## PDHonline Course E263 (1 PDH)

# Laboratories Best Practices: On Site Power Systems

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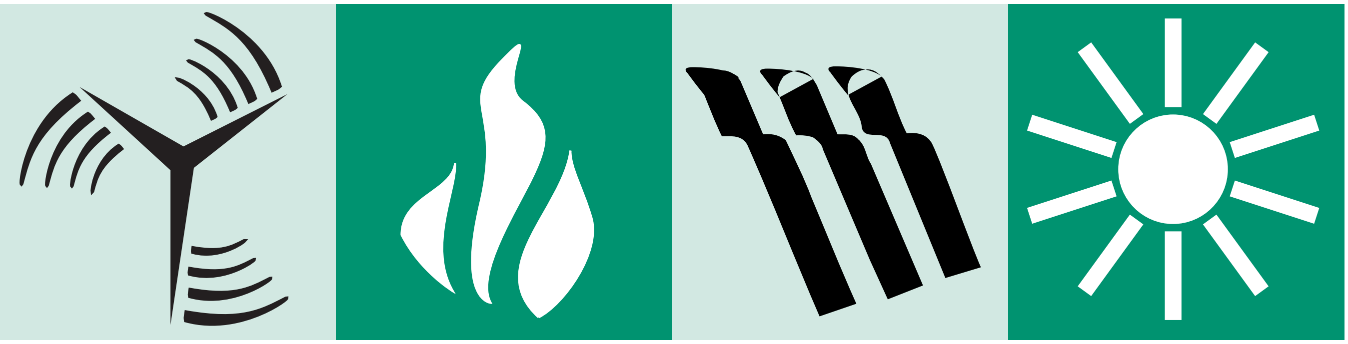

# LABORATORIES FOR THE 21ST CENTURY: BEST PRACTICES

Bernard Blesinger/PIX12552

This combined heat and power system at the Bristol-Myers Squibb laboratory in Wallingford, Connecticut, could meet 100% of the lab's power requirement, if necessary.

# ON-SITE POWER SYSTEMS FOR LABORATORIES

## Introduction

Because of their unique requirements for lighting, ventilation, and equipment, laboratory buildings use a considerable amount of energy. The reliability of that energy is very important. Laboratories must be able to conduct research without power interruptions, which can damage both equipment and experiments. Generating power and heat on site is one good way to enhance reliability; it can also improve fuel utilization while trimming utility costs.

When should laboratory managers consider on-site power generation or combined heat and power systems for their facilities? Some answers to that question are in the guidelines and "rules of thumb" presented here. Actual costs and benefits for a particular facility can be determined through a detailed feasibility study.

EPA
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Federal Energy Management Program

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A rooftop photovoltaic (PV) system produces electricity on site at the Environmental Protection Agency's facility in Research Triangle Park, North Carolina.

This guide to on-site power systems is one in a series on best practices for laboratories. It was produced by *Laboratories for the 21st Century* ("Labs 21"), a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. Geared toward architects, engineers, and facility managers, these guides provide information about technologies and practices that can be used to design, construct, and operate safe, sustainable, high-performance laboratories.

## Technology Description

On-site generation systems—also called distributed generation (DG) systems—are small, modular, decentralized, grid-connected, or off-grid energy systems. These systems are located in or near the place where the energy is used. They are also known as *distributed energy* or *distributed power* systems. Although there is no textbook definition yet for DG technologies, they are generally considered to be those that produce less than 50 megawatts (MW) of power.

