FUEL CELLS AND THE ENERGY FUTURE IN LATIN AMERICA AND THE CARIBBEAN

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ABSTRACT

The Department of Energy's National Energy Technology Laboratory (NETL) is developing fuel cells for various applications in partnership with the private sector. Fuel cell technologies - solid oxide fuel cells, molten carbonate fuel cells, and polymer electrolyte fuel cells – are being developed for the distributed generation market shortly after 2003. Some of the evolving fuel cell systems are incorporating gas turbines in hybrid configurations. The combination of the gas turbine with the fuel cell promises to lower system costs and increase efficiency to enhance market penetration. Hybrid efforts are underway at Honeywell, Fuel Cell Energy and Siemens Westinghouse. In the long-term, solid state fuel cell technology with stack costs under $400/kilowatt (kW) promises deeper and wider market penetration in a range of applications including a residential, auxiliary power, and the mature distributed generation markets.

In the United States, the Solid State Energy Conversion Alliance (SECA) with its vision for fuel cells in 2010 was formed to commercialize solid state fuel cells and realize the full potential of the fuel cell technology. Likewise, in Latin America efforts are underway to synergize the fundamental research and development efforts by scientists as well as the marketing and commercialization undertakings that have been evolving in the last 5 years. These endeavors are particularly solid in Brazil and Argentina and, to a lesser extent, in Mexico. Recently, organizations representing the scientific, business and government sectors from these three countries, and with the encouragement and participation of U.S. homologous entities, decided to form the Latin America Fuel Cell Council. The mission, goals, and scope of this council are still being constituted. In principle, the council will serve as the pivot point to bridge the efforts among all participants, leverage resources, avoid duplication of effort, search for funding sources, and to serve as the nucleus of information and support for fuel cell development and deployment in Latin America.

Fuel cells are an excellent option for distributed generation where access to natural gas (or other hydrocarbon-based gas such as biomass gas) is available. Fuel cells environmental qualities, high efficiency, modularity, fuel flexibility, siting ability, low maintenance requirements, etc. make them a player in Latin America and the Caribbean energy mix.

INTRODUCTION

In the United States, the Department of Energy (DOE) is the largest provider of funds for fuel cell technology. DOE's Office of Fossil Energy (FE) 2002 budget for the fuel cell program was $52.1 million (MM). The slightly smaller budget in transportation for DOE's Office of Renewable Energy and Energy Efficiency is devoted entirely to fuel cells for transportation. Most of the funding supports industry partners in materials, fuel reforming, and other R&D areas, as well as other national laboratories.

There has been tremendous increase in interest in fuel cells over the past few years. It is estimated that $1 billion per year is now being spent on fuel cell R&D. In the transportation sector, many fuel cell development teams involving major automotive giants have been formed. UTC Fuel Cell estimates that 6-7 automotive companies are spending $100 million per year each. Total market capitalization had reached $16 billion in 2000 and Stock Market investment is paying for fuel cell manufacturing facilities and demonstrations.

A fuel cell is an electrochemical device, not a combustion device. The chemical energy in the fuel is directly converted to electrical energy. This is not the case with technologies utilizing combustion. In the proton conducting fuel cell, hydrogen is ionized at the anode and migrates across the fuel cell electrolyte. Electrons cannot go through the electrolyte so, as they are produced, they move energized through the external circuit. Electro-neutrality is preserved. All this happens spontaneously and chemical energy is converted into electrical energy. Because combustion is not involved, fuel cell emissions are 100-1000 times lower than required by U.S. law. One of the three principal components of a fuel cell, the fuel processor converts the fuel - landfill gas, anaerobic digester gas, natural gas, diesel fuel, jet fuel, methanol, ethanol, propane, etc. - to the hydrogen required by the fuel cell. The power module contains the fuel cell stack. Finally, the inverter, generally required, converts the DC power produced by the fuel cell to AC power.

