Distributed Generation with Natural Gas Engines: Fulfilling the Potential

These flexible, reliable, economical energy sources can help utilities integrate decentralized power into a sound business strategy that addresses a variety of today's challenges.

Todd Scott
Senior International Accounts Manager for Latin America with Caterpillar Financial.

Michael A. Devine
Gas Product/Marketing Manager with the Electric Power Gas Group of Caterpillar Inc.

February 2015

Introduction

The business model for North American electric utilities is changing rapidly. Market realities increasingly dictate a transition away from centralized power production and toward smaller, more flexible generating facilities closer to the source of the load.

The need for service reliability is a key driver of this trend; widespread and extended power outages after Superstorm Sandy magnified the concern and the need for a more resilient grid. Distributed power sources can have a significant impact on improving reliability.

Among potential sources of distributed power, natural-gas-fueled reciprocating engine-generator sets stand out as eminently suitable. They are quick to install, economical to own and operate, extremely reliable, and relatively easy to site and permit. In distributed applications, they can help utilities advance multiple business objectives.

Utilities exploring distributed generation are often venturing outside their comfort zone. If reliant on purchased power, they may be unaccustomed to owning, operating and dispatching generation and unfamiliar with the nuances of project development and financing. Those accustomed to operating large power plants and may feel uncomfortable with aggregating and dispatching smaller power units. In either case, an experienced project partner can provide valuable guidance.

It takes care and teamwork to develop distributed generation projects that meet financial and performance goals. All players must collaborate closely: utility, financier, developer, general contractor, equipment supplier, maintenance provider and equipment operator. The aim must be to develop a bankable project in which all risks – technical, commercial, financial, legal, regulatory and political – are allocated to the parties best qualified to manage them.

World of Potential

Utilities of all sizes – investor-owned, municipals and cooperatives – face similar threats to their traditional power-supply paradigms. Today, centralized power plants and high-voltage transmission lines are extremely expensive to build and politically difficult or nearly impossible to permit and site.

While distributed generation provides a workable alternative, many utilities are unsure how best to value it, deploy it and incorporate it into their systems: The technologies and the development processes are outside their historic business expertise. Fortunately, the expertise to deploy distributed generation, including knowledge of economics and operations, is readily available.

Typically, distributed generation systems are installed at strategic locations on the distribution network, often at substations, sometimes hosted by major power users, such as large commercial or industrial customers. Often, the utility dispatches the generation as dictated by customer power demand, market power prices, and other factors, creating a win-win for the utility and host customer.

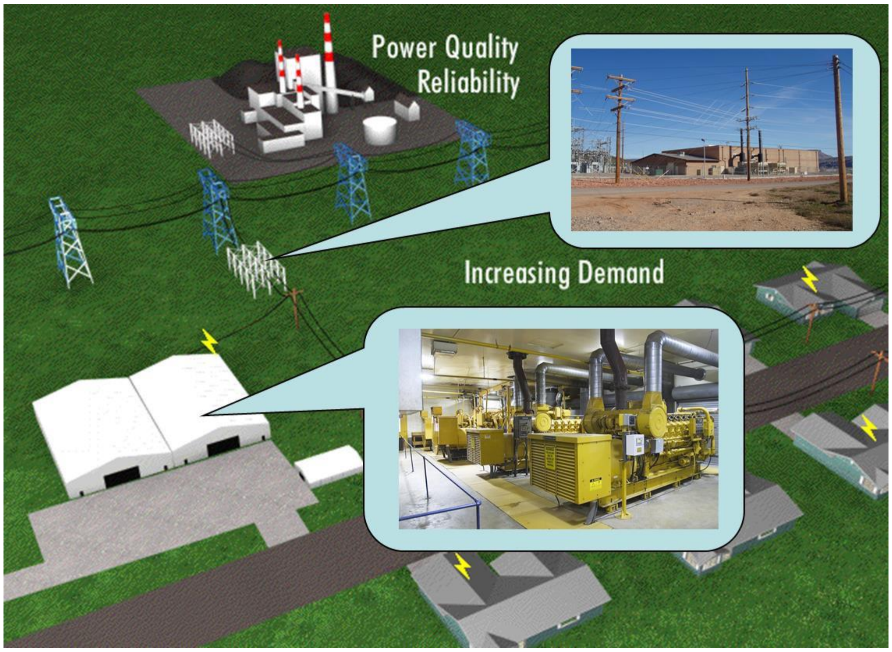

Figure 1: Traditional paralleled system with generators feeding the critical load from a common buss through battery-based UPS.

Motivations for distributed generation include:

Reliability. Small generating sources such as natural gas engine-generators are inherently reliable. In addition, they can be located so as to shore up areas of grid instability, helping to prevent localized outages, provide VAR support and ensure consistent voltage, essential to protecting customers' computers and sensitive instrumentation. Distributed units also provide a measure of redundancy in case of central facility outages.

Cost deferral. Small, decentralized generating units help delay investments in large centralized fossil-fuel power plants. Furthermore, strategically placed units can forestall investments in costly new transmission lines and distribution network upgrades.

Environmental compliance/sustainability. Regulatory pressures are forcing the phase-out of many coal-fired power plants; decentralized gas-fueled units can help replace them. Today's advanced gas engines are compliant with emissions regulations, and air-quality permitting is generally straightforward.

