PEM Fuel Cell Development for a Deregulated Marketplace

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This paper discussed Ballard's recent advances in the development of PEM (proton exchange membrane) fuel cell stationary power plants. It also covers Ballard's commercialization plan and its current status, providing a unique insight into the electric generation market, and considering the role that fuel cells will play in a deregulated electric utility market.

Ballard has received significant recognition in the application of PEM fuel cells for transportation applications. This paper discusses the synergy between the development of PEM fuel cells for automotive applications and Ballard's stationary power plant development. Recent advances at the fuel cell stack and system level are discussed as they relate to Ballard's stationary product development.

This paper also considers the problems and opportunities that will result from the massive industry change being brought on through utility deregulation and restructuring. This market change creates a significant opportunity for fuel cells as on-site generation solutions. A review of these problems and opportunities provides insight into appropriate fuel cell applications for a deregulated utility market. These applications are discussed in context with current market conditions and consumer behavior.

Introduction

The electric utility industry is in a period of rapid change. Deregulation, wholesale and retail wheeling are quickly becoming realities as legislation to end electric utility monopolies on the sale of electricity is introduced in California. At the same time, states such as New Hampshire and Massachusetts are moving ahead aggressively to allow retail customers to choose their electricity supplies (Coles, 1996). The advent of competition in the electric utility industry is leading to corporate upheaval and restructuring as utilities adopt new business techniques and structures.

Today's electric utilities, accustomed to captive consumers through regulated service territories, are entering a changed business environment as they face competition for customers. These utilities must adapt to their environment by taking measures that will include changes to organizational assets, structure and culture. To date, much debate has focused on the need to lower costs to ensure success in the evolving competitive arena.

But utilities and others hoping to succeed in this new market will need to do more than lower costs. They must create high quality customers service in order to create a competitive advantage that will retain and hopefully increase their customer base.

Successful will be those that position themselves as innovative energy companies who understand the value different customers place on power. Rather than focus on asset planning, these successful companies will bring a market focus to provide tailored solutions to address customer needs.

In addition to the advent of competition in the electric utility industry, utilities in North America are faced with relatively low demand growth, public pressure to avoid adding transmission and distribution capacity, more stringent environmental requirements, and other constraints that will change how they increase their generating capacity. Large, central generation additions that have been the industry norm will not always make economic sense in the new operating environment and will be replaced by smaller, distributed additions to generating capacity.

Because of their modularity, efficiency and environmental benefits, fuel cells are a favored solution to implement distributed power concepts. Energy companies and others looking to maximize revenue potential will provide tailored energy solutions with distributed fuel cell power plants.

The market changes brought about by deregulation and moderated by the existing business environment will provide substantial market opportunities for fuel cells. Interestingly, though, these emerging opportunities may not necessarily follow the classic views of fuel cell opportunities. To understand these emerging opportunities, this paper provides a review of the classic fuel cell opportunities. With primary focus on the North American market, this paper then provides an insight into markets that will emerge from deregulation, and may offer substantial greater market potential, leveraging all of the classic fuel cell market opportunities.

Classic Fuel Cell Market Opportunities

The classic fuel cell product concept has been a multi-megawatt, high electrical efficiency (40%+), steam cogenerating, site erected power plant to capitalize on the classic fuel cell benefits of high electrical efficiency and high temperature operation. The classic virtues of fuel cell power plants are summarized as follows:

- T&D deferral
- Energy loss savings
- Emissions offsets
- Improved reliability
- High efficiency
- Waste heat

(O'Sullivan, 1993)

This vision has been promoted for the following classic fuel cell markets:

A. Large steam cogeneration
B. Large grid connected power plants
C. Dispersed utility support
D. Rural / remote power

A discussion of each of these follows:

A. Cogeneration

The cogeneration market has long been viewed as a substantial opportunity for fuel cell power. Cogeneration is a technique that uses the heat a power plant releases during the production of electricity. An attempt is made to utilize both the electricity and heat to the fullest extent possible, although depending on the application, either heat or electricity may have higher value to the user. With high electric and high overall efficiency, fuel cells are seen as the ultimate cogeneration system.

