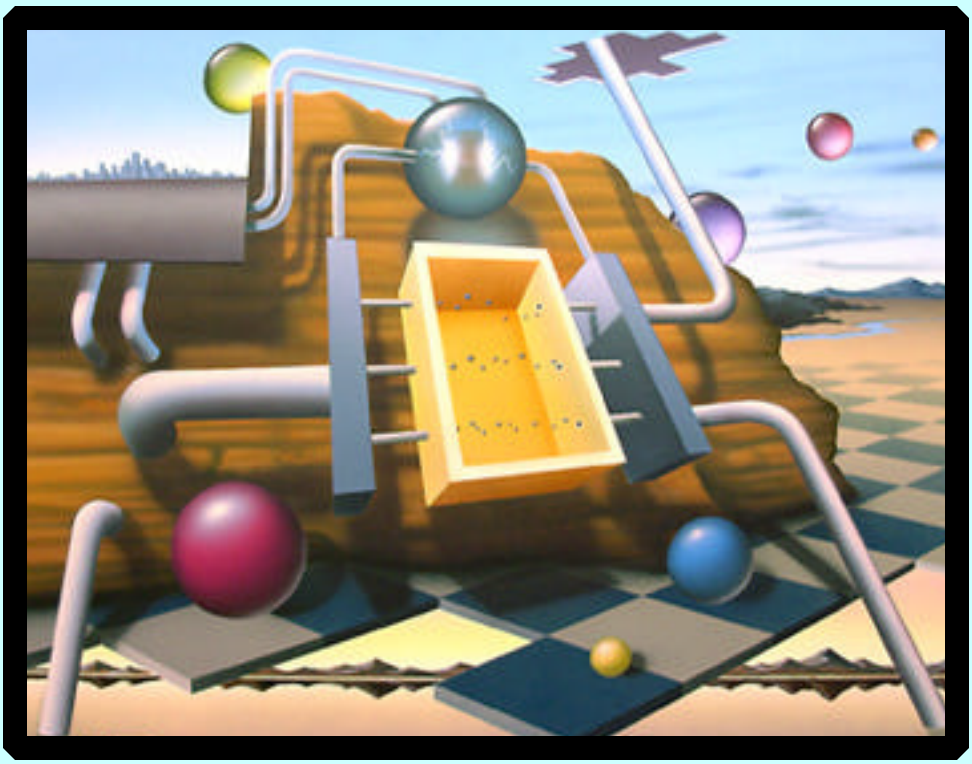
Accelerating the Commercialization of
Fuel Cells in Texas



Texas Comptroller of Public Accounts

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Executive Summary

The 2001Legislature directed the State Energy Conservation Office (SECO) to develop a statewide plan for accelerating the commercialization of fuel cells in Texas and to submit a report on this plan to the House Energy Resources and Senate Business and Commerce Committees no later than September 15, 2002.

SECO was instructed to "draw conclusions about the availability and efficacy of alternative mechanisms that might be created in cooperation with the private sector, utilities, and other agencies to accelerate the commercial availability and economic viability of fuel cells for use in this state."[1] In addition, SECO was instructed to appoint a Fuel Cell Initiative Advisory Committee (FCIAC) to advise it on the development of the plan.

SECO has identified a number of initiatives that the state could use to encourage the commercial availability of fuel cells and the economic viability of a Texas-based fuel cell industry. These initiatives are embodied in this report's recommendations.

Technology and State of the Industry

Fuel cells are electrochemical devices that combine hydrogen and oxygen to produce electricity, heat and water. Hydrogen is the ideal fuel for fuel cells, but at present it must be derived from fuels such as natural gas, propane and methanol.

While fuel cell technology is not new, continuing discoveries will affect the size, efficiency, and ultimately the cost of fuel cells. Rapid breakthroughs can be expected to lower the cost of fuel cells and increase their efficiency and performance.

The fuel cell industry, as with many others based on emerging technologies, is caught between its need for further research and the development of mass manufacturing, and the inability to fund either adequately. Private investment has not been forthcoming in significant amounts, and most fuel cell manufacturers lack sufficient unit sales to gain economies of scale. FCIAC estimates that fuel cell manufacturers must be able to produce and sell 1,000 megawatts of generation capacity in Texas to achieve competitive pricing and industry self-sufficiency. This estimate compares to 87,000MW currently being generated in Texas.

Markets and Applications

Ultimately, the fuel cell market will determine the fuel and fuel cell of choice for each application. There are four main applications for fuel cell use—stationary, portable, mobile and micro—each facing its own set of challenges. The fuel cell market, in turn, can be divided into three segments. *Early adopters* are consumers ready to buy now. The

1 Texas H.B. 2845, 77th Leg., Reg. Sess., 2001, Bill Analysis, Enrolled Version, p. 1.

transportation market includes mobile and portable applications. The *infrastructure* market refers to manufacturers and other heavy industries and the public sector. Each market segment will require considerable adjustment to make widespread use of fuel cells.

Benefits and Challenges

If widely used, fuel cells could provide both public and private benefits due to their ability to provide high-quality, efficient and clean energy. The largest benefit of fuel cells may lay in their ability to improve air quality, but other benefits include energy security, improved power reliability, transmission and distribution relief, consumer savings and economic development.

But these benefits cannot be realized until a series of hurdles are overcome. The main problem is the high cost of today's fuel cells. Additional challenges are the need for capital investment, the lack of harmonized codes and standards, various infrastructure concerns including regulatory issues and the need for technical training and public education. In addition, fuel delivery and storage present unique challenges for the transportation market. Resolution of these challenges will require the efforts of both the private and public sectors.

Government Role

Government must play a role in the development of this technology by supporting research and development and "priming the pump" in the marketplace by funding demonstration projects and purchasing fuel cells as they become available. The federal government has been the largest public investor in fuel cell technology, but its efforts are focused primarily on niche markets and the long-term development of mobile applications.

