

Multiple Benefits of Distributed Fuel Cell Generation in Commercial Buildings

Joel N. Swisher, Rocky Mountain Institute

ABSTRACT

There is a great deal of interest in distributed generation (DG) technologies to reduce electricity generation and distribution costs, while improving reliability of service. This paper explains the economic benefits of fuel cell DG. Although several existing technologies can provide DG on a scale suitable for commercial customers, fuel cells are cleaner and quieter than gas turbines and engines. Compared to solar and wind power, fuel cells are more reliable and dispatchable, attributes that are needed to deliver distributed economic benefits.

Background

Several prominent manufacturers of fuel cell systems have made announcements of forthcoming products aimed at the residential building market. For example, General Motors announced recently that they will adapt their vehicular fuel cell technology for use in homes, and Honda has developed a residential-scale co-generation unit.

However, careful analysis of the costs and benefits of DG indicate that fuel cell technology is far more attractive if applied in commercial buildings, or in mixed commercial-residential developments. Several benefits are more readily captured in the commercial sector: premium reliability of service, co-generation of heat and power, distribution costs savings, and economies of scale in the balance-of-system costs. These benefits are discussed below and in much more detail in a recent Rocky Mountain Institute report (Swisher, 2002).

Remote power systems are another market niche for DG technologies. However, their economic benefits are limited by high fuel costs, limited reliability, lack of thermal loads, and poor matching of output with loads. The economic benefits of DG technologies such as fuel cells are likely to be far greater for grid-connected applications, especially those in the commercial sector.

Fuel Cells: A Small, Clean, Reliable Power Source

Fuel cells can run on natural gas with high-efficiency, little pollution and few moving parts. Thus, they offer a potential power source that is clean, reliable and flexible in size. The major remaining obstacle is cost. The present (2002) cost of a kilowatt (kW) of fuel cell capacity is about 7-10 times that of the combined-cycle combustion turbines that are used in today's new, central generating stations. Fuel cells are also several times more costly than small, mass-produced reciprocating gasoline or diesel engines used as backup generators.

Once they are in operation, fuel cells can be inexpensive to operate. Maintenance costs are expected to be low due to relatively few moving parts, and the high efficiency and useful heat by-product provide for low fuel costs. Fuel cells are a high-capital-cost, low-energy-cost power source. Compared to efficient central combined-cycle stations, the energy

cost advantage is small, so it is essential to reduce the capital cost disadvantage in order to make fuel cells competitive.

There are two ways to reduce fuel cells' capital cost disadvantage against central combined-cycle stations. One way is to reduce the cost of fuel cells, and numerous manufacturers are working hard to achieve cost reductions in each of the fuel cell technologies now under development, as they enter high-volume production. The other way is to build the value side of the equation—to find additional economic benefits that fuel cells can deliver by virtue of their smaller size and greater flexibility, as well as their quiet, clean operation. Co-generation of electricity and heat energy is a significant benefit made possible because fuel cells can be sited near customers and in crowded urban centers.

Small DG sources can provide many other benefits, which are discussed in more detail below. They include the modularity and flexibility that comes with small scale, the potential to reduce distribution grid capital and operating costs, and the ability to increase reliability for customers who need it. Finally, the environmental benefits of fuel cells are becoming ever more tangible in value.

Changing Trends in the Electricity Industry

The market conditions in the electric power industry have changed dramatically during the last ten years, and the forces of change have been at work for at least two decades. The industry maxim that "bigger is better" now no longer applies; bigger is no longer better all the time, or even most of the time. The reasons include industry restructuring, environmental constraints, reliability needs, new technology, the inevitable aging and deterioration of the existing power supply infrastructure, and renewed concerns about energy supply security.

The introduction of competitive electricity markets via restructuring has been a chaotic process, both in the U.S. and abroad, and the process is far from complete. Some of the chaos in the U.S. results from the lack of uniform policies or rules. In the power sector, only long-haul transmission and wholesale trade are regulated at the Federal level. The rest of the industry is regulated by state-level public utility commissions or boards, resulting in 50+ different regulatory regimes and policies. At present, the status of restructuring ranges from full competition to continued full regulation, with many states somewhere in between.

