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Heat Recovery: Enhancing Payback from On-Site Prime Power

Gas-fueled engine generators are cost-effective and reliable where utility outages are common and power quality is inconsistent. Heat recovery from the prime movers can help make such installations more cost-effective and sustainable.

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Introduction

When local utility power is unreliable or power quality is suspect, on-site prime power generation with natural-gas-fueled engines is a proven alternative. Today's engine-generators produce cost-effective electricity with extremely high availability and low emissions.

In many situations, it is feasible to capture and use heat from the generating sources, making on-site generation even more financially attractive. Many candidates for self-generation are large industrial or agricultural facilities that have significant space and process heat loads. Here, hot water and steam recovered from engine exhaust and fluids can supplement existing boilers and other heat sources.

The addition of heat recovery can boost overall power system efficiency from 40 or 45 percent to 70 or 80 percent, or even higher. However, it is not necessary to invest in sophisticated combined heat and power (CHP) systems that wring every calorie/Btu from the fuel. The only requirement is that the value of the heat captured significantly exceeds the cost to install and maintain the heat recovery equipment, ensuring an attractive return on investment.

As technology steadily improves engine efficiency, reliability and reduces emissions, it is increasingly worthwhile to weigh the advantages of CHP as a component of on-site prime power systems.

Gaining Independence

On-site prime power is a viable option for many large power users, but especially where local utility grids are unstable. Power can be especially unreliable in remote areas and in developing countries facing rising demand that outstrips new supply.

Gas-fueled generators can enable industrial and commercial users to operate independent of the utility grid, or at the minimum provide backup power to sustain production through extended outages. Furthermore, reliable power with a stable sine wave protects sensitive computers and electronic instrumentation against damage that can be caused by voltage fluctuation on utility systems.

On-site generation has the added virtue of helping users lock in predictable costs of electricity production. Gas engines also help to displace carbon emissions from coal-fired utility generation by using clean-burning fuels, which can include "opportunity fuels" like landfill methane, wastewater treatment digester gas, biogas from food processing waste or manure, and others.

Proven Sources

Gas engines have proven themselves reliable as prime power sources, especially as advances in control, materials and design have enhanced efficiency, extended maintenance intervals, and boosted reliability. The latest configurations develop high power output in footprints up to 50 percent smaller than earlier-generation units, providing an excellent fit on space-constrained sites or in small engine rooms.

When maintained and operated effectively, these units routinely achieve availability as high as 98 percent, shutting down rarely except for scheduled maintenance and overhauls. Installed costs typically range from $450 to $850 per kW, depending upon system sophistication; lifetime operating costs as low as $0.06 cents per kWH are achievable.

Installation is fast and simple: complete engine-generator packages can be online and producing power within a few months from the date ordered. Multiple units can readily meet power requirements up to 50 MW; capacity can be added in increments to accommodate planned business growth. Gas engines are relatively straightforward to site and permit: emissions can meet the world's toughest air-quality regulations, in most cases without the expense of exhaust aftertreatment
Today's engines readily tolerate challenging conditions such as high altitude and high ambient temperatures. They perform efficiently in continuous, full-load operation; in intermittent service; and in following variable, cyclic loads. The technology is simple and well understood: qualified service technicians and replacement parts are easily available in-country around the world.