States working in the area of fuel cell technology fund research and have taken various steps to energize the commercial market. Texas has funded some research projects but thus far has made no attempt to improve the market for fuel cells.

Texas has established a market for the trade of reductions in pollutant emissions through emission reduction credits (ERC). Fuel cells can generate pollution reductions directly and indirectly, but no mechanism yet exists for earning ERCs for indirect emission reductions.

Summary Observations

The attainment of FCIAC's 1,000 MW fuel cell generation goal would require state participation in and stimulation of the early market. Neither the public nor private sectors on their own can resolve the many challenges facing the widespread use of fuel cells.

The state would benefit from forming a public/private partnership to guide both the development of fuel cell policy and plan implementation. The success of any such effort would depend on the continuing support of political leaders and the willingness of private and public participants to share information for the greater good.

Recommendations

By fostering the commercialization of fuel cell energy, Texas can move into the lead among the states and nations in directing this new technology development. To accomplish this, the following recommendations should be considered.

Texas should:

- create the aforementioned public/private partnership;
- adopt concrete goals for fuel cell development within the state;
- encourage and assist the formation of a Texas Consortium for Advanced Fuel Cell Research;
- become an early adopter of fuel cell technology;
- use "off-take" utility purchase contracts to acquire fuel cell-generated power;
- develop and fund demonstration projects;
- reserve a percentage of current research dollars for matching-grant or cost-share dollars for fuel cell projects;
- assist in the development of fuel cell training and education at all levels;
- provide financial incentives to support the FCIAC goal;
- allow transmission and distribution companies to own fuel cells offering "distributed" (on-site) power generation;
- amend state laws, regulations and permits to accommodate fuel cells in all applications;
- continue efforts to ensure that fuel cells can generate both direct and indirect emission reduction credits;
- support and pursue the adaptation of national codes and standards to accommodate the use of fuel cells;
- participate in regional and national consortiums and partnerships; and
- allow all fuel cell-powered vehicles to use High Occupancy Vehicle Lanes on Texas highways.

These recommendations support an interlinked strategy of coordinating research, coordinating technical training, and providing appropriate incentives to spur the development of the Texas fuel cell market.

Acknowledgements

During the preparation of this report, the State Energy Conservation Office (SECO) was fortunate to have the involvement of a number of individuals and organizations. First and foremost, SECO wishes to thank the members of the Fuel Cell Initiative Advisory Committee (FCIAC) for their efforts and commitment to this project. The experience represented on the committee was of the highest caliber and the information provided by the members was invaluable. SECO also appreciates the work done by the staff of Fuel Cells Texas, Inc. on the behalf of the FCIAC in the research for and preparation of the FCIAC team working papers.

State agencies were also quite involved in this process. SECO wishes to thank the Texas Department of Transportation and the Texas Railroad Commission for allowing individuals from their staff to serve as members of FCIAC. The Texas Commission on Environmental Quality, the Texas Public Utility Commission, the Texas General Land Office and the Texas Department of Economic Development all provided staff to assist the FCIAC and SECO in the preparation of this report. Other state agency involvement came in the form of individual participation in an informal State Agency Fuel Cell Initiative Working Group that provided guidance and support.

The FCIAC meetings held around the state over the last year would not have been possible without the help of many individuals and organizations. Our thanks goes to Mr. George Mitchell, Ms. Patrice "Pete" Parsons and Mr. Bruce Rauhe of the Houston Advanced Research Center; Dr. Jerry Matthews of the Texas Council on Environmental Technology; Mr. Jim Crites and Mr. Rusty Hodapp of the Dallas/Fort Worth International Airport; and Mr. Alan Montemayor and Mr. Joe Redfield of the Southwest Research Institute. Each of these entities not only provided facility space but also provided invaluable staff support to the FCIAC during the meetings.

SECO wishes to thank the many individuals who provided information to the committee in either written form or as presentations during the meetings. Additionally, appreciation goes to the many individuals who attended and took part in the meetings of the FCIAC. A special thank you is sent to Mr. Dub Smothers of San Antonio who was instrumental in the success of the FCIAC meeting held in that city and who also provided ample information to SECO and the FCIAC during this process.

Finally, SECO wishes to thank Mr. Randy Dunham for the cover art entitled "Fuel Cell Power To The City" which can be found at http://www.randydunham.com.

A list of the many individuals involved in the processes outlined above may be found in Appendix 3.

Accelerating The Commercialization of Fuel Cells In Texas

Introduction

Fuel cells are electrochemical devices that make electricity *chemically* rather than by combustion. Because of this, they virtually eliminate the primary drawback of engines, boilers and combustion turbines: air pollution. Fuel cells offer the promise of substantial gains in energy efficiency *and* a major increase in environmental quality. They promise clean electrical energy for a wide range of applications, ranging from micro and portable applications such as cell phones and computers, to stand-alone power sources for homes and businesses, to the eventual replacement of the internal combustion engine in autos.

The fact that fuel cells produce electricity with dramatically lower environmental impacts is their primary attraction. Even so, there are other important reasons to accelerate the commercialization of fuel cells. They could increase the nation's energy security due to their ability to use a range of different fuels and our ability to place them wherever power is needed. And Texans could benefit from the economic development and job creation associated with the rise of this industry.

In Texas, a number of market conditions are driving the potential demand for fuel cells. Among these is an increasing need for on-site ("distributed") power, due to the state's ongoing challenges with transmitting electricity to where it is needed most. Texas has a 1950s-style transmission and distribution system designed to carry power from relatively large power plants located near the customers they were meant to serve. Texas' energy transmission and distribution companies are finding it difficult to build enough new transmission facilities to connect new power generators with expanding population centers, leading to spiraling costs and a heightened chance of "brownouts" and blackouts. Distributed fuel cell power offers an alternative to the construction of conventional power plants as well as additional poles and wires, particularly in urban areas.

