Free Fuel: Too Good to Be True?

by Dr. Åke Almgren
President and CEO
Capstone Turbine Corporation

Landfill gas fuels several microturbine arrays in California and elsewhere.

As consumers, communities and countries look for ways to improve their ability to produce and utilize electric power, the competitive benefits of distributed generation (DG) versus centralized power are looking better and better.

By generating power on the site where it is consumed, DG incorporates not only the generation function, but also the transmission and distribution functions; and in some cases, the backup power function as well.

It's not hard to see how savings are realized when transmission and distribution costs are eliminated. The same is true when you can eliminate separate backup generators. However, the real beauty of DG is that on a macro-level, you don't have to make a binary choice between DG and the traditional model of centralized power plus a transmission and distribution grid. Instead, DG is best approached as a supplement, instead of an alternative, to grid power.

On-Site Fuel

In distributed or centralized power applications, the source of fuel is a key aspect for the best choice of the generating technology and location. To be truly DG, one can also argue that the fuel should be available on site. In that regard, photovoltaics (PV) stand out. The sun, or more precisely, sunlight, is the "locally available" fuel for the PV modules.

There would probably be a consensus that PV is the ideal DG technology, if it were not for two shortcomings: high initial cost and a lack of fuel during the dark hours of the day. However, thanks to growing production volumes and new manufacturing processes, the first cost continues to come down. And the dependability issue can at least partly be offset by energy storage.

Other sources of renewable energy also meet the criteria of local fuel. Similar to sunlight for PV, wind is the local fuel for wind generators and streams are the local fuel for individual hydro generators.

Still there is a major difference. Wind and hydro are in most cases remote power. Unless generated at the same site as the consumption of the power, wind and hydro power do not meet the strict definition of DG.

Wind has become competitive at the point of generation thanks to strong growth and the economy of scale resulting from going up in size to 3-megawatt units. The larger unit size has unfortunately a downside. Locations for large wind farms tend to be increasingly remote ("beyond the horizon"). That makes the interconnection more costly, which reduces some of the overall economic benefits of this clean power.

There is a renewed interest in small (less than 50-megawatt) hydro projects. They are clean and viewed as more environmentally friendly than large hydro projects. Still, permitting a hydro generator tends to be a challenge and initial costs are relatively high. The aspect of the connection to the grid is similar in nature to that for wind, but seems of less magnitude

Fossil-fuel-based DG technologies, such as reciprocating engines, are in most cases dependent upon a fuel infrastructure. This can be in the form of a natural gas grid or a truck-based delivery system that refuels an on-site storage tank for diesel, kerosene, propane, etc. Relying on a fuel tank on site and delivery trucks has the disadvantages of additional costs for delivering and storing the fuel and potential for disruptions in the fuel supply or delivery mechanism.

Natural gas is convenient where the infrastructure exists. The problem is that in most parts of the world, there is no gas grid or the gas grid is not as well developed as in the United States.

In fact, even in the countries with a gas grid, there is no guarantee that gas will be the lowest-cost fuel for on-site generation. Unlike large power plant gas buyers, most DG installations must buy at retail and are, therefore, much more exposed to price fluctuations.

Residential PV.

Capturing "Free" Fuels

Fortunately for DG, there are other sources of fuel that are locally available. In the case of oil and gas E&P operations, gas is often being vented or flared, with no capture of its economic value. The amounts of vented and flared gas are significant. The Department of Energy (DOE) estimated that in 1999, about 3,355 billion cubic feet of gas was vented or flared in connection with dry gas production.

This amount of wasted energy corresponds to 50,000 megawatts (MW) of power generated by combined cycle gas turbines (CCGT). That amount of power would cover all the power demand in California, even at peak.

In some areas, like Nigeria, more gas is vented or flared than is sold as dry gas! Based on the 1999 numbers and assuming deployment of DG to capture the vented and flared gas for power production instead, it should be possible to generate over 5,000 MW of power – almost the same amount of power as the available installed power generating capacity of the Nigeria electric system.