Taking a simplified approach, this market originally developed as a result of heat requirements. Industrial companies that use steam in their manufacturing process found it economical to generate electricity with any excess steam. Companies with large heat (especially steam) requirements found generating both steam and electrical power to be more economical than generating steam alone and purchasing electricity. The development of the cogeneration market received substantial stimulation by the PURPA legislation that created tax credit status for cogenerators and the ability to require utilities to purchase power from "qualifying facilities".

Unfortunately, however, the conventional steam cogeneration market may not be the most appealing entry opportunity at this time. According to Frost & Sullivan, "the market for cogeneration equipment in the U.S. is in a state of decline as competition intensifies and the market matures." These large systems also need a steam host, and a lack of steam hosts in areas of growing electricity requirements is restricting the ability to grow this market (1995). In addition, in North America and Europe in particular, many steam system operators are looking to move away from steam to hot water in order to reduce their dependence on skilled boiler engineers and technicians.

The fact that the steam cogeneration market is in decline and highly competitive suggests that it may not be an ideal target for fuel cell power plant market entry. Moreover, as the fuel cell power plant is a high electrical efficiency generator, its relative lack of waste heat may actually restrict its suitability for the classic cogeneration customer.

The fuel cell power plant should be looked at the other way around. Rather than a heat source with some electricity, it is an electricity source that can be used for cogeneration applications. Thus, fuel cell power plants should first be evaluated based upon customer electricity requirements and then evaluated for possible cogeneration benefits. This approach should yield the highest extractable market value for fuel cell power plants as electricity normally has higher value than heat.

B. Large Power Plants

The market for large, high efficiency power plants is another market often promoted for fuel cells. While there is good potential here, this market is highly competitive with relatively small amounts of capital for developing new, emergent technologies.

Technology development for power plants of this size requires tens of millions of dollars just to build a demonstration plant. While funding through collaborative research was possible in the past, the new competitiveness requires that previous collaborators become tomorrow's competitors, and such collaboration is inherently restricted. The appetitive for large government sponsored development of new technology has also disappeared with governments struggling to manage their budgets.

Moreover, with the high performance of existing technologies, there is little incentive to develop emerging technologies. Current competitive offerings such as combined cycle gas turbines are pushing electrical efficiency levels higher and higher, and are available at very competitive price levels. It is also possible with large, conventional technology installations to afford pollution abatement equipment. Other environmental concerns such as noise and vibration generally do not pose a significant challenge for these conventional power plant installations as they are generally located away from population centers.

In summary, while it may hold promise, this market does not necessarily maximize the differentiating opportunities for the benefits of fuel cell power plants in terms of efficiency, emissions, noise and vibration.

C. Dispersed Utility Support

Dispersed, utility support power is an excellent long-term opportunity for fuel cell power plants. Compelling arguments have been presented for distributed additions which will allow utilities to add capacity in small increments relatively quickly and near to the load (Dunnison & Wilson, 1994; Pratt et al, 1994). In so doing, the utility obtains the benefits of distributed generation in the form of capital investment savings, and strategic value benefits (Muller & Hirschenhofer, 1995).

While the arguments are sound, this market has not yet taken off. Part of the reason for the lack of significant growth is that conventional technologies do not necessarily suit the needs of this market well. With their modularity, efficiency and environmental benefits, fuel cell power plants better fit these market needs but are only now becoming available.

There is some optimism for accelerated market growth based on the activities of many utilities who are pioneering and leading the way with the use of conventional technologies as distributed resources for Peak Shaving (also known as Standby Generation). While the upside for this market may be greater under deregulation with "Distribution Companies" (e.g. akin to Municipal Utilities), it is likely to be a lagging as opposed to a leading trend. Investments that generate revenue may receive greater priority than those that fix problems. If distribution companies have some regulatory authority to continue a "return on asset" business practice like regulated utilities, this market may present an earlier opportunity for fuel cell power plants than is currently anticipated.

