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April 8-9, 1998

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CHAPTER 15

FUEL CELLS FOR HOSPITALS; ELECTRONS BY PIPE

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Thomas A. Damberger, CEM

ABSTRACT
Traditionally, electrical and thermal energy is produced in a conventional combustion process. Coal, fuel oil and natural gas are common fuels used for electrical generation, while nuclear, hydroelectric and solar are non-combustion processes. All fossil fuels release their stored energy and air pollution simultaneously when burned in a contemporary combustion process.

To reduce or eliminate air pollution, the combustion process must be shifted in some way to another type of process. Extracting pollution-free energy from fossil fuels can be accomplished through the electrochemical reaction of a fuel cell. A non-combustion process is a foundation from which pollution-free energy emerges, fulfilling our incessant need for energy without environmental compromise. Distributed generation with fuel cells is energy security with an on-site power supply, essentially, electrons by pipe.

ENERGY-POLLUTION: A HEALTH NEXUS

Understanding and estimating societal costs of energy are at best difficult, but they include the expense society must face when cleaning up the environment. Scientists worldwide are trying to disembarrass the conundrum of environmental and human costs associated with its usage.

A study by Jane V. Hall, an economist at the California State University at Fullerton, indicates that about 1600 greater Los Angeles residents die each year because of air pollution, costing the economy about $10 billion annually.[1]

On November 30, 1992, at a fuel cell conference in Tucson, Arizona, Thomas Gross, from the Department of Energy stated in his keynote address, in 1991 $45 billion were spent on health-related air pollution illnesses nationwide. Health issues related to pollution and energy usage are a big factor that has only recently, been recognized.

As reported in the *Los Angeles Times* "pollution is blamed for 64,000 deaths annually in 239 metropolitan areas." [2] That includes more than 8,800 in Los Angeles, Long Beach, Riverside, San Bernardino, Anaheim and Santa Ana areas alone. There is a direct link between poor air quality and the failing health of those living in energy intensive areas, such as Los Angeles.

The American Lung Association (ALA) affirms "children raised in the Southern California Basin suffered a 10%-15% loss in lung function compared to children from less polluted areas."[3] Hundreds of similar studies link ozone pollution from transportation and energy sources to the debilitating impacts on the heart and upper respiratory airways of both humans and animals. The ALA publication goes on to mention "animals exposed experimentally to ozone over many weeks show irreversible lung damage—an alarming finding."

THE ELECTROCHEMICAL PROCESS

Imagine, if you will, a battery that remains fully charged at all times, never running out of electricity. Essentially, a fuel cell is that battery. With a constant fuel supply, it continually converts the chemical energy of hydrocarbons (typically hydrogen and oxygen), electrochemically into virtually emission-free electricity and thermal energy. A fuel cell operates with a fuel and an oxidant, using two electrodes and an electrolyte. It shares many of the operational characteristics of a battery (Figure 1).

The electrochemical conversion generates electrical and thermal energy without combustion. The electrochemical process operates on the hydrogen component of natural gas (a hydrocarbon), LPG or methanol, which for the most part, are sulfur-free.

