Putting Together a High-Efficiency, Reliable and Bankable Biogas-to-Power Plant

Heat recovery from gas-fueled engine-generators can help make distributed resources more cost-effective and sustainable.

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Introduction

Distributed generation is valuable in helping electric utilities deal with challenges of supply/demand balance, power quality, and infrastructure cost. Among many benefits, small generating sources located near points of end use help forestall investments in central power plants, transmission lines and distribution systems.

In recent years, natural-gas-fueled reciprocating engine-generators have proven highly suitable for distributed generation. They are economical to install and operate, extremely reliable, and relatively easy to site and permit. Increasingly, they offer a bonus benefit: In the right settings, the capture of heat from engine exhaust and fluids – combined heat and power (CHP) – makes the financial picture of distributed generation more appealing.

When sited at or near a host facility with a significant heat demand, a generating system with heat recovery can supplement existing boilers or other heat sources. In these situations, it is not necessary to invest in sophisticated systems that wring the maximum available heat from the engines. The only requirement is that the value of the heat captured significantly exceeds the cost to install and maintain the heat recovery equipment.

As technology steadily improves engine efficiency and reduces emissions, it is increasingly worthwhile to weigh the advantages of CHP when considering distributed power installations.

DG: A Proven Concept for Utilities

Trends in electric power markets have conspired to move distributed generation into the mainstream. Demand for power, especially power used during peak demand periods, has risen steadily, even though the recent global recession. At the same time, central power plants and transmission lines needed to fill the demand have become more costly – and politically difficult or in some cases impossible to site and permit.

Furthermore, environmental concerns and air-quality regulations have tended to shift the mix of fuels used to produce electricity, in general away from coal and fuel oil and toward natural gas and renewable sources (wind, biomass, solar). New small-scale generating technologies have emerged and existing technologies have improved, making distributed generation more cost-competitive. Because these systems are flexible and can be permitted and installed quickly, they are attractive to utilities facing near-term capacity needs.

The power industry recognizes distributed generation as a way to relieve localized and seasonal power shortages, serve new localized load growth, and prevent areas of voltage instability. Placed at strategic locations on the grid, distributed generation systems can bolster capacity while supporting distribution system voltage and power factor, at the same time reducing transmission and distribution losses.

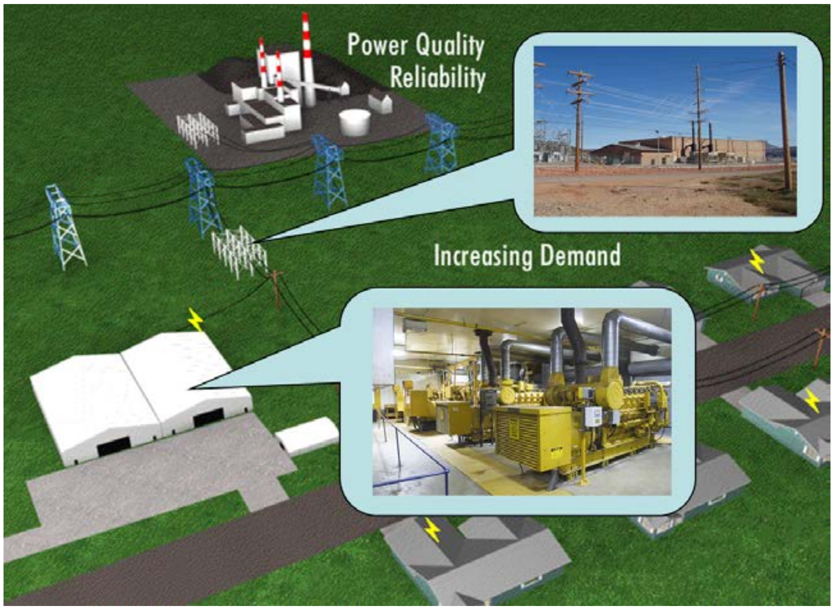

Figure 1: Small scale distributed generation is sited by electric utilities at the substation level or at the point of end use.

