ENERGY FOR EVERYONE
propane

The Ultimate Guide to Commercial Generator and CHP Retrofits

ADDING RESILIENCE WITH HIGHER PERFORMANCE.

Propane Education & Research Council

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Protecting the safety and security of your project

Commercial building owners and operators are making great strides in improving the energy efficiency of their buildings, but another central component of building performance stands in stark contrast: the reliability of the power supply.

A 2022 report from the North American Electric Reliability Corp. (NERC) found that large portions of the country are at risk of blackouts as higher temperatures lead to more demand for energy. Commercial and industrial companies are feeling the impact, with 44 percent of companies in one survey reporting power losses at least monthly.

For many businesses, those power losses can be catastrophic. A loss of power can impact vital systems like smoke, fire, elevators, refrigeration units, heating and cooling equipment, health and safety equipment, communications, and many other applications. A business without power might lose customers to the competition, risk its reputation, and lose the confidence of employees and clients. There are financial risks as well: the cost of lost inventory such as perishable foods, lost wages and overtime, and accommodations for inconvenienced customers.

Just as businesses and organizations are battling higher energy costs by improving the efficiency of their buildings and equipment, building owners can also take the resilience of their power supply into their own hands with on-site power generation. Propane standby generators and combined heat and power (CHP) systems provide a backup source of power for a building's electrical loads when the power grid is interrupted.

In some types of projects, backup power is mandated by building codes and standards. In those cases, energy and facility managers may seek to upgrade their backup power solution by minimizing carbon emissions or using a resilient, on-site, and low-maintenance source of fuel. In other optional scenarios, businesses might seek to enhance their resilience with a generator that protects the power supply.

In this guide, we provide an overview of propane commercial standby generator and CHP technologies that can enhance both resilience and sustainability. We'll take a look at several real-life project examples and the business cases that made standby power viable. No matter where your project is located, propane is a readily available fuel that can be immediately and efficiently converted to on-site power. Let's make a plan to protect the safety and financial security of your client or business.

Propane generators provide resilience and emissions benefits

For commercial buildings upgrading their backup power systems, standby generators are a common, proven solution. They're available in a variety of sizes and capacities, and they can use different, or even multiple, fuel sources. Important factors to consider when evaluating generators for your project include performance, reliability, and emissions.

PERFORMANCE AND RELIABILITY

Generators fueled by diesel, natural gas, and propane can all provide cost-effective standby power for commercial facilities, but each type of generator has pros and cons. Diesel generators, for example, are cost-effective for larger, single-engine applications over 200 kW. But a significant challenge for diesel systems is the stability of the diesel fuel.

Diesel degrades over time via oxidation, which leads to the formation of sediments and gum that can clog fuel filters and injectors if not treated. Diesel storage systems require either manual regimens or automatic fuel maintenance systems to keep the system reliable. The need for either automatic fuel maintenance systems or manual operations increases the total ownership cost of the diesel system, a factor to include in the evaluation of fuel and equipment options.

Natural gas and propane, on the other hand, do not have fuel stability or maintenance concerns. The biggest difference between these two fuels is that propane is stored on site, while natural gas is delivered by pipeline. In some cases, natural gas is simply unavailable, and where it is available, the infrastructure is not 100 percent reliable. Outages could occur, or some buildings could be subject to curtailment based on the utility's operating policies. Natural gas distribution will be shut down during a seismic event, cutting off supply. Propane storage provides a resilient source of on-site fuel and, in many cases, can be used in concert with natural gas in dual-fuel generators.

EMISSIONS

With many businesses and architecture, engineering, and construction firms striving to improve the environmental performance of their projects, generator emissions are another important consideration. A 2022 report from the Propane Education & Research Council (PERC), "Power Generation: The Emissions Shifting Problem," found that replacing diesel generators with propane can provide emissions benefits.