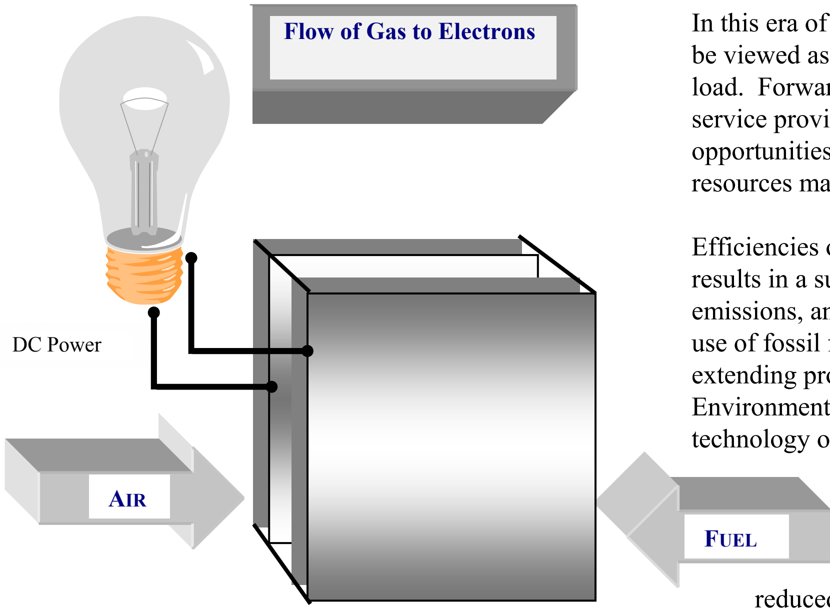


Figure 1

The quintessence of a fuel cell is a pair of electrodes, similar to those of a battery. The negative electrode (anode) uses hydrogen, and positive electrode (cathode) uses oxygen, both are separated by an electrolyte. Chemical reaction within the cell is a result of combining hydrogen and oxygen ions (oxygen from air and hydrogen from natural gas or other fuel source) interacting in an exothermic or heat-releasing reaction.

Typically, natural gas is fed to a reformer after being mixed with steam. Hydrogen from a hydrocarbon molecule must be separated from the carbon through a process called reforming. Once reformed, the hydrogen is ionized. The ionized hydrogen ions flow through the electrolyte toward the positively charged cathode. Hydrogen ions combine with oxygen at the cathode, producing heat, water, and small amounts of carbon dioxide (CO_2) from the reformer (Figure 2). The electron flow produces an electric current.

Fuel cells are a compact, silent and an environmentally clean technology without the pollution found in a present-day combustion process. Fuel cells reduce on-site emissions, directly lessening financial, societal and environmental costs of providing energy services for that site. On-site electrical generation enhances energy security.

In this era of deregulation, the fuel cell can also be viewed as a tool to retain or build customer load. Forward thinking and aggressive energy service providers will benefit from the opportunities presented by this new distributed resources market.

Efficiencies of the electrochemical process results in a substantial reduction of greenhouse emissions, and in turn, leads to a more efficient use of fossil fuels on the generation side; extending proven reserves by many decades. Environmental impacts of the fuel cell technology on ground-level air pollution are especially dramatic.

Criteria pollutants such as oxides of nitrogen (NO_X) emissions are reduced by up to 90 percent or less than 1 ppm. Emissions from modern combustion technologies using fuels such as natural gas, oil, or coal are extreme as compared to fuel cells (Figure 3). As a real-life comparison, emissions from a typical fuel cell are cleaner than the ambient air in the Los Angeles area, and as such, are exempt from air quality permits in California.

Another contributing factor that influence fuel cell efficiency is that, unlike a conventional Unconstrained by the thermodynamic limits of combustion or limitations of the Carnot cycle, fuel cells use 40 percent less fuel than a contemporary power-generation system**.**

PROCESS FLOW

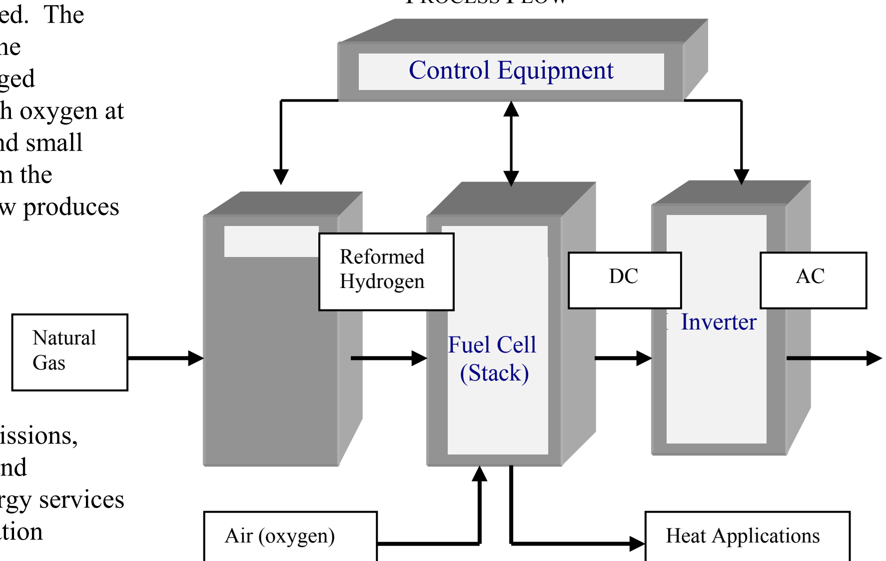


Figure 2

Another contributing factor that influence fuel cell efficiency is that, unlike a conventional power plant, the fuel cell has no moving parts and does not require the mechanical energy of a rotating shaft, or lubrication. Fuel cells (as an electrochemical engine) are capable of attaining very high efficiencies quietly and with virtually no emissions. In addition, they may ultimately have a lower maintenance cost.