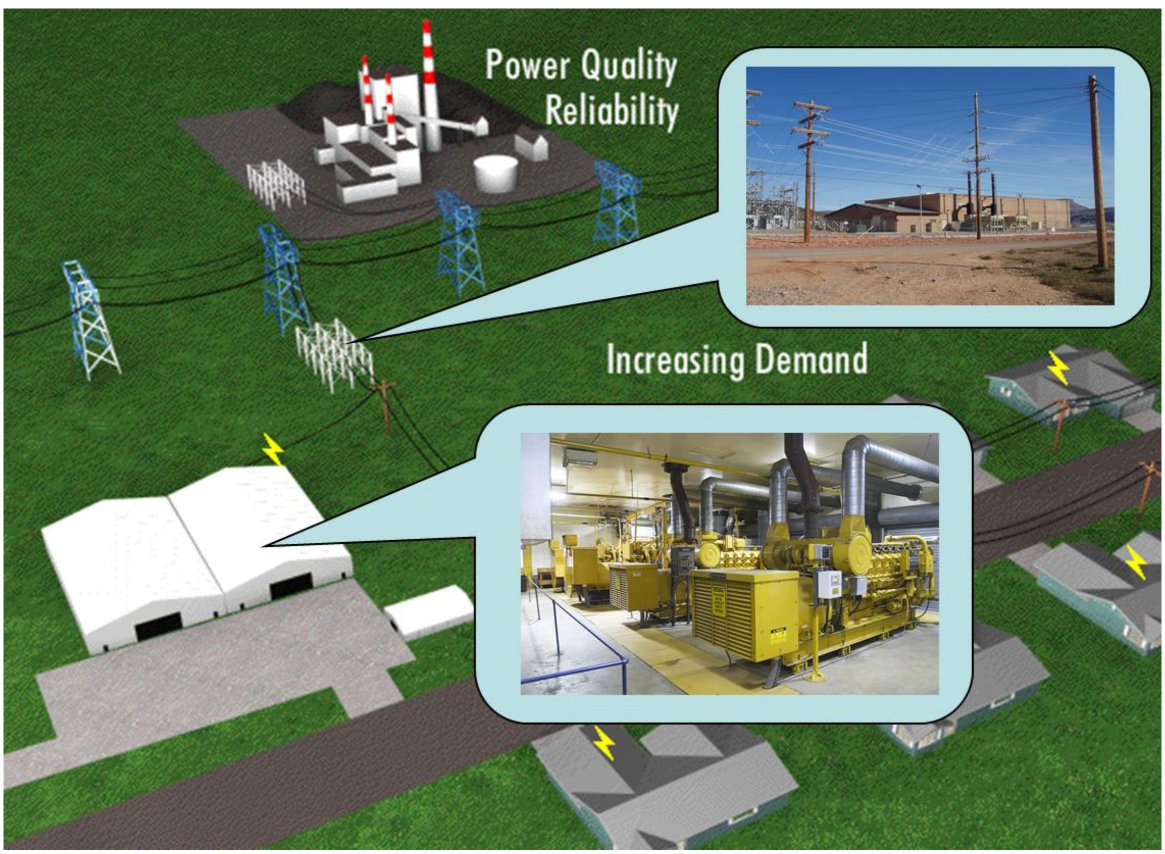

Figure 1: Small scale distributed generation is sited by electric utilities at the substation level or at the point of end use.

The CHP Bonus

CHP substantially enhances gas engines' inherent fuel economy. It can be applied not only to gas-fueled engines but also to diesel units, which have a large installed base, notably in Asia. Prospects for CHP in on-site prime power applications are best where:

- Host facility heat and electric loads occur at the same times of day.
- Generator fuel price is relatively low.
- The local, regional or national government offers financial incentives for energy efficiency projects.
- The organization needs to meet sustainability, energy efficiency, or greenhouse gas reduction goals.