Propane engines can improve air quality by providing significant particulate matter and nitrogen oxides (NOx) emissions reductions relative to diesel, according to the PERC report. Depending on whether the engine is optimized for propane, propane generators can also provide CO_2 emissions reductions. We cover these findings in more depth on page 5.

Selecting the right CHP technology for resilience

Combined heat and power units are used primarily for their energy-efficiency benefits as replacements for high-efficiency water heaters or boilers. But some CHP units are available with black start capabilities that allow them to provide standby power when the electric grid goes down, making them effective upgrades to a building's power resilience.

Whereas diesel is commonly used for backup generators, most CHP systems use propane or natural gas to generate electricity to power a home or building while also producing hot water that can be used for space conditioning and many other building functions. CHP systems are known for their energy efficiency and environmental benefits because the heat and power are produced on site, eliminating efficiency losses from the power plant.

A report from the U.S. Department of Energy, Department of Housing and Urban Development, and Environmental Protection Agency, the "Guide to Using Combined Heat and Power for Enhancing Reliability and Resiliency in Buildings," notes that CHP systems enabled a number of critical infrastructure and other facilities to continue their operations when the grid went down during and after Hurricane Sandy.

"Properly sized and configured CHP systems can effectively insulate facilities from a grid failure," the guide says. "In so doing, they provide continuity of critical services, and free up power restoration efforts to be focused on other facilities." The guide provides insight on the requirements for CHP systems to operate independently from the grid and on evaluating CHP against traditional boilers and standby generators.

RELIABILITY REQUIREMENTS

To operate independently during a power outage, CHP systems must have four features, according to the guide:

1. **Black start capability**: Much like a car requires a battery to start, a CHP unit must have an electric signal from a battery or backup generator to start operating in an outage.
2. **Generator capable of operating independently**: To operate without grid power, CHP systems must use synchronous (rather than induction) generators, and they require additional safeguards to ensure they cannot cause safety hazards by exporting power to the downed grid.
3. **Capacity**: The size of the CHP system must be matched to the critical loads in the facility. The guide provides additional insight on the decision about whether to: a) size the system for optimal efficiency and designate critical loads that will be supplied during a grid outage or b) size the system for all of the site electrical requirements and arrange to export power to the grid or operate at partial load on typical days.
4. **Parallel utility interconnection and switchgear control**: Appropriate controls are required to transition to serve critical loads without overloading the generator capacity.