The effects of restructuring are profound in some parts of the electricity industry. Competition in power generation has begun to impose greater market discipline, such that utilities can no longer build hugely expensive nuclear and coal-fired plants with full confidence of recovering capital costs. Central steam-turbine generation plants stopped getting more efficient in the 1960s, stopped getting cheaper in the 1970s, stopped getting bigger in the 1980s, and stopped getting built in the 1990s.

The newly-imposed financial discipline in electricity generation is even being applied to still-regulated utilities in the form of "performance-based" regulation. Today, producers must be confident that sufficient demand exists and that prices will support the revenues needed to justify investments in new capacity.

Small Is Profitable: The Economic Benefits of Distributed Generation

Power generation plants are getting smaller, and DG is part of this trend. Below, we address the benefits of DG, and specifically fuel cells. Another part of the story is that the transmission and distribution (T&D) grid needs refurbishing and upgrading, but not necessarily with simply more wires and transformers. The best solutions could involve a combination of these technologies, together with targeted energy-efficiency measures and properly sited DG, storage, switching, controls and communications technologies. The benefits of distributed generation include several general categories:

- Energy cost savings from avoided electric and thermal energy purchases
- Option values from small scale, modularity, short lead time and high flexibility
- Distribution capacity cost deferral if correctly sited in time and place
- Electrical engineering cost savings in losses and ancillary services
- Utility and customer reliability benefits, including premium-power service
- Environmental benefits from emission costs and siting advantages

Energy Cost Savings

The use of DG to supply electricity saves the cost of purchasing that electricity from the grid, and some applications may provide additional revenues from exporting power. The value of electricity saved or sold depends on the regulatory and pricing regime in which the local distribution utility operates. Net metering policies, under which DG operators receive the retail electricity price for their output, are the most advantageous. However, in most instances today, DG is more likely to receive only the lower wholesale power price. Another advantage of DG, because it can be sited near customers, is its ability to co-generate heat and power, providing additional savings in avoided heating fuel purchases.

Option Values

When central power generation costs were an order of magnitude cheaper than small generation, there was no reason to consider DG if a connection to the grid was available. Today, however, new technology has brought the cost of DG within the range of that of central generation, even as the cost of central combined-cycle generation has fallen. With DG costs approaching the competitive range, it makes sense to sharpen the financial economics pencil and explore the economic benefits of small scale and high flexibility.

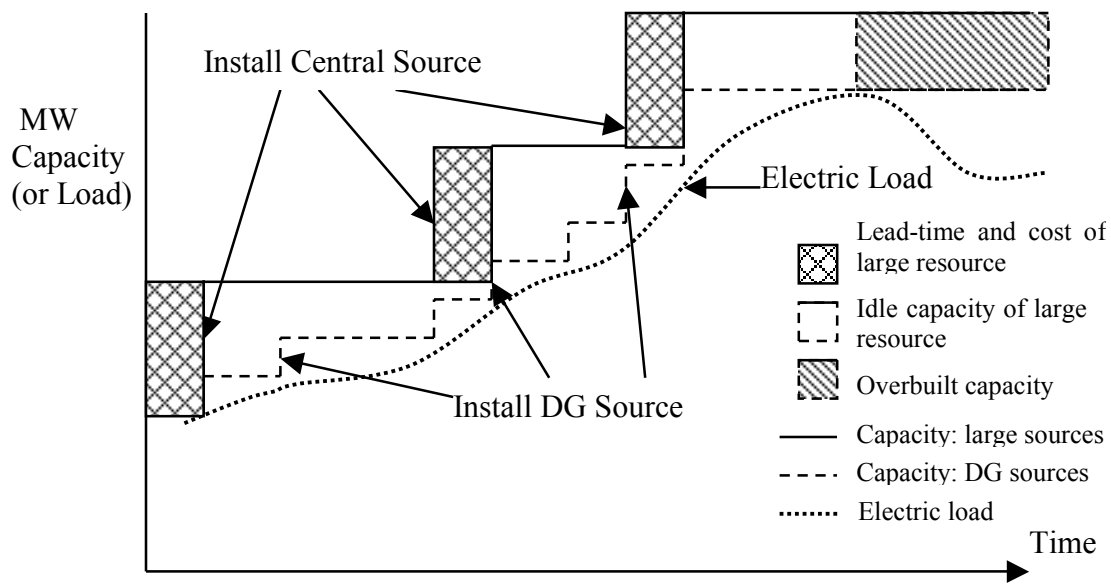
Because electricity is prohibitively expensive to store in large quantities, it is like a commodity with a short shelf life, such as milk. Imagine if one could only buy milk in 100-gallon barrels, and that it took several days for an order to arrive. We would no doubt be sure to order earlier than necessary to avoid running out; we would often have an excess of milk; and a lot of milk would be unused and spoiled because of its short life. Wouldn't it be more efficient to get milk in 1-gallon bottles at a local store? We would save so much from reduced spoilage that we could afford to pay a higher unit price for the milk. This premium, based on the option to buy as little or as much as we need, just when we need it, is the "option value" that comes from small size and flexibility.