D. Remote / Rural Power

The remote / rural power market needs small, efficient power plants, and is generally willing to pay a significant premium when compared to grid power. A fuel cell power plant that offers high efficiency and relatively small capacity is a natural fit for this market. While this is true, it can be more difficult to sell to and service customers who are widely dispersed in rural and remote areas. Consequently, providing fuel cell power for rural and remote markets may be a significant challenge, especially in the introductory stage of this or any new technology.

It is worth reflecting on the emergence of our current electric system for insight on the urban vs. rural population dilemma. In their analysis of the successes of the electric industry during its emerging years, the Henry Ford Museum notes, "Cities offered two attractions to the entrepreneurs of electric lighting:

> Lots of customers, close together, who could be economically wired into the system;
>
> Lots of investors with the money to finance the system.
>
> Once homes and factories were wired for lighting, it was a short step to use electricity to power fans, heaters, and machinery."

The urban markets hold similar promise for new technologies such as fuel cells. There are many more potential customers with great needs and the ability to finance the solutions to their needs. These customers are easier to sell to and service from a logistics point of view. From a strategic point of view, establishing this new technology in urban centers will make it easier to ultimately service the rural marketplace.

These classic fuel cell market opportunities have led to products and product concepts that are reflective of these markets. Fuel cell power plant products planned for these markets, for example, are typically greater than one megawatt in capacity and require custom engineered, site erected multiple sub-system power plants. While such characteristics may be acceptable for large, central power plants, they are unlikely to be acceptable to

tomorrow's customer for distributed generation who is contemplating "power in my backyard". For fuel cell power plants to be successful, they must be developed with a view to the actual customer requirements, rather than from a classic utility planning point of view.

Today's Market Context

If these classic fuel cell markets are good, but not perfect, what are the best markets for fuel cells today? Beginning with consideration of the most appropriate capacity, the best early markets for fuel cells will include the following features:

Power plants of 100 to 500 kW capacity
Commercial and small industrial market segments
Power quality
Commercial cogeneration

A. 100 to 500 kW Capacity

Opinions on appropriate capacity for fuel cell power plants have varied widely from tens or hundreds of megawatts to recent proposals for residential power plants in the sub-10 kilowatt range. A review of the market data suggests that rather than pursue multi-megawatt markets, there are large markets at one megawatt and below, though these applications are definitely larger than the residential fuel cell power plant applications. Power plants with output capacities less than one megawatt dominate the U.S. non-utility market. Figure 1, for example, provides reciprocating engine orders from June 1994 to May 1995. While this data does not include sub-megawatt plants, the trend of larger markets at smaller output capacity can be observed. Figure 2 illustrates the distribution of non-utility power plants in the U.S. This data does show large markets for power plant installations that are less than one megawatt in capacity.

Having observed this trend, the next question is where is the most significant market opportunity in the sub-megawatt range? Figure 3 provides a breakdown of non-utility power plants with capacities of less than three megawatts. The data indicates that the largest market is for power plants in the 100 to 500 kW range. In this 100 to 500 kW market, fuel cells have the greatest efficiency benefit over the existing competition. Currently available fuel cell power plants also have substantially better part-load efficiencies and produce significantly less noise and air emissions than the existing competition. Fuel cell power plants in this capacity range are well suited to provide customer value and meet user requirements.

In terms of price competitiveness, it is a common misconception to compare the capital cost of small power plants directly with central power plants. It is more appropriate to market the comparison on a cost of delivered electricity and customer value basis. In terms of the benefits of distributed generation, EPRI has estimated that, while variable, this

benefit can be as high as five cents per kilowatt hour (1992). With these economic benefits and high efficiency small, distributed fuel cell power plants should penetrate the market with capital costs that may be two to three times that of the central generating plant on a per kilowatt basis (Teagan & Marge, 1995).

B. Power Quality

Providing high quality power is one method of creating value for electricity consumers and power quality represents a significant market for fuel cells. The U.S. market for power quality mitigation equipment is expected to grow from $2 billion in 1992 to approximately $5.6 billion in 2002, with an 11% compound annual growth rate. In 1992, commercial users made up 70% of this market (EPRI, 1994).

Power quality issues are receiving significant attention worldwide and many utilities are seeking solutions to improve the power quality their customers receive. Eskom of South Africa, for example, recently initiated a program that recommends customer-side solution for power quality problems and assists in financing the equipment purchases if the customer cannot afford to purchase it initially (Ioannou, 1996).