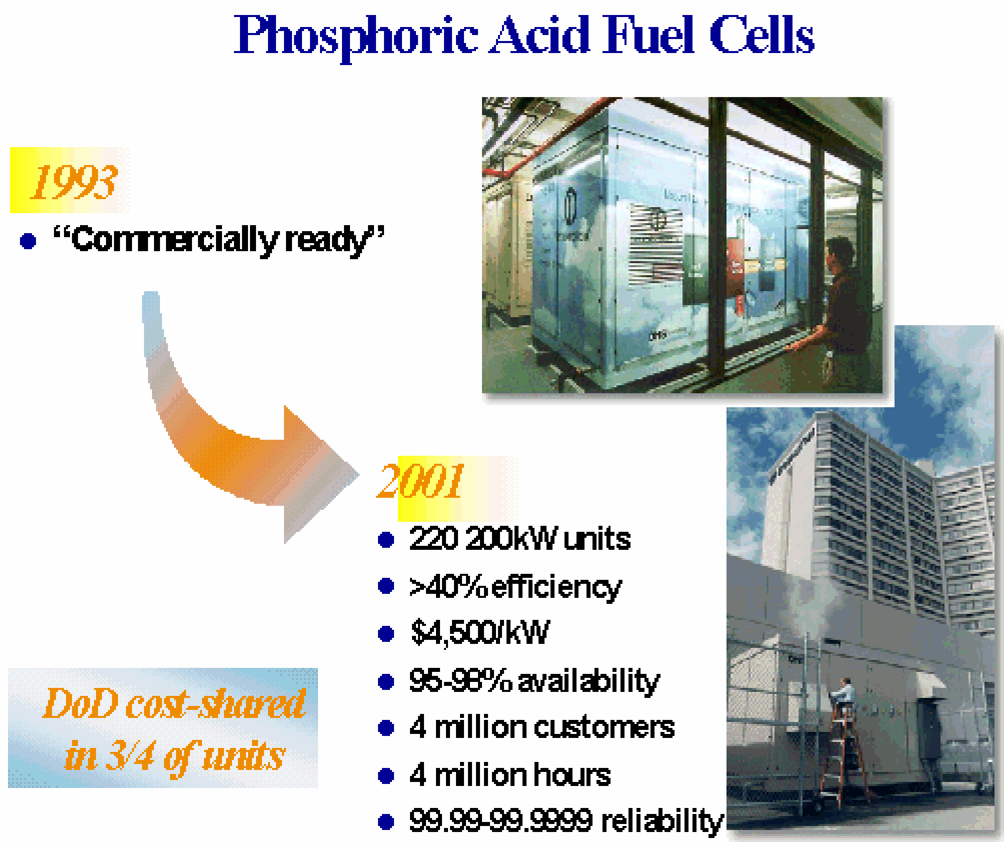
TYPES OF FUEL CELLS

TYPE	TEMPERATURE	PRIME CELL COMPONENT	CHARGE CARRIER
• Solid Oxide	2000 °F	Ceramic	O--
• Molten Carbonate	1250 °F	Stainless Steel	CO_3--
• Phosphoric Acid	400 °F	Graphite-based	H+
• Polymer Exchange Membrane	160 °F	Carbon-based	H+

There are four fuel cell types under widespread and intense global development - phosphoric acid fuel cell (PAFC), molten carbonate fuel cell (MCFC), solid oxide fuel cell (SOFC), and polymer membrane fuel cell (PEMFC). They differ in operating temperature and electrolyte type. DOE is involved in all types of fuel cells, but has played a large financial role in the development of PAFC, PEMFC, MCFC, and SOFC.

Phosphoric Acid Fuel Cells (PAFC)

In 1993, the International Fuel Cell (now UTC Fuel Cell) 200-kilowatt (kW) units were deemed "commercially ready" and DOE research funding was concluded. Since 1993, nearly three-quarters of the 220 ONSI 200-kW phosphoric acid fuel cells manufactured by UTC Fuel Cell have been cost-shared all or in part by the U.S. Department of Defense's Global Climate Change Program.