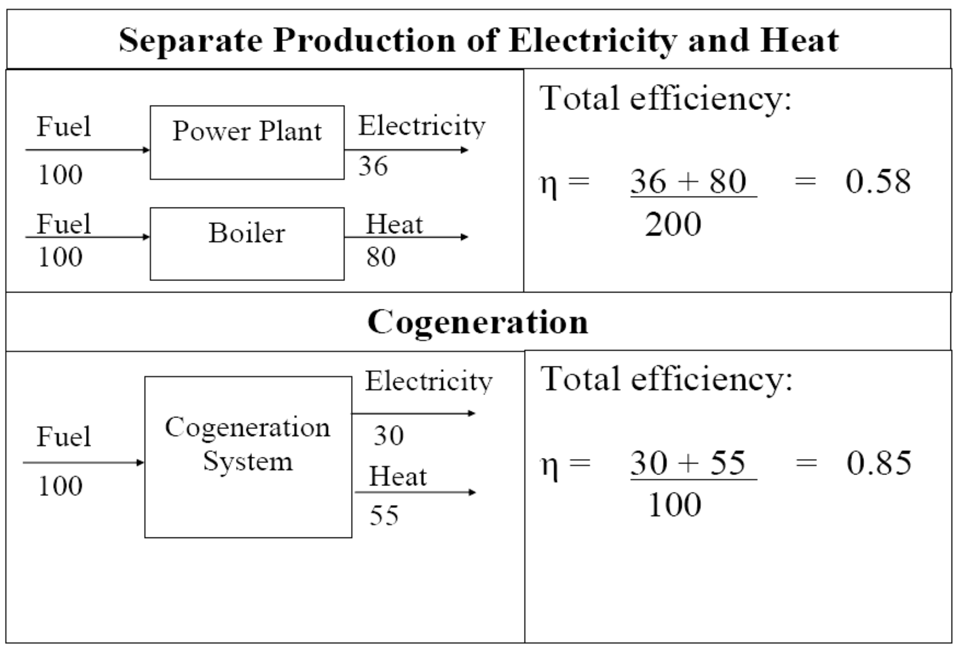

Figure 2: Comparison of total resource efficiency between a power plant and boiler vs. a gas generator set cogeneration system.

In general, CHP offers the greatest rewards where engines operate at continuous full load duty and where the site has a significant heat load. However, CHP can be economically viable in a great many other kinds of settings.

Engines offer multiple heat sources for recovery. Exhaust gas provides by far the highest temperatures and the greatest heat output. It can generate intermediate-pressure steam for purposes like boiler feedwater preheating, and low-pressure steam for sterilization, pasteurization, space heating, tank heating, humidification, and other uses.

Heat also can be extracted from the engine jacket water, oil cooler and aftercooler to produce warm or hot water for space heating and various industrial processes.

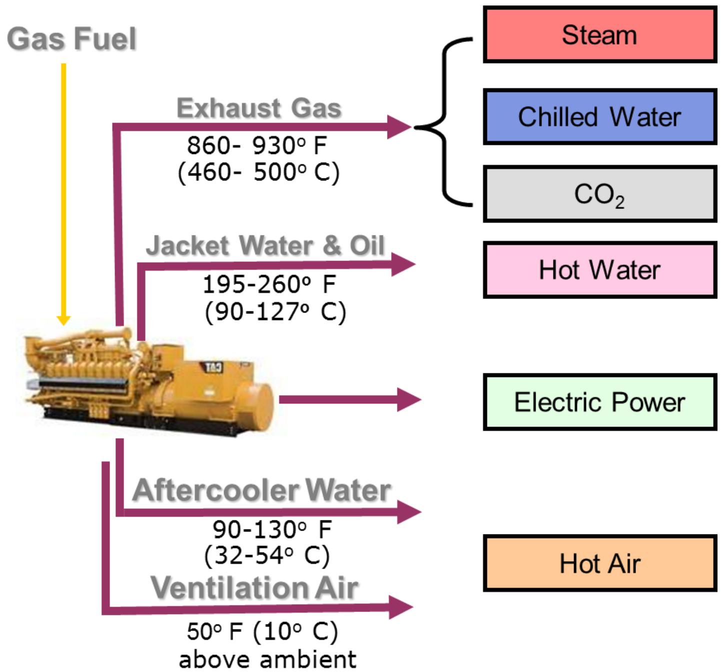

Figure 3: Engine circuits that heat can be economically recovered from with typical temperatures available.

While steam and hot water are the classic heat outputs in CHP systems, they are not the only ones: They can be converted to other forms to suit additional purposes. Steam or hot water can be passed through heat exchangers to create hot air to feed equipment such as kilns and dryers. The heated air in turn can be mixed with fresh outside air to enlarge the volume and enable precise temperature control. In addition, hot water and steam (or exhaust itself) can be passed through absorption chillers, which use heat instead of electricity as the energy source, to produce cold water for space or process cooling.

Carbon dioxide is another useful engine combustion byproduct. Engine exhaust rich in CO_2 can be cleaned in a catalyst reductor, cooled and fed to a process.

All this means great flexibility in using the products of fuel combustion. Heat-recovery systems can be configured to deploy some heat for water and steam production and the balance to absorption chillers – a concept called tri-generation.

