OPPORTUNITIES AND CHALLENGES FOR FUEL CELLS IN INDIA

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Introduction

Recent U.S. initiatives such as Freedom CAR exemplify a growing commitment to energy conversion using fuel cells because of their efficiency and environmental advantages. The growing feasibility of fuel cells has important implications particularly for developing countries like India. Fuel cells could make available an opportunity to provide clean energy to India's population of one billion and reduce its energy supply-demand gap. Such opportunities, however, are tempered by enormous technical and economic challenges. Technical challenges include identification and development of suitable fuel cell technologies for applications often unique to the developing world. Some of the available fuels might call for modified reforming technologies to produce hydrogen. Economic challenges include the need for more stringent environmental regulations, incentives for cleaner forms of energy, infrastructure development, and a less risk-averse business climate.

Increased Capacity and Productivity of Energy Conversion and Utilization

The consulting firm, McKinsey and Co., Inc., in a recent study said that India needs economic growth of 10% every year to avoid societal conflict and satisfy the needs and aspirations of a population that is already at one billion and growing. Providing energy required to fuel such economic growth is not a trivial issue of simply producing more petroleum, natural gas, and electricity. Because of constrained resources and new environmental drivers, e.g., the Kyoto Protocol to which India is a signatory, a significant increase in the productivity of energy conversion and utilization is required.

Fuel cells, in principle, could provide that jump in both environmental and economic productivity. For example, from an environmental productivity perspective, it is estimated that a 200 kW fuel cell-based power plant will generate 60% less carbon dioxide than a coal or natural gas fired power plant. Although fuel cells for transportation are an area of intense research in the developed world and have relevance for public transportation in developing countries like India, e.g., buses and railways, this paper will highlight the role of fuel cells for power generation which will most likely be the first commercial application of fuel cells in India.

Fuel Cells for Power Generation

In 2000, the total electricity generation capacity in India was almost 100,000 MW, the bulk of which came from coal-fired power plants (see Table 1 for a distribution of power generation by fuel-type). On a per capita basis, electricity sold to consumers in India was a paltry 0.3 MWh as compared to 11 MWh in the U.S. Obviously, with development, per capita electricity consumption in India is bound to increase in the future. Although generation capacity has been growing at 5% annually, growth needs to be 15% to meet the target economic growth rate of 10%.

More substantially, there needs to be a drastic improvement in the efficiency or productivity of both electricity generation and transmission and distribution (T&D). Currently, India's productivity levels are abysmally low at 34 and 4% of those in the U.S. for the generation and T&D of electricity, respectively. While policy reforms will certainly improve these productivity levels substantially, they cannot be expected to account entirely for the growth required in electricity generation.

Fuel cells for power generation have the most near-term potential in three Indian markets. The first of these is the premium power market i.e., segments willing to pay a premium for power supply that is adequate and, more importantly, reliable. Because of shortage (exceeding 11% in 1997) and uncertainty of power supply, several segments of this market, e.g., hotels, hospitals, information technology companies, and certain manufacturing plants, have invested in some form of captive power generation. These segments that already have some form of captive power generation will evolve into niche markets for fuel cells. The Tata Energy Research Institute recently studied this niche markets and found that the key issues are cost and the availability of fuels for either direct use in fuel cells or reforming to produce hydrogen. Some results from this study are presented in Table 2. While some segments of this markets will support capital costs of $3,000-4,000/kW, extensive penetration will occur only when the costs come down to $500-1,000/kW.

The second market could comprise remote and rural areas where electricity supply is currently unavailable and difficult because of infrastructure problems. These areas would typically use locally available opportunity fuels such as biomass. It is expected that significant governmental incentives and support would create and sustain this niche market.

The final market comprises large stationary-power generation using fuel cells particularly if technologies using molten carbonate and solid-oxide fuel cells become cost-effective and commercially available. A significant problem with the Indian power industry is T&D losses of the order of 20-25% of total electricity generated, as compared to less than 2% in the U.S. Although effective policy reforms should reduce this number considerably, any continuation of this situation could result in the development of a strong distributed fuel cell-based power generation market.

It is expected that the distributed power generation market will see players besides typical power producers. These new entrants could include fuel supply and transport companies seeking growth through the fuel cell-based power generation. These markets will, however, become real only if the cost of fuel cell-based power decreases from current estimates of $3,000-5,000/kW to $800-1,000/kW or less.