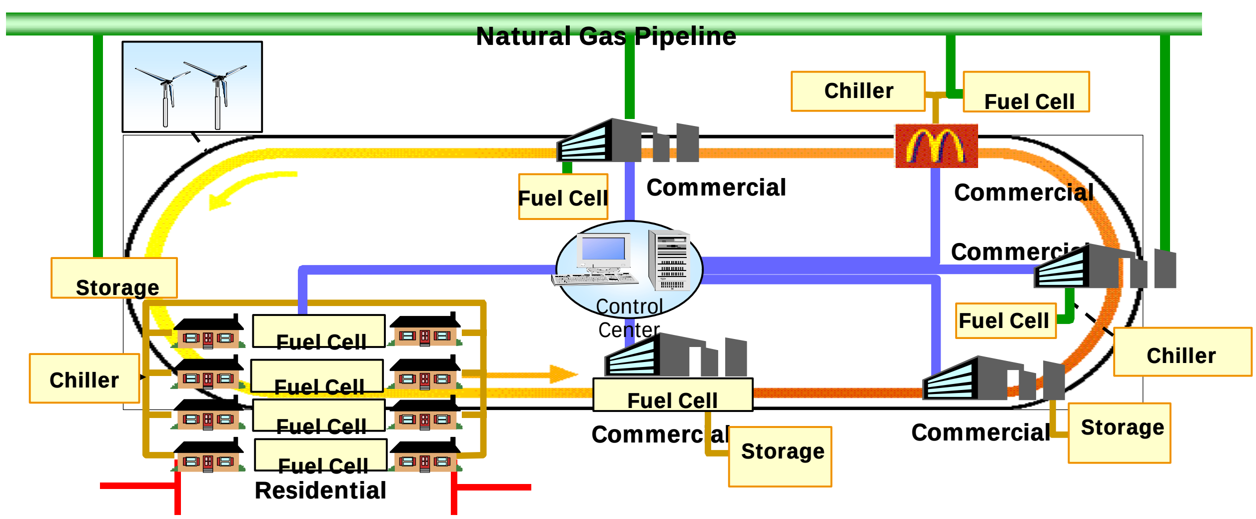


While the PAFC remains very expensive and its widespread use may never be achieved, UTC Fuel Cell is given the credit of pioneering fuel cell deployment. These turnkey units are installed worldwide, four of them in Brazil. The performance of these units, except for their high cost, is the basis of many fuel cell claims. They produce electricity at around 40 percent efficiency, and also produce heat for domestic hot water and space heating. The units are operating very reliably. To date, they have accumulated more than 4 million hours of operation and 4 million customers.

PAFC's are used in some of the most reliable power plant applications in the world - PAFC's, flywheels, and AC-motors combine to achieve extremely high reliability (up to 99.999999%) at the First National Bank of Omaha. UTC Fuel Cell has been actively developing and trying to market their systems in combined heat and power (CHP) and premium power applications. They have targeted the distributed generation market.

Distributed Generation (DG)

Distributed Generation is a new paradigm that can change the way electric power generation is thought of. DG can be seen as the Gateway or Dell personal computer (PC) concept applied to fuel cells. Gateway and Dell use "mass customization" to keep PC costs low and meet the exact needs of their customers. DG was Thomas Edison's original vision. He wanted electricity to be generated locally and use an arrangement similar to the one shown below.



In the stationary area, the first deployment of fuel cells will be in DG. They can be used in substations to support overall grid reliability; in off-grid, where transmission and distribution are not available or are too costly to increase capacity (9% of electricity is lost in transmission and distribution); as back-up power; or in conjunction with energy storage. The distribution companies of today may be the transmission companies of tomorrow.