Moreover, Texas faces both current and anticipated governmental air quality mandates calling for dramatic reductions in pollutant emissions. The majority of the state's population resides in 38 urban counties that do not meet federal clean air standards. Admittedly, most of our air quality problems stem from motor vehicles, and it will take time for fuel cell technology to be adapted, produced and marketed successfully for use in passenger vehicles. Even so, stationary applications for fuel cells appear very promising in the relatively near term and could have an immediate, positive effect on the environment.

Texas has the research capacity to help advance this technology and help set national standards for its development. Texas also is home to a considerable portion of the world's oil refining capacity, and these companies are well positioned to develop new products to support the fuel cell industry. At present, there is no clear national center for the early development and deployment of fuel cells, although Ohio, Connecticut, California,

Massachusetts, New Jersey, New York and Michigan have fuel cell commercialization strategies in place or under development. Texas still has time to seize its chance to become a new energy leader and further diversify its economy.

The 2001 Legislature directed the State Energy Conservation Office (SECO) to develop a statewide plan for encouraging the commercialization of fuel cell technology in Texas and to submit a report on its efforts to the House Energy Resources and Senate Business and Commerce Committees no later than September 15, 2002. The present report provides 15 recommendations fulfilling SECO's legislative charge to:

> …draw conclusions about the availability and efficacy of alternative mechanisms that might be created in cooperation with the private sector, utilities, and other agencies to accelerate the commercial availability and economic viability of fuel cells for use in this state.[2]

Fuel Cell Initiative Advisory Committee

The 2001 Legislature also directed SECO to appoint a Fuel Cell Initiative Advisory Committee (FCIAC) to advise it on the development of the plan. FCIAC comprised 17 members drawn from disciplines outlined in the legislation; the committee's membership is listed in Appendix 1.

The committee met four times between November 2001 and May 2002, at the Houston Advanced Research Center at the Woodlands; the Center for Energy Studies at the J.J. Pickle Research Center in Austin; the Dallas/Fort Worth International Airport Maintenance Offices at DFW International Airport; and the Southwest Research Institute in San Antonio. Various invited guests made presentations at each meeting, and the committee also heard public comments.[3]

Working Teams

FCIAC members committed a considerable amount of time to this voluntary effort and should be commended for their work. After discussing the various topics the report should cover, the committee divided into the following working teams:

Applications
Barriers
Benefits
Demonstrations
Education/Public Outreach

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[22] Texas H.B. 2845, 77th Leg., Reg. Sess., 2001, Bill Analysis, Enrolled Version, p. 1.
[3] All meeting information, including meeting overviews and presentations, may be found at the SECO website: http://www.seco.cpa.state.tx.us.

(working teams continued)

Incentives

Appendix 2 lists the membership of the various teams.

SECO also formed a State Agency Fuel Cell Working Group to assist the various committee teams in their deliberations. Each team met periodically and provided working papers to SECO containing recommendations that form the basis of the present report.

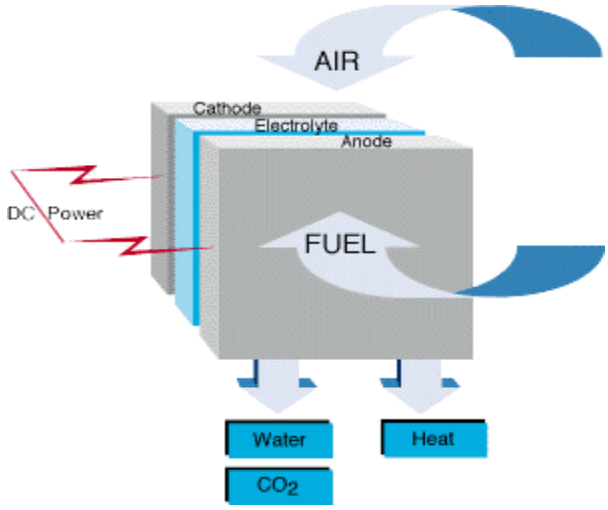
While some teams provided their own staff support, others requested the assistance of Fuel Cells Texas, Inc. (FCT), a trade association seeking to accelerate the commercialization and deployment of fuel cells in Texas through public education and the promotion of state-sponsored initiatives.

SECO wishes to thank FCT for its assistance in the preparation of the papers submitted by the Applications, Incentives, Benefits and Barriers teams. These papers may be found at the SECO website: http://www.seco.cpa.state.tx.us.

I. Fuel Cell Technology

Fuel cells are electrochemical devices that combine a fuel, typically hydrogen, and an oxidant, typically the oxygen in ambient air, to produce electrical power, heat and water. This common feature defines all fuel cells, regardless of the specific technology involved (Exhibit 1).

Exhibit 1: Fuel Cell Diagram



Source: U.S. Department of Defense.

The fuel cell principle was first demonstrated in 1839, but received little attention until the late 1950s, when NASA began looking for a way to provide reliable electrical power for their spacecraft. Fuel cells have been used in all U.S. manned spacecraft since the Gemini program and today provide power to the space shuttle fleet.

Types of Fuel Cells

Although many types of fuel cells have been devised, four common types are being considered for mass production.

The proton exchange membrane fuel cell (PEM) is the type most commonly associated with uses in vehicles. For stationary uses, the favored fuel cell is the phosphoric acid fuel cell (PAFC), although molten carbonate fuel cells (MCFCs) and solid oxide fuel cells (SOFCs) also are under development for stationary uses. The latter two operate at higher temperatures that yield higher efficiencies and high-grade heat for cogeneration—the simultaneous production of electrical and thermal energy, the latter in the form of steam, hot water, hot air or any combination of the three.