This option value applies even more powerfully to electricity generation. Central generation plants, as well as T&D capacity, are “lumpy” investments; i.e. they come in large increments. Often, a large unit is built to meet demand that is expected to exceed existing capacity by only a small amount. This leads to excess capacity that remains idle but still incurs costs. Smaller units can reduce the need to overbuild to meet expected demand growth. Traditional utility regulation rewarded overbuilding, but the financial discipline of a competitive market will surely penalize producers with idle capacity.

In addition, the modularity that accompanies small scale can improve the rate of response to demand changes. If new customers suddenly require unexpectedly large amounts of power, then small, modular DG units can usually be in service faster than large central stations. The short lead-time of smaller units is thus an advantage in responding to demand changes without building unnecessary idle capacity (see Figure 1).

Short lead-time also reduces the carrying costs of plants under construction, which can reduce the present-value cost of the plant itself. As in the milk example above, reducing the lead-time also reduces the incentive to overbuild, as it is easier and less expensive to increase capacity in response to demand growth when it occurs.

Figure 1. Comparison of Capacity and Cost Impacts of Adding DG or Central Sources¹



Distribution Cost Deferral

DG can also offset costs in the T&D system, providing additional financial benefit to the utility. Until recently, most utilities treated T&D costs as unavoidable components in the expansion of the generation network, based on engineering rules of thumb designed to maintain accepted system reliability criteria. Also, traditional regulation prevented utilities from charging different prices to different customers, for example charging more distant

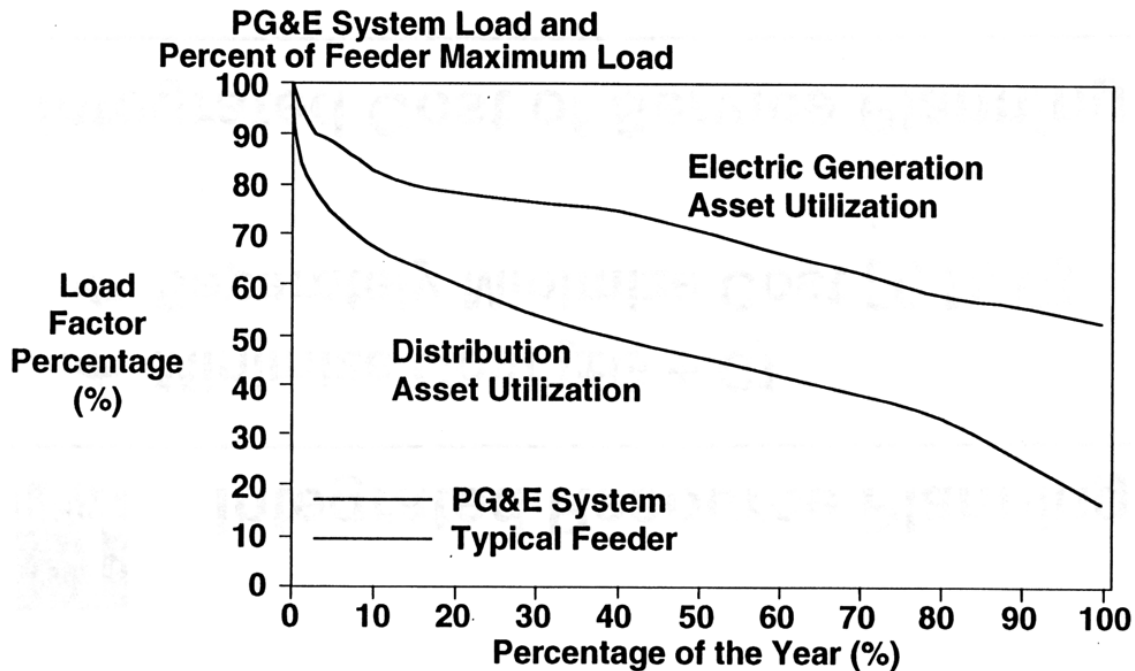
¹ The central source is available in large capacity increments and has a long lead-time. The DG source is available in flexible capacity increments and has a short lead-time. Option value benefits of DG compared to the central source include 1) increased lead-time and cost of central sources, 2) increased cost of idle capacity that exceeds existing load, and 3) increased cost of overbuilt capacity that remains idle.