Distributed Generation: End user concept

Distributed generation can appeal to end users, as well, especially where time-of-use or real-time pricing apply. In such cases, the ability to host a distributed resource can give a business a valuable hedge against market price volatility, or enable the profitable sale of energy to the grid. Applications can include:

- Prime power systems for complete control over reliability and power quality.
- Standby power sized to sustain critical production loads (not just bare-minimum emergency needs).
- Peak shaving systems to minimize demand charges or spikes in costly on-peak utility power usage.
- Demand response installations, in which the utility dispatches the equipment during times of peak demand on the grid and rewards the host with rate incentives.

Virtues of Gas Engines

Gas engine-generator sets are proven in distributed power applications. Today's advanced gas engines operate with uptime often approaching 98 percent and with electrical efficiency as high as 45 percent. The latest configurations develop high power output in footprints up to 50 percent smaller than traditional units, providing an excellent fit on space-constrained sites or in small existing engine rooms.

Installation is fast and simple: units can be online and producing power within a few months from the date ordered, at attractive installed system costs from $450 to $600 per kW. Multiple units can readily meet power requirements up to 50 MW; capacity can be added in increments to accommodate planned growth. Gas engines are relatively straightforward to site and permit; emissions can meet the world's toughest air-quality regulations.

The units perform well in intermittent service, operate efficiently with variable, cyclic loads, and readily tolerate high altitude and high ambient temperatures. They are built for flexibility to operate on gases of varying quality, including natural gas, landfill gas and wastewater treatment digester methane. The gas engine technology is simple and well understood: qualified service technicians and replacement parts are readily available worldwide.

The CHP Bonus

CHP enhances gas engines' inherent fuel economy – overall efficiency of 75 to 80 percent is routine, and efficiencies up to 90 percent are achievable (see Figure 2). In general, the longer the annual operating hours, the greater the potential for profitable CHP.

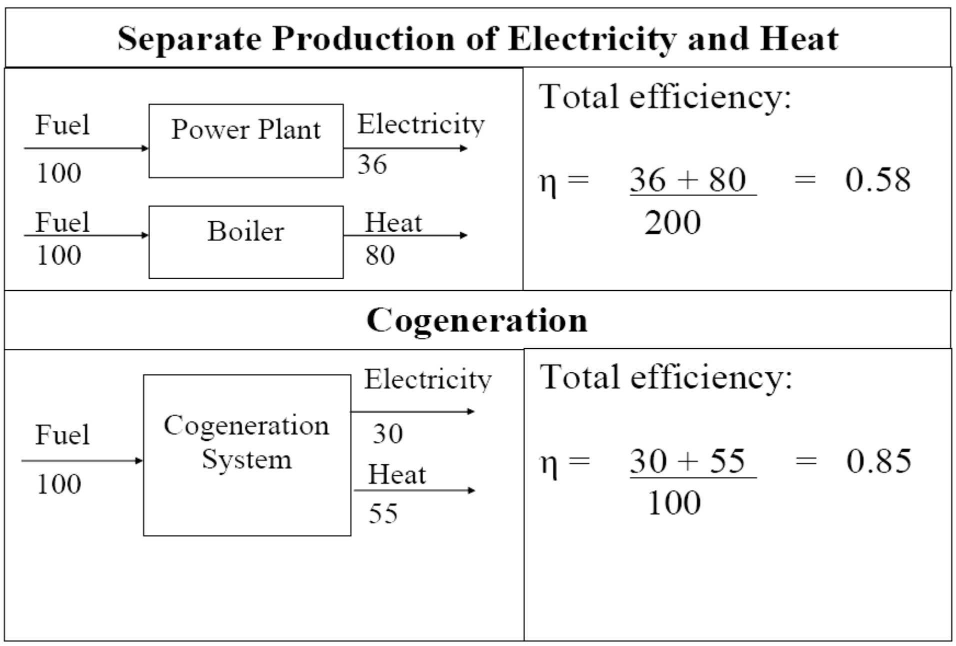

Figure 2: Comparison of total resource efficiency between a power plant and boiler vs. a gas generator set cogeneration system.