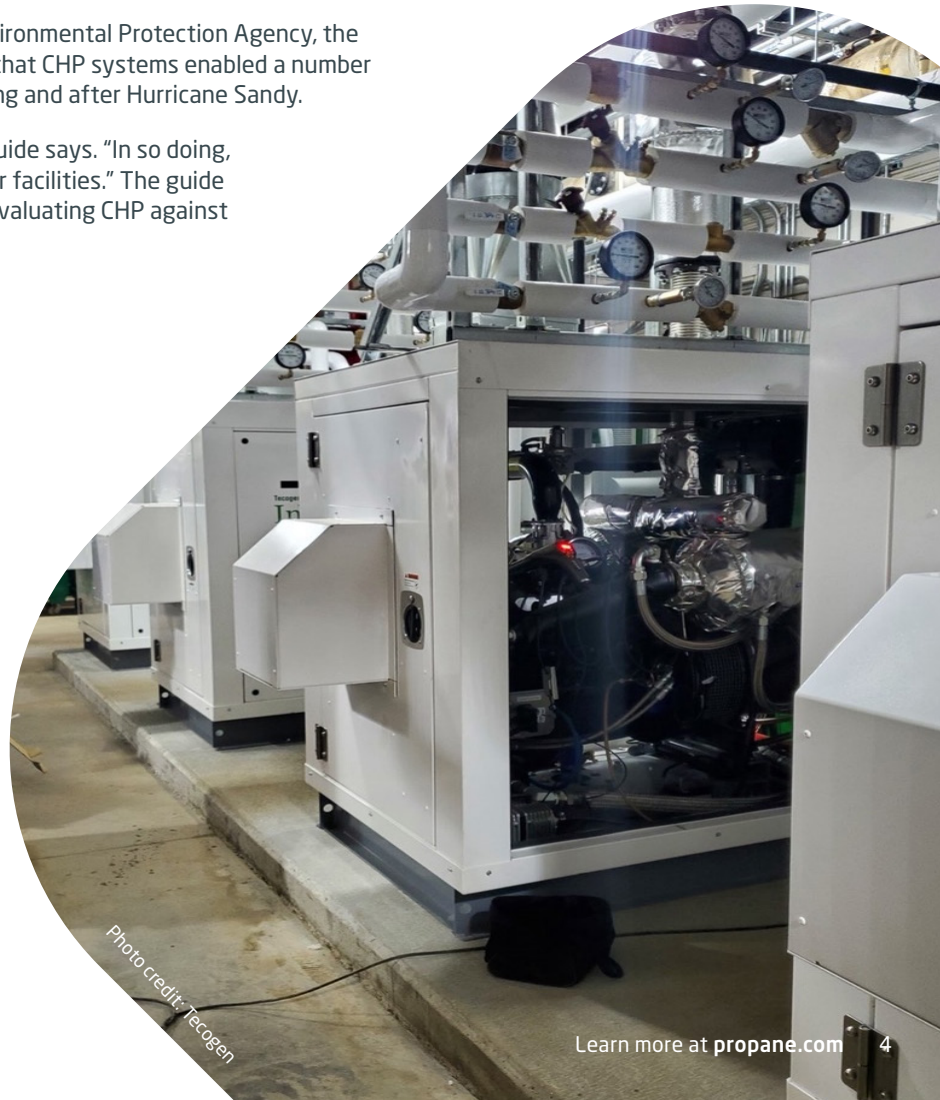

Photo credit: Tecogen

The benefits of propane generators vs. diesel

A recent report provides architects and engineers with data on the emissions performance of different types of generators.

As climate change and resulting extreme weather events wreak environmental and economic havoc on the globe, power outages have become one of the most direct and dire problems to solve.

In California, for example, public safety power shutoffs have been implemented as a stopgap measure for mitigating wildfires that have greatly intensified in recent years because of climate change. And the U.S. as a whole isn't faring much better, with the country enduring more blackouts (both unplanned and scheduled) than any other developed nation.

To deal with the increase in power outages, much of the focus has turned to power generators as a partial solution. But with all the options available, which fuel source is ideal? "Power Generation: The Emissions Shifting Problem," a recent report from PERC, sheds light on this question with evidence that shows propane can provide emissions and resilience benefits, particularly compared with diesel.

"Replacing diesel assets with propane-powered equipment will continue to push us toward significant air quality improvement and decarbonization," says Gokul Vishwanathan, author of the report and director of research and sustainability at PERC.

As architects and engineers evaluate power generation solutions that can provide resilience in the face of outages — and help in the battle against climate change — this report provides clear data to help inform their decisions. On the next page, we cover some of the highlights..

1. Propane can displace diesel generators in many markets and significantly improve air quality, mainly by lowering the release of NOx and particulate matter into the air. The use of backup generators has surged in recent years. In California, for example, the number of backup generators has increased 34 percent from 2018 to 2021 in the Bay Area Quality Management District and 22 percent from 2020 to 2021 in the South Coast Air Quality Management District, according to M.Cubed, an economic and public policy consulting group. Currently, 90 percent of the backup generators in both the districts are powered by diesel.

But this prevalence of diesel generators doesn't mean they're the best choice for architects and engineers worried about air quality. Propane engines can improve air quality by providing significant particulate matter and NOx emissions reductions relative to diesel, according to the PERC report. Depending on whether the engine is optimized for propane, propane generators can also provide CO_2 emissions reductions. (See the report for the full comparison data.)