customers proportionately for higher distribution costs. Instead, they were forced to subsidize high-cost customers at the expense of others.

With restructuring, and especially performance-based regulation, there is greater pressure on electric suppliers to control capital expenditures, and it is becoming feasible to use varying customer price structures, based on the cost of service. These changes open the door for distribution utilities to take action to reduce costs, or increase revenues, in high-cost areas that they were traditionally expected to subsidize. DG can play a major role in this strategy, but first utilities need to identify the areas where potentially high costs are expected and to target DG (and energy efficiency) specifically to those areas.

It is important to note that, like generation, T&D expenditures are lumpy. Moreover, distribution capacity is actually utilized even less of the time than generation capacity, as shown in Figure 2, because being closer to the load, it serves fewer customers whose loads are less diversified. This means that these large, lumpy distribution investments are idle much of the time. Thus, deferring such investments can yield significant cost savings.

Figure 2. Comparison of Load Duration Curve for Distribution Feeders vs. Generation²



Recent analytic advances in determining utilities' area- and time-specific (ATS) costs more accurately have important implications for the siting and design of DG sources. This method has been applied by numerous electric utilities in the U.S. and Canada, and its use has been adapted to utilities in Brazil, Hong Kong, Israel, the Philippines and South Africa.

² A load duration curve shows the fraction of the time that the load is equal to or less than a given fraction of its annual maximum. The area under the curve is the load factor, an indication of the utilization of the supply resource. Generation resources see a much higher load factor than most distribution resources, because they serve all customers and see the maximum load diversity. The data are from Feinstein, 1993.

The most important innovation of the ATS method is to distinguish the marginal distribution capacity cost (MDCC) from the familiar system-level utility capacity and energy costs. Unlike the system-level utility costs, which are most sensitive to generation and bulk transmission costs, area-specific costs largely depend on distribution and local transmission capacity costs. As a result of pursuing this kind of analysis, a distribution utility may discover an option to choose the least-cost means to serve incremental demand from a significantly expanded list of resources:³

- Develop small-scale *DG facilities* located near the source of load growth (Swisher, 2002),
- Use *differentiated rates* to encourage customers to limit demand during peak hours (EPRI, 1994),
- Promote *energy efficiency* for customers or uses that drive the peak demand (Swisher and Orans, 1996),
- Rely entirely on central-grid power, and incur the costs of *new T&D capacity* to transport the power to customers with new and/or increasing loads.

One consistent result of ATS analysis is that T&D costs vary widely in time and place, creating large variations in MDCC values. Thus, ATS costing allows precise targeting of DG projects in areas where the distribution utility costs are relatively high. Where DG capacity can defer new T&D capacity, it has an economic deferral value to the grid.

In theory, higher utility costs mean higher value for DG alternatives, potentially allowing more attractive investments in such sources as fuel cells. By selectively targeting projects to minimize utility costs, it should be possible (albeit still difficult in practice) to improve the terms that the utility offers for privately produced power from DG sources.

If utilities know what their area-specific costs are, they will know where and when their costs are significantly higher than the system average. The timing is important, because cost estimates must be forward-looking. Thus, high-cost areas can move around in space and time (see Figure 3). Some utilities have many such areas, while others will have few if their general level of excess distribution capacity is relatively large.