Supply firming. Renewable portfolio standards and renewable energy credits are encouraging solar and wind energy development. Incorporating these intermittent resources is a challenge to utilities; the use of engine-driven generators is a cost-effective way to firm those resources.

Demand response/load shaping. The Smart Grid concept calls for increasingly distributed small resources that can be dispatched quickly to meet changing demands on the system. Distributed resources hosted and operated by end-users, but dispatched by the utility, can help shape the load profile, such as by reducing customer loads during periods of extreme peak demands on the overall grid.

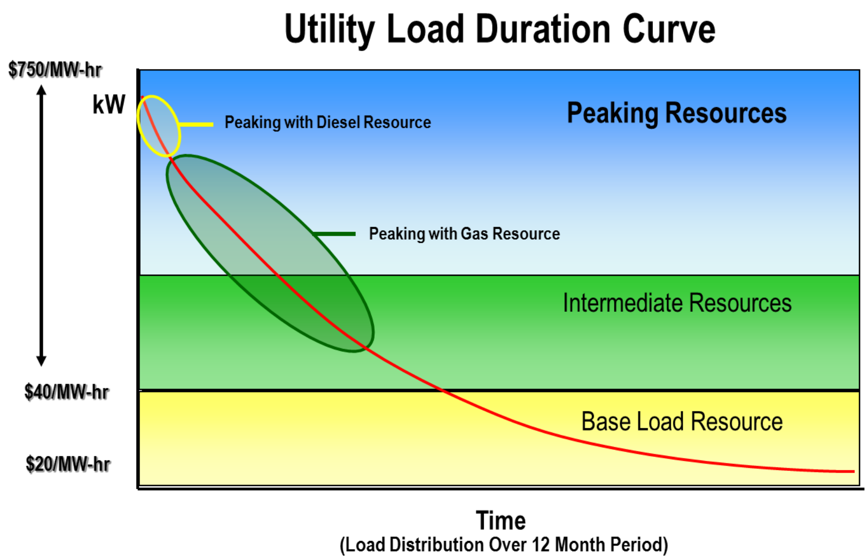

Figure 2: Peak Reduction Possible with gas reciprocating resources.

Security. Spreading generation over multiple sites instead of concentrating it in a few locations limits the ability of a single weather event or terrorist act to cripple the entire electrical system.

Community development. By helping to keep power reliable and rates competitive, distributed generation helps local utilities retain major commercial and industrial customers and encourage their expansion, thus sustaining and increasing job opportunities and promoting economic growth.

Virtues of Gas Engines

Gas engine-generator sets are proven in distributed power applications. Today's advanced gas engines operate with a capacity factor (or availability) 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 of order placement, at attractive installed system costs from $450 to $600 per kW. Multiple units can readily meet power requirements up to 50 MW or more; capacity can be added in increments to accommodate growth. These smaller capacity increments also allow for dispatch flexibility while maintaining high fuel efficiency. Turndown on larger units usually comes at the expense of 10 to 20 percent or more in output efficiency.

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

In some settings, gas engine-generators offer the bonus benefit of combined heat and power (CHP): Heat captured from engine exhaust and fluids can produce steam, hot water, hot air or chilled water (by way of absorption chillers) for utility customers to use for space conditioning or process needs. CHP significantly enhances overall efficiency.

Checking Feasibility

Gas-fueled distributed generation can face many of the same economic and technical challenges as other types of power projects. A handy and quick way to check a project's feasibility is to apply a "five finger test." A project has potential to go forward if all five of these conditions are met:

- An air-quality permit is attainable at reasonable cost.
- Adequate cooling water is available and 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 and is not precluded by contract.

For small utilities reliant on purchased power, interconnection can be a substantial hurdle. Many have all-requirements contracts with a supplying utility or wholesale energy provider that preclude them from self-generating power. Of course, such contracts can be renegotiated, and investor-owned utilities generally are becoming more flexible as they themselves face generation capacity shortages and transmission system constraints. A willingness to renegotiate the all-requirements clause for small-utility distributed generation helps energy suppliers defer future capacity additions that may be too difficult to complete in the near term without costly transmission and distribution investments.

Distributed generation is also more difficult where electrical infrastructure at a host site must be upgraded and modernized to handle the installation.

Assuming the project satisfies the "five finger test," distributed generation is generally most favorable where:

- Purchased power costs are relatively high while fuel prices are relatively low.
- The site or general area requires high electric reliability and power quality.
- The equipment host has a high electrical load (and ideally a heat load that could benefit from heat recovery).
- The distributed generation system can double as a standby power source for the host.
- Low-cost "opportunity fuel" (such as landfill or digester gas) is available.
- All parties involved share a basic understanding of the distributed generation concept, the risks, and the benefits.

Critical Financing

Financing is a key hurdle for any power project. Here, the relative size and simplicity of distributed generation systems can allow public utilities to look outside their traditional avenue of bond issuances. While at today's interest rates municipal bond financing can be next to free (depending on the issuer's financial position), there are sound reasons to explore private financing through a utility's existing banking relationships, and/or financing supplied by an equipment vendor.

