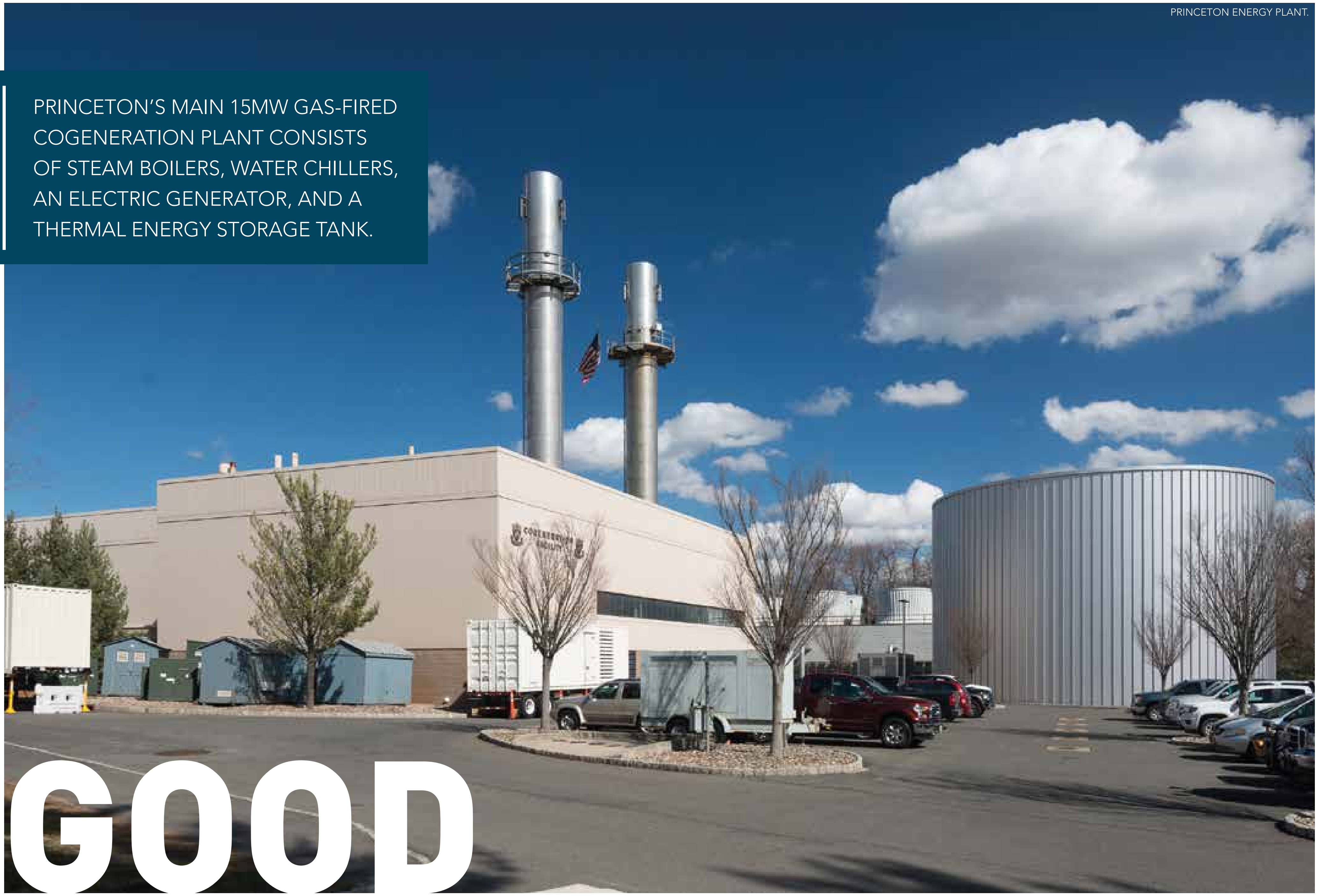
PRINCETON ENERGY PLANT.

PRINCETON'S MAIN 15MW GAS-FIRED COGENERATION PLANT CONSISTS OF STEAM BOILERS, WATER CHILLERS, AN ELECTRIC GENERATOR, AND A THERMAL ENERGY STORAGE TANK.

GOOD NEIGHBOR

Sustainable Business Magazine speaks to Ted Borer, Energy Plant Manager at Princeton University, about natural disasters, economic dispatch, and the community benefits of microgrids.

The story of district energy at Princeton University goes back to the 1860s, when Princeton began using coal-fired boilers to produce steam and distributed it to a dozen buildings. By the 1890s, the university began using a back-pressure steam turbine to generate electricity, sending the steam out at a lower pressure, and using the electricity to power lighting. For much of the twentieth century Princeton ceased onsite generation and purchased power through the public utilities, though in the 1960s the campus brought in central air conditioning, with steam-turbine-driven pumps in a chiller plant.

By the 1980s, however, Princeton's sixty-year-old boilers had come to the end of their useful life. "The question was: Do we rebuild the boilers?" says Ted Borer, Energy Plant Manager at Princeton University. "Looking at the spark spread over a number of years, it became obvious that the most financially attractive lifecycle was going to be building a CHP plant."