Electrical Engineering Cost Savings

In addition to capacity deferral value, DG can provide economic benefits to distribution utilities by reducing costs in the operation and maintenance of T&D systems. These potential electrical engineering benefits include:

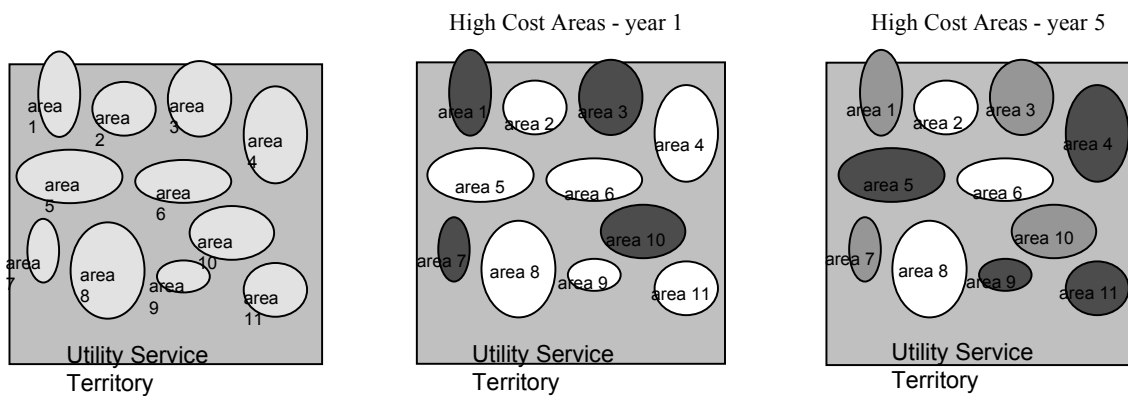
- **Reduction of Losses.** DG can reduce system losses by reducing the current flow from the transmission system through the transformers and conductors on the distribution system. DG-based loss reduction also reduces the distribution utility's total installed capacity (and corresponding cost) as seen by the transmission system.
- **Voltage Support.** DG can support voltage in areas of the distribution system that suffer large drops at high loads, replacing voltage regulators and line upgrades.

³ The comprehensive approach to least-cost distribution planning is sometimes labeled local integrated resource planning (LIRP), which is a promising application of the ATS costing method. See Lenssen, 1995. New applications, in the restructured environment, are labeled energy resource investment strategy (ERIS).

Voltage support is provided by injecting power into the system at the DG site, thereby reducing the current and corresponding voltage drop from the substation to the area. DG can also regulate voltage by balancing fluctuating loads with generation output.

- **Reactive Power Support.** DG can help balance reactive power flows on a distribution system with both real and reactive power injection. Real power injection reduces current in the conductors, which is a major source of reactive power demand that is typically treated with banks of capacitors. Improved reactive power flow (as indicated by a higher power factor) reduces current and losses on transmission and distribution components, and helps control system voltage.
- **Equipment Life Extension.** DG can provide value for equipment life extension in aging facilities, especially if transformers and feeder lines are under heavy loading. If DG is used to keep loading levels on these facilities below a predefined de-rated value, the DG source can defer the transformers' or lines' replacement costs.

Figure 3. Comparison of Conventional DG Siting to Targeted (ATS-Based) Approach



*Conventional approach:
Based on system-level costs,
all areas look the same...*

*Based on area-specific costs:
Some high cost (dark) areas are attractive for DG now,
but other areas become the high-cost (dark) areas later.*

Another advantage is that fuel cells are direct current power sources. Like certain other DG technologies, fuel cells rely on an inverter to convert DC power to AC power. Correctly designed inverters can provide voltage and reactive power support in a distribution system (Dugan and Ball, 1995). This can offset costs of capacitor banks, voltage regulators, and other equipment. Additional modest cost savings result from extending the life of transformers and feeder lines.

Reliability Benefits

One of the most exciting prospects for DG technology is the potential to provide valuable benefits in terms of improved customer reliability. One consequence of the emergence of today's digital economy is the need for premium-reliability power in facilities operated by a wide range of businesses. A customer's cost for a power outage, and thus the value of preventing the outage, is increasing. The outstanding questions are then:

- How much is premium-reliability power worth?
- Which customers are willing to pay for premium-reliability power?

- To what extent can DG provide the needed reliability?
- How can the reliability benefits be captured for the DG owner?