First, it can be difficult to issue saleable bonds for distributed generation: Project costs, typically $5 million or less, may not justify the time and expense of bond issuance.

Second, the relative speed of private financing can offset the advantage of low interest on bonds, which typically require a much longer approval process that can be fraught with delays. It may be worthwhile to pay an extra point or two of interest for fast-turn private financing for the advantage of having the project online, and generating revenue, months or years sooner. If advantageous at a later date, that loan's remaining balance can be folded into a bond issue covering other additional projects or can be refinanced (aggregated or syndicated) into a single long-term loan.

In place of bond financing, some public utilities enter power purchase agreements (PPAs), allowing an independent project developer to handle the financing and assume the financial risk. Aside from that, there are two basics forms of financing that carry different risks for the lender and utility.

Balance sheet financing requires the utility to pledge, in effect, its "full faith and credit" toward a project. Financing in this scenario is relatively quick and easy to obtain: The lender receives surety in the form of the utility's track record, assets, cash flow and profitability. This means lower risk for the financier and therefore generally a lower interest rate.

Non-recourse project financing applies where a utility prefers not to carry a generation project on its balance sheet and operates it instead as a separate business entity. Here, no proven, stable parent company stands behind the payment obligations: The project's financial viability depends solely on its own revenue, profit and cash flow. Due diligence becomes much more stringent and the review process more involved. Because the financier's risk is greater, the interest rate is generally higher.

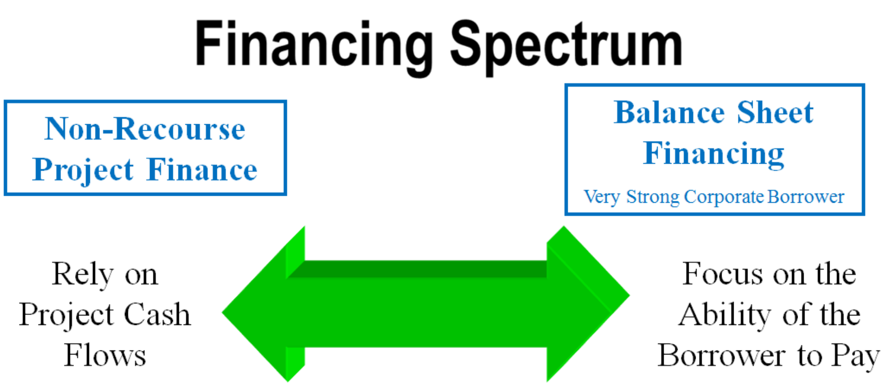

Figure 3: The terms and conditions for financing a project depend greatly on the type of financing one is looking for.

Essentially, from a lender's perspective, the difference between balance sheet and project financing is like the difference between investing in a blue-chip corporation versus a startup company.

Structuring Projects

Any distributed generation project needs a legal framework of agreements that bind all sponsors and stakeholders. Financiers typically require a single party, such as a general contractor, to be accountable for engineering, procurement and construction – essentially for seeing the project through to completion. This accountability is typically secured by a performance bond. Under this structure lie legally binding contracts, including:

- Lender loan and security agreement.
- Off- take contracts (such as for purchase of power, or power and heat in CHP).
- Fuel supply contract.
- Power generation equipment supply agreement.
- Operation and maintenance agreement.
- Interconnection agreement.

Risk Identification, Mitigation and Management

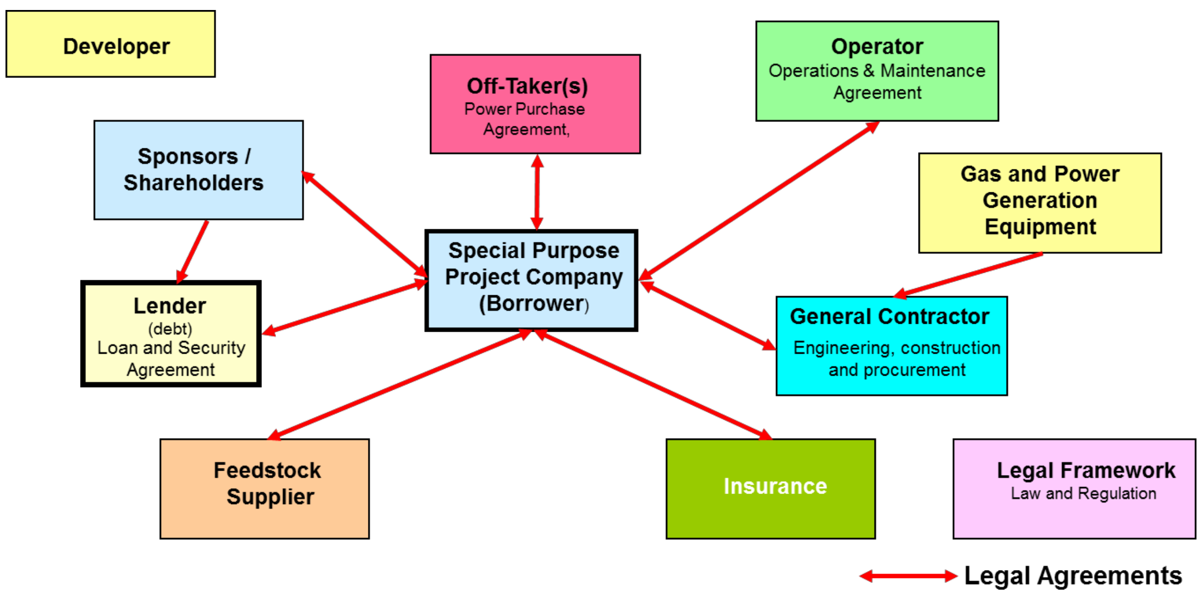

Figure 4: Each Agreement and each relationship contains risks. For proper risk mitigation, all agreements must work together, be consistent, and not be in conflict.