Efficiencies of the electrochemical process result in a substantial reduction of criteria pollutants and green house emissions. This results in a more efficient use of fossil fuels on the generation side; extending proven reserves by many decades.

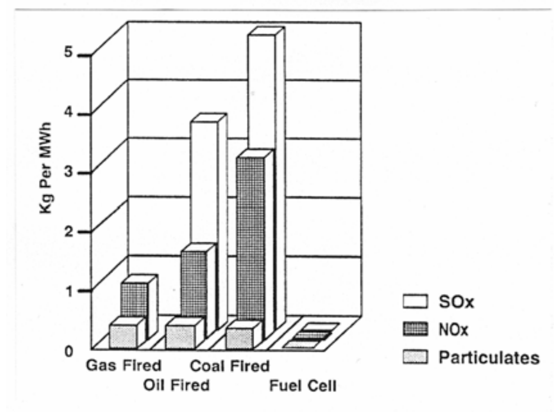


Figure 3

A PRESCRIPTION: FUEL CELLS FOR HOSPITALS

Hospitals notoriously have an insatiable appetite for reliable energy. Electricity and natural gas as commodities must be reliable and have a low cost. Energy conservation measures in hospitals usually have a low priority when competing for a position in the capital budget. The purchase of a new magnetic resonance imaging machine or other piece of expensive medical equipment usually takes a higher priority. However, when considering long-term survival of sensitive electronic medical equipment, power quality becomes a crucial element.

During the late 1980's, it became clear that obtaining capital funding for an unknown technology, such as fuel cells, was an impossibility. Structuring a methodology to obtain fuel cells for a series of hospitals, was at best, a difficult proposition. Perseverance, partnerships, and long-term no-risk contracts are the only vehicles that would work in a risk-adverse organization. With the assistance of in-house legal counsel, partnerships and long-term contracts with utility partners were developed. This was the enabling formula, which became a blueprint for the successful fuel cell program at Kaiser Permanente.

In 1989, the Southern California Gas Company and Kaiser Foundation Hospitals entered into a public/private partnership agreement to test the reliability and feasibility of distributed generation using a fuel cell to power a hospital.

Comparison to Utility Generated Pollution
(pounds per megawatt-hour)

Criteria Pollutant	Average US Utility Emission	PC25 Emission
NO_X	7.65	0.016
CO	0.34	0.023
Reactive Organic Gases (ROG)	0.34	0.0004
Sulfur Oxides—SO_X	16.1	0
Particulates—PM_{10}	0.46	0
Carbon Dioxide—CO_2*	2.43	1.13
(with heat recovery credit)		0.61

* pounds per kilowatt hour
Source: ONSI

The initial plan was to install four 200kW phosphoric acid fuel cells at three hospitals. The rationale for this conservative approach was to improve onsite power quality, energy security, reduce on-site emission, and lastly, to realize financial savings.

ONSI Corporation, a subsidiary of International Fuel Cells, manufactured the proposed fuel cells. United Technologies Corporation is their parent company. ONSI Corporation has a fully automated manufacturing facilities and a market-ready product.

Southern California Gas Company installed the first fuel cell in January 1993 at the 200 bed Anaheim Medical Center. Two fuel cells were installed early in 1994 at the 215 bed Riverside Medical Center.

The Northern California Region of Kaiser Permanente entered into an agreement with the Sacramento Municipal Utility District (SMUD) to install an ONSI fuel cell at the South Sacramento Medical Center. It too, has performed well operating in cogeneration mode since the early 1990s. The hospitals fully utilize all electrical and thermal energy production from the units.