The value of customer reliability, which reflects the avoided cost of power outages, is difficult to estimate and appears to be changing rapidly. DG-provided reliability can reduce inconvenience, discomfort, direct costs, and opportunity costs from lost sales or production. The sum of these is the value of service (VOS). VOS varies widely, from low residential values to more than \$1000 per outage, even momentary, for commercial customers.

Most existing VOS studies are still based on surveys of traditional industries, where sustained loss of refrigeration or prime movers could incur substantial costs. Today, however, even the briefest outage could be crippling to many digital-economy businesses. The rapid pace of technological change and the new business models evolving in the information and telecommunications industries makes these customer reliability benefits the most difficult to quantify at present.

To what extent can DG enhance reliability, and why haven't utilities taken advantage of this resource in the past? The answer depends, to a large degree, on how reliability is defined. Utility grid design focuses on providing a uniform level of reliability under conditions of peak demand. Traditional generation system design aims for an outage probability of 0.0003, or 99.97% reliability (3.5 "nines"). This level is achieved, despite the 90-95% reliability of generation plants, by having excess reserve capacity available.

Because the majority of outages is caused by faults in the distribution system, from interference by trees, animals, cars, etc., rather than by generation, the true reliability is about 99.9% (3 "nines"). Even at this level, it is difficult for a DG system to improve peak availability beyond that of a wires-only system. To do so, the DG capacity would have to serve the entire peak load at a high level of reliability.

However, if most of the reliability value is associated with lower loads, and in particular with specific, critical loads, then DG can improve reliability beyond that of a wires-only solution by reducing the probability of losing critical loads. For these loads, DG can increase the reliability to more than five "nines," and higher with additional redundancy.

Thus, DG sources such as fuel cells can provide customer reliability services that wires alone cannot. DG can provide protection of critical loads from sustained outages far beyond what a typical uninterruptible power supply (UPS) can provide, and it can respond to problems caused by momentary interruptions faster than conventional standby generators.⁴

To increase reliability value, a fuel cell system must use highly reliable components, redundancy of multiple components, or both. Because more and better components increase costs, there is a trade-off between reliability value and capital cost. Also, the fuel cell system must be operated and maintained to ensure its availability when outages occur. Some quantity of hydrogen storage can mitigate the risk of fuel-supply failure, either from component failure or interruptions in natural gas supply. The latter risk can also be further mitigated by bottled gas as an on-site backup supply.

Unlike the value provided by distribution capacity deferrals or engineering cost savings, customer reliability benefits provide value directly to the customer. This means that DG developers have the opportunity to market DG reliability benefits (and other values to the

⁴ Conventional standby generators are not capable of responding to instantaneous power interruptions. Rather, they rely on a battery-powered uninterruptible power supply (UPS), together with fast-response power electronics to provide ride-through power until the generator can carry the load.

extent possible) directly to the customer. For example, the flagship Conde Nast building on Times Square in New York uses a combination of fuel cells, solar photovoltaics, and doubled energy efficiency to attract tenants at premium rents, using the advantage that the building's two most reliable power sources are located within the building itself.

Fuel cells are more expensive than traditional standby generators and battery-based UPS systems. However, batteries provide only a limited duration of support, they tend to lose capacity over time, and they have high maintenance and space requirements. While conventional generators are less expensive than fuel cells, the potentially high VOS for fast-growing market segments such as data centers suggests that customers could be willing to pay a cost premium for high-reliability power, if fuel cells can offer other advantages.

Environmental Benefits

Reciprocating engines, small turbines, microturbines, and other DG technologies can provide similar distributed benefits as fuel cells. With a typical size range of 1-5 MW, DG sited near a substation for distribution support would be a good fit for new combustion turbines, which have fuel-to-electricity efficiencies as high as 42%. In the size range less than 100 kW, DG sited near loads and at the end of feeders might be candidates for microturbines.

Both of these turbine technologies have lower costs than fuel cells, at least at present. Reciprocating engines are even cheaper. How, then, can fuel cells find a large enough market niche to enter this market and build sales volume in order to reduce costs? The answer depends, among other factors, on the regulatory feasibility of siting DG sources, based on environmental requirements. In particular, many potential DG applications will be in non-attainment areas for NO_x. In these areas, DG will receive increasing scrutiny with regard to air emissions. This is bad news for reciprocating engines, and probably for small gas turbines, but it is good news for fuel cells and renewable sources.