Other sources for local fuel are "light green" biomass renewable energy sources such as wood and agricultural waste, and biogas (predominantly methane) at landfills and wastewater treatment plants.

Biomass is a large renewable energy source. In 1999 about 35 million megawatt-hours of electric power in the U.S. were produced using wood and wood waste. That amount equals roughly the electricity to power 700,000 homes.

The Energy Information Administration (EIA) estimates that the amount of economical biomass power could be doubled by 2020. Additional growth potential for biomass is possible by cultivating dedicated biomass fuels, which is already happening in locations including Iowa and Brazil, where crops are grown for ethanol production.

While biomass is most often used as a primary fuel, it also has applications as a supplement to coal in large centralized power plants. Unfortunately, lack of suitable small-scale technologies have so far held back biomass as fuel for DG applications. It is too bad.

Based on EIA estimates, more than 16 percent of the available biomass resources in the U.S. are not economical for power generation because of the cost to obtain the feedstock.

Most biomass power is produced by burning the biomass, generating steam for a turbine that produces electricity. A serious downside with the traditional biomass power generation is the emissions.

That challenge has triggered research and development into more sophisticated combustion systems as well as gasification processes. Gasification will likely hold the key for "clean biomass" as it will for "clean coal."

Through anaerobic processes, nature is constantly producing methane from biomass, wastewater, livestock manure, etc. These so called biogas opportunities are much smaller than the biomass resources, but still very significant and seemingly very suitable for DG.

It is difficult to identify and accurately measure all the methane being vented. Most estimates probably underestimate the total potential, since very low concentration or excessive dispersions may make such sources to be considered non-recoverable. Indicators of what may be available can be illustrated by some examples.

EPA has estimated that one million tons of waste, roughly the waste from two million people in the U.S., in a landfill, will generate methane gas equal to 7 million kWh in a year. Methane will continue to be generated for up to 20 years until the waste energy is fully depleted. That indicates a theoretical potential of 1,000 MW of power, if all the U.S. landfill methane could be collected and used for power generation.

Something that appears too good to be true generally is. The fuel may be free at the source, but there is a cost to collect and, if necessary, to clean it.

EPA identified early on the landfill gas opportunity in 1996 and launched the Landfill Methane Outreach Program. It helped increase the number of gas utilization projects at landfills from 162 in 1996 to 330 projects five years later. Still, there is a good potential for further growth.

An array of microturbines at a closed coal mine in Japan turns methane into power while exhausting the CO_2 back into the mine.

Another example is China. It is estimated that China generates about 48 billion tons of wastewater per year. Presently, only about 2.4 billion is treated. The government reportedly is planning to build 3,000 new wastewater treatment plants. Those could correspond to a potential of generating over 1,000 MW of power.

A third example is Malaysia, where methane is a by-product at palm oil production mills. Most of that is today vented, but, if captured and turned into electric power, would represent several hundred megawatts of power.

Is it appropriate to term vented or flared gas, biogas and biomass "free fuels," when they are not being commercialized? In cases where there is a restriction or penalty for venting the gas, this potential fuel may have a negative cost!

However, something that appears too good to be true generally is. The fuel may be free at the source, but there is a cost to collect and, if necessary, to clean it.

Environmental Benefits

Even if it is not free, the recovery of biogas or other vented or flared gas resources can stand on its own economic merits. In addition, it delivers major environmental benefits. Methane vented directly into the atmosphere is over 20 times more negative for global warming than the same amount of CO_2.

To make the environmental matters worse, vented gas includes toxic elements as well; for example, NOx. As a first line of defense against the toxic elements, the gas can be flared. It reduces the problem, but even after flaring, NOx levels are generally 20-40 parts per million (ppm).

And flaring is still a complete waste of the energy, since the only output is more heat to the atmosphere.