Fuel Processing Issues

The availability of fuels for either direct use or reforming to produce hydrogen will be a critical issue. Hydrogen, natural gas, methanol, gasoline, and diesel are all typical fuels or hydrogen sources for fuel cells. Of these, gasoline and diesel are currently produced in surplus of demand in India. However, consumption rates for both are going to increase substantially in the near future. Further, sulfur specifications for these fuels are much higher than tolerated by reforming catalysts or the fuel cells. The remaining fuels, hydrogen, natural gas, and methanol, are all in short supply. The utilization of these fuels in fuel cells could also be limited because of safety and infrastructure considerations. For example, widespread use of compressed natural gas for public transportation was recently not found viable because of the absence of a pipeline-based distribution network.

Two other fuels, dimethyl ether (DME) and renewable biomass, could become important in the long-term for hydrogen production. Key success factors for a DME scheme are access to cost advantaged gas, proximity to market, and the presence of credible business and technology partners. DME is distinct from liquefied natural gas (LNG) because (1) DME requires cheaper receiving facilities and (2) a competitively priced fuel on a much smaller scale can be delivered.

In the late 1990s, one of this paper's authors conceptualized and spearheaded the DME Project Consortium which included British Petroleum, Indian Oil Corporation (India's largest publicly-owned oil company), Gas Authority of India (India's largest natural gas company), and the Indian Institute of Petroleum (India's premier downstream petroleum research and development organization). The project was initially established to promote DME as a clean alternative to diesel fuel. Rapid changes in market economics, however, changed the project's focus into positioning DME as a fuel for power generation. Briefly, the plan was to produce DME directly from methanol using Haldor Topsoe's proprietary technology (licensed to BP). DME from such a plant, ideally located in the Middle East, would be shipped to India via tanker and sold to power generators to produce clean electricity. Economic feasibility studies had suggested a viable rate of return for such a project. Although the project has been shelved, it remains an interesting and viable proposal.

Sixty percent of India's labor is employed in agriculture which is the cornerstone of the country's economy. Agriculture-derived biomass is a renewable feedstock that is underutilized for generating energy. Recently, several initiatives have been taken to exploit the use of agricultural biomass for power generation. There is strong governmental support for these initiatives and technologies utilizing renewable feedstocks for hydrogen production, e.g., hydrogen production using carbohydrates, should be advantageous for the fuel cells market.

Conclusions

Several economic and environmental drivers are motivating developing countries like India to evaluate fuel cells. The development of new fuel cell technology that is cost-effective, suited to local needs, and employs region-specific and opportunity fuels should be commercially successful. This paper has highlighted the Indian situation with respect to the need for fuel cells, the power generation needs, and identified specific fuel supply strategies to meet any growth in fuel cells.

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Table 1. Electricity generation in India (1998) and the U.S. (1999) by fuel type.

Fuel	Percent of electricity generated in India	Percent of electricity generated in U.S.
Coal	71	58
Natural gas	8	9
Oil	1	3
Nuclear	2	20
Hydro	18	10
Total	100	100

Table 2. A summary of issues concerning representative niche markets for stationary power generation using fuel cells in India.

Market	Power needs (MW)	Potential fuel cell (FC) types[1]	Potential FC-based electricity	Comments[2]
Hotels	0.5-5.0	PAFC, MCFC, SOFC	Multiple 0.2-0.25 MW units	Natural gas must be available
Chlor-alkali industry	5-45	MCFC, SOFC	Multiple 0.2-0.25 MW units	Hydrogen readily available; balance of plant requires heat
Pulp and paper industry	2-50	MCFC, SOFC	Multiple 0.2-0.25 MW units	Natural gas must be available; balance of plant requires heat
Dairy industry	<5	PEMFC, AFC, PAFC	One or two 10-50 kW units	Biogas reforming technologies for hydrogen will be an advantage
Telecom and IT	<5	PEMFC, AFC, PAFC	One or two 10-50 kW units	Natural gas must be available

[1]PAFC, Phosphoric acid fuel cell; MCFC, Molten carbonate fuel cell; SOFC, Solid oxide fuel cell; PEMFC, Polymer electrolyte membrane fuel cell; AFC, Alkaline fuel cell.
[2]It is trivial to state that cost is an issue common to all markets.