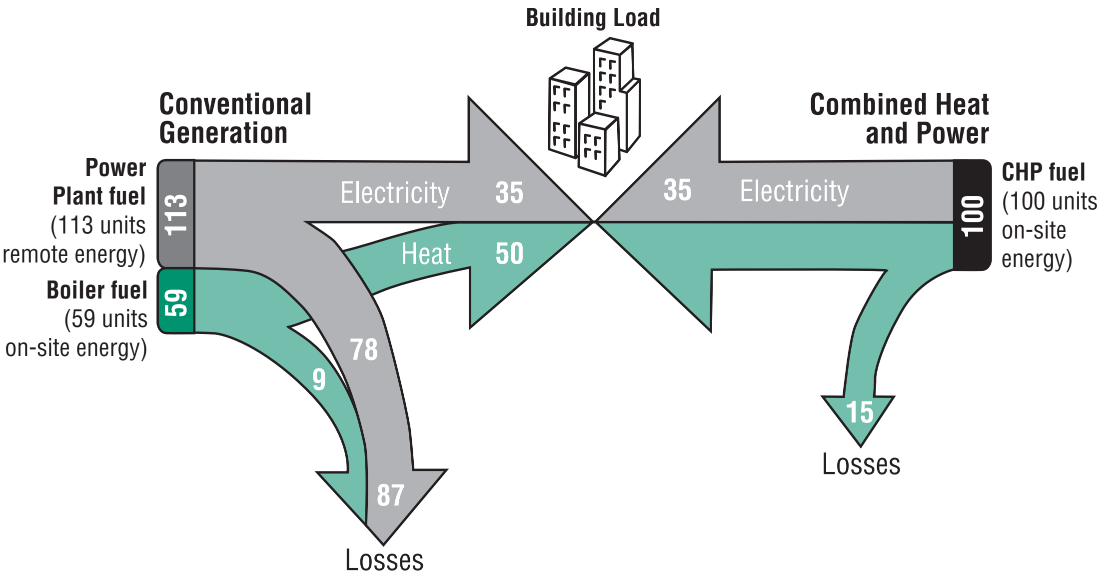
These systems can be installed on site to meet a variety of needs, such as for—

- High-quality, reliable power;
- Standby power, especially where utility-supplied power is interrupted frequently or for long periods, and where standby power is required for safety or emergencies;
- Low-cost energy, where electricity or fuel costs (or both) are high;
- Stand-alone or off-grid systems, where extending the grid is too expensive or impractical;
- Peak shaving, where demand costs are high; or
- Combined heat and power (CHP), where thermal energy can be used in addition to electricity.

Because they are installed close to the load, DG systems avoid some of the disadvantages of large, central power plants, such as transmission and distribution losses over long electric lines.

In CHP systems, two forms of useful energy—usually electricity and heat—are generated simultaneously from a single fuel source. Because CHP allows the waste heat resulting from electricity production to offset a facility's thermal energy needs, these systems are potentially 70%–85% efficient in utilizing fuels. The diagram on page 3 illustrates this. The conventional approach to meeting most facilities' energy requirements is to purchase electricity from a central utility and generate heat separately on site using a fossil-fuel-fired boiler. This approach requires 72 more units of input energy to produce the same 35 units of electricity and 50 units of heat that the hypothetical CHP system produces. The inefficiencies of the conventional approach are the result of—

- Thermal inefficiencies in the combustion process of the central generating plant;
- The inability to use the waste heat of the central generating plant (except in combined-cycle plants);



In comparison to conventional generation, combined heat and power systems are more efficient.

- Transmission and distribution losses from the central generating plant to the load;
- Thermal inefficiencies of the on-site boiler.

Because they are located close to the load and allow optimum use of waste heat, properly designed CHP systems can be more than twice as efficient as the average U.S. fossil-fuel power plant.

Laboratories in particular are excellent candidates for CHP systems, for several reasons:

- Power interruptions or power quality problems can have negative impacts on sensitive electronic