Today, Princeton's main 15MW gas-fired cogeneration plant consists of steam boilers, water chillers, an electric generator, and a thermal energy storage tank. There are also back-pressure steam turbines elsewhere across campus. The chilled water plant from the 1960s remains, in an upgraded form. "It was originally all steam-driven," says Mr. Borer. "Now as we've grown we've added a lot of electric-driven machines and reduced a couple of the steam driven machines, which gives us the flexibility on most days to pick whether we'd like steam-driven equipment or electric-driven equipment, allowing us to economically dispatch those assets. We also added thermal storage in 2005, which allows us to buy more inexpensive electricity at night or weekends, and to shut down our electric-driven equipment when electricity's very expensive."


MR TED BORER, ENERGY PLANT MANAGER AT PRINCETON UNIVERSITY.

HURRICANE SANDY

The resiliency of the system was dramatically put to the test during Hurricane Sandy in 2012, when much of the Eastern seaboard was out of power for days. "The State of New Jersey was largely dark," says Mr. Borer. "Because of our system, we were able to run the campus using our gas turbine in a co-gen mode, and were able to provide steam and chilled water. We scaled back some of the loads so the demand was less than what we might need on a peak day, but we were able to keep all the core business running throughout the entire storm."

As well as preserving research, some of it decades in the making, and avoiding the shutdown of any mission-critical activities, Princeton's functioning heating, cooling, and electricity allowed them to contribute to the community-wide recovery efforts. "One thing that might not be obvious about having a microgrid is that, though it helps you take care of yourself, it can also help your neighbors," says Mr. Borer. "We were able to be a place of refuge for the first responders who were out there helping the community, so they had a place which was clean, well-lit, and warm, where they could get a meal and have meetings and recharge their cellphones and their radios. We were also able to offer the community a big gymnasium where we set up a lot of beds, where people could stay if the power was off in their homes." ▶


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RELIABLE EMERGENCY SYSTEM

During Hurricane Sandy, Princeton discovered a significant benefit of a district energy system compared to backup generation systems. "If you have a diesel generator which is only for emergencies, and you kick it on during an emergency, it'll probably work," says Mr. Borer. "But maybe it hasn't been maintained recently, or maybe you tested it but you didn't run it for six hours, or even thirty hours. And it turns out the radiator is clogged with dirt, and when you run it for thirty hours, it overheats and fails. But if you run it every day, for revenue and savings, it will be ready when you want it. We witnessed that with the hospital down the street. Their emergency generator ran fine for a while but failed over time, and they nearly had to evacuate the hospital, because it was only an emergency asset, not a day-to-day asset. The advantage of a microgrid with CHP is you run it every day, and in doing so you exercise the equipment."

ECONOMIC DISPATCH

The Facilities Engineering team at Princeton run their CHP plant every day using a sophisticated economic dispatch system, combining analysis and real-time data to determine which assets to use for best economic benefit. "The system is always asking: 'Is it more cost-effective to run a steam-driven chiller or an electric-driven chiller?'" says Mr. Borer. "'Should I burn natural gas or diesel fuel? If I'm running two identical chillers, should I run one at a hundred percent and one off, or is it more efficient to run one at eighty percent and one at twenty percent, or both at fifty percent?' We don't look at just the design numbers for those two chillers, but we actually do real-time measurements. Maybe this one ran on a really dusty day, and that one ran on a really clean day. Or this one got cleaned and that one didn't get cleaned. They're going to perform differently. We do real time measurement of the efficiency of every major piece of equipment, so even two identical chillers will get dispatched at different load points because of their most recent performance."

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"WE HAVE 180,000 DIFFERENT DATA POINTS WHERE WE'RE MEASURING TEMPERATURES AND PRESSURES AND HUMIDITIES ALL ROUND CAMPUS."

On the demand end, the team at Princeton Facilities Engineering also maintain a constant stream of real-time operating data. "We're looking for things like simultaneous heating and cooling," explains Mr. Borer. "Looking for one piece of equipment that trends very differently than others and asking what's wrong with it. We have 180,000 different data points where we're measuring temperatures and pressures and humidities all round campus."

This economic dispatch system has benefits for the grid overall. "When we generate as much power as we possibly can on a peak day, effectively we're unloading the power grid at the time when it's most stressed, and we're avoiding asking the utility to run their least efficient and most polluting equipment," says Mr. Borer. "Then when we buy power in the middle of the night, we tend to be loading up the base load equipment, which is primarily nuclear and very low carbon footprint."

IMPROVING, EVOLVING

The Princeton Energy Plant is in a state of constant evolution. "If it's broken, we look for ways to fix it so that it won't fail the same way again; if it is working, we look for a way to make it more efficient or reliable," explains Mr. Borer. "We've changed boiler feed pumps and retrofit them with variable frequency drives, and we've used a new style of pump, so now what used to be a sixty-horsepower pump is only a thirty-horsepower pump, but it's running on a variable frequency drive so it uses even less than half the energy that it used to. We've added what we call a free cooling heat exchanger that can either run in series with one of our chillers or by itself. A chiller normally uses a cooling tower to reject its heat to the environment, and then the ▶

COGENERATION FACILITY STAFF

PRINCETON ENERGY PLANT MAIN SYNC PANEL.