All these contracts must fit together without mismatches or conflicts. It may take several iterations of the contracts before all the relationships and responsibilities between the parties are properly integrated.

Managing the Risks

Delivering the benefits of distributed generation means responsibly addressing the risks inherent in building and operating the facilities. While the projects tend to be relatively small – generally 1 to 10 MW – they may have “soft costs” (legal, development and other fees) similar to those of larger projects. Every relationship within a project represents a risk that needs managing. In general, the more players, the greater the difficulty in mitigating the risk: One party’s failure to perform can undermine an entire project. Project contracts need to be structured so as to assign each risk to the party best qualified to manage it.

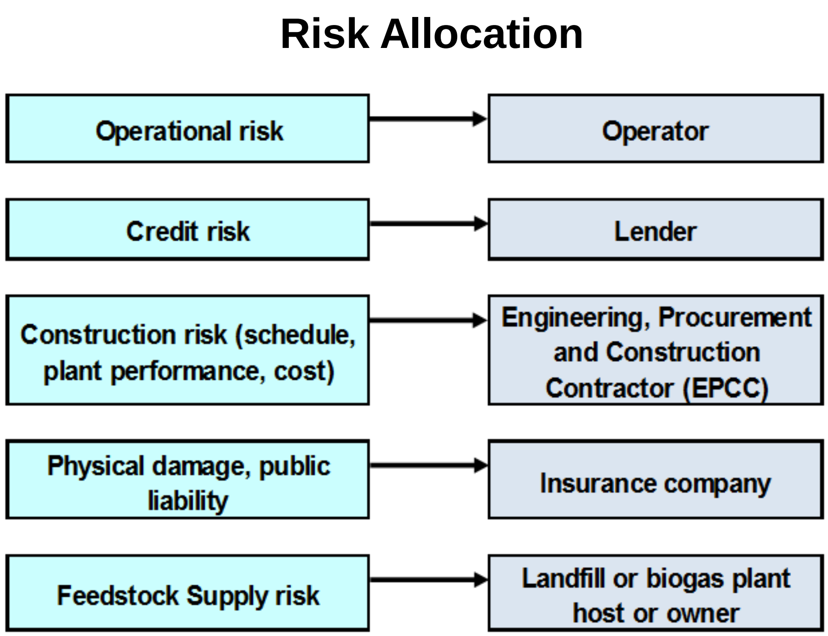

Figure 5: Each risk must be assigned to the party who is best prepared to manage it. Each contract must have appropriate compensation for ‘failure to perform’.

Fuel Supply Risk

A distributed generation project is unlikely to succeed if the long-term fuel supply is unpredictable or the fuel quality is uncertain or unacceptable. The project is sure to fail if the fuel supply is often interrupted or curtailed, or if poor fuel quality keeps the equipment from operating at full rated output or drastically increases maintenance costs.
This concern is magnified where a project relies on a non-traditional fuel, such as landfill or digester gas. In every case, the utility needs an ironclad, long-term contract with a fuel supplier. For projects fueled by natural gas, the contract must provide reasonable certainty about the fuel price and availability. In either case, a lender will typically require an agreement that ensures suitable fuel supply and pricing for two years beyond the loan repayment term.

Revenue Risk

Similarly, if selling power or heat, a project needs a long-term energy purchase agreement that binds the energy purchaser to a specific volume of kilowatt-hours, therms, or both, at agreed-upon prices. Short-term purchase agreements or buy-as-needed contracts are generally not considered financeable unless a strong guarantor agrees to repay the loan regardless whether the energy can be sold. A suitable contract typically includes a mandatory purchase (take-or-pay) obligation: The energy buyer cannot default on a purchase for any reason, including, for example, a malfunction of equipment within the buyer's control that stops the flow of energy. As in fuel supply agreements, an energy purchase agreement typically needs to extend two years beyond the loan repayment term.

Technology Risk

Not all generating technologies are designed, manufactured, and serviced with equal quality. It is incumbent on the utility or general contractor (engineering, procurement, construction) to ensure that the equipment supplier can deliver prime movers, generators, heat recovery systems and ancillary equipment with a track record of performance in similar applications. While initial installed cost matters to project success, proven reliability and ongoing maintenance cost matter a great deal more. As part of due diligence, a utility should ask all prospective equipment suppliers to offer references and data on successful projects of similar size and type, operating on a similar fuel.