Power quality is one aspect of power value, a concept which is gaining wide recognition. The basis of the power value concept is that customers should be able to address their power needs through the appropriate selection of price, reliability, quality, etc. Under the conventional regulated system, customers have no such choice and it is virtually impossible to provide power quality solutions without using on-site power.

Due to the quality problems experienced by commercial and small industrial users, applications that provide high quality, reliable electricity are becoming increasingly popular. Secure or premium power applications utilize a stand-alone generating device, such as a fuel cell power plant, to provide high quality, reliable electricity to critical loads with unique requirements (Sanders & Merkle, 1995). These applications ensure that the load receives constant power by using the utility grid for back-up power in the event of a power plant outage.

This can be compared favorably with the standard power quality system of a UPS and standby generator. With the UPS system, when the grid fails the load is picked up (or bridged) by the UPS until the standby genset can come on line. Unfortunately, however, the customer risk is compounded by the number of systems used for this backup and the fact that they are not used except in an emergency situation. This standard system requires the customer to purchase two power devices, and as a passive system represents expensive insurance. A fuel cell, on the other hand, is an active, high efficiency, and high quality generator.

In the secure power or premium power installation envisioned with a fuel cell power plant, the fuel cell provides primary power for sensitive loads and is backed up by the grid; while

the grid provides primary power to the non0sensitive loads. The customer is able to extract the best of both worlds – grid and distributed generation for a true tailored solution. These strengths allow fuel cell power plants to provide an ideal system for the large market for premium power applications.

The value of the fuel cell replacement for a UPS/standby generator is minimally equivalent to the capital costs and extra installation costs for this combination.

C. Commercial / Small Industrial

Of all the market segments for electric power, it can be argued that the commercial and small industrial customers are the least likely to benefit from deregulation and increased competition in the electric industry. These customers are generally too small to receive significant attention from large electricity generators, and will not receive the same regulatory price protection as the residential consumer.

At the same time, these segments provide the best opportunity for new technology and power quality products. As noted above, these customers already represent the heart of the power quality market. Commercial and small industrial customers will provide further opportunities for new generating products to solve their unique problems, just as they provided opportunities for products like the PBX systems that emerged after the telephone industry's deregulation to solve their telecommunications problems.

D. Commercial Cogeneration

Commercial cogeneration is another ideal market for fuel cell power plants.

Commercial cogeneration applications will provide both electricity and heat for commercial buildings and industries requiring relatively low temperature heat such as hospitals, hotels, institutions (e.g. universities), and the food processing industry. This market will likely lag slightly behind the secure power market.

Implications

The commercial and small industrial market segments need an appropriate product to meet their power requirements. A PEM fuel cell power plant, like that being developed by Ballard Power Systems, is such a product. Ballard is developing a truly modular, self-contained, single unit power plant for the heart of the commercial / small industrial market.

The 100 to 500 kW output range for commercial and small industrial applications such as premium power appears to offer a tremendous opportunity for fuel cell power plants. This market can be expected to place high value on the fuel cell power plant's benefits over conventional alternatives. From the utility or energy provider perspective, satisfying customer demands with distributed power – as opposed to dispersed generation - will also

provide an avenue for them to address issues discussed in the earlier section covering classic dispersed generation yet closer and better tailored to actual load centers and energy consumption. It is a much more powerful approach to follow market demands, afterwards leveraging the installed capacity back as a secondary opportunity to provide system level support and similar 'network' benefits from distributed power plants.

It is envisioned that after the premium power market for PEM fuel cell power plants has developed, it will be followed by the commercial cogeneration, utility support, rural / remote, and utility distributed power markets. Ballard believes that the overall PEM market development will begin with stationary and transit bus markets opening closely together, followed by the AEV automotive market, the broad automotive market, and the market for residential fuel cells as a derivative of automotive applications.