## Summary of Cost and Performance Parameters for Distributed Generation Technologies

| Technology | Size Range (kW) | Installed Cost ($/kW)[2] | Heat Rate (Btu/kWh) | Approx. Efficiency (%) | Variable O&M ($/kWh) | Emissions[1] (lb/kWh) |  | Waste Heat Temp. (°F) |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | $NO_x$ | $CO_2$ |  |
| Diesel Engine | 1–10,000 | 350–800 | 7,800 | 45 | 0.025 | 0.017 | 1.7 | 100–260 |
| Natural Gas Engine | 1–5,000 | 450–1,100 | 9,700 | 35 | 0.025 | 0.0059 | 0.97 | 100–260 |
| Dual Fuel Engine | 1–10,000 | 625–1,000 | 9,200 | 37 | 0.023 | 0.01 | 1.2 | 100–260 |
| Microturbine | 15–250 | 950–1,700 | 12,200 | 28 | 0.014 | 0.00049 | 1.19 | 400–500 |
| Combustion Turbine | 300–10,000 | 550–1,700 | 11,000 | 31 | 0.024 | 0.0012 | 1.15 | 600–1,200 |
| Fuel Cell | 5–50,000 | 5,500 + | 9,700 | 35 | 0.01–0.05 | 0.000015 | 0.85 | 140–600 |
| Photovoltaics | Limited by Available Area | 6,000–10,000 | — | N/A | 0.002 | 0.0 | 0.0 | — |
| Wind Turbine | 0.2–5,000 | 1,000–3,000 | — | N/A | 0.010 | 0.0 | 0.0 | — |

Notes:

(1) Nationwide utility averages for emissions from generating plants are 0.0035 lb/kWh of $NO_x$ and 1.32 lb/kWh of $CO_2$.

(2) For internal combustion technologies, the high end of the range indicates costs with $NO_x$ controls for the most severe emissions limits.

Source: DOE Federal Energy Management Program, *Using Distributed Energy Resources: A How-To Guide for Federal Facility Managers.*

equipment; an unexpected outage can undo months of scientific work or damage important laboratory specimens.

- Laboratories typically use more energy per square foot than commercial facilities do; therefore, on-site generation can result in substantial energy cost savings.
- Laboratories tend to have a good mix of on-site thermal and electric needs.

CHP can be more cost-effective in facilities that have central heating systems, because much of the infrastructure needed for heat and power generation and use is already there.

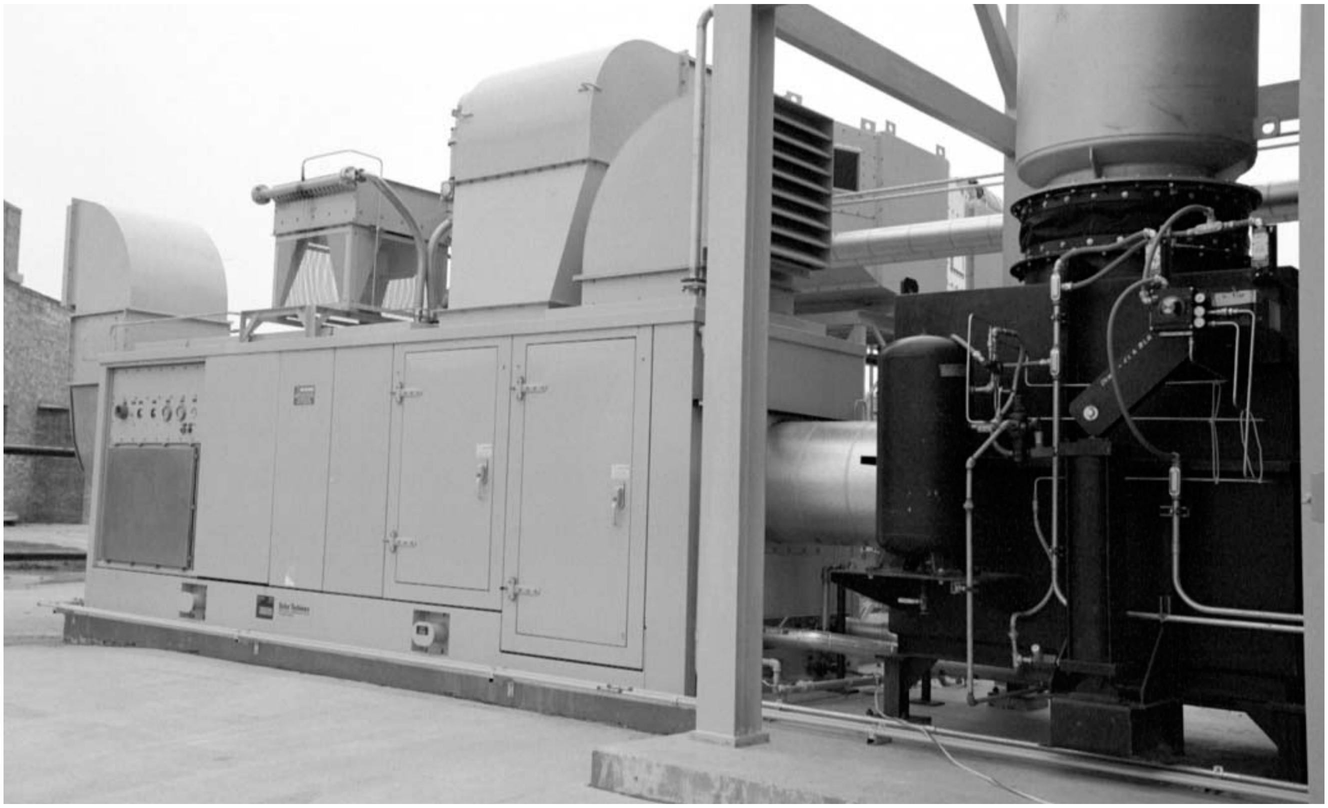
Several different technologies can be effective for on-site generation. They include—