Operations Risk

The best generating technology's performance is only as good as the ongoing support it receives in the field. Improper maintenance or poor operating practices can lead to unplanned downtime. In addition to the impacts on customers, outages put the project's financial results in jeopardy. Project owners should expect an equipment supplier to have a substantial product support infrastructure. This support should include remote monitoring and diagnostics, on-demand technical support, fully qualified service technicians able to respond in less than 24 hours, and a local parts stocking and distribution network that ensures prompt delivery of genuine original-equipment replacements. Project lenders often require a reserve account for major maintenance to be established and funded over time to cover these periodic costs. An attractive option is to enter a complete operations and maintenance agreement with the equipment supplier that covers all planned service at an annual fixed cost. (This generally will negate the need for the project owner to establish a reserve account.)

Permitting risk

Each market has its own permitting regimen. Permits may be needed for environmental compliance, construction, air space, noise, forestry, and a variety of other requirements. The permitting authorities may be national, state or local. It is essential to understand the permit processes and allocate appropriate time to permitting.

Construction risk

The engineering, procurement and construction phase of a project requires an experienced contractor. It is essential to couple this experience with proven equipment, contracting and component suppliers. Guarantees of key milestones, such as project completion date, net electrical and thermal output, and the operating (or plant) heat rate based on local fuel parameters, help to ensure an on-time delivery of the project. Penalties for missing any guaranteed parameter should be sufficient to compensate for the resulting cost or loss of energy output.

Insurance risk

The entire project must be adequately insured against physical damage and public liability for accidents, property damage and personal injury. It should also be insured against lost revenue from business interruption, such as from a storm, flood or fire. Many financiers now also require separate coverage for environmental damage and liability.

Inflation risk

The financial model needs to include an adequate inflation factor covering both revenue and expenses. This escalator should include inflation in construction capital costs as well as long-term inflation that may affect operating costs, such as replacement parts, labor, rents and general expenses.

Political risk

Increasingly, energy projects face public scrutiny and can be derailed by public opposition. Small-scale distributed generation projects face much less resistance than coal-fired power plants or major transmission lines, but it is a mistake to assume they will escape any attention. The utility can mitigate political risk by undertaking public outreach through its established communication channels and relationships, and through special efforts, ranging from community meetings to one-on-one contacts with prospective neighbors. Physical accommodations like sound-attenuated equipment enclosures and neighborhood-compatible building features, can go a long way to ease public concerns.

Project Economics

After all risks are considered, the success of a distributed generation project comes down to its economic and operational performance. Clear performance criteria established well in advance of project startup can help guide decision-making through the equipment selection and construction stages. For example, unreliable power means significant loss of revenue; poor power quality means significant expenses to the utility and its customer.

A project lender will require a detailed financial model that shows all assumptions and follows generally accepted accounting principles to portray the project economics accurately. The model should be user-friendly, allowing the lender to review various “what-if” scenarios and test the strengths and weaknesses of the project economics.

Revenue

Base revenue assumptions amount to the value of the net kilowatt-hours (and therms) produced, and the services provided and sold. That in turn depends upon:

- **Availability.** Revenue is lost anytime the generating equipment does not operate, such as during scheduled or unscheduled maintenance and repairs, or at times when the fuel is supply reduced or interrupted.
- **Load factor.** Expressed as a percentage, this is the amount of power the generating equipment produced, versus the amount it ideally could have produced if operating continuously at full rated load during the measured period.
- **Derates.** High ambient temperature and high altitude may keep the generating equipment from achieving its nameplate capacity rating.
- **Firming/shaping revenue.** Some utilities collect fees from power providers such as wind farms for having generators on standby to firm the renewable resources.

Capital Expense

Capital costs include total physical plant costs: engines, heat recovery equipment (if applicable), distributed controls, power management system, station supervisory systems, and associated electrical, mechanical and civil work. Also included are interest during construction, legal and development fees and other soft costs, performance and completion bonding, reserves for cost overruns (typically 10 to 20 percent contingency) and project schedule management.

Operating Expense

Operating costs include staffing, fuel, service, parts and consumables, maintenance and repairs, and periodic overhauls. These costs can be minimized through techniques such as fluid analysis, condition monitoring and predictive maintenance methods, which may include fluid analysis, condition monitoring, vibration analysis, and iron trending. Operating expenses also include the cost to maintain and exercise generating resources installed to provide redundancy. A maintenance agreement with a local engine-generator dealer and other major equipment suppliers makes it easy to predict these costs over time and limit financial risk.

In determining economic performance, the equipment’s efficiency is important, but not nearly as important as its availability (uptime). Simply stated, anytime the generating equipment is offline, it produces zero revenue. Its kilowatts of capacity are devalued when its hours of operation are reduced.

To illustrate: Assume two 4 MW units, an electricity sale price of $70 per MWh, and a fuel production cost of US$4.55/MM Btu. Now assume that both units operate at 97 percent availability, but that Unit A is 43.7 percent efficient while Unit B is 44.6 percent efficient. In that scenario, the more efficient Unit B has a net revenue advantage of US$23,892 (1.97 percent).