FUEL CELL PERFORMANCE

A review of the fuel cell performance during 1995 at the Kaiser facilities was particularly revealing. The continuing success of Kaiser's fuel cell program exemplifies their reliability, energy security, financial savings, and environmental benefits. It is a codification of a blueprint to a successful program.

Location	Capacity	Availability
Anaheim	200 kW	89.3%
Riverside #1	200 kW	99.5%
Riverside #2	200 kW	98.2%
Sacramento	200 kW	92.0%
Pasadena #1	200 kW	(TBD)
Pasadena #2	200 kW	(TBD)
Riverside	1200 kW	(TBD)

1995 performance data
***Source*: ONSI**

The calendar year 1995 was chosen for this report due to availability of full operational data. Additionally, each fuel cell had completed several thousand hours of operation. Fuel cells located at the Riverside hospital have set several world records for long-term operation.

"Recently, two ONSI fuel cell power plants installed by Southern California Gas Company at Kaiser Permanente Hospital broke a world record for continuous use. One unit has operated for 8,996 hours without a shutdown, the second for 8,450 hours before a shutdown for maintenance (a year is 8,760 hours)"[5] according to the Gas Research Institute. Since that time, another unit located at a Tokyo Gas Company site surpassed the Kaiser record with 9,477 hours to its credit.

Unquestionably, worldwide performance of more than 100 commercially produced fuel cells by ONSI is a tribute to their engineering skills and the technology. Accumulated operating time for their fuel cells exceed 2,000,000 hours. Many other manufacturers are still struggling to get beyond the early Beta test site.

ADDITIONAL UNITS FOR KAISER

With the record of accomplishment of the early units, Kaiser Permanente announced mid-October of 1995 that they signed an agreement to install two fuel cells at the Southern California executive offices in Pasadena.

The executive office at Walnut Center is a seven-story, 340,000 square foot office building. This facility is a 24-hour administrative support operation, does not include patient care. The connected load is over one megawatt.

After a series of meetings with the City of Pasadena, city officials gave approval to install two fuel cells. It is expected that ONSI will ship these units within the municipally owned utility service area sometime during late 1998. When completed these fuel cells will provide electricity, hot water and assist an absorption chiller for air conditioning of the building.

High temperature (250^0 F) heat will be used for driving up to 60 tons of absorption chilling. The low temperature (140^0 F) heat will be used for domestic hot water. All electricity will be used in dedicated circuits allowing continuous operation should the electric grid fail. System design makes full utilization of all energy produced by the fuel cell.

Historically, this is the first time that Kaiser intends to install units in an office complex. All other fuel cell systems operate in hospital settings. It is also significant to note that these are the first commercial units in the U.S. privately purchased without utility participation. Aside from financial savings and reliability benefits, a Federal grant of $1,000 per kilowatt provided the additional impetus leading to a contract.

Shortly thereafter in early 1996, another landmark agreement was signed to install six additional units at the Riverside Medical Center. It should be noted that if the Riverside contract were completed, it would have a total of eight fuel cells powering that facility with 1600 kW. Total connected load for the hospital is about 2400 kW. Most Kaiser hospitals in Southern California have between 1-6 mW connected loads, which are fairly constant loads. The intent at the Riverside facility was to incorporate two fuel systems with separate ejectors, allowing propane to be used as a backup fuel. Each reformer has the ability to process natural gas and/or propane if the natural gas supply were interrupted.

The backup fuel system is to insure an uninterrupted fuel source in this seismically active region. The San Andreas earthquake fault and many other faults are not far from this facility. A 30,000-gallon underground propane storage tank is within a few feet of the proposed site of the new fuel cells. It is estimated that this quantity of propane will support a fleet of six fuel cells running continuously for more than one week. The two early units will remain without a backup fuel supply.

THE FUTURE POTENTIAL

Kaiser's total connected load for 200 buildings located in Southern California is about 70 mW. Early in 1996, a preliminary survey was conducted to determine the potential number of fuel cells that could be applied at these facilities. It was concluded that the potential was 160-200 kW units. To extrapolate a little further, it is estimated that the nationwide Kaiser organization could conceivably support up to 500 fuel cells. The market potential for Kaiser alone is four times the total production of ONSI fuel cells to date.