2. Dedicated propane engines and renewable propane can help with decarbonization. Unlike generators that have been retrofitted to work with propane, dedicated propane engines are designed to work with the fuel from the start and are optimized to reduce CO_2 emissions while increasing efficiency.

And there's more than one type of propane available to put in that generator. Renewable propane, produced from renewable feedstocks such as used cooking oil and animal tallow using hydrotreated vegetable oil process, is identical to conventional propane structurally and functionally. But it can lead to a 50-70 percent reduction in lifecycle CO_2 emissions compared with conventional diesel and can accelerate deep decarbonization. And to add to the fuel's flexibility, blends of conventional and renewable propane are also practical solutions for accelerating the crucial process of decarbonization.

3. CHP solutions provide significant reductions in NOx, particulate matter, and CO_2 emissions. CHP systems generate power with higher efficiency by reusing the engine's exhaust to create heat for buildings or hot water. Propane is used for several CHP solutions in the 1 kilowatt-1 megawatt range. Typically, the engines employed have higher thermal efficiency (more than 30 percent fuel to electrical conversion efficiency), higher durability (40,000-60,000 hours), and low emissions. And depending on the unit, a 16-43 percent reduction in CO_2 emissions can be achieved.

When considering resilience, CHP solutions are a great fit for residential, commercial, and industrial applications by providing not only electricity but also heat, hot water, and cooling during power outages, depending on the model and setup. When used in CHP mode, these solutions can have more than 80 percent fuel conversion efficiency to electricity and useful heat.

In addition, propane opens the door for fuel cells, a technology that boasts high efficiency and low emissions — and that seldom runs on diesel.

For a deeper dive into these insights and more, download the full report: "Power Generation: The Emissions Shifting Problem**."**

Cumulative fleet backup generator emissions comparisons of CO_2 (figure 1), particulate matter (figure 2), and NOx (figure 3) for different fuels.

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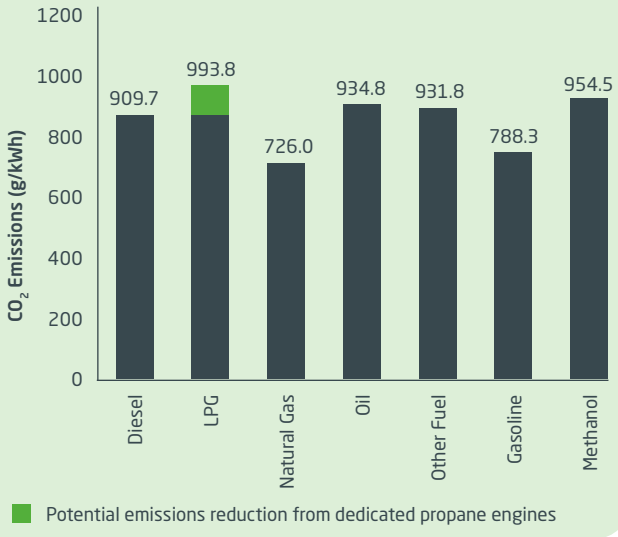

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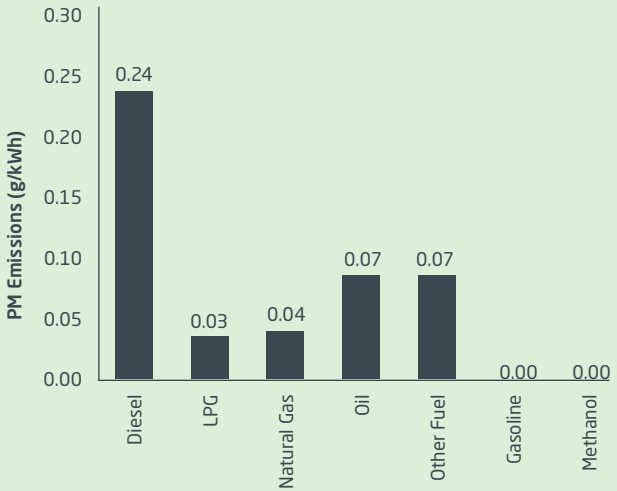