Stationary PEM Fuel Cell Development

Ballard Power Systems is working to develop and commercialize natural gas PEM fuel cell power plants for stationary power markets. Ballard fuel cell power plants will be targeted at the distributed power generation below 1.5 megawatts in size and initially for the 100 to 500 kW market range. This market provides Ballard with a competitive edge against internal combustion engines, the primary competition in this size range, because Ballard fuel cell power plants exhibit the good neighbor characteristics which are a prerequisite of power plants today. They are quiet, vibration-free and environmentally benign. Fuel cell power plants also operate with high efficiency, reliability and responsiveness to load demands.

PEM's capabilities of flexible operation and multiple market platforms is a tremendous asset for its success in the stationary power market. In 1994, Ballard successfully completed the first stage of its stationary power plant commercialization program with the construction and successful operation of a 10 kW natural gas fueled, proof-of-concept power plant. The program is now well into its second phase, the development and construction of a natural gas fueled, market entry power plant targeting the 100 to 500 kW market range.

Construction of the engineering prototype power plant for the 100 to 500 kW market range is underway at Ballard's stationary power facility. Successful operation of the power plant subsystems up to full power has been proven in preparation for final assembly of the first unit. In these activities, Ballard has made some substantial breakthroughs. The PEM stack will incorporate injection molded composite parts (see Figure 4). This is a first for PEM and the fuel cell industry and represents significant cost savings. Final assembly of the first power plant with mechanical and electrical verification is planned for the first quarter of 1997. Commissioning and initial testing will be completed during the second quarter of 1997. Extensive field testing and evaluation of the power plant will then commence and additional units will be deployed at committed host sites later in 1997 and 1998. Ballard/s initial commercial sales will follow shortly thereafter.

Ballard's initial entry product will be lightweight for lower cost, have a small volume or envelope, small footprint, and few connections for maximum location flexibility. Ballard will follow this product with additional products (larger and smaller in capacity) to aggressively pursue market opportunities as the present themselves.

Commercialization Strategy

Ballard has received significant recognition for transportation applications. The company's stationary power plant development benefits from advances in transportation applications (and vice versa) since improvements to the technology for one application impacts the other.

Like its primary competition, the internal combustion engine and the gas turbine, PEM fuel cells benefit from multiple market applications. Ballard has developed and delivered fuel cell stacks and fuel cell systems for transit buses, submarines and automobiles as well as stationary / distributed power. Ballard has also developed strategic relationships with leading players in all of these industries. PEM fuel cell multiple market applications allow Ballard to increase production volumes, leverage development funding, establish fuel knowledge and infrastructure, improve the basic technology, and establish supplier networks and value chains. All of these synergies benefit Ballard's overall development programs.

Just as the diesel engine was used in stationary applications long before automobiles, the road to fuel cell powered automobiles will go through stationary power. Investments made to realize automotive products will first be commercially realized in stationary power plants. A number of companies such as General Motors have determined that PEM fuel cells are capable of reaching the challenging automotive criteria, including volume, weight, and price (General Motors Corporation, 1993). At the International Grove Fuel Cell Conference in October 1995, Ballard announced that a Ballard fuel cell has already achieved the power density (power per weight and volume) required for use in an automobile (Ballard, 1995).

Ballard is working with many of the world's leading automotive companies including Daimler-Benz, General Motors, Honda, Volkswagen, Volvo, Nissan, Mazda, and Renault/Peugeot to develop fuel cell systems for passenger vehicles. Matthew Fronk, Technical Director, GM Fuel Cell Project, Delphi Automotive Systems division of General Motors Corporation has stated that "Proton exchange membrane fuel cells are considered to be close to a manufacturable product by the major auto makers of the world/ Utilizing this technology in conjunction with electric and hybrid/electric platforms offers the American public the most flexible types of 'clean' vehicles yet conceived." Ballard, 1995). These sentiments are echoed by Lars-Göran Rosengren, Research Director of Volvo who recently stated, "Fuel cells offer the promise of power clean, efficient vehicles which have

the range and passenger capacity of today's internal combustion engine powered models." (Ballard, 1996).

The fact that PEM fuel cells are applicable to both transportation and stationary power / electricity generation markets has significant benefits for the technology's continued development. The stationary power marketplace will benefit greatly from the automotive investments in PEM fuel cells. It is reasonable to expect that Ballard will produce stationary power plants on an accelerated timeline, quickly reaching commercialization milestones, including cost, as a direct result of the cross-leverage from the multiple market applications.