- Diesel, natural gas, and dual-fuel reciprocating engines;
- Combustion turbines and steam turbines;
- Microturbines;
- Fuel cells;
- Photovoltaics; and
- Wind turbines.

Energy storage technologies, such as batteries and flywheels, often complement DG systems. Some systems might need a fuel storage capability, as well. Thermally activated technologies such as desiccant dehumidifiers, service water heaters, and absorption chillers are also possible components of a CHP system.

CHP systems—which can include reciprocating engines, combustion or steam turbines, microturbines, or fuel cells—may be the most appropriate on-site generation systems for laboratory facilities. However, photovoltaic systems and wind turbines can be a good choice for electric-only applications in which the attributes of renewable energy systems, such as reduced emissions, are valued. Photovoltaics produce “green” energy from the sun, operate quietly, and require little maintenance; they can also be specially designed as an integral part of a building’s roof, wall, skylight, or other element, which is known as *building-integrated PV* (BIPV). Wind turbines can be appropriate where there is sufficient land area, an adequate wind resource, and suitable laboratory siting characteristics. The table on page 3 shows some performance characteristics of DG and CHP technologies.

For more information about DG and CHP, see *Using Distributed Energy Resources: A How-To Guide for Federal Facility Managers*, on the FEMP Web site (see also page 8).



Dennis Jones, USDA/PIX12537

A combined heat and power system at the U.S. Department of Agriculture's National Animal Disease Center, Ames, Iowa.

## Waste Heat Utilization Options

| Waste Heat Temperature | Applicable Technologies | Appropriate Uses for Waste Heat |
|---|---|---|
| No waste heat needed | • Solar photovoltaics<br>• Wind power | • Not applicable |
| Low-temperature waste heat (about 140°F–500°F) | • Internal combustion engines<br>• Proton exchange membrane fuel cells (PEMFCs)<br>• Phosphoric acid fuel cells (PAFCs)<br>• Microturbines | • Domestic hot water<br>• Space heating<br>• Makeup air heating and reheating<br>• Liquid and solid desiccant dehumidification<br>• Preheating boiler feedwater and condensate return<br>• Radiant flooring<br>• Building cooling in single-effect absorption chillers |
| High-temperature waste heat (about 600°F or more) | • Gas turbines<br>• Steam turbines<br>• Molten carbonate fuel cells (MCFCs)<br>• Solid oxide fuel cells (SOFCs) | • Steam<br>• Building cooling using double- and triple-effect absorption chillers<br>• Solid desiccant dehumidification<br>• Other process uses |

## Design Considerations

When considering a DG or CHP project for your facility, always begin with a preliminary screening or scoping audit to evaluate the proposed project's cost-effectiveness. These are some design considerations to keep in mind during your evaluation:

- ***Minimize electric loads*** with energy-efficient equipment and practices before implementing CHP or other forms of on-site generation. This may allow you to specify a smaller generator and minimize the capital investment required for your DG or CHP project.