New DG emission standards under consideration in California and Texas will make it difficult for turbines, and nearly impossible for reciprocating engines, to meet the permitting standards (California, 2000; Texas, 2000). Fuel cells and renewable technologies, on the other hand, should have little difficulty meeting these standards. For example, air quality regulation in Southern California, where emission standards are the tightest in the country, explicitly exempts fuel cells from permitting requirements, even in base-load applications.

It is important to note that these proposed regulations and other permitting requirements govern the siting of DG sources, not their operation. Stringent siting criteria will make it more difficult for other DG technologies to compete with fuel cells in providing capacity, where the other technologies would otherwise have a cost advantage (i.e., their cost per kW is less than fuel cells). The relative ease with which fuel cells can be sited confers a significant time, and therefore, financial, benefit on this technology.

Once a DG source is sited, its operating cost may not be very important, because such applications as capacity deferral and grid support require relatively few operating hours per year. The capacity, not the energy, is the source of value. The lower energy costs of fuel cells provide no economic advantage if high capacity costs prevent their installation in the first place. Even if conventional DG technologies have to buy expensive emission credits to operate, or even pay carbon taxes in the future, their lower capacity costs will prevail in applications that require few operating hours, but only if they can obtain siting permits.

Thus, air emissions benefits are most likely to make fuel cells more competitive compared to other DG sources in terms of initial siting and permitting, helping to overcome the capacity-cost premium of fuel cells. Emission benefits are less important in terms of operating cost, where high-efficiency fuel cells already have an energy-cost advantage. An emissions advantage will be most important in urban areas that are non-attainment for NO_x, as in most of California and cities in other states.

The Bottom Line

We have identified many sources of economic benefits of distributed generation, but it is important to observe that not all of these benefits necessarily occur together in the same applications. Moreover, all of these benefit values are highly site- and technology-specific, and their evaluation often requires rather detailed technical and economic analysis. We can study an example based on experience with estimating these benefits.

Although it is difficult to generalize the economic benefits of DG, their magnitude seems to be significant. A fuel cell DG system could provide the following distributed benefits (Swisher, 2002):

- Electric energy value—Regardless of DG benefits, the energy produced by a fuel cell system would be worth about \$100-150/kW-year, assuming the system is sized to provide base-load power and operate almost continuously.
- Thermal energy value—Especially in a commercial application, the waste heat recovered from the fuel cell can provide fuel savings of about \$100-150/kW-year.
- Option value—In an area with fast but uneven growth, the added cost of overbuilding generation that could be avoided by widespread use of DG is about \$50-200/kW-year.
- Deferral value—In a high-cost area, with distribution capacity constraints and moderate growth, the deferral value would be about \$50-200/kW-year, assuming that these areas are targeted with sufficient DG capacity to defer capacity expansion.
- Engineering cost savings—In a “problem” distribution area, properly cited DG can avoid the cost to re-conductor feeders, add capacitor banks, and install voltage regulators, worth about \$50-150/kW-year. Reductions in losses are worth about \$25/kW-year.
- Customer reliability value—In a commercial application with a high value of service, a highly reliable DG system that reduces outage risk for critical loads provides a reliability value of \$25-250/kW-year, depending on the customer value of service.
- Environmental value—The environmental benefit of fuel cells’ low emission rate is unlikely to be realized directly, but it makes fuel cells easier to site than other DG.

In addition to the electric and thermal energy values, any one of the other DG values make the total DG value reach about \$400/kW-year or higher. In an area where all these benefits are realized, the total DG value could reach about \$800/kW-year or higher.

The relationship between these benefit values and the allowable costs for fuel cell systems depends on our assumptions about fuel cell financing. Conventional commercial financing requires about 20% annual cost recovery, while a 30-year residential mortgage would require only about 10% annual cost recovery.