PRINCETON'S CHILLED WATER PUMPING SYSTEM.

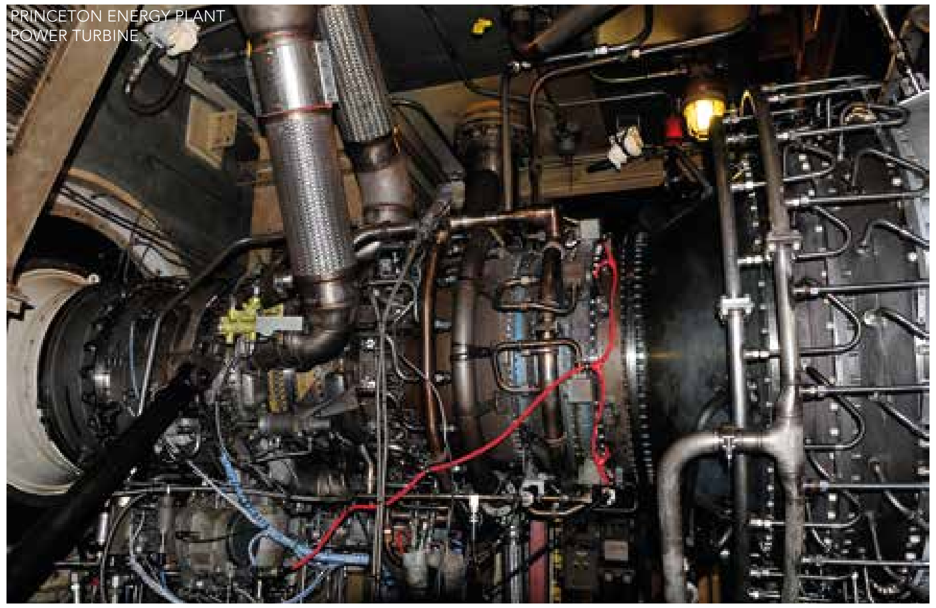
chiller runs a refrigeration compression cycle to cool off the water. But if it's cold enough outdoors, you can just run cold cooling tower water through a heat exchanger and cool off the chilled water that way. And it uses much, much less energy. We've also figured out a way we can run the heat exchanger in series with chillers, allowing the heat exchanger to do work on a much warmer day than we could if the heat exchanger was doing all the work, which increases the period of time we can do free cooling. We're using way less electricity in the chilled water plant this winter than we did in previous winters."

COLLATERAL BENEFITS

On the demand side, Princeton is tightening up their buildings' energy consumption. "Since we last spoke, the university has launched itself well into a process of changing over 100,000 lightbulbs," says Mr. Borer. "That saves us not only kilowatts and kilowatt hours, but the LED lights need to be changed a lot less frequently. So that's a hundred thousand ladder climbs that you don't need to do, and you're not risking a person falling. Your injury rate goes down, and the maintenance time goes down too. It all adds up."

"When you look at the whole process, some of these things which might be done just to reduce carbon footprint, they have two or three other layers of benefit," says Mr. Borer. "For example, right now we're in the process of buying new air compressors. The old ones are 20 years old; they've come to the end of their effective life. But we're buying new ones with variable frequency drives. They're going to save us a whole lot of money from energy, but also the plant becomes quieter. That just lowers the environmental stress in the plant. You can think in terms of collateral benefits. You do something wrong, there's often collateral downstream damage. When you do something right, there's often unanticipated benefits which surprise and delight you."


PRINCETON ENERGY PLANT GAS TURBINE.


PRINCETON ENERGY PLANT POWER TURBINE.

SCALABLE TECHNOLOGY

Beyond the boundaries of the campus, Mr. Borer sees the next step as being the widespread adoption of microgrids and CHP in cities across North America. "When you've got population density, if you can put up a power plant that is an appropriate scale for that community then you can really double the efficiency, because you're going to make electricity and then distribute thermal energy," says Mr. Borer. "The challenge is you need courage. You need to make a decision that might be a 20- or even a 50-year decision, and if you're focused around the next "quarterly earnings call", the next annual report or the next 3-year period, you're anti-motivated to do these things. But if you can think about the lifecycle of the process, it's by far the best financial decision."


PU'S SOLAR COLLECTOR FIELD (SCF).

"All this stuff scales up; all this stuff scales down," says Mr. Borer. "All these things can be impactful on a national and global scale, and they really all translate down to the residential scale. I say that having put a lot of my own personal money into it at my home. A lot of these pencil out with a 5- or an 8-year payback. And if I look at my youngest child and realize I'm going to be in the house for a decade, it's a no-brainer. It's financially attractive, and incidentally I'm reducing my personal carbon footprint. From a business continuity standpoint, it can't be about extracting the most possible money in the next three months or three years. If you want business continuity, look ten, twenty years out. With that kind of courage, we all win." □


PRINCETON CAMPUS.