As with its other applications, Ballard's strategy for fuel cell stationary power plants is to work with strategic partners. Ballard incorporates their insight into market requirements as part of the commercialization program. Ballard's partners are forward-looking companies that recognize the changes that are occurring in the electric utility industry and the opportunity to expand their businesses in a changing marketplace. The development and construction of the prototype unit continues as relationships with strategic partners move forward.

Figures

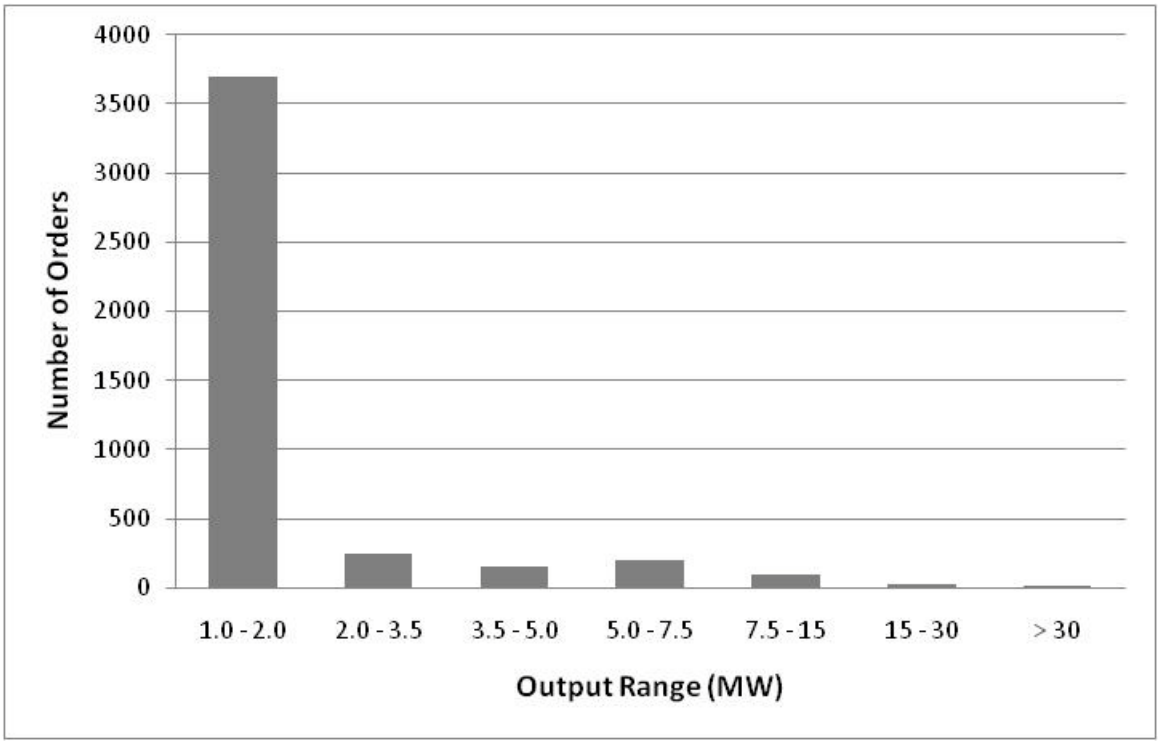

Figure 1: Diesel, Gas & Dual Fuel Engine Orders, June 1994 - May 1995 (*Diesel and Gas Turbine Worldwide, 1995*)