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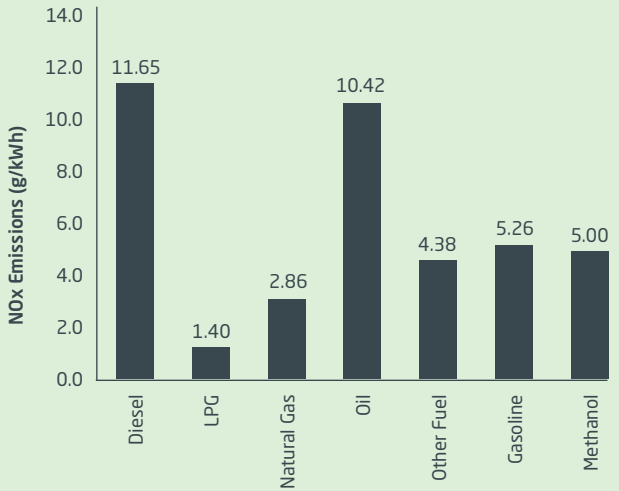

Propane tank sizing for standby generators

Learn how to select propane tank sizes and equipment to ensure resilient commercial backup power.

The rise of natural gas and propane as relatively cheap, plentiful fuel sources has created a virtuous cycle when it comes to commercial standby generators. With building operators seeking fuel cost savings and the ability to avoid the extra maintenance required with diesel fuel storage, generator manufacturers have responded with new, cost-competitive gas and propane options.

"Investments by generator set manufacturers to expand and invest in their product lineups has resulted in some positive momentum for gaseous generators in this space," says Mark Taylor, a technical marketing advisor at generator manufacturer Cummins. In fact, he says, prices for gaseous generators in capacities up to 200 kW are in line with diesel options.

For architects and engineers specifying generators in that size range, propane generators are more likely to be part of the consideration set than in the past. They're a viable option for projects without access to natural gas or in jurisdictions where natural gas solely provided by the utility isn't reliable enough for life-safety loads.

But to maximize the resilience benefits of propane generators, it's helpful for engineers to brush up on propane storage tank sizing to make sure the generators function as expected. Luckily, Taylor says, sizing and selecting a propane fuel system can be very approachable for consulting or design engineers once they start down the path.

SIZING FOR VAPORIZATION RATE

For both natural gas and propane, one major concern is to ensure the fuel source can provide adequate fuel pressure needed by the generator set at full load. When it comes to propane storage tank sizing, engineers should be careful to size the tank not only to last for the duration of an outage but also to provide an adequate vapor withdrawal rate.

Even if the tank is sized for overall capacity to meet the building's NFPA 110 Class — the minimum number of hours the emergency system should run without refueling — a larger tank may be needed to meet the generator set's fuel consumption at full nameplate rating, Taylor says. The local ambient temperatures can also impact this calculation and should be considered.

Sizing propane storage for vaporization rate is a factor that should be considered for any project using propane, notes Jim Bunsey, director of Superior Energy Systems, which engineers and installs propane systems. He recalls a correctional facility he recently worked with that doubled the building's square footage and decided to simply double its backup propane storage, from two 1,000-gallon tanks to four.

While that amount of storage would have been enough to supply the facility for a day, the boilers and other equipment in the addition required a vaporization rate higher than those four tanks could produce.

PROPANE STORAGE SOLUTIONS

Adding more or larger propane storage tanks isn't the only option. In some cases, moving a tank underground can keep it warm enough in cold climates to improve the vaporization rate. In others, engineers can turn to direct-fire vaporizers.