Historically, diesel-fueled generators were used for distributed power, operating for as few as 100 to 500 hours per year to help carry the highest daily and seasonal peaks. More recently, as air-quality regulations have grown stricter and as diesel fuel prices have risen, gas units have become a preferred generating source. Their lower operating costs can allow them to run economically for only a few hundred hours per year, as continuous base-load units, or anywhere in between, as electric power market conditions dictate.

For units hosted on customer sites, these extended hours help justify investment in heat-capture equipment. Heat recovery in turn improves economics so that it becomes cost-effective to operate the systems for up to 4,000 annual hours – essentially half the year – or even more. Economically viable CHP configurations can range from complete heat recovery systems optimized for large, continuous process heating demands, to systems with low-cost coolant circuit heat exchangers for limited domestic water or space heating.

Engine exhaust provides by far the highest temperatures and the greatest heat output. Exhaust heat can generate intermediate-pressure steam for purposes like boiler feedwater heating, and low-pressure steam for processes like sterilization, pasteurization, space heating, tank heating, humidification, and others. 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 (See Figure 3).

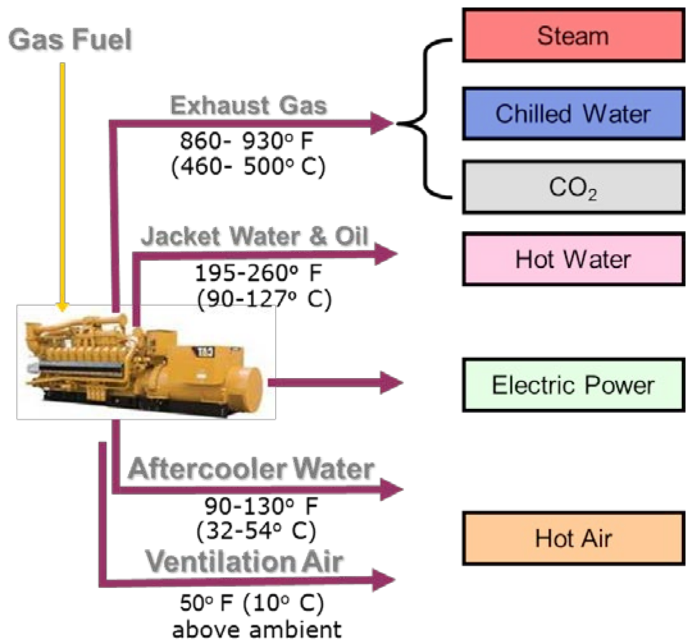

Figure 3: Engine circuits that heat can be economically recovered from with typical temperatures available.

Right Time and Place

CHP does not fit every distributed generation site: Some heat loads are too small to justify a heat-recovery investment. That aside, CHP is generally most feasible where:

- Host facility heat and electric loads coincide.
- Utility electricity prices are relatively high.
- Generator fuel price is relatively low.
- The local utility or government entities offer efficiency incentives.
- Sustainability, energy efficiency, or greenhouse gas reduction goals need to be met.

Sites with high potential for distributed generation with CHP include wastewater treatment plants, hospitals, universities, district energy systems, and process industries such as food, chemicals, petroleum refining and paper.

A key question to answer is which engine heat sources to tap to satisfy the heat load economically. A full-time (continuous-duty) distributed generation system may easily justify investment in a full heat-capture system, including an exhaust heat recovery boiler producing steam to meet a substantial heat load.

Figure 4: Four G3520C generator sets in a combined heat and power plant provide electric power, hot and chilled water to a large office complex in São Paulo, Brazil*.*
Photo courtesy of Ecogen.

On the other hand, a system operating 2,000 or 4,000 hours a year may be better served by a less sophisticated jacket water heat recovery system to generate hot water for supplemental process or space heating.

While hot water and steam are the classic engine 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.

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 5). Alternatively, systems can be configured produce space heat in winter and air conditioning in summer.