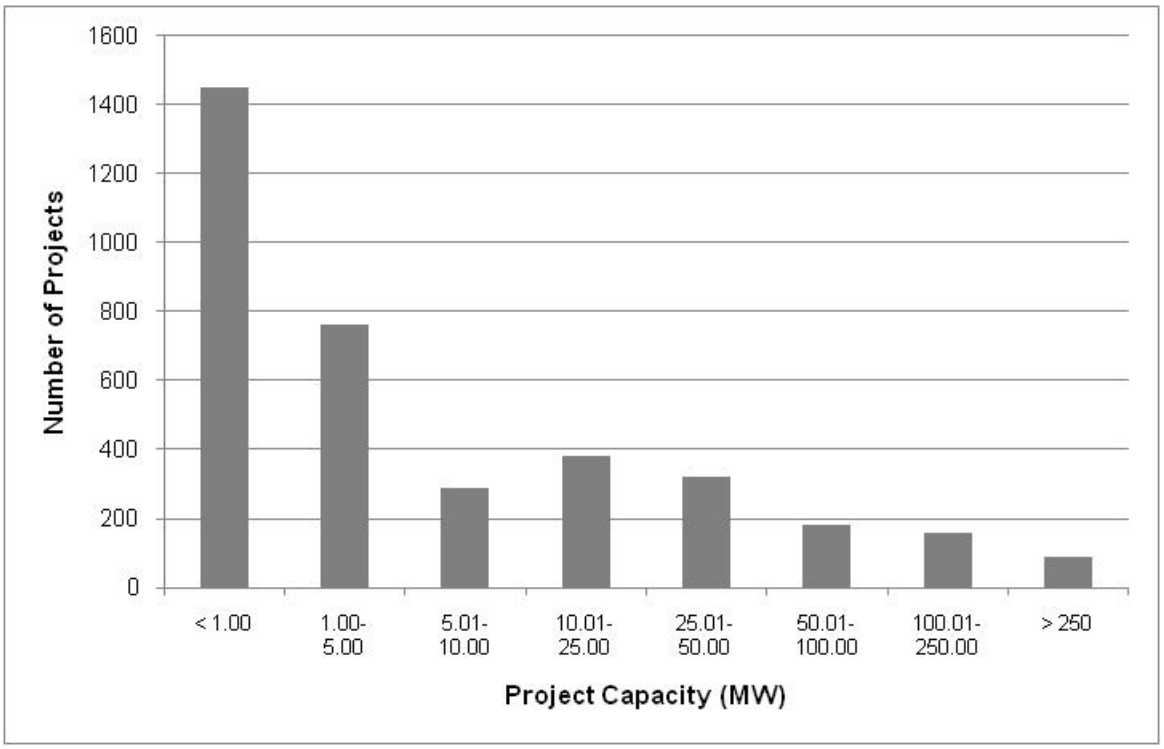

Figure 2: Number of U.S. Non-Utility Power Plants by Project Size (Utility Data Institute)