Value of Efficiency

	Unit A	Unit B
Gen set kW	4,000	4,000
Gas Price $/mmbtu	$ 4.50	$ 4.50
Value of Energy Produced $/MW-hr	$ 70.00	$ 70.00
Generator Efficiency	97.0%	97.0%
Engine Heat Rate BTU/min	520,700	510,286
Capacity Factor	97.0%	97.0%
Generator Set Electrical Efficiency	43.7%	44.6%
Fuel Consumed/yr mmbtu	265,470	260,160
Cost of Fuel/Year	$ 1,194,613	$ 1,170,721
MW-Hour produced	33,989	33,989
Fuel Cost /MW-hr	$ 35.1473	$ 34.4443
Value of Power Produced	$ 2,379,216	$ 2,379,216
Net Revenue (Fuel Cost vs Power Produced)	$ 1,184,603	$ 1,208,495
Difference of Fuel and Power Produced		$ (23,892)
		Savings on Unit A over Unit B

Now for the same two units, assume that electrical efficiency is the same at 42 percent, but that Unit A's availability is 97 percent and Unit B's is 90 percent. In this scenario, the more available Unit A has a revenue advantage of US$85,487 (7.22 percent).

Value of Capacity Factor

	Unit A	Unit B
Gen set kW	4,000	4,000
Gas Price $/mmbtu	$ 4.50	$ 4.50
Value of Energy Produced $/MW-hr	$ 70.00	$ 70.00
Generator Efficiency	97.0%	97.0%
Engine Heat Rate BTU/min	520,700	520,700
Capacity Factor	97.0%	90.0%
Generator Set Electrical Efficiency	43.7%	43.7%
Fuel Consumed/yr mmbtu	265,470	246,312
Cost of Fuel/Year	$ 1,194,613	$ 1,108,404
MW-Hour produced	33,989	31,536
Fuel Cost /MW-hr	$ 35.15	$ 35.15
Value of Power Produced	$ 2,379,216	$ 2,207,520
Net Revenue (Fuel Cost vs Power Produced)	$ 1,184,603	$ 1,099,116
Difference of Fuel and Power Produced		$ 85,487
		Savings on Unit A over Unit B

It is unusual for only one parameter – efficiency or capacity factor – to be fluid in the evaluation of a project. It is far more common when comparing options for both units being evaluated to have different values. So now assume that for the same two units the fuel efficiency for Unit A is 43.7 percent while Unit B efficiency is 44.6 percent. Also assume that the capacity factor for unit A is at 97.0 percent while the capacity factor for Unit B is 90.0 percent. In this scenario, even though Unit B had the highest fuel efficiency, the more available Unit A still has a revenue advantage of US$63,319.

Value of Efficiency and Capacity Factor

	Unit A	**Unit B**
Gen set kW	4,000	4,000
Gas Price $/mmbtu	$ 4.50	$ 4.50
Value of Energy Produced $/MW-hr	$ 70.00	$ 70.00
Generator Efficiency	97.0%	97.0%
Engine Heat Rate BTU/min	520,700	510,286
Capacity Factor	97.0%	90.0%
Generator Set Electrical Efficiency	43.7%	44.6%
Fuel Consumed/yr mmbtu	265,470	241,386
Cost of Fuel/Year	$ 1,194,613	$ 1,086,236
MW-Hour produced	33,989	31,536
Fuel Cost /MW-hr	$ 35.1473	$ 34.4443
Value of Power Produced	$ 2,379,216	$ 2,207,520
Net Revenue (Fuel Cost vs Power Produced)	$ 1,184,603	$ 1,121,284
Difference of Fuel and Power Produced		$ 63,319
		Savings on Unit A over Unit B

Any economic analysis needs to consider potential revenue stream risks (decline in gas volume or quality, power line outages that interrupt power sales) and upsides (more and better-quality gas than expected, favorable renegotiation of an energy purchase agreement or fuel supply pricing, greater-than-expected equipment availability). Developers will commonly present financiers with worst, best and most likely case risk scenarios to help bracket the project economics opportunity.

All project economics need to be understood within the context of the utility's electricity costs and rate structure, components of which include:

- On- and off-peak prices and demand charges.
- Standby charges.
- Real-time pricing schemes.
- Non-availability penalties.
- Available incentives (utility or government).
- Interconnection fees.
- Wheeling charges.
- Tariffs.

- System operational impacts that require changes in distribution grid protection procedures. (Distributed generation may require updating distribution circuit-specific monitoring and protection schemes.)

Technical Considerations

Utilities respond best to a complete distributed generation solution presented in terms they understand. Such a solution includes:

- Application and plant design.
- Fuel availability and consistency with the right purity and at the appropriate pressure.
- Engine/generator technology selection.
- Electrical grid interconnection.
- Direct customer (host) interconnection, if any.
- Permitting (noise, emissions, zoning, and others)
- Waste management (generally not an issue with gas engines except for used oil and fluids).
- Heat recovery equipment (exhaust heat boilers, jacket water/oil cooler/aftercooler heat exchangers, absorption chillers).

Putting it All Together

A great way to determine whether a distributed generation project is appropriate in a given case is to work with an experienced partner with proven qualifications to do the initial analysis, manage the risks and analyze the economics. Ideally, this party should be able to take the project from initial review through construction and operations. Engine-generator manufacturers are ideally suited to perform this function. Most have a diverse technology portfolio, a well-developed dealer network and a strong financing arm. The right manufacturer can bring to bear:

- A variety of generating technologies in power ratings to suit the application. This can include engines designed specifically to suit 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, including 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

Utilities' traditional business models increasingly face challenges as markets change, customers' needs evolve, and alternate generating technologies improve. Distributed generation can help utilities address critical concerns of reliability, grid stability, sustainability, capital deployment, and more.