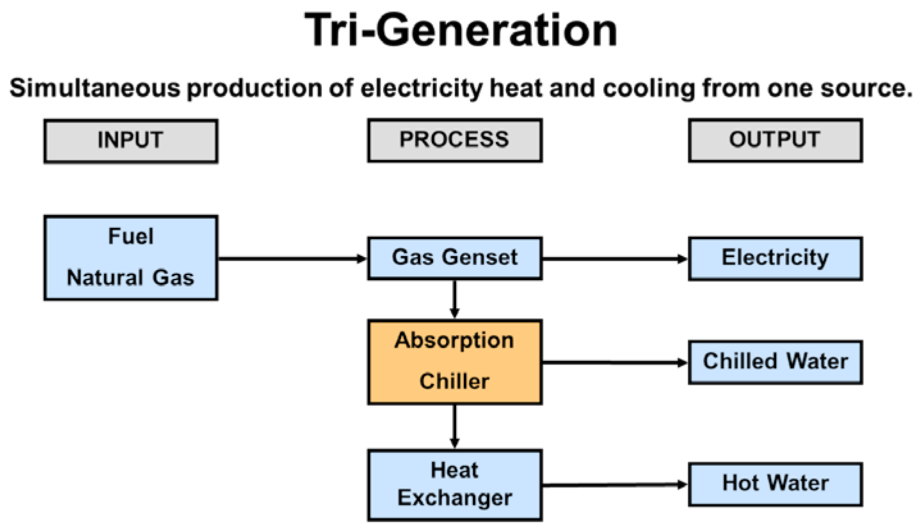

Figure 5: Tri-generation heat flow diagram.

Always the essential question is whether the economic gain from heat recovery offsets the incremental cost of the equipment. Fortunately, CHP is not limited to highly engineered systems. Simple and well-conceived heat recovery can improve the economics of many distributed generation projects with only a modest additional investment.

Almost any application that entails roughly 1,000 or more annual operating hours offers potential for economical heat recovery from the engine cooling circuit. A simple shell-and-tube or plate-and-frame heat exchanger can produce water at 180^o to 210^o F (82^o to 99^o C), depending on the jacket water temperature.

The captured heat displaces some costs for fuel or utility electricity. To the extent that the this heat supports energy needs during times of peak electric load, total electric demand and thus demand charges may also be reduced. Examples of low-intensity, limited-duty cogeneration include:

- Commercial real estate. Office buildings can cost-effectively operate generator sets during business hours, avoiding utilities' highest time-of-use rates. If heat recovery from a jacket-water heat exchanger can then partially offset the cost of fuel for space heating, water heating or dehumidification, return on investment improves.

- Light industry. A small or mid-sized manufacturer with an on-site generator set could install a heat exchanger in the engine cooling system loop, with a thermostatically controlled diverter valve to regulate the flow to the in-plant load, thus cost-effectively satisfying a variable hot-water requirement.

- Hospitality. Hotels can readily use heat recovery for domestic hot water, laundries, kitchens or swimming pool heaters. In summer, the recovered heat can power absorption chillers or desiccant dehumidifiers.

- Food processing. Food producers can recover jacket water heat for light process loads such as raising dough, or to produce hot water for cleaning and sanitizing. Depending on the size and character of the heat load, such systems can be cost-effective in single- or multiple-shift service, even if heat demand is cyclical or seasonal.

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 the need for a costly service upgrade.
Electrical interconnection is available at reasonable cost.

Assuming that test is met, the decision comes down to economics. If the distributed generation project is feasible in its own right, then CHP can enhance the bottom line, provided the value of the heat recovered (thermal credit) exceeds the incremental costs to install the heat recovery equipment (principal and interest), and to operate and maintain it (staffing, components, consumables, service, repairs).

Putting it All Together

One way to simplify a distributed generation 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 a power rating 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, and CHP projects in particular. This can include knowledge of development processes, project economics and incentive programs, 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 distributed generation projects even more financially attractive. These are favorable times to explore CHP as a value-added component of projects that help utilities and their large customers operate more reliably, cost-effectively, and sustainably.

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