The Fuel Cell System

In addition to the actual fuel cell module, or "stack," the cell includes other mechanical and electrical components—so-called balance-of-plant (BOP) items. BOP items may include:

- fuel supply/storage
- compressors/blowers/pumps/filters/heat exchangers
- electric power conversion and utility grid interface systems
- water treatment systems
- fuel reformer

The fuel reformer is a device that can strip hydrogen from any hydrocarbon fuel, from natural gas to gasoline, for use as fuel in the fuel cell stack. At present, most reformers strip hydrogen from natural gas, although others can derive hydrogen from methanol and gasoline. Waste products from the reformation process primarily include carbon dioxide and nitrogen, along with trace amounts of carbon monoxide, hydrocarbons and other substances.

The development of commercial fuel cell technologies hinges on the fuel to be used. For the foreseeable future, many industry watchers believe the undisputed fuel of choice will be natural gas. Its production and delivery system is in place, as are the necessary codes and standards for handling and transport.

Fuel Cell Applications

The application is likely to dictate the type of fuel and fuel cell to be used. These applications fall into four broad categories: stationary, portable, mobile and micro (Exhibit 2).

Exhibit 2: Fuel Cell Applications

Application	**Power Rating**	**Uses**
Stationary	5 kW - 40 MW	Residential and commercial power units, combined heat and power, premium power,* uninterruptible power supplies
Portable	1-50 kW	Wheel chairs, golf carts, truck and rail refrigeration units, road signs, space vehicles and satellites

Mobile	25-150 kW	Light- and medium-duty vehicles, buses, industrial trucks, naval and submarine vessels
Micro	1-500 W	Cell phones, personal digital assistants, notebook computers, some military hardware, portable electronics

* "Premium power" applications require highly reliable power with no fluctuation in voltage.
Source: State Energy Conservation Office and the Fuel Cell Initiative Advisory Committee.

To date, most fuel cells have been used for stationary applications. About 300 stationary fuel cells are operating worldwide in both the public and private sectors, generating about 50 megawatts of electricity, enough to power about 20,000 average-sized homes. These fuel cells are providing facilities with both heat and power or serve as emergency power sources during power-grid failures.

The most visible use of portable fuel cells still is in the space program. Other potential applications include recreational uses, truck and rail refrigeration units, emergency backup power supplies and small remote loads such as lighted road signs.

Micro applications, by some estimates, will reach widespread commercialization first. One head of a fuel cell company has said that within two years, micro fuel cells could be competitive with the lithium-ion batteries commonly used in notebook computers.[4] This would provide broad public exposure to fuel cells and could help pave the way toward their early acceptance. Companies already have developed fuel cell units to power laptop computers and lights, and expect to be able to power cell phones and other portable electronic devices as well. While this use doesn't face many of the challenges other applications face, miniaturization itself is still a major challenge.

Mobile applications will include automobiles, mass transit, light and heavy-duty commercial transportation and military vehicles. These applications are likely to be the last commercialized in large numbers due to an array of hurdles including price, reliability and the difficulties of hydrogen storage. By most estimates, fuel cell-powered cars will not be widely available in less than 10 years.

Recent Advances

While fuel cell technology is not new, new discoveries and challenges are constantly emerging that could affect the size, efficiency and ultimately the cost of fuel cells.

[4] Manfred Stefener, CEO of Smart Fuel Cell, as quoted in by R. Gaertner, "Fuel Cells That Fit in a Laptop," *Wired News* (January 23, 2002), http://www.wired.com/news/technology/0,1282,49717,00.html. (Last visited August 3, 2002.)

PEM fuel cells, for instance, once attracted the most commercial interest because the materials needed for their production are readily available. But PEMs have not developed at the pace of other types of cells. In Europe, SOFC-based cogeneration units, producing both heat and electricity, are being delivered to customers, while PEM devices have not yet advanced to marketability.[5]

In all, the future of fuel cell technology seems extremely bright. Among recent advances:

- new technology has reduced the operating temperatures of some large stationary fuel cells to less than that of a kitchen hot plate, an innovation that should reduce the cost of the materials used to make the cells.[6]
- one company expects to commercialize a small, high-performance fuel cell for use in laptop computers within the next five years.[7]
- an outdoor equipment provider expects to offer a fuel cell-powered "camping generator" in 2003.[8]

[5] European Fuel Cell Forum, "Fuel Cells as Watershed?" April 30, 2002, http://www.efcf.com/media/ep020430.shtml. (Last Visited August 3, 2002.)
[6] European Fuel Cell Forum, "Fuel Cells as Watershed?" April 30, 2002, http://www.efcf.com/media/ep020430.shtml. (Last Visited August 3, 2002.)
[7] Casio, Inc., "Success in R&D of Optimal, Small-Scale, High-Performance Fuel Cells for Portable Devices," *News Release* (March 13, 2002).
[8] Interview with Stephen Kukuch, Ballard Power Systems, August 21, 2002.

II. Markets

In theory, a fuel cell can be small enough to power a laptop computer or large enough to power a city. Ultimately, the market will determine the fuel and fuel cell of choice for each application.

Principia Partners, a market research firm, has stated that the market for fuel cells that generate electricity will grow to $3 billion by 2005; Alliance Business Intelligence predicts that the market for stationary fuel cells used to generate onsite power will grow to $10 billion by 2011.[9] A 2002 report by Price Waterhouse Cooper stated that the industry "could achieve a compounded average annual growth rate of over 60 percent over the next decade."[10] According to *Hart's European Fuels News*, many analysts believe that "fuel cells won't achieve significant market penetration for stationary sources until 2008 and automobiles until 2010."[11]

A draft report to Congress by Scientech, Inc., an energy and environmental consulting firm, separates the potential fuel cell market into three segments:

- Early Adopters
- Transportation
- Infrastructure

Early adopters are those ready and willing to buy fuel cells now. This market primarily wants stationary, portable and micro devices. It represents private and public customers who require dependable and high-quality "premium" power (delivering a strong, unwavering current of electricity). Financial firms, which can lose large sums of money if their power supplies are interrupted, are a good example of this type of customer.