- ***Know your current utility costs***, including energy and demand costs; they help you determine whether a DG or CHP system will be cost-effective at your facility. Often, the "spark spread" between the cost of electricity and the cost of natural gas determines cost-effectiveness. But other impacts, such as power quality and emissions, should also be taken into account. The effect of the project on your facility's load profile must be carefully evaluated for savings to be estimated accurately.

- ***Consider anticipated change***s in your facility's energy requirements over the life of the DG or CHP system.

- ***Determine fuel costs and availability*** at your site; they will help you decide which DG technologies and applications are most appropriate in your area. Complete a fuel cost sensitivity analysis to see how changes in fuel prices will affect the economics of the proposed system. If possible, consider long-term gas contracts to reduce the volatility of fuel costs over time; high fuel costs combined with low electric rates make many forms of DG uneconomical. In addition, fluctuations in gas pressure, flow, and heating value must be considered in regard to fueling DG and CHP systems.

- ***Make your CHP system cost-effective*** by optimizing the amount and use of waste heat. CHP systems are usually sized to accommodate the thermal energy needs of a facility rather than the electric needs, but this is not a hard-and-fast rule. To improve a project's economics, it is important to consider every possible option for using the waste heat, such as for space heating and cooling, hot water, chilled water, steam, process needs, and other uses. See the table on this page for more information about using waste heat.

- ***Know your local air quality requirements;*** they play an important role in the selection of a technology for a particular DG or CHP application. An "air permit" may be required to construct, replace, and operate this equipment. Permits can be costly and difficult to obtain if they are not specified and planned for early in the design process. Additional equipment, operations, and material handling issues also need to be considered in areas where tailpipe treatments are required to meet air quality requirements.

- ***Investigate potential interconnection requirements*** early in the project evaluation process, because they vary from state to state and from utility to utility. It can be costly and time-consuming to delay finding out about the requirements for interconnecting a DG system to the local electric grid.

- ***Become familiar with your utility's rate structures.*** Utilities often have complicated rate structures with fixed charges, demand charges, block charges, and time-of-use rates that can affect the economics of on-site generation. For example, installing a CHP system may allow you to purchase energy under "interruptible rates" and thus save money. An interruptible rate is a less expensive rate structure, which allows your utility to interrupt your electric service for a brief time; during that time, your facility's energy needs would be met by your on-site generation system. On the other hand, potentially costly backup or standby charges may be imposed if you need electric service when your generator goes down for maintenance or repair. Not all utility rate structures are designed to provide affordable standby power service.
- ***Plan for adequate maintenance.*** On-site generation requires additional maintenance. Is your current staff capable of maintaining the new equipment? If not, consider a post-installation maintenance contract that ensures seamless operation and maintenance of the new equipment while providing training for on-site staff to maintain equipment in the future.

## CHP systems are most practical and cost-effective when—

- Electricity prices are high (more than 5¢/kWh, in general) or when most of your facility's annual energy costs go to demand charges.
- The ratio of average electric load to peak load is greater than 0.7.
- A central or district heating and/or cooling system is already in place, or there is a need for process heat (in general, hot water or steam).
- The "spark spread" (difference in price per million Btu between gas and electricity) is greater than $12/MBtu.
- The CHP system will operate more than 6,000 hours per year.
- The thermal demand closely tracks the electric load.
- High-quality, reliable power is critically important to your mission.
- Existing equipment (such as boilers, chillers, or backup/standby generators) are old, inefficient, and need to be replaced.
- New facilities are in early design stages.

Source: Oak Ridge National Laboratory

## Codes and Standards

In general, DG and CHP system installations are subject to the same permitting and evaluation process as other site or facility modifications. The National Electric Code, the National Life-Safety Code, and the International Fuel Gas, Plumbing, Mechanical, Building, and Fire Codes are the key references for local code officials. For the most part, these codes do not address some of the newer DG technologies, such as microturbines and fuel cells. And most code officials have little or no experience with issuing permits for such installations. Therefore, code officials may require a number of design, test, and documentation reviews before approving a DG system.