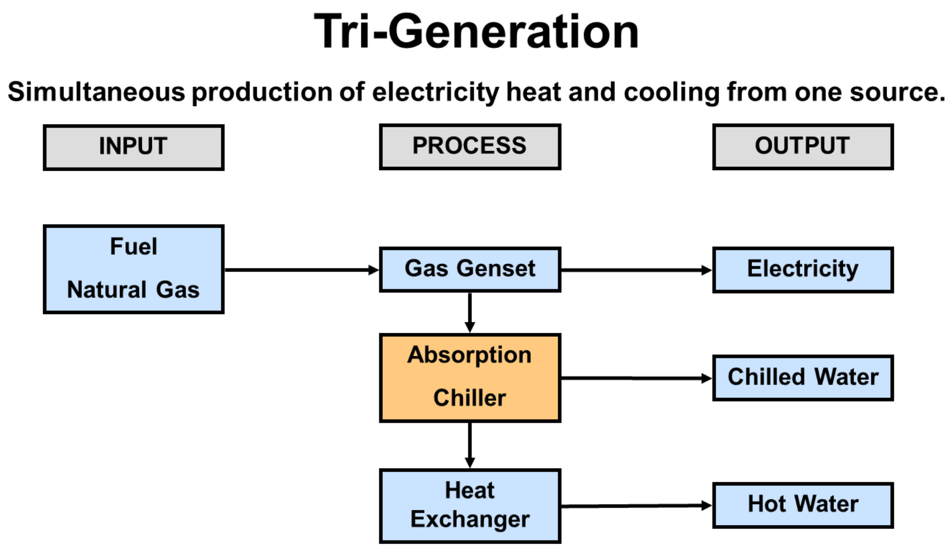

Figure 4: Tri-generation heat flow diagram.

Alternatively, systems can produce space heat in winter and air conditioning in summer. Taking efficiency to the ultimate, a single engine-generator set can deliver electricity, heating, cooling and process CO_2 – a concept called quad-generation

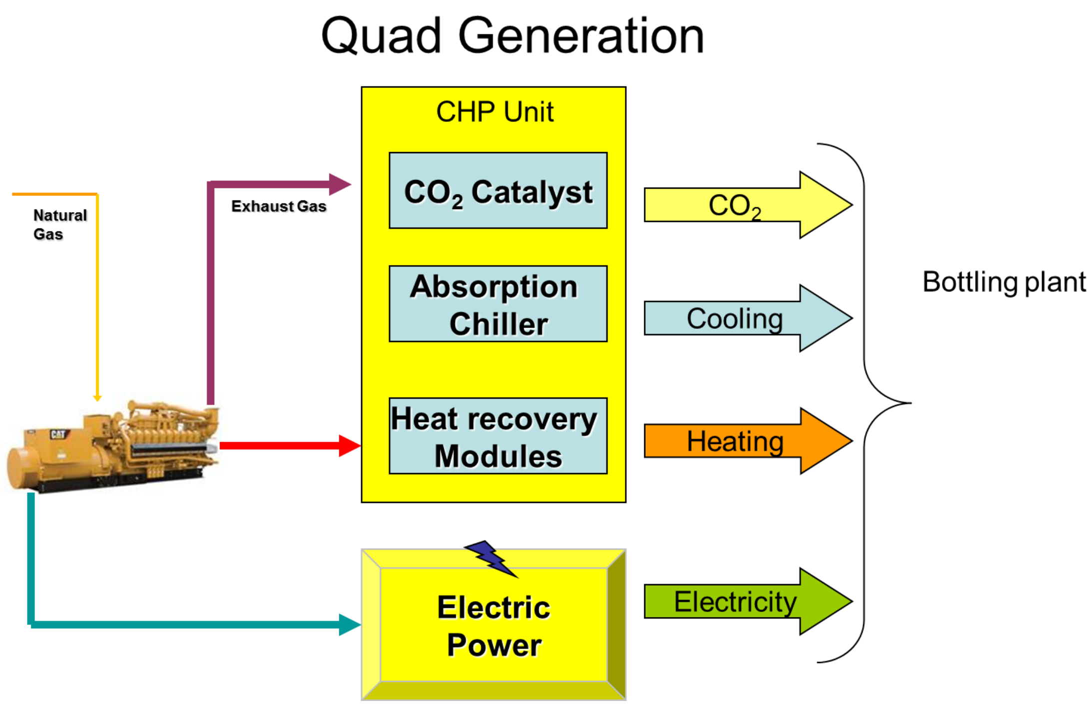

Figure 5: Quad generation is tri-generation with the addition of CO_2 recovery.