The *transportation* market includes automobiles, buses and light and heavy equipment that would use fuel cells for propulsion and auxiliary power. These customers could include individuals, governments and commercial vehicle fleets, using fuel cells in both portable and mobile applications. The earliest adopters in this market segment are likely to be subsidized mass-transit providers with central fueling infrastructures.

The *infrastructure* market includes manufacturers and other heavy industries and the public sector.

These markets will require considerable adjustments to make widespread use of fuel

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[9] Scientech, Inc., "Fuel Cells: Generating Enthusiasm," by Ken Silverstein, July 12, 2002, http://www.secure.scientech.com/issuealert/article.asp?id=1314. (Last visited September 4, 2002.)
[10] Price Waterhouse Cooper, "Fuel Cells: The Opportunity or Canada," June 2002, http://www.pwcglobal.com/extweb/ncsurvres.nsf/DocID/F7279B67D838C55685256BD1004B652B. (Last visited September 11, 2002.)
[11] Robert Gough, "Investors Shy From Fuel Cells As Markets Fail To Materialize," *Hart's European Fuels News* (June 12, 2002).

cells. The public sector must review its laws and regulations for any necessary modifications. The private sector, in turn, must begin building the necessary manufacturing, distribution and fuel supply infrastructure. Both sectors must work to build appropriate codes and standards and to provide consumers with objective information on safety, reliability and performance. None of these tasks will be easy, but all are necessary if we are to reap the full benefit of this promising new technology.

III. State of the Industry

The most widely sold fuel cells currently cost about $4,500 per kilowatt (kW), in addition to fuel, maintenance and installation costs. FCIAC estimates that a cost of $1,200/kW would be very competitive with other forms of power generation for premium power applications requiring highly reliable power. For widespread use in residential applications, the cost should be in the $400/kW range to be competitive.

The key to reducing costs will be less expensive and more widely available materials; additional product research and development (R&D); and manufacturing techniques adapted for mass production. With new investment capital, manufacturers will be able to fund additional product development and purchase the state-of-the-art assembly equipment needed to reduce their unit costs.

Today, most fuel cell manufacturers are relatively small operations, without automated production lines and advanced process monitoring; some depend largely on visual inspection to ensure quality control. Such assembly is prone to high rework and scrap rates. Skilled technicians, rather than low-cost assembly labor, must be used to support production. Similarly, the industry currently lacks advanced software for production management, shop floor control, materials requisition and planning and other quality control systems. Moreover, low-volume manufacturers cannot qualify for bulk pricing on many material purchases.

Consequently, fuel cell manufacturing costs presently are driven by relatively high labor costs, inadequate inventory management, low yields and lengthy production times. On the other hand, the largest fuel cell manufacturers are at least financially stable, as are those conducting the majority of privately funded R&D. However, without an infusion of new capital, they will not be able to attract volume sales and generate the economies of scale needed to reduce the cost of fuel cells.

While federal and other public-sector activity in fuel cell development has increased, it has focused narrowly on mobile and niche applications, and private investment is limited. Furthermore, the industry is overcoming an image problem based upon early missed production targets, delayed deliveries and a lack of objective performance data. In addition, early adopters must address safety concerns and the present uncertainty as to which types of fuel cells will ultimately prove commercially viable. All of these factors have increased investor caution, and while none seems to present an insurmountable hurdle, all must be resolved.

According to the FCIAC, to reach a production level that could help them achieve competitive pricing and industry self-sufficiency, fuel cell manufacturers must be able to sell a total of 1,000 megawatts (MW) of generation in Texas by 2010, with more or less equal production growth across the total fuel cell market. And a thousand megawatts is not a large amount compared to the 87,000 MW that Texas' utility generators are already capable of producing.[12]

[12] E-mail communication from Richard Greffe, Texas Public Utility Commission, August 12, 2002.

IV. Six Key Benefits

Because of their ability to deliver clean energy in a wide range of applications, fuel cells promise to be a key technology now and in the future. Fuel cell commercialization offers society significant economic, environmental, health and energy security benefits.

Environmental Improvement

Widespread use of fuel cells in both the early adopter and transportation markets will have a positive effect on Texas' air quality. A 1999 air quality study of the Houston area, for instance, concluded that ozone and fine particulate pollutants may lead to the premature deaths of as many as 435 persons per year in the region, not including those under the age of 30.[13] The use of fuel cells in the Houston and Dallas-Fort Worth metropolitan "non-attainment" areas would reduce emissions of nitrogen oxides (NOx), sulfur oxides, and small particulates, all known to cause respiratory ailments and heart disease.

Exhibit 3 illustrates the potential of fuel cells fueled by natural gas to reduce nitrogen oxide emissions below that of the current standard set by the Texas Commission on Environmental Quality (TCEQ—formerly the Texas Natural Resource Conservation Commission). The Fuel Cell Initiative Advisory Committee estimates that the installation of 1000 MW of fuel cell power between 2004 and 2009 could prevent the addition of 1,916 tons of nitrogen oxides into Texas skies.

Exhibit 3: Emissions Reduction, Natural Gas Fuel Cells

Year	MW Added (yr)	Total MW (accum)	TCEQ NOx Limit (lb/MWH)*	Molten Carbonate Fuel Cell NOx emissions (lb/MWH)	Total NOx Savings (tons/yr)
2004	50	50	.47	.002	102
2005	150	200	.14	.002	121
2006	200	400	.14	.002	242
2007	200	600	.14	.002	363
2008	200	800	.14	.002	484
2009	200	1,000	.14	.002	604
				Total NOx Savings (tons)	1,916

* TECQ NOx limit for new generating units less than 10 MW

Source: Fuel Cell Initiative Advisory Committee.

