, except for a very small percentage of treated graywater. A composting system replaces the existing toilets and feeds into a composter in the home's basement.

Water Security in the Desert

A solar-powered Grundfos pump powers a new off-grid water supply in this Arizona home.



STEVE GOLD'S DECISION to take his remote Cave Creek, Arizona, home completely off-grid came from a desire to be prepared for a major power outage, whether caused by a natural disaster or grid failure. Although his water supply was a free community well, he still had a \$900 annual electrical bill for his portion of the pumping. So he decided to dig a new well and power it with a sun- and wind-powered pump.

What appeals to Gold about having his own water supply is a combination of self-sufficiency, unlimited water and free energy for operating the pump. While battery maintenance isn't "really a big deal," battery replacement, if needed, is expensive. Also, distilled water must always be in ready supply to keep the batteries topped off, Gold adds.

Gold says it was well worth the \$2,500 cost to hire a hydrologist who was able to help pinpoint a location prior to well drilling, which meant "we were able to drill a 10 GPM well the first time." The Grundfos *SQF 2* was selected for its dual voltage AC and DC and the ability to pump from 350 feet deep. "Our well is 450 feet, and the pump sits at 350 feet," Gold explains. The *SQFlex* can be combined and adapted, according to the conditions of the installation site. The pump's backup battery system can store any extra energy generated and take over when the primary source is not available.

The first battery bank was four batteries totaling 48 VDC (volts of direct current), but Gold says this became problematic during the night: if the voltage ran down to 38 VDC, the system would turn off. The addition of a second battery bank of 48 volts wired in parallel now provides plenty of power during the night to run the pump.

As for the steep upfront investment, Gold explains: "The way I see it, this setup currently produces free water. The initial investment of \$18,900 may seem like a lot; [if I] divide this by my old \$900 electric bill, it would take me 20 plus years to recoup the investment, but this wasn't my primary goal of going off grid."

Gold admits that one of the biggest challenges was the elimination of *E. coli* from the water, a procedure that involved shocking the well with bleach, and which was finally successful



Workhorse. The Grundfos *SQFlex* water supply system is fitted with a permanent magnet motor, which enables the efficient use of energy from a wide range of supply options. It's an ideal solution for remote areas like Cave Creek, where water is scarce. www.grundfos.com

after three attempts. To ensure water quality and safety, Gold advises others to test the new well water, shock it with bleach and set up at least an inline whole-house filter for sediment.

"As long as there is daylight and charged batteries for night, the reliability of this setup is 100 percent," says Gold.

Gold still plans to achieve energy independence for his home. As a step in that direction, he recently installed an OutBack Power Systems *Radian* system for his garage workshop, which enables it to function 100 percent off grid. The setup allows Gold to operate an air compressor, LED lighting and general electrical outlets in the workshop. "Eventually we will tie this into the house," Gold adds. "One hour at a time."

The Price of Independence

Cost breakdown for Steve Gold's well and solar-powered pumping system

Hydrologist to pinpoint drilling of the well	\$2,500.00
Well drilling	\$7,500.00
Grundfos pump <i>SQF-2</i>	\$1,700.00
Grundfos 200 controller	\$300.00
3 250-watt solar panels	\$600.00
8 12-volt deep-cycle batteries (2 banks of 48 VDC in parallel)	\$800.00
Charge controller	\$300.00
OutBack Power Systems inverter	\$1,700.00
Installation of well pump, piping and pressure tank	\$3,500.00
Installation of batteries, panels and controller via friends and family	\$0
Total cost of system	\$18,900.00

Good Neighbor

Brookfield Residential built its PureBlue Home in the Washington, D.C., metro area to demonstrate a net-zero-energy and water-efficient home with mass-market appeal.

IMAGE CREDIT FOR ALL PHOTOS THIS SECTION:
BROOKFIELD RESIDENTIAL





Marketing Strategy. The PureBlue Home's open plan is appealing to a range of potential homeowners, as is the prospect of low water bills and nonexistent energy bills.

AS A COMMUNITY homebuilder and land developer with a presence across the country and in Canada, one of Brookfield Residential's biggest objectives had been to find new ways of becoming a more sustainable company. What resulted was the PureBlue Home, a concept home in the Washington, D.C., metro area completed in March this year. The main goal? To design a home with zero energy bills and reduced water demand. With a HERS score of -1, the house has already demonstrated high performance.