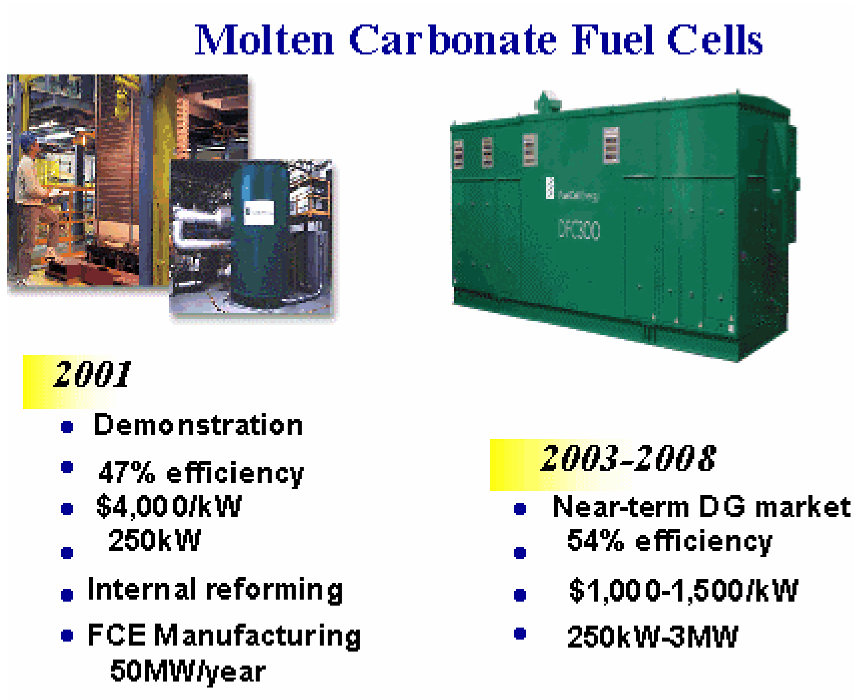
Fuel cells can reduce the cost of energy services. On the supply side, the small incremental sizes allow investments to closely match demand growth. This saves money, making DG the low cost solution in many areas. DG as a locally-dispatched neighborhood microgrid could be the future. Commercial DG applications are also a viable avenue for efficiency and cost savings to businesses.

Credible market studies have identified a sizeable market even at costs ranging $1000 - 1500/kW. DG has an estimated potential of 2 gigawatt (GW)/year, $2 billion/year world-wide market by 2010 even if fuel cell distributed generation captures only 10 percent of the total estimated DG market expected to emerge. This is enough market for the MCFC and tubular SOFC developers, FuelCell Energy (FCE) and Siemens Westinghouse Power Corporation (SWPC) repectively, to have the incentive they need to continue development.

Molten Carbonate Fuel Cells (MCFC)

FuelCell Energy, Inc. is DOE's industrial partner working to develop molten carbonate fuel cell technology. FuelCell Energy's technology is an externally manifolded, internally reformed design. The company built a 5-megawatt (MW) per year manufacturing plant at Torrington, Connecticut, and expects to increase its capacity ten fold, to 50 MW per year, within the next 5 years.

Testing of pre-commercial Direct FuelCellϑ units evolved from the Santa Clara, California, experience and has been extremely successful. During 2000, a 250 kW unit completed 11,800 hours of grid connected operation at the company's Danbury facility. Performance degradation of the stacks has been minimal, about 0.3 percent per 1,000 hours. Also during 2000, FuelCell Energy's European partner, the MTU unit of DaimlerChrysler, operated a 250 kW unit in excess of 7,000 hours. This test continued into 2001. More recently, a 250 kW unit was started at Rhoen Klink hospital in Germany. This unit, in cogeneration mode, has exceeded overall thermal efficiency of 85%, providing electricity, steam, and hot water for the hospital.