Using these ratios, a DG value of \$400/kW-year would translate in to an allowable capital cost of \$2000/kW with commercial financing, or \$4000/kW with mortgage financing. A DG value of \$800/kW-year would translate in to an allowable capital cost of \$4000/kW with commercial financing. The \$2000/kW value is considered achievable in the near future by fuel cell manufacturers, while the \$4000/kW value is commercially achievable today, or nearly so. This means that with proper design and siting, fuel cell DG systems can be cost-effective today, based on the value of their distributed benefits.

The mechanism for capturing these benefits for the DG owner is often not obvious. Some DG advocates present DG as an alternative to utility service, suggesting that customers can profit most from supplying their own electricity independently. Without any utility connection, however, it would be difficult to capture most of the distributed benefits we have identified here. Thus, the economic justification for an off-grid strategy is weak.

Because of the need for utility data to evaluate DG benefits, and because these benefits tend to accrue most directly to the utility, it is hard to imagine capturing their value without some degree of cooperation with the incumbent distribution utility. Such cooperation can be facilitated by collaborative work toward technical and procedural standards, such as the Institute for Electrical and Electronic Engineers interconnection standard that is under development and expected to be released soon.

Even when ATS analysis clearly demonstrates high avoided costs of distribution capacity and potential benefits from DG, there may also be other, more conventional solutions. Indeed, ATS analysis can help utilities find less expensive approaches to implementing traditional T&D upgrades and expansion.

Similarly, end-use technologies provide distributed benefits by eliminating or deferring the need for T&D upgrades by strategically reducing or shifting peak customer loads. Targeted demand-side management (DSM) programs to reduce the area peak load can be part of the least-cost design to relieve distribution constraints (Swisher and Orans, 1996). These programs range from tariff structures such as curtailable rates and real-time pricing to equipment rebates and direct installation programs. While this approach has practical limitations to implementing programs with sufficient scale and speed to defer distribution capacity, both DG and DSM can contribute to a least-cost distribution planning solution.

Early Markets and Commercialization Paths

One early market niche with substantial distributed benefits would be the high-cost distribution “hot spots,” indicated by ATS cost analysis, particularly those in areas with emission constraints. Because both distribution constraints and emission constraints are likely to occur in urban areas, there should be many areas that meet these criteria at any given time. As discussed earlier, the main challenge for the DG owner is to capture the distribution benefit that accrues most directly to the utility.

Another promising market, albeit a difficult market to quantify, is serving commercial customers with premium reliability needs. Again, this market is especially attractive for fuel cells in areas with emission constraints, and these areas also tend to correspond to areas with a high concentration of premium-reliability customers. The advantage of this market is that the DG owner can charge the customer directly, without depending on the utility to identify attractive areas or to capture the benefits of DG.

Thus, the near-term commercialization path for fuel cells appears to be grid-connected fuel cell systems in commercial buildings, communication providers, semiconductor fabrication facilities,⁵ and other facilities that have coincident needs for high reliability and low emissions. The most cost-effective applications will be in locations with high avoided costs, as indicated by distribution constraints or ATS cost analysis.

Conclusion

There is significant value in siting DG where it can defer distribution investments, reduce utility engineering costs, improve customer reliability, and provide both heat and power. These benefits are pertinent to commercial building applications, and their values can equal or exceed the basic energy value of a DG source, making dispatchable DG technology such as fuel cells attractive in many areas. The ability of DG owners to capture such value depends on the tariff structures and regulatory treatment of distribution utilities. Cooperation with these utilities will probably be necessary to capture the greatest value from fuel cell DG.

Fuel cells are well suited to provide distributed benefits, despite the lower present costs of competing technologies. To compete successfully against small turbines and engines in urban applications, fuel cells must be cleaner and quieter, and indeed they are far more environmentally benign. Compared to clean, renewable sources such as solar and wind, fuel cells have the advantage of being highly reliable and dispatchable, i.e., able to start up and operate at any time. This attribute is necessary to deliver most types of distributed benefits.

Thus, fuel cells in commercial buildings fill an important market niche by delivering both environmental and distributed economic benefits. To the extent that distributed benefits of DG can be captured, fuel cells have great potential to provide clean distributed energy.

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⁵ Fuel cells can give semiconductor fabs several benefits: reliable power without massive battery UPS, waste heat for process heat and cooling, ultra-pure hot water (replacing a costly process input), on-site hydrogen supply (displacing an expensive process reagent), and emission reduction credits.

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