FCIAC also notes that fuel cell use would lead to reductions in the emission of carbon dioxide and other products. In stationary applications, fuel cells are more efficient at

[13] Fuel Cell Initiative Advisory Committee, Benefits Team working paper, May 2002, p. 4.

converting natural gas into useful electricity than many competing technologies.

The transportation market, however, would have the greatest impact on air quality. The U.S. Department of Energy (DOE) projects that if just 10 percent of the nation's automobiles were powered by fuel cells, the total emissions of regulated air pollutants from autos would be cut by a million tons per year; in addition, about 60 million tons of carbon dioxide would be eliminated.[14]

Energy Security

Fuel cells also promise to reduce America's dependence on foreign oil. The world produces 75 billion barrels a year, or 25 million barrels a day, while the US produces just 8 million barrels a day and uses 19 million. According to the U.S. Geological Service, the world's total consumption will exceed production by 2030. Between 1995 and 2000, new sources of oil accounted for only one of every nine barrels used.[15]

For the foreseeable future, natural gas, propane and methanol could supply the fuel requirements of stationary and portable fuel cells. Because these fuels are domestically produced, U.S. reliance on imported oil could decrease as fuel cells are deployed in larger quantities. In the transportation sector, DOE projects that shifting 10 percent of the nation's vehicles to fuel cell power would reduce oil imports by 800,000 barrels a day, or about 13 percent of the current total. Using fuel cells to replace other oil-based applications, such as oil heaters, diesel backup generators and gasoline-powered lawn tools, could further reduce oil imports.

Improved Power Reliability

Stationary fuel cell applications provide additional economic benefits in the form of highly reliable power. Many industries need uninterruptible power delivered at a constant voltage; fuel cells can provide it. Downtime due to power failures or interruptions can be costly both to business and consumers, especially in areas such as stock brokerage, credit-card transactions, financial services and telecommunications.

Transmission and Distribution Relief

Fuel cells also could help relieve transmission and distribution constraints. For instance, the Dallas-Fort Worth (DFW) Metroplex, one of the nation's largest urban areas, consumes 25 percent of the total electric load managed by the Electric Reliability Council Of Texas (ERCOT), which oversees electricity distribution for most of Texas. ERCOT believes that new air-quality regulations and the rapid pace of DFW growth will necessitate the construction of new, high-voltage transmission lines, and that even then the Metroplex cannot be served adequately without more local generation of electricity.

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[14] Fuel Cell Initiative Advisory Committee, Benefits Team working paper, May 2002, p. 7.
[15] U.S. Geological Service, "Are We Running Out Of Oil?" by L.B. Magoon, http://geopubs.wr.usgs.gov/open-file/of00-320. (Last visited September 5, 2002.)

As a practical matter, however, the construction of new central power stations and high-voltage transmission lines in dense urban areas is a difficult, expensive and time-consuming process. In addition, new federal requirements to reduce air emissions by 2007 will further limit the feasibility of new power plant construction in the DFW Metroplex. The U.S. Environmental Protection Agency (EPA) and TCEQ have designated the four-county area as a "non-attainment" area for ground-level ozone, produced in part by NOx emissions. To conform to the new State Implementation Plan (SIP), which outlines how Texas will comply with the federal Clean Air Act, existing DFW power plants will be required to either retrofit their facilities with new NOx reduction devices or reduce or cease their operations altogether.[16]

The Metroplex has an immediate need for a clean power source such as fuel cells that can be located at or near the points of power consumption. Fuel cells could allow DFW and other Texas metropolitan areas to continue their economic growth while maintaining or improving their air quality.

Consumer Benefits

Broader use of fuel cells would provide economic benefits to consumers as well. With adjustments to Texas' current "net metering" rules, consumers using fuel cells could sell excess power back to the power grid while lowering their utility bills.

The widespread use of fuel cells should lower the utility bills even of consumers who remain on the traditional power grid. Utility customers pay for all costs of the utility system, including the construction of generation facilities and transmission lines and any increase in fuel feedstock costs. These costs are substantial; Texas' Public Utilities Commission recently authorized a power company to build three high-voltage lines at a cost of *$750,000 per mile*.[17] Widespread use of stationary fuel cells would lessen the need for such costly expansions.

The consumer also pays for utility investments in overbuilt generation and transmission capacity. The creation of large central generating stations and transmission lines typically generates large amounts of "growth" capacity that may go unused for years. The small size of fuel cells and their flexibility and variety in use would allow utilities to add capacity incrementally, as needed, with shorter lead times and reduced financial risk. Less-frequent expansions of transmission lines also should reduce the incidence of litigation between utilities and landowners.

Economic Development

Texas could benefit greatly from the development of a fuel cell manufacturing industry in the state. In 2001, the U.S. market for fuel cells was about $218 million. According to Business Communications Company (BCC), a technical and market research firm, this

[16] Fuel Cell Initiative Advisory Committee, Benefits Team working paper, May, 2000, p. 10.
[17] E-mail communication from David Hurlbut, Texas Public Utility Commission, July 8, 2002.

market will increase to $2.4 billion by 2004 and $7 billion by 2009.[18]

Providing the fuel cells to accommodate that growth, however, would require a manufacturing base that simply does not exist at present. The industry will have to build its plants *somewhere*, and Texas offers an existing infrastructure of world-class research and educational institutions, technical colleges and manufacturing capacity.

In a study performed for this report, the Texas Department of Economic Development (TDED) estimated that every dollar spent in the Texas economy by the fuel cell industry would generate 66 additional cents elsewhere in the Texas economy.[19] Businesses that would benefit include makers of advanced materials and industries that supply instruments, controls, electronics and components.[20]

Additionally, Texas would garner "indirect" and "induced" economic benefits (Exhibit 4). (Indirect benefits are sales and purchases made by related industries, while induced effects are those derived from related businesses and employees spending their earnings in local economies.)