Several standards authored by Underwriter's Laboratories (UL), the National Fire Protection Association (NFPA), and the Institute of Electrical and Electronics Engineers (IEEE) specifically address the installation of DG and CHP systems:

***UL 2200*** is a commonly cited reference for combustion engines and gas turbines in stationary power applications. It does not specifically refer to microturbines, but it could be considered to include that technology.

***NFPA 853, the Standard for the Installation of Fuel Cells,*** provides for the design, construction, and installation of fuel cell power plants with a capacity of more than 50 kilowatts. It covers natural gas and a number of other fuel sources.

***NFPA 3***, the *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, works in conjunction with UL 2200 to apply to the installation and operation of these CHP technologies. Like UL 2200, it can be extended to microturbines.

***IEEE 1547***, the *Standard for Distributed Resources Interconnected with Electric Power Systems*, addresses technical requirements for the safe interconnection of DG systems to the local electric distribution system.

## Performance Examples

A variety of CHP projects are already operating successfully at a number of laboratory facilities across the country. Two good examples are a Bristol-Myers Squibb laboratory in Wallingford, Connecticut, and the Agricultural Research Service (ARS) National Animal Disease Center (NADC) in Ames, Iowa.

## Key Questions for DG/CHP Project Teams

### *Predesign*

First, you might want to find out if other facilities in your area have installed on-site generation. Find the contact person at each facility and ask what lessons they learned, such as—

- What did they do that helped the project along?
- What would they have done differently?

Investigating opportunities for on-site generation can involve many different specialists or contracting firms. For instance, an engineering firm is usually hired to perform the initial scoping study. Design engineering documents are put together by a qualified A/E firm. And a construction firm or general contractor is usually responsible for building the system. Many utilities also support CHP projects and can offer valuable expertise; some may offer incentives.

### *Selecting consultants*

In selecting a contractor to design and install your DG or CHP system, ask the following questions:

- How many DG or CHP systems have you designed and installed? What types of technologies and what system sizes have you worked with?
- Will you be able to secure all necessary permits and interconnection studies for this project?
- Have you ever had problems with interconnecting DG or CHP systems to the grid? Were they "showstoppers"? If not, how did you solve them?
- Who will be responsible for system maintenance?

The 4.8-MW gas turbine system operating successfully at the Bristol-Myers Squibb facility is a good model for replication. Despite relatively low energy costs at the site—about 7¢ per kilowatt-hour blended rate—the system has a payback period of just 5 years. This is because the project team paid close attention to steam loads at the facility, considering the cooling side as well as the heating side. By accounting for all the chiller plant loads and other steam-driven equipment, they were able to optimize waste heat utilization year-round for system economics. Should utility power be lost, the CHP system with backup generator sets can supply 100% of the facility's energy needs. A knowledgeable facility engineer and project manager—and reliable data—have been the keys to the success of this installation.

The ARS NADC in Ames is a major U.S. Department of Agriculture center for research on livestock and poultry diseases. A 1.2-megawatt cogeneration system at the site now provides highly reliable power and helps the NADC control utility costs in several ways. For example, by generating power on site, NADC was able to purchase electricity at less expensive, interruptible rates. Furthermore, the steam generated by using the waste heat of the combustion process is a by-product that can be used year-round for the thermal loads associated with sterilizers, hot water, and wastewater pretreatment. Using the technical resources and expertise of the unregulated subsidiary of the serving utility—while designing, installing, and interconnecting the CHP system—helped to make the project a success. Because capital funds were limited, the project was completed with financing through a "super" energy savings performance contract coordinated by the U.S. Department of Energy's Federal Energy Management Program.

## Conclusion

Installing an on-site generating system, such as CHP, can be a good way to trim utility costs and enhance energy reliability at laboratory facilities. Numerous siting, permitting, and interconnection issues can be involved. However, they do not need to be barriers for laboratories that want to control costs, reduce environmental emissions, enhance fuel efficiency, and ensure reliable heat and power for sensitive equipment and important research projects.

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