As field-proven sources of low-emission energy, available on demand, natural-gas-fueled engine-generators can be practical, economical additions to utility supply portfolios. These are opportune times to explore the technology in detail and evaluate its potential to lend business stability in a fast-changing world.

Sidebar

Distributed Generation: The Value Proposition

Several variables drive value in distributed generation projects. A basic knowledge of success criteria helps lead to productive and profitable installations.

Reliability

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. Multiple shafts (engines) are better than one – redundancy helps minimize reliability issues. Smart grid applications will enhance the benefits of distributed generation, as it will make customer-specific solutions easier to tailor to a site. For example, utilities will be able to send price signals directly to users.

System Capital Deferral

Distributed generation is relatively easy to employ and can be an excellent alternative to building new transmission lines in a time when such projects often meet stiff political resistance. Environmental concerns and air-quality regulations have tended to shift the mix of generation fuels 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.

Renewable Integration

Regulatory trends and the increasing viability of renewable resources have expanded the use of non-carbon-emitting generators. The unique attributes of renewables require special planning considerations. For example, renewables are often remotely located, requiring significant transmission links, sometimes over challenging terrain. Wind and solar resource variability requires ancillary services such as voltage support, frequency control, increased base-load unit dispatch flexibility, and spinning reserves. In addition, available capacity at times of peak demand can be significantly less than the nameplate capacity. Entities responsible for bulk power system reliability must account for these attributes to ensure that wind and solar are reliably integrated into the system.

Heat Recovery

Combined heat and power enhances gas engines' inherent fuel economy – overall efficiency of 75 to 80 percent is routine, and efficiencies up to 90 percent are achievable if sufficient heat load is available. In general, the longer the annual operating hours, the greater the potential for profitable CHP. Engine exhaust provides by far the highest temperatures and the greatest heat output. Exhaust heat can generate intermediate-pressure steam for uses like boiler feedwater heating, and low-pressure steam for processes like sterilization, pasteurization, space heating, tank heating and humidification. Heat also can be extracted from the engine jacket water, oil cooler and aftercooler to produce warm or hot water for space heating and industrial processes.

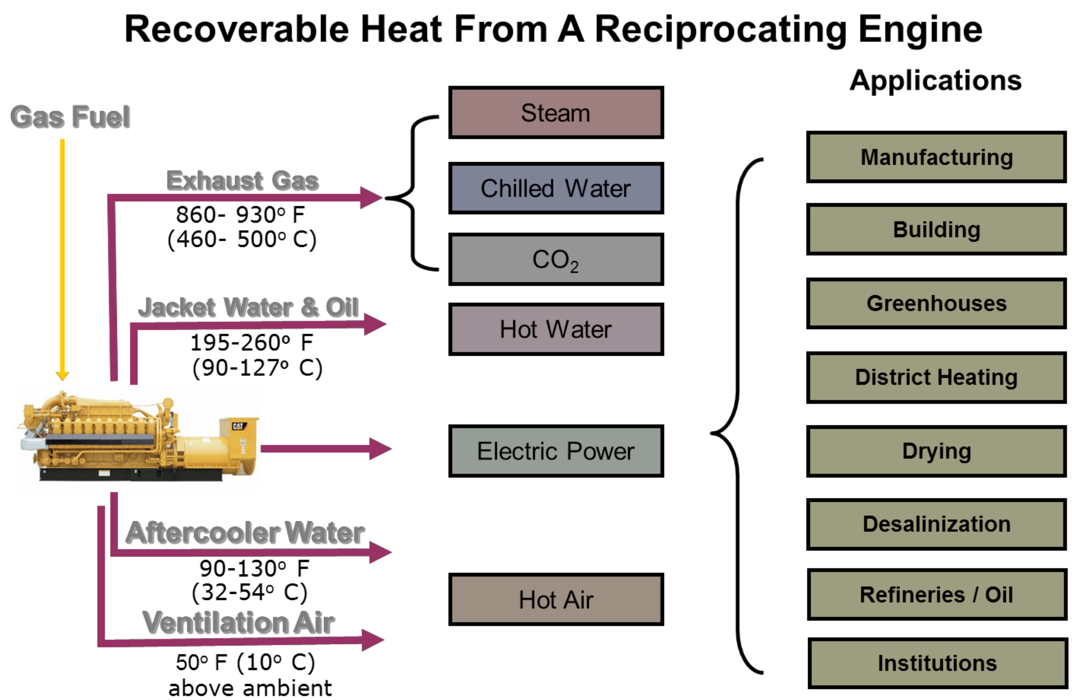

Figure 6: Recoverable heat from a reciprocating engine and potential applications.

Understanding Dispatch Criteria

The installation of distributed generation assets is only the beginning. The key to success is knowing when to dispatch them. That in turn depends on understanding the strike price – the per-kWh cost at which running them becomes financially beneficial. To get the most value from distributed generation, it is essential to understand the dynamics of regional power markets and the utility's current and projected load profiles.