"It works like a water heater, except we're actually heating the propane to boil it off, to create vapor pressure so they can run their system," Bunsey says. That's the solution the correctional facility employed, allowing the facility to maintain the storage in place. For standby generators, vaporizers can often utilize heat from the generator's engine coolant.

A vaporizer can also help solve tricky engineering challenges, such as property restrictions that limit the size and placement of propane tanks. "We have found in the commercial space, real estate can be a crucial decision driver," Taylor says. "Anything to decrease the footprint of the system is always a key marketing selling point. And so a vaporizer and liquid withdrawal can get you a smaller tank."

BACKUP POWER FOR BUILDING RESILIENCE

Engineers are experts at predicting and planning for the known risks and challenges to a design, and enhancing a building's resilience is all about navigating potential risks.

"In the world of emergency backup power, your power system is as strong as your weakest link," Taylor says. "In certain scenarios, the resilience of the fuel supply could be that weak link." Buildings with diesel-fueled generators should ask how long it can take to get a fuel truck on site if a prolonged outage occurs.

Propane fits right in as a means of mitigating against the shortcomings of a diesel-only or a natural-gas-only fuel strategy, Taylor says. "Diesel fuel requires continued maintenance; it does have a shelf life," he says. "A gaseous generator set that is fueled by utility natural gas and on-site propane with automatic changeover offers the best of both worlds. Propane basically lasts the life of the tank, so adding it to the fuel readiness of utility natural gas, without the maintenance of diesel, can be a very compelling option for many end users."

And, of course, when utility natural gas is out of the picture, using propane on its own to fuel a generator set also maintains the benefits of a low-maintenance fuel, Taylor adds.

Your propane supplier or a specialist such as Superior Energy Systems can help you design your propane storage system to ensure your backup power meets your resilience expectations. And generator manufacturers such as Cummins can help make fuel selection decisions, in addition to offering online resources and technical content. Finally, check out our Ultimate Guide to Standby Power Generation for a collection of valuable resources to help create more resilient buildings.

A standby propane system consisting of a propane-air mixer and water-bath vaporizer designed by Superior Energy Systems.

Propane and solar provide remarkable savings for off-grid mining camp

Solar photovoltaics backed by a propane generator provide $3 million in lifetime savings.

Despite nearly a century of mining activity, a mining project called the Stibnite Gold Project in central Idaho still contains valuable deposits of gold and other minerals, such as antimony. Mineral exploration firm Midas Gold set up an exploration camp on the site, which it has been studying since 2009 with the goal of opening a world-class mine. The camp includes a core shed, maintenance shop, fuel depot, several office trailers, and a handful of year-round staff members.

THE OFF-GRID CHALLENGE

Midas Gold's exploration camp is remote, even by Idaho standards. Located 100 miles northeast of Boise, along the boundaries of the Frank Church-River of No Return Wilderness — the largest contiguous wilderness area in the Lower 48 — the site is "at the edge of nowhere," as the company describes it. In fact, the nearest electrical grid power is 15 miles away, in the 60-person town of Yellow Pine.

Midas Gold plans to connect to the grid when all the permits are secured. In the meantime, the camp must use on-site power generation. In the early days of the camp, that meant using large, fuel-hungry diesel generators to power the camp's lighting, computers, engine block heaters, and other essential equipment.

In addition to being expensive, the smelly, inefficient diesel units weren't a fit with the company's environmental objectives. The camp required an off-grid power solution that would reduce both emissions and costs.

THE PROPANE AND SOLAR SOLUTION

To overhaul the camp's power usage, Midas Gold worked with clean-energy consultant Kelley Dagley to design and build a new power system around two clean sources of energy: solar photovoltaics and propane.

The highly automated system is one that could be used by any business operating off the grid. The company installed a 12-kW solar array on the roof of the camp's fuel depot (the solar capacity will likely double) alongside an 80-kWh battery for power storage. A 15-kW Generac EcoGen propane generator, designed specifically to work with off-grid renewable energy applications, kicks on to recharge the battery when additional power is needed. Together, the solar inverters and propane generator provide the same peak power capacity as a full-size prime diesel generator.