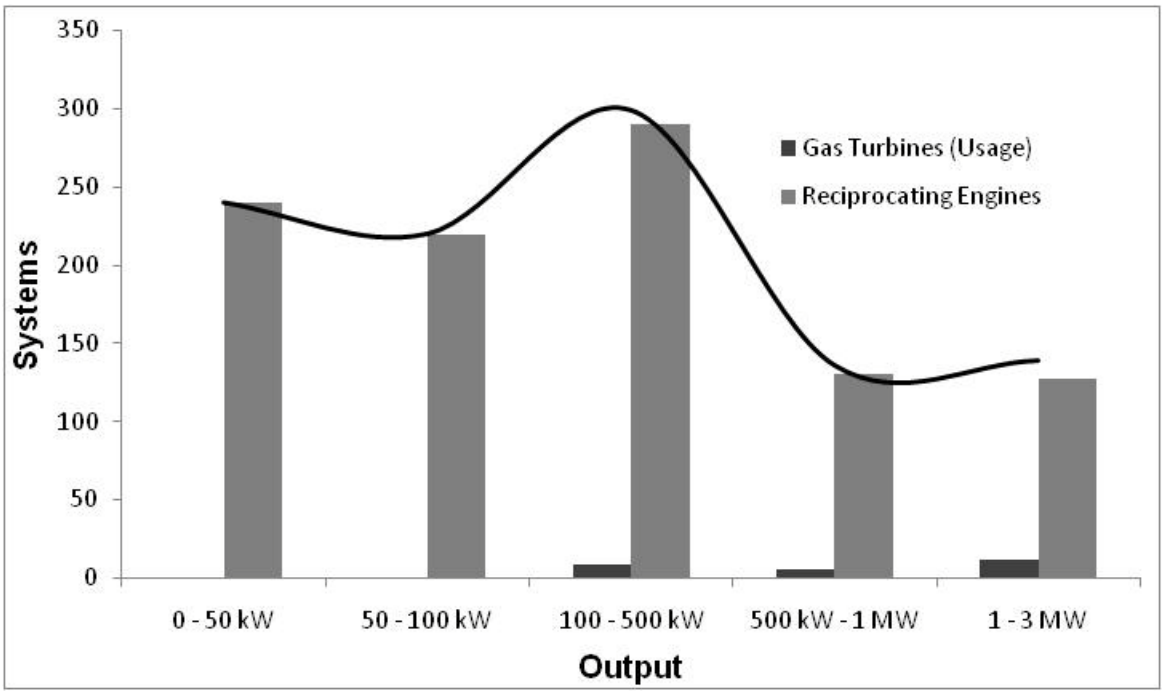

Figure 3: U.S. Non-Utility Cogeneration Installations (Utility Data Institute)

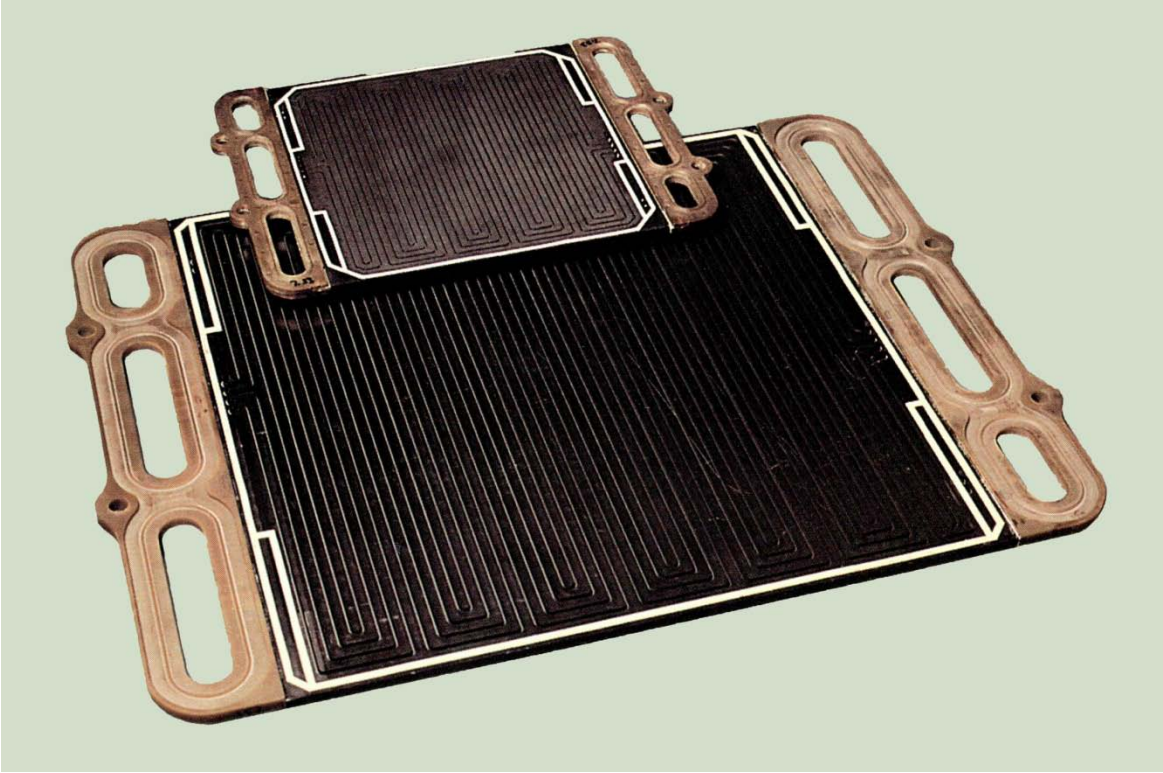

Figure 4: Fuel Cell Plates with Injection Molded Composite Components (Ballard Annual Report 1995)

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