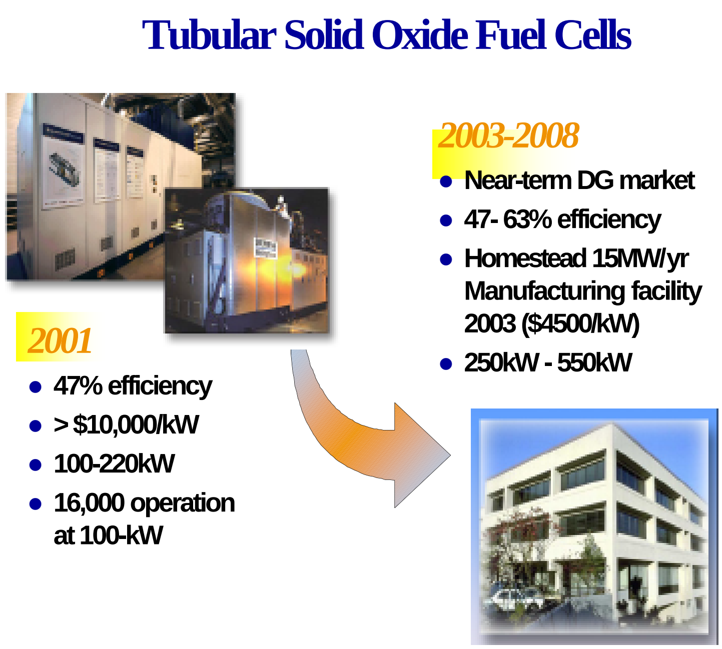


The design of FuelCell Energy's market-entry, 3-MW direct fuel cell powerplant has been completed. In response to market interest, FuelCell Energy will also offer a 1.5 MW design, as well as a 250 to 300 kW unit. Performance characteristics and early production units have been identified. Two 250 kW units are expected to be tested shortly at two U.S. sites. Additionally, FuelCell Energy has designed a direct fuel cell/turbine hybrid system based on a non-combusting turbine, with efficiency approaching 75% (LHV). Under DOE's Vision 21 program [1], Fuel Cell Energy is testing a subscale unit with a Capstone microturbine - the first MCFC hybrid.

Many 100% cost-shared demonstrations are planned. Some dozen 250-kW system demos are planned. Demonstrations are underway at Los Angeles Department of Water and Power and Mercedes Benz. A 500-kW unit will be tested at the Naval Surface Warfare Center in Philadelphia, with cost-shared funding from the Office of Naval Research. EPA is cost-sharing a 1-MW unit that will be tested on municipal sewage digester gas at a site in Kings County, Washington.

Tubular Solid Oxide Fuel Cell SOFC

DOE has cost-shared development of the tubular SOFCs since the early 1980s. SWPC is close to commercialization. A two-cell system operated for more than 70,000 hours (about 8 years) with virtually no degradation in performance. SWPC has provided a benchmark of long-term operability, and this should translate into lower operating and maintenance costs.



1 Vision 21 is the U.S. Department of Energy's new initiative for developing the technology needed for ultra-clean, 21st century, energy plants. The goal of Vision 21 is to effectively remove, at competitive costs, environmental concerns associated with the use of fossil fuels for producing electricity and transportation fuels.

The DOE program goals in the 2004 to 2008 time frame are to have SOFC's up to 1 MW in size, at a cost of $1,500 per kilowatt, operating at up to 60% efficiency (See SECA's goals below). The remarkable environmental performance of the fuel cell makes it a likely candidate to help mitigate pollution. This is a key distinguishing feature of the technology. A tubular SOFC CHP system operating in the Netherlands shows an electrical efficiency of 45% and a thermal efficiency of 74%. The unit operated 16,600 hours with emissions of NO_X and other contaminants at the detection limits. PAFC and MCFC have achieved similar environmental performances. SWPC, like FCE, is planning many demonstrations over the next three years. These include a demonstration at Ontario Power in Toronto in 2003 and at the new EPA R&D Center at Fort Meade, Maryland. The demonstrations include several European demonstrations partially funded by the European Commission.

Polymer Membrane Fuel Cell (PEMFC)

DOE supports a very small stationary PEMFC program in the U.S unlike Japan, for example, where the government has a large commitment towards the technology. However, PEMFC developers, financed by the stock market, are attempting to attack most markets – commercial, building, residential, auxiliary power unit (APU), micro-grid, transportation propulsion, and battery replacement. There are some 44 PEMFC developers in the United States alone.

These low-temperature fuel cell developers must rely on the use of currently unavailable hydrogen as a fuel or face the formidable task of cost-effectively and efficiently reforming and cleaning conventional fuels – like natural gas.

Solid State Energy Conversion Alliance (SECA)

If a common-module can be produced for these vast markets, one can achieve the high volume needed to reduce costs. This approach is called "mass customization." SECA - the Solid State Energy Conversion Alliance - was formed by NETL and the Pacific Northwest National Laboratory (PNNL) to accelerate the commercial readiness of planar solid oxide fuel cell systems expected to be in the 3-10 kW size range by taking advantage of the projected economies of production from this "mass customization" approach.