"Originally, we considered a diesel generator, but it was harder to come by one that would work well with a renewable energy system, that was also affordable, and that was spec'd to meet EPA Tier 4i emissions regulations," says Dagley, who is also vice president of the Idaho Clean Energy Association. "The EcoGen is specifically designed to do exactly what we're using them for, which is a backup to solar generation. And it meets all the EPA standards."

Today, the camp is run completely on solar and propane; solar is also used to power two microwave relays and an air monitoring station. To improve the camp's energy performance, Midas Gold took a number of steps to reduce its electrical usage. Motion sensors shut off lighting when not in use, and a remote power monitoring system can shut down the power to unnecessary equipment, like engine block heaters on equipment that won't be used for weeks.

The poorly performing electric heat pump in the main office trailer was replaced with a propane furnace that performs better in cold weather. Even when the temperatures dip into the negatives, Dagley says, "It's toasty warm." In all, the camp was able to reduce its usage to about 30 MWh per year.

MILLIONS IN FUEL SAVINGS

Dagley used sophisticated solar modeling and examined diesel prices 20 years into the future to calculate the ROI on Midas Gold's investment. The results were remarkable. The propane generator itself cost less than $5,000; the entire solar and propane power system cost about $169,000. That investment yields a 27 percent tax-free dividend in the first year, growing 7 percent every year for 25 years. The capital payback is in just over two years, including a 30 percent tax credit in the first year. The company expects to save about $3 million in diesel costs over the life of the project.

Project lifetime savings:

$3 MILLION

PROPANE IMPROVES CAMP LIFE

"The quality of life around the core shed area has improved greatly," Dagley says. "It's quiet most of the time because now the propane generator comes on only as needed, plus it runs quietly. It operates at full capacity, so it doesn't have to run nearly as long — unlike the diesel generator idling 24/7, which puts out a little bit of a stink. Propane is a lot cleaner just from a usability standpoint."

MEETING ENVIRONMENTAL OBJECTIVES

In addition to reducing carbon emissions by eliminating the use of diesel fuel, the company has also reduced the chance of a diesel fuel spill while hauling the fuel alongside the East Fork of the South Fork of the Salmon River and other area streams. "Every fuel truck we keep off the road reduces risk, and we view propane transportation as a safer alternative in the event of a traffic accident," says Jeff Root, Midas Gold's land manager.

"Despite improved environmental performance by the modern mining industry, mining companies still face negative perceptions," says Bob Barnes, Midas Gold's COO. The exploration camp will serve as an example for the environmentally friendly approach the company is committed to. "As we go into the permitting process, taking a sustainable approach reflects how we want to run the project now and in the future," Barnes says.

Midas Gold staff pose with the EcoGen propane generator. From left to right: Chuck Eilers, Lead Equipment Operator; Kelley Dagley, Dagley LLC; Bob Barnes, COO; Richard Moses, Field Operations Manager; Layne Mouritsen, Field Operations Supervisor.

How the Army National Guard saves $60,000 annually with CHP

Two military support facilities in Maine demonstrate the energy and carbon emissions savings that combined heat and power systems can achieve.

A.J. Ballard has a passion for finding new ways to make his buildings more resilient and efficient.

As energy manager for the Maine Army National Guard (MEARNG), Ballard wasn't content with building envelope improvements and a solar photovoltaic installation at MEARNG's Aviation Support Facility in Bangor, Maine. Instead, Ballard has pioneered the use of micro-combined heat and power (micro-CHP) systems in MEARNG's facilities to cut energy costs and carbon emissions while improving resilience and redundancy.