Fitting the Application

A key consideration in CHP for on-site power is which engine heat sources to tap to satisfy the heat load economically. Some facility heat loads may be too small to justify any CHP investment. On the other hand, a continuous-duty, full load power system at a major process industrial site may easily justify investment in a full heat-capture system, including an exhaust heat recovery boiler and heat exchangers for all three engine fluid heat sources. Likely candidates for this high-intensity CHP include:

- Industries such as food processing, chemicals, petroleum refining, textiles, plastics and paper.
- District energy systems serving multiple buildings with power, cooling and heating.
- Institutions such as hospitals, colleges and universities.
- Hospitality facilities such as major hotel and resort complexes.
- Wastewater treatment plants.

Sites with potential for CO_2 utilization include commercial greenhouses (to speed crop growth and improve yields) and soft drink bottling (for carbonation).

Scaling Down

In every case, the essential question is whether the economic gain from heat recovery substantially exceeds the incremental cost of the equipment. Simple and well-conceived heat recovery can improve the economics of many distributed generation projects with modest heat or cooling loads.

For example, a simple and inexpensive shell-and-tube or plate-and-frame heat exchanger in the engine jacket water circuit can produce water at 180^o to 210^o F (82^o to 99^o C), depending on the jacket water temperature. This heated water can displace some costs for boiler fuel or utility electricity. Applications for this limited, low-intensity form of CHP include:

- **Commercial real estate.** Heat recovery can partially offset the cost of fuel for space heating, water heating or dehumidification.
- **Light industry.** A small or mid-sized manufacturer could install a heat exchanger in the engine cooling loop, with a thermostatically controlled diverter valve to regulate the flow to the in-plant load, fulfilling a variable hot-water requirement.
- **Hospitality.** Captured heat can supplement hot water supplies for laundries, kitchens or swimming pool heating year-round, and help power absorption chillers or desiccant dehumidifiers in summer.
- **Food processing.** Food producers can use recovered heat for light process loads such as raising dough, or to produce hot water for cleaning and sanitizing.

When Fuel is “Free”

The ultimate cost-effectiveness is possible on sites able to produce their own fuel for prime power production. These “opportunity fuels” include landfill gas, wastewater treatment digester gas, and residual gases from facilities such as food processing facilities, livestock operations and produce farms. In each case, waste products can be anaerobically digested to produce methane fuel (biogas).

While homegrown fuel eliminates the cost of pipeline natural gas, it calls for advanced engine maintenance and operating practices or special engine design characteristics; in many cases both are beneficial. This is because biogases, depending on their source, contain acid-forming substances, grit, excessive moisture, and siloxanes (compounds found in household cleaning and personal hygiene products), all of which can shorten engine component life.

Maintenance and operating practices to address biogas fuels include:

- Fuel treatment systems to condense or screen out impurities.
- More frequent lube oil and other fluid analysis and shorter oil-change intervals.
- More frequent spark plug cleaning and replacement.
- Shorter intervals between top-end, in-frame and major overhauls.

Biogas challenges also can be addressed be selecting “hardened” engines with design features that protect against fuel impurities. Under certain conditions, these engines can operate with near-normal maintenance intervals and with less intensive fuel treatment. Engine hardening modifications include:

- Crankcase ventilation to eject acid-forming gases and water vapor.
- Elevated jacket water temperatures to help prevent condensation of water and formation of acids on metal parts. (Figure 6)
- Replacement of bright metals (aluminum and unprotected steel) with corrosion-resistant stainless steel or brass on certain components.