A study by DOE/NREL in 1998 looked at methane from dairy and swine farms in the U.S. It estimated that if all recoverable methane at these farms were converted into electricity, it would yield 160 MW. That may not be a large amount of power, but the corresponding environmental benefits are huge. Since recovery eliminates the methane from being vented into the atmosphere, it represents a reduction in greenhouse gas emissions equivalent to the CO_2 emissions from about 3,500 MW of generating capacity from traditional fuels.

In 2001, the Los Angeles Department of Water and Power (LADWP), as part of their Green Power program, installed at Lopez Canyon Landfill microturbines to produce 1.5 MW of power, instead of just flaring the gas. Compared with the emissions from the flare system, this particular installation will eliminate 10,000 pounds of NOx per year, which is the equivalent of permanently removing 500 cars from Southern California roads.

As illustrated by the two examples, one can argue that for reducing greenhouse gases, it can be more cost efficient to capture methane than reduce CO_2. Further, biogas from landfills, waste water treatment, animal waste, etc., is categorized as renewable. Power produced from the biogas is "green energy" and may even demand a premium as such.

Microturbines at sewage plants create power from biogas while exhaust heat maintains temperature of the sewage digester vats.

Resource Recovery Technologies

Most of the utilized potential of resource recovery has been accomplished in power plants from a few MW to over 100 MW. The size is typically decided by the optimization of power plant costs and costs for collecting and cleaning the fuel. Most of the large power plants burn the fuel and use the heat to generate steam, which powers a steam turbine. In the 1-10 MW segment, reciprocating engines dominate, but gas turbines are also used.

Continued progress in the development of reciprocating engines makes them increasingly suitable for sub-MW installations, in particular, the 0.5-1 MW range. New technologies are enabling additional opportunities in the sub-MW range all the way down to a couple of kW.

This new area of development is particularly important, since it is in the sub-MW segment that one can find "perfect" DG opportunities, where the amount of the local fuel can match or at least offset part of the local power demand.

Microturbines have in a short time demonstrated their capabilities in the sub-MW segment for landfills, wastewater treatment plants and livestock waste applications.

In some aspects they have superior characteristics, such as the ability to run on low-Btu gas and produce radically lower emissions (NOx) than reciprocating engines. In fact, the Los Angeles County Sanitation district measured NOx emissions from a microturbine routinely operating on 35 percent methane landfill gas at a remarkably low 1.3 ppm (at 15 percent O_2).

Carbon monoxide (CO) was measured to be 36 ppm, methane 2.2 ppm and the destruction of non-methane organic compounds was verified at 98.6 percent. The microturbines do not require any post-combustion cleanup devices, but they require gas compression.

Fuel cells are also being installed at landfills and wastewater treatment plants. The technologies used so far are phosphoric acid (PAFC) and molten carbon (MCFC). The upside of using fuel cells is a relatively high electric efficiency and also low emissions, while the downside is a high initial cost.

For the future, one may expect resource recovery to be an excellent application for Stirling engines, thanks to their concept of external combustion. This technology should enable use of a variety of biogas and biomass fuels, while eliminating most of the need for pre-cleaning of the fuel and/or post-cleaning of the emissions.

The enabling opportunities of using new technologies to find economical solutions, while solving environmental problems, are demonstrated by innovative new concepts.

Especially for sites producing biogas/biomass less than 100 kW, and maybe even less than 10 kW, the Stirling engines can have a great potential, provided the initial cost is competitive.