SECA will produce the deep cost reductions are needed before fuel cells will be widely deployed in truly mass markets. SECA, a short-term, ten-year program focused on driving the fuel cell costs down to $400/kW.

DOE estimated that a 5-kW planar SOFC (PSOFC) system can reach $400/kW at reasonable manufacturing rates. This low-cost potential is very important. With this low-cost potential, the PSOFC has the potential of wider and deeper market penetration than the other fuel cells.

The fact that planar SOFC can achieve its low-cost at small sizes is also important. At the small sizes it has a chance of reaching more and bigger markets. At the 3-10kW size it is suitable for stationary, transportation, and military residential, APU, telecommunication, and UPS/battery replacement applications and markets. These markets are vast. These markets include the automotive markets and no industry knows how to reduce costs as well as the automotive industry.

For the existing MCFC and TSOFC developers, the market is large – 2 GW/yr is $2 billion/year at $1000/kW, but for SECA fuel cells it is enormous. However, the residential and APU markets are very large. In addition, if the modular 3-10 kW units can be "ganged" or "scaled-up" to larger sizes with no increase in cost, then commercial, microgrid and other DG markets will be attainable. Further scale-up could result in penetration of the bulk power market.

Fuel Cells in Latin America and the Caribbean

Fuel cells are an optimal choice for Latin America's and the Caribbean's energy mixes. From the perspective of diversification of energy portfolios, fuel cell offers great potential as an alternative to extensively-used hydropower and other clean energy power generation options such as solar or wind, as long as fuel is available. However, fuel cell's fuel flexibility potentially allows usage of regionally available fuels such as ethanol in Brazil and biomass gas from landfills, digesters, bagasse, and other sources which are available everywhere. Of course, issues such as fuel reforming are still being considered and are the basis of research in the U.S., Japan, Europe as well as Latin America.

Fuel cell R&D in Latin America exists to a substantial degree in Argentina, Brazil, and Mexico. Brazil has purchased four fuel cells from UTC Fuel Cells through their Latin American representative, Sieco S.A. (Argentina). COPEL, an electric utility in the state of Parana, purchased three phosphoric acid fuel cells and intends to advance their understanding of fuels cells and its applications for further deployment in Brazil through its association with LACTEC, an R&D laboratory. Similarly, Petrobras (with CENPES, its R&D laboratory) has also purchased a phosphoric acid fuel cell, making Brazil a principal emerging market for fuel cell commercialization. Many institutions in Argentina and Mexico have also expressed similar interest in fuel cell technology and development.

PC25 in Curitiba, State of Parana, Brazil

Rural electrification efforts in developing countries are a matter of social and economic development. Much has been devoted to try to electrify isolated areas with no economically feasible or practical access to a grid. Here, options have also been reduced to diesel generators with their consequent environmental problems or solar or wind alternatives, not always economically viable or with high maintenance requirements.

MORE MATERIAL TO BE ADDED:
FINISH RURAL ELECTRIFICATION ASPECT
FUELS AVAILABLE IN LATIN AMERICA AND THE CARIBBEAN
MARKET PENETRATION IN LAC
LATIN AMERICA FUEL CELL COUNCIL

FINALIZE CONCLUSIONS

CONCLUSION

The Department of Energy has been sponsoring fuel cell development for 25 years. The challenge of reducing fuel cell costs is still before us. Through SECA program is well designed to meet that challenges of the future. If highly efficient, ultra-clean fuel cell technology can move from niche markets to widespread use in stationary power applications, the result will be significantly reduced emissions. In Latin America and the Caribbean, fuel cells offer a clean energy option for distributed power generation so long as a hydrocarbon-based fuel is available or can be made available (as in the case of LNG). The challenge for Latin America and the Caribbean, and the rest of the world, is to achieve widespread utilization so as to lower fuel cell capital cost. This can be achieved thorugh partnerships with U.S. developers and others conducting research on the various matters that would allow for lower initial costs. Gathering in associations such as the proposed Latin America Fuel Cell Council, will strengthen the initiative by leveraging the efforts in all aspects: research, development, and deployment.

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