3D load graphs can help managers understand hourly, daily and seasonal load patterns. In the accompanying annual load graph (Figure 8), the x-axis represents day of year, the y-axis represents the hour of the day, and the z-axis represents system demand (in megawatts). The graph shows visually what is happening on the system hour by hour, every day of the month, and every month of the year. Load patterns, most critically the peak load periods, become clear:

- Areas shaded blue represent periods of low usage, essentially base-load periods when the cost of generation is low.
- Areas shaded in red represent intermediate load periods. These loads are

typically fulfilled by large combustion turbines that run for relatively long periods at somewhat higher but still predictable operating cost.

- Areas shaded white represent times of peak demand. In general, the higher the peak, the higher the per-kWh cost of energy. These are the periods in which distributed generation sources like reciprocating gas engines are most likely to come into play.

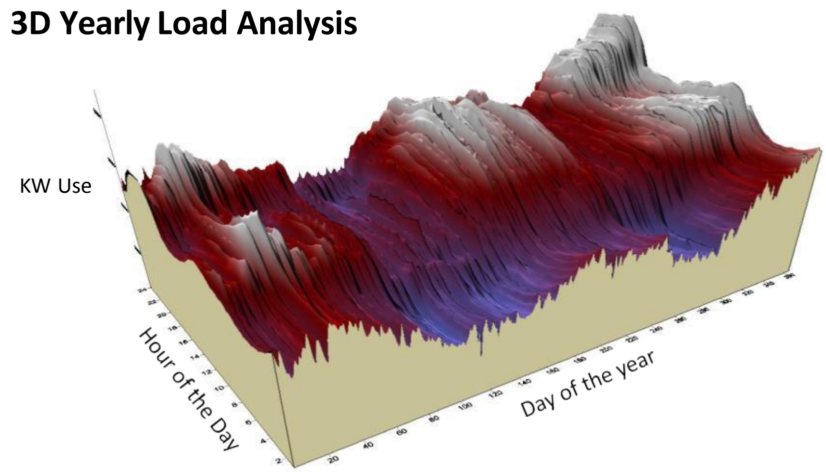

Figure 7: Annual utility load profile
Chart used with permission from Black Diamond Solutions Inc.

For a given utility, the timing and height of peaks depends on factors that include the local climate and population patterns (e.g. seasonal versus year-round population). A key question is whether to meet peaks by generating power or purchasing it on the market. The answer depends on a careful analysis of the costs of each option. In general, in-house generation pays when it costs less per kWh than purchasing power.

By carefully calculating the total cost of generation for each unit, accounting for all capital and operating expenses, a utility can “stack” its generating resources and set a strike price for each one, as in the accompanying table (Figure 8).

Generation Assumptions

Assumptions

Natural Gas $7.50 $/mmBtu

Unit	Type	Capacity (kW)	Heat Rate Btu/kWh	Fuel Dth/Hr	Fuel $/mWh	Maintenance $/mWh	Strike Price $/mWh
Unit #1	CAT 3516 CLE	1,360	9,860	13.41	$73.95	$ 18.04	$91.99
Unit #2	CAT 3516 CLE	1,360	9,860	13.41	$73.95	$ 18.04	$91.99
Unit #3	CAT G-399	650	12,009	7.81	$90.07	$ 18.04	$108.11
Unit #4	CAT 3520	1,850	9,860	18.24	$73.95	$ 18.04	$91.99
Unit #5	CAT 3516 Lean Burn	750	10,788	8.09	$80.91	$ 18.04	$98.95
Unit #6	CAT 3516 Lean Burn	750	10,788	8.09	$80.91	$ 18.04	$98.95
Unit #7	CAT 3520	1,850	9,860	18.24	$73.95	$ 18.04	$91.99
Unit #8	CAT 3520	1,850	9,860	18.24	$73.95	$ 18.04	$91.99

Figure 8: Calculating the strike price of local resources

Of course, the cost of purchased energy rises with the height of the peak on the load graph, while the cost of generation remains fixed, absent any major swings in fuel cost. Therefore, as the load curve ascends, the cost advantage of gas-fueled generation increases. That advantage increases further if transmission constraints limit capacity to import purchased power from the grid.

Service references
SEBU6400-05
SEBU8554-03
SEBU7681-17

About the Authors

Todd Scott (Todd.Scott@cat.com) is a Senior International Accounts Manager for Latin America with Caterpillar Financial.

Michael A. Devine (Devine_Michael_A@cat.com) is Gas Product/Marketing Manager with the Electric Power Gas Group of Caterpillar Inc., based in Lafayette, Ind.

About Caterpillar

For more than 85 years, Caterpillar Inc. has been making progress possible and driving positive and sustainable change on every continent. With 2014 sales and revenues of $55.2 billion, Caterpillar is a technology leader and the world's leading manufacturer of construction and mining equipment, clean diesel and natural gas engines and industrial gas turbines.

Cat Gas Solutions: www.catgaspower.com
Online Community: https://caterpillar.lithium.com/t5/Electric-Power-Generation/ct-p/EPG
YouTube: http://www.youtube.com/CatPowerGeneration
Contact a Dealer: http://cat.com/dealer-locator

LEXE0831-00 February 2015