REAPING ENVIRONMENTAL BENEFITS

On the average, as compared to current technologies such as gas turbines, each fuel cell at Kaiser prevents more than 2,000,000 pounds of total emissions from entering the environment each year. This is inclusive of the so-called greenhouse gas, carbon dioxide, an emission the world community is trying to limit.

The fleet of fuel cells at all Kaiser sites has already reduced annual emissions by more than 8,000,000 pounds. This is a significant inroad to a cleaner environment and, organizationally, a testimony to the commitment of the health of members and employees. If all fuel cell contracts listed in this paper are fulfilled in the next few years, annual emissions from Kaiser facilities will be reduced more than 24,000,000 pounds due to fuel cells alone. Other Demand-Side Management (DSM) efforts would yield a reduction of many more millions of pounds of emissions.

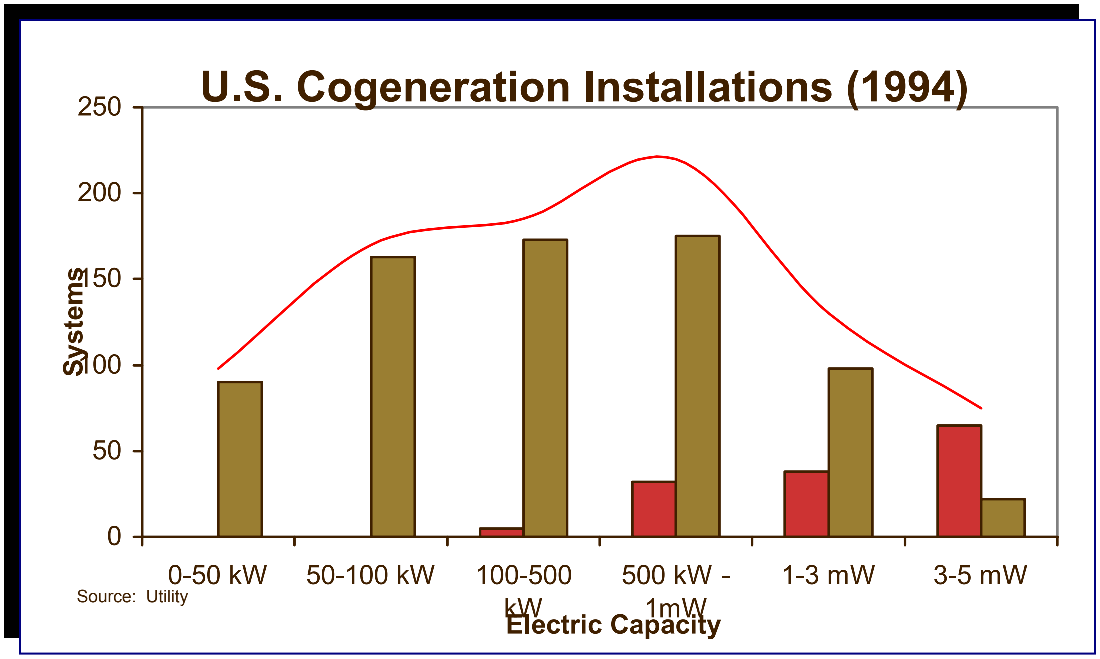
U.S. ENERGY NEEDS

Prognosticators of the electric power industry forecast 172 gW of new generating capacity will be needed by the year 2010 to meet the expected growth needs in the U.S. Repowering and replacement of aging equipment are not elements of this oracle. Additionally, with the worldwide deregulation movement sweeping the globe, fuel cells become an important green technology for utilities to use in their distributed resource planning.

Quantity and capacity of on-site cogeneration projects built during 1994 are graphic example of the market demand for on-site distributed resources, according to the Utility Data Institute. Fuel cells built with a 200 to 500 kW nominal rating can be added incrementally to meet customer needs. When considering cogeneration, hospitals have a large need for steam while medical clinics and offices have little need for any thermal energy.

DEREGULATION & FUEL CELLS

Though California historically has been the vanguard of deregulation, this movement appears



to be in the more advanced stages in Europe. However, in California, the Public Utility Commission (PUC) and others have committed to the breakup (deregulation) of the electric industry by January 1, 1998. This target date met with a delay due to several contributing factors. Nonetheless, the process will continue. Essentially, the PUC is breaking the vertically integrated electric utility monopoly into three segments:

- Generation
- Transmission
- Distribution

For the immediate future, transmission and distribution will remain regulated. Long term consequences can only be imagined at this point. One thing is for certain, regulators are forcing a sometimes-painful metamorphosis of the electric utility industry. The natural gas industry went through the same evolution in the early 1990's.