Exhibit 4: Effects of the Development of Fuel Cell Manufacturing in Texas

Effects	Output	Jobs	Payroll
Direct	**$33,903,672**	**200**	**$6,621,904**
Indirect	**$14,550,713**	**158**	**$4,655,497**
Induced	**$ 8,005,699**	**95**	**$2,428,079**
Total	**$56,460,084**	**453**	**$13,705,480**

Note: all values are in estimated 2003 dollars. The table is based on the following assumptions: by the year 2003, stationary plants are in place in Texas producing 20,000 kW and paying an average wage of $33,275 with capital investment, payroll and sales of $42.3 million annually. The estimate employs a model based on electrochemical generators.
Source: Texas Department of Economic Development.

[18] Fuel Cell Initiative Advisory Committee Benefits Team working paper, May 2002, p. 11.
[19] Texas Department of Economic Development, *Potential Impact Of A Fuel Cell Industry*, draft report (Austin, Texas, July 2002).
[20] Environmental Research institute of Michigan, Center for Automotive Research, *Positioning the State of Michigan as a Leading Candidate For Fuel Cell and Alternative Powertrain Manufacturing*, by Brett C. Smith (Ann Arbor, Michigan, August 2001), p.6.

In the words of the TDED report:

> Overall, for every one job created in the state's fuel cell industry, an additional 1.2 jobs would be created elsewhere in the economy. And for every $1 increase in wages in the fuel cell industry, wages in the Texas economy as a whole could increase by $1.[21]

[21] Texas Department of Economic Development, *Potential Impact Of A Fuel Cell Industry*, draft report (Austin, Texas, July 2002).

V. Challenges to the Industry

The benefits described in the previous section will be realized only if the challenges facing the fuel cell industry are resolved.

Bill Fry, vice president for Quality Assurance & Environmental Affairs for the H.E.B. grocery chain, offered his company's perspective on fuel cells to FCIAC at its May meeting. He noted the difficulties faced when HEB changed its mobile fleet to liquefied natural gas (LNG) and discovered the lack of infrastructure support. It cost HEB $2 million to, among other things, train mechanics to work on the engines, resolve special permit issues concerning their fueling stations and resolve various regulatory issues.[22]

The experience provided an object lesson for the company and highlighted several significant hurdles that must be surmounted before a company such as H.E.B. can adopt fuel cell technology:

- costs competitive with the existing power grid;
- reliability equal to the existing power grid;
- access to rapid repairs for fuel cell technology;
- minimal regulatory barriers;
- and no compromise in safety.[23]

Cost

The cost of fuel cells is undoubtedly the most important concern in the industry's development. Factors affecting cost include the state of the technology, manufacturing costs, access to capital, liability concerns and product performance, as well as infrastructure issues including codes and standards, regulatory reform, fuel delivery and storage, technical training and public education.

At present, fuel cell power is too expensive to compete in the marketplace. The most widely sold fuel cells cost about $4,500 per kilowatt output, in addition to fuel, maintenance and installation costs. FCIAC estimates that a cost of $1,200/kW would be very competitive with other forms of power generation for premium power applications that require uninterruptible, clean and unwavering electric service. For widespread use in residential applications, the cost should be in the $400/kW range.

Technology advancement should result in reduced production costs through less expensive parts and increased efficiency. Some new fuel cells have produced good operating efficiencies at much lower operating temperatures; this means less-expensive stainless materials might be used. [24]

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[22] Presentation to the Fuel Cell Initiative Advisory Committee by Bill Fry, H.E.B., May 16, 2002.
[23] Presentation to the Fuel Cell Initiative Advisory Committee by Bill Fry, H.E.B., May 16, 2002.
[24] European Fuel Cell Forum, "Fuel Cells as Watershed?" April 30, 2002, http://www.efcf.com/media/ep020430.shtml. (Last Visited August 3, 2002.)

Production costs also are driven up by the labor-intensive production processes currently used and the lack of modern mass-production techniques. As unit volume for their products increase, manufacturers will be able to make investments in improved plants and equipment, thereby driving down manufacturing costs. Two manufacturers, Fuel Cell Energy and Siemens-Westinghouse Power Corporation, are currently building new factories on the East Coast to increase their manufacturing capacity and efficiency.[25]

Advanced technology also will affect the size of fuel cells, which should directly affect the market acceptance of micro applications. Similarly, dramatically improved reformer technology may one day allow mobile fuel cells to run on ordinary gasoline.[26]

Capital Investment

An infusion of capital into the industry could fund modern production techniques as well as aggressive research and development, both of which would help drive unit costs down. While governmental activity in fuel cell development has increased, it has been too narrowly focused on mobile and niche applications (such as for use by the military or NASA), and private investment capital has not been forthcoming in significant amounts.

To ensure consistent, substantial investment, the industry must meet development milestones and overcome potential skepticism amongst certain members of the investment community. Missed early production targets, delayed deliveries and a lack of objective data all have worked to increase investor caution. Uncertainty in the market also is due to the rapid development of the technology, which could easily favor one approach over another—leaving some investors high and dry.

Codes and Standards

The lack of harmonized codes and standards at all governmental levels can affect the ability of consumers to, for instance, obtain liability or homeowners insurance or even to get the fuel cell permitted and installed. The lack of objective performance and reliability data can make consumers understandably reluctant to depend on fuel cells as a primary source of electricity. Both of these factors affect sales potential.