New Concepts

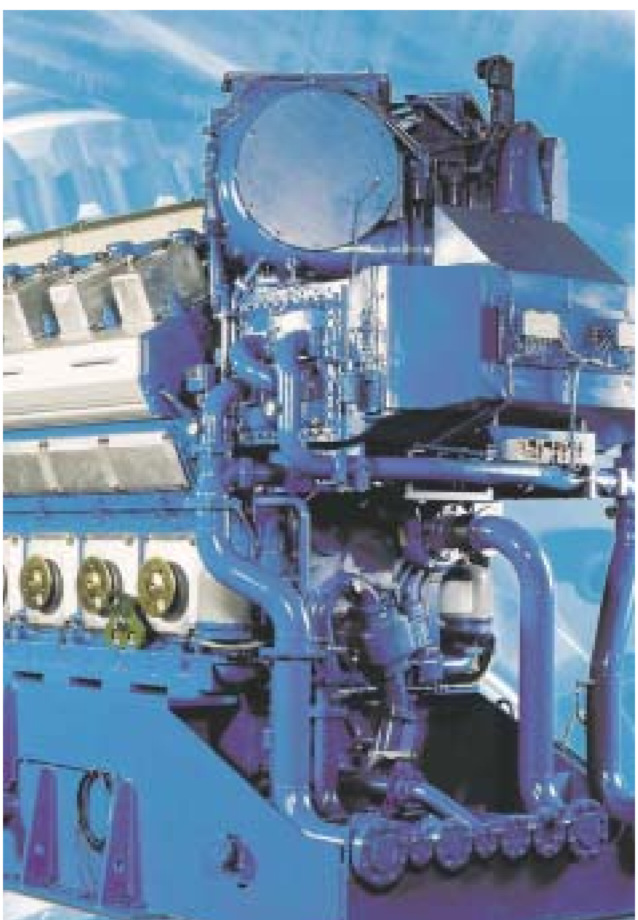
The enabling opportunities of using new technologies to find economical solutions, while solving environmental problems, are demonstrated by innovative new concepts.

For example, in Japan, Meidensha has commissioned a pilot plant to turn used cooking oil into electric power. A reformer turns oil waste from restaurants and other commercial kitchens to a liquid fuel, biodiesel, which feeds into a microturbine producing electricity.

Another example of an innovative solution focused on recycling of food waste was developed by EXY Corporation in Japan. It is a complete system solution starting with disposers in the homes to collection satellites at apartment buildings and commercial centers. The food waste is turned into a liquid, which is collected and processed. The methane from the process is transformed into electric power by microturbines or fuel cells.

Nevertheless, one should make no mistake believing that the resource recovery potential is big enough to substitute for traditional fuels in bulk power production.

Resource recovery is not "free fuel." The cost of collecting, transporting, and cleaning these fuels is frequently the biggest barrier against their economical use.



Wartsila - Reciprocating Engine; Photo provided by Stewart & Stevenson

Resource recovery is not “free fuel.” The cost of collecting, transporting, and cleaning these fuels is frequently the biggest barrier against their economical use. This challenge is the opportunity for DG, providing on-site solutions.

Resource recovery and DG are a very good fit, enabling economic solutions with large environmental benefits. ■

Dr. Åke Almgren is president and CEO of Capstone Turbine Corporation, a public American company focused exclusively on the commercialization of micro-turbine power generation technology. Founded in 1988, Capstone is the world’s premier developer, designer and assembler of microturbine systems for on-site power production and for use in hybrid electric vehicles.

Since Capstone introduced its C30 in December 1998, and C60 in September, 2000, more than three million documented hours of operating time at customer sites have been accumulated among 2,400 units shipped by the end of 2002.

Prior to Capstone, Dr. Almgren spent an accomplished 26-year career at ASEA Brown Boveri (ABB) Limited, a worldwide power solutions company. While there, he served as president of various divisions, managed the operation of 36 plants in 28 countries, and led turnkey projects in the U.S., Canada, Brazil and India. Before relocating to the U.S. in 1991, Dr. Almgren was president of Autoliv, based in Stockholm, Sweden. Under his leadership, the automotive restraint company established a North American presence and expanded into the development of airbags.

Dr. Almgren holds a Ph.D. in engineering from Sweden’s Linköpings Tekniska Hogskola and a master’s degree in mechanical engineering from Sweden’s Royal Institute of Technology.

He is an early advocate of distributed generation and believes microturbines and other emerging technologies will increasingly supplement more conventional technologies for generating and distributing electric power.