Under a new ascendancy of decreased regulation, the natural gas industry once again is allowed to compete for a market share of the $200 billion electricity generation business. Gas companies will now be allowed to sell molecules and electrons. However, for the customer compromise of service may be in the offing. Power quality, availability, and infrastructure issues are now emerging as critical areas of need. A reliable energy service must be assured through the entire deregulation process. Fuel cells can play an important role levelizing the inevitable diurnal fluctuations in demand.

In this era of deregulation, the fuel cell can also be viewed as a tool to retain or build customer load. Forward thinking and aggressive energy service providers will benefit from the opportunities presented by this new distributed resources market. Finally, under California law, fuel cells are exempt from the so-called competition transition charge (CTC). CTC charges help utilities amortize the debt of stranded investments.

ELECTRONS BY PIPE

With deregulation as a worldwide backdrop, we can now address distributed generation. The dictum of electrons-by-pipe becomes the most effective delivery system of electric energy and a more efficient utilization of resources. It is, in reality, delivery of electrons to the end user through the natural gas infrastructure. Many Energy Service Companies (ESCO's) are currently trying to capture market share through distributed resources.

Fuel cells enhance and help stabilize the electric grid. The fundamental theory is to rethink the large centralized power generation system and build an infrastructure of distributed resources with fuel cells as the centerpiece. With this paradigm shift, the grid becomes more secure, power-quality enhanced and air quality improved. Utilities and ESCO's that take advantage of this opportunity can retain market share, gain many new long-term customers and use, or sell emission credits.

The original long-term concept was to have each Kaiser hospital powered by a fleet of fuel cells for the ultimate in energy security. In this scenario, the utility grid becomes the emergency back up for electricity. It would reduce the need for large diesel generation sets, which are a high maintenance item and seldom used. With fuel cells, power quality is enhanced for each facility adding a layer of protection for sensitive electronic medical equipment at the entire hospital. Local and regional air quality improvements would theoretically reduce health-related illness caused by poor air quality. Conceivably, overall healthcare costs should be reduced.

An ancient medical motto needs repeating; *Primum Non Nocere*—First, Do No Harm. Hospitals are places for convalescing and healing. A place where they should first, do no harm, not contribute to an antithetic philosophy. For a hospital, doing no harm should extend to the energy they use at each facility. Fuel cell energy is an anthology of green energy, power quality, clean air, and energy security. Energy security is equally important and certainly of primary importance in a hospital setting. This is especially true, if you as a patient, are on the operating table during a power glitch, or worse yet--a power failure.

WESTERN POWER GRID FAILURE

On July 1, 1996, a massive failure of the Western power grid plunged 14 states into darkness with a power outage. The July outage received national media attention, while nationwide hundreds of smaller outages occur on a regular basis. Seldom are there reports of these failures, as many go unreported outside their local area of coverage. Innumerable failures are the result of a lack of reinvestment in essential elements of the nation's electrical infrastructure.

Just over a month later, on Saturday August 10, 1996, it happened again. Another major power outage affected most of the Western power grid. The first of a series of "dominos" of this multi-state system, located in the Pacific Northwest at the Keeler-Allston 500,000-volt line, experienced a catastrophic failure. Subsequently, 13 McNary hydroelectric generating units sensed the systems instability and went off line.

Several system weaknesses were pointed out in a report produced by the Western Systems Coordinating Council including inadequate tree-trimming practices, operational practices, and instructions to dispatchers--all of which played a significant role in the severity of this system-wide failure.

At the heart of this dilemma is a fundamental conflict between the utility industry's historical self-imposed "*obligation to serve*," and the pressures of cost cutting due to the competitive nature of deregulation. Local spinning reserves on August 10th were vastly inadequate to meet the demand. Typically, electrical demand on holidays and weekends is generally low. This was not a typical case. Demand for electricity spiked due to a high-pressure weather system which brought soaring temperatures to the entire region. People were trying to find relief from the heat by staying indoors, close to their air conditioners.