Combined heat and power systems save energy and reduce carbon emissions by reusing the heat that is produced when generating electricity. Ballard worked with Dalkia Aegis, a manufacturer, developer, and installer of propane and natural gas micro-CHP systems, to design CHP systems for two of his facilities. The first, a 75-kW micro-CHP system at the Aviation Support Facility, demonstrated how much energy savings micro-CHP can achieve, says Dan Burke, vice president of sales and marketing for Dalkia Aegis.

The Maine Army National Guard's Northern Maine Readiness Center.

"We know that it's cut 30 percent of the facility's energy consumption, creating about $60,000 of savings per year," Burke says. The project, which won an Energy Star CHP award, served as a model for future CHP projects with the Army National Guard and specifically for MEARNG's new Northern Maine Readiness Center (NMRC), a 45,000-square-foot facility in Presque Isle, Maine, serving the Army National Guard 185th Engineer Support Company.

FUELING CHP WITH PROPANE

The Army National Guard has locations all over the country, and not all facilities have access to natural gas. MEARNG's Aviation Support Facility and NMRC, for example, could not access natural gas to power the CHP system, so Dalkia Aegis designed the systems to run on propane. "Propane provides that resilience factor," Burke says. "Even if there is natural gas, some of the facilities that are mission-critical could have both natural gas and propane. Our systems have the ability to run on both."

The NMRC uses two 10-kW micro-CHP units from Yanmar as the primary heat sources for the low-temperature radiant slabs used in the building, as well as for domestic hot water. The micro-CHP units are tied together with propane boilers for backup heat, with the boilers kicking in automatically when additional heat is needed or if the CHP systems go down.

The micro-CHP system also meets a new directive from the Army to provide resilience and redundancy in its facilities by providing a backup power source. If the NMRC is affected by one of Northern Maine's numerous outages caused by an aging grid or severe weather, the CHP units continue generating power to keep the facility's administrative offices functioning.

"Given the storms of the century that are now happening every year, more and more attention is being paid to the expense and the issues that occur when a building doesn't have power," Burke says. "It causes folks to reconsider how they look at resilience and backup power. A diesel generator may not do it anymore."

FEWER CARBON EMISSIONS THAN GRID ENERGY

While energy savings have historically been the primary driver for facilities looking at CHP systems, resilience and carbon footprint reduction have become more important in recent years, Burke says. He sees a common misconception among potential clients that because micro-CHP systems run on propane or natural gas, that they are creating additional carbon emissions.

In reality, because micro-CHP systems are so efficient, they can heat and power a facility with fewer carbon emissions than relying on today's power grid. "CHP is something that folks can do today that reduces your carbon footprint immediately," Burke says. That feature resonates particularly for building owners and architects working in cities where carbon emission reductions are mandated by law.

In the near future, facilities may also be able to bring cleaner fuels into the mix such as hydrogen, which can be mixed with propane or natural gas, and renewable propane or natural gas.

Architects and engineers might also be surprised by the small footprint and quiet operation of today's micro-CHP systems. A typical unit fits in a 4-by-8-foot footprint about as large as a sheet of plywood, and with noise levels around 70 decibels, they can be the quietest piece of equipment in the boiler room. That makes them a great option for facilities where lots of people are using heat and hot water, such as multifamily buildings; healthcare and nursing homes; hospitality and athletic centers; prisons; and, of course, Army bases and barracks.

"The NMRC is being used as an example with other Army National Guard bases and military installations as a positive example and something that others should do," Burke says.

At the Maine Army National Guard's Northern Maine Readiness Center, two 10-kW micro-CHP units provide domestic hot water and primary heating for the building's radiant slabs.

Q&A WITH THE DESIGNER

Check out the Studio Session interview with Architect magazine editor-in-chief Paul Makovsky; A.J. Ballard, energy manager at the Maine Army National Guard; Andy Rudnicki, senior mechanical engineer and firm associate at WBRC; and Tim Kingston, a director of R&D at GTI Energy.

Watch the webinar here.

Access additional resources on propane.com

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