"The challenge of building a net-zero house in a standard community—that's a big challenge. And in a mixed climate, that's an achievement in itself," says Mark Leahy, president of Pinnacle Design and Consulting and architect for the PureBlue Home.

Although the team had a lot of flexibility to play with the design, it was Leahy who helped narrow down what has become a very popular floor plan for the demo house.

In the case of community housing, one of the first goals was to fit a super energy-efficient (net-zero-energy, in this case) design into the parameters of a standard lot. Because the team also wanted to focus on livability and to create a design that was truly replicable, the PureBlue Home became an open plan.

"It's easy to do a one-off, but how do you get that mass-market appeal?" says Leahy. "We wanted to focus in on how folks really live, how to make it more livable, like with the floor plan. People

don't really use a formal living room and dining room anymore, so we designed a great room, a large central space with nine-foot ceilings."

The 4,033-square-foot home includes three bedrooms, with the option for a fourth. In addition, the house features a home office tucked away from the main space—a necessity for the increasing number of people working from home. "And if you can keep people off the roads, you're using less fuel for cars," adds Marc Dalessio, production manager at Brookfield Residential.

The PureBlue team tried to achieve net-zero energy without "throwing a bunch of technology into the game," says Leahy. "Part of the design involved making the energy envelope as tight as possible. So we created a simple box to seal up any penetrations into the house." The footprint, essentially a simple rectangle, also conserves materials.

Once the lot and orientation were determined, the team needed to decide on the optimum number of windows to best balance daylighting and solar gain. "In a community, you have a house on either side of you," Leahy explains. "You don't have an open view for solar heat gain, unlike being near a field or something. We had to determine if we could get enough light for solar heat gain, especially because of the shadow of the house next door."

NET-ZERO STRATEGY

The PureBlue Home features structural insulated panels (SIPs), which eliminate thermal bridging and help create a tight envelope. Sample panels are even on display in the model home to help visitors

continued on page 48

(LEFT) Demonstrating Savings. Captured rainwater and filtered graywater feed an efficient Rain Bird drip irrigation system, which waters the drought-tolerant landscaping in this D.C.-area demonstration home.

understand exactly how the house achieves its net-zero energy goal.

The home also incorporates a reflective low-E housewrap, triple-pane low-E windows and an energy recovery ventilator, or ERV.

The PureBlue Home's water-saving strategies run the gamut from efficient fixtures to recycling. The home features Kohler touchless toilets and Delta touchless faucets. *Rainwater HOG* storage tanks collect both graywater and rainwater, which supply a drip irrigation system. Porous pavement made from recycled tires minimizes stormwater runoff. To minimize landscape irrigation, the team used plants native to the area, including drought-tolerant shrubs.

Solar panels, LED lights and low-VOC products had all been used in previous Brookfield test homes. However, dropping costs allowed for more LED lights. The tight envelope called for greater use of low-VOC products, and the net-zero energy goal required the use of solar panels on a much larger scale.

Because Brookfield had to work within the parameters of a housing community, Dalessio says it made sense to stay on grid and work with the utility company. "That saved us the costs of buying a large battery supply. Off grid is a great concept for more remote areas where utilities are not as reliable. But as batteries become more efficient and the price goes down, it would make more sense to have a battery system and use it to charge your home. But for this house, it made most sense to connect. And as these are communities outside the city, there's lots of commuting, and the residents can charge their electric vehicles with the grid supply," Dalessio says.

FUTURE PLANS

While the various sets of data (including electric, gas and water usage) are being gathered, the PureBlue Home is likely to remain



Going Below Zero. A 9.95 kW array from SolarCity helped the PureBlue Home earn its -1 HERS rating.

open to the public for as long as possible.

Currently, Brookfield is adapting the open floor plan, which has received much positive feedback, to work in a community house that would not yet include the sustainable features of PureBlue Home.

"Those may or may not be added to Blue Program. It's still early to see what makes sense, because we know there will be cost premiums on the technologies. Customers have options for an upgrade on how green they want to be, but the PureBlue Home, as of now, is just a lab home to learn what does work," Dalessio says. **GB**



Second Life. Graywater from bathroom sinks, showers and the washing machine passes through the multiple filters of the Aqua2use system before being stored in *Rainwater HOG* tanks located under the deck.