The cost of an outage to business can be staggering. Other factors that emerge can take on an even more surreal face. The possibility of losing a life in a hospital setting due to a power failure became a very distinct possibility.
One of the findings that the western power grid failures of 1996 revealed was that many hospital emergency generators failed to operate when needed. This type of failure is unacceptable. Life safety and a secure energy source for any hospital should be of primary concern. A hospital powered by fuel cells would have been immune from these system-wide failures. There would be no compromise of service.

COMPETING TECHNOLOGIES

The last related issue this paper will address are competing technologies. Due to the convergence of deregulation, the Clean Air Act of 1990 and many new energy efficient technologies, we are entering a golden era of power production. Coupled with a rising tide of competition comes a growing variety of new, small modular power generating systems and related control technologies.

Micro-turbines are about to enter the distributed resources equation as a technology that has evolved from the turbo-generator industry. Manufacturers such as Allied Signal, Capstone Turbine Corporation, and Elliott Energy Systems are staged to enter the power generation market with micro-turbines in the 30 to 100 kilowatt ranges.

Their low capital costs are a major factor for widespread use in distributed generation applications. A $350-$500 kW estimated capital cost is expected. Long-term reliability of micro-turbines is yet to be defined; though, they are expected to be certified as Best Available Control Technology (BACT).

Another emerging technology, $SCONO_X$™, a tail-pipe solution, virtually eliminates emissions of CO, NO_X and SO_X from power plants using a variety of fossil fuels. $SCONO_X$™ employs a platinum based catalyst that reduces total emissions levels to those cleaner than the ambient air in Los Angeles. This technology is typically used on the exhaust-side in large power plant applications, and it can operate at temperatures as high as 700^0 Fahrenheit. $SCONO_X$™ is in the process of being certified as BACT and will bring many power plants into compliance with the onerous provisions of the Clean Air Act.

Both technologies reduce total emissions to near those of a fuel cell. One thing that is known, technology continually rewrites the competitive equation and will change the very nature of strategic planning for many utilities.

In order to remain competitive, fuel cell manufacturers need to reduce capital cost of equipment (currently $3,000 kW) to near current technology prices ($800-$1,500 kW). There are optimistic price predictions for fuel cells in automotive applications--near the $80 kW range. Scale-up to a stationary sized system with balance-of-plant could incrementally increase the price per kilowatt installed.

Although, many of the virtues of a fuel cell application for premium power have value, its value cannot exceed the outer-elastic limits for such power. Inevitably, market forces will define what outer-elastic value it is willing to pay for this technology.

CONCLUSION

Technology is the engine that drives societal change throughout history. The regulatory arm, empowered by society, is the fuel of a continuing evolution of technology, discovery, and application.

Development of the steam boiler, reciprocating engine, gas turbine, electrical generation, and a distribution system transformed industrialized societies. Technological refinements in energy conversion systems and tail-pipe solutions have resulted in a more efficient use of fuel at a lower cost.

The fuel cell is a bridge from the combustion process to an electrochemical reaction, converting fuel-energy into electricity and heat. This bridge is a conduit to pollution-free energy and is often looked to as a link in the renewable hydrogen fuel chain. Capital cost of fuel cell equipment is still marginal and must be reduced in price to be competitive with current technology.

Public/private partnerships help facilitate many installations of fuel cells, especially at Kaiser Permanente. The concept of electrons-by-pipe for distributed generation, greatly enhances a hospitals power quality, energy security, and air quality. Moreover, partnerships directly benefit everyone. Partnerships are a no-risk tool, helping facilitate the installation of fuel cells in hospitals.

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[1] Hall, Jane V. and Arthur Winer, "Valuing the Health Benefits of Clean Air," *Science*, February 14, 1992, Volume 255, pp. 812-817

[2] Cone, Marla, Grit in L.A. Air Blamed in 6,000 Deaths Yearly," *Los Angeles Times*, May 9, 1996, A1.

[3] California Thoracic Society, the medical section of the American Lung Association of California "*Air Pollution: A Cloud Over Your Child's Health*" October 1993, p.5.

[5] Gas Research Institute, *Power Generation Tech Update*, "Distributed Utility Update" May 1996, p.5