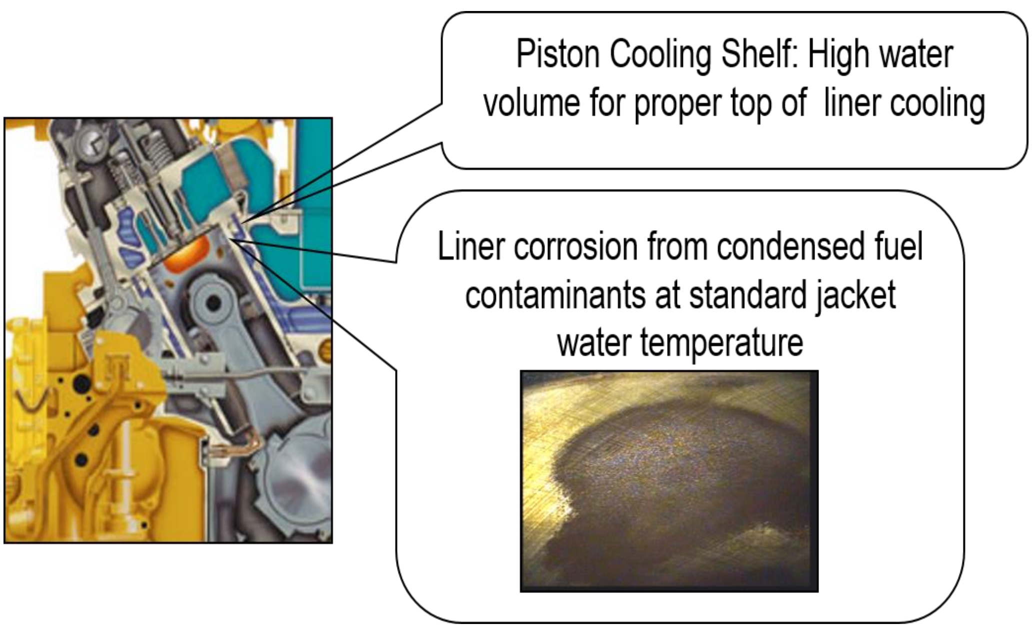

Figure 6: Cylinder liner corrosion and pitting caused by fuel borne hydrogen sulfide mixing with water in the combustion process to form sulfuric acid that condenses on the liner surface. Elevated jacket water temperatures protect internal engine components from corrosion by preventing condensation of water, not allowing sulfuric and other acids to form.

Even when hardened engines are used, some fuel treatment and some acceleration of maintenance and overhaul schedules may well be necessary. Every project is different, and approaches to fuel impurities must be weighed on a fuel-quality and site-specific basis.

Is it Feasible?

A first step in exploring a distributed energy/CHP project is to determine whether it meets a standard "five finger test" for electrical project development. A project has potential to go forward if it meets all five of these criteria:

- An air-quality permit is attainable at reasonable cost.
- A wastewater discharge permit, if needed, is attainable.
- Land and building space can accommodate the engines and heat-recovery equipment.
- Natural gas service is available without undue inconvenience or cost (such as the need for a costly gas service upgrade).
- Electrical interconnection is available at reasonable cost.

If that test is met, the feasibility question comes down to economics and business imperatives: Will the cost of electricity be competitive? Or do issues of power quality and business continuity outweigh power cost considerations?

If the on-site power project itself is feasible, the next question is whether CHP can make it more attractive. This means weighing:

- The incremental cost of heat recovery equipment (principal and interest).
- The incremental operations and maintenance costs (staffing, components/supplies, service, repairs).
- The incremental cost savings (or revenue) from heat energy.

Putting it All Together

Assessing such projects is not easy for the uninitiated. One way to simplify an on-site power project with CHP is to work with a partner well qualified to outline and manage the risks and analyze the economics. One option is an engine-generator manufacturer with a diverse technology portfolio, a well-developed dealer network and a strong financing arm. That partner can bring to bear:

- A variety of generating technologies in gas or diesel configurations and in power ratings to suit the application. This can include engines designed to operate on low-energy biofuels and engines engineered for local ambient conditions, altitude, fuel quality, and performance objectives.
- Dealerships with broad experience operating and maintaining power generation equipment. Such dealers can offer service programs ranging from basic planned maintenance and overhauls to comprehensive long-term service agreements.
- Dealerships able to manage whole-project engineering, procurement and construction and supply all engines/generators, heat recovery systems and other equipment.

- Expertise in financing power projects. This can include knowledge of development processes, government incentive programs and project economics, and capacity to finance entire projects rather than equipment only.
- Ability to provide construction financing that converts to long-term financing on project completion.

Moving Forward

CHP offers opportunities to make on-site power generation projects even more financially attractive. These are favorable times to explore CHP as a value-added component of projects that help power users gain independence from unreliable grids and operate reliably, cost-effectively, and sustainably.

About the Author

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