Infrastructure

For the transportation market, hydrogen carries special infrastructure requirements—high costs and safety issues that are, as a ChevronTexaco executive recently remarked, "virtually prohibitive, in the near term." A hydrogen infrastructure for the transportation market could by some estimates cost billions and require as long as 50 years to establish.[27]

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[25] Fuel Cell Initiative Advisory Committee, Barriers Team working paper, May 2002, p. 5.
[26] Tom Koppel and Jay Reynolds, *A Fuel Cell Primer: The Promise And Pitfalls* (2000), p. 14.
[27] Testimony by Don Paul, vice president and chief technology officer, ChevronTexaco, , to the U.S. House Energy and Commerce Committee, Subcommittee on Oversight and Investigations, June 6, 2002,

Other aspects of the fuel cell market face serious infrastructure challenges (Exhibit 5). For example, stationary, portable and micro applications all must deal with regulatory issues, while portable and micro applications also face significant hurdles concerning fuel storage.

Exhibit 5: Overview of Barriers by Market

Market	Primary Barriers
Stationary	Fuel cell cost; codes and standards; technical training; reformer technologies; product performance; emission credits; fuel safety
Portable	Fuel cell cost; size; weight; fuel availability; systems integration and product development; fuel safety
Micro	Compatibility between fuels and fuel cell materials; product size and weight; fuel cell cost; safety; fuels transport rules and codes
Mobile	Fuel cell performance; fuel standardization; fuel availability and safety; investment risks due to changing technology; fuel cell cost; automotive testing and vehicle safety; vehicle insurability; repair and parts supply infrastructure

Source: Fuel Cells Texas, Inc.

Training And Education

Another barrier to the general adoption of fuel cells is a lack of relevant training and education. The development and deployment of fuel cells will require a workforce of scientists, engineers and technicians with suitable expertise. Trained technicians will be needed for fuel cell installation, operation and maintenance, and trained scientists will be needed to continue to advance the technology.

At present, Texas universities offer only a few scattered courses and research programs on fuel cells. Education in the broader sense, moreover, will be needed to increase the public's familiarity and comfort with the new technology. This learning curve must be followed if fuel cells are to gain wide acceptance.

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http://www.chevrontexaco.com/news/speeches/2002/2002jun02_don_paul.asp. (Last visited August 4, 2002.)

VI. Government Role

Because of the major investments in manufacturing, technology and infrastructure needed to bring fuel cells to the marketplace in a meaningful volume, some government intervention will be essential. Government has and should continue to support R&D, fund demonstration projects and purchase commercial fuel cell products as they become available.

Federal Government

The federal government is the largest public investor in fuel cell technology, following a long tradition of supporting emerging technologies with potential public benefits. Its current approach is to provide some support for fuel cell research in all applications while focusing on the transportation market.

DOE recently awarded a series of million-dollar cost-sharing contracts to assist companies in the further development of Solid Oxide Fuel Cells and has formed a "FreedomCAR" research partnership with the nation's automobile manufacturers to develop technologies for the mass production of affordable, hydrogen-powered fuel cell cars.

As noted above, the federal government also has invested in various niche applications for fuel cells. For instance, NASA has developed fuel cells to provide a reliable, self-contained power source for spacecraft electronics. The military has exploited other niche applications, such as micro fuel cells to power personal electronics and satellites and stationary fuel cells to provide power in remote locations.

While these efforts all have been useful, the narrowness of the current federal approach may hold back the commercialization of the industry as a whole.

Industry-watchers are urging the federal government to change the direction of its efforts. A *Draft Fuel Cell Report to Congress by Scientech Inc*., an energy and environmental consulting firm, has suggested that the government consider a demonstration program, overseen by a body of industry and consumer stakeholders, to periodically provide the Department of Energy with information to "determine if further investment in fuel cell and hydrogen technologies is warranted" at different stages. This would involve ongoing technology and market assessments, something federal fuel cell projects have not stressed in the past.[28]

Federal grants also can be used to place fuel cells in the field. For instance, a Department of Defense grant recently allowed Austin Energy to purchase and install a Phosphoric Acid Fuel Cell, the first fuel cell in Texas to feed power directly into the electric grid.[29]

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[28] Sentech, Inc., Draft *Fuel Cell Report to the Congress, Interim Assessment* (June 2002), p. vi., http://www.sentech.org. (Last Visited, August 3, 2002.)
[29] Austin Energy, "Austin Energy Eyes Fuel Cell Business", *News Release* (June 16,2002).

State Efforts

A number of states have attempted to support early fuel cell development through mandates and direct and indirect customer incentives. Their efforts highlight the sort of aggressive action needed to help Texas firms make the state a fuel cell leader.

Some states, for instance, have broadened their renewable portfolio standards, which require retail electric providers to purchase a minimum percentage of renewable energy, to accommodate fuel cells. Two states, Massachusetts and New Jersey, levy a "system benefit charge" on electric bills that subsidizes the purchase of renewable energies including energy from fuel cells.

California has included fuel cells in its Self Generation program, which provides rebates to end users who install clean power-generating technology, but has concentrated its efforts on mobile applications. According to the California Air Resources Board, "Zero emission vehicles…and near-zero emission vehicles are a key element of California's plan for attaining health based air quality standards."[30] The state also is becoming an early adopter of the technology; an EPA official told the review team that "Honda and Toyota…will be offering at least 20 or 30 fuel cell automobiles to California fleets in 2003."[31]

Connecticut's Clean Energy Fund, also capitalized by a system benefit charge, funds clean energy projects at their earliest stage of commercialization.[32] Massachusetts' Renewable Energy Trust Fund supports a Premium Power program that encourages the commercial use of fuel cells as reliable on-site power sources for business and industry. Michigan's NextEnergy Project is designed to advance research, development, commercialization and manufacture of alternative energy sources in both the stationary and transportation markets.[33]

New Jersey's Renewable Portfolio Standard program is funded by a system benefit charge and includes fuel cells in its definition of "renewable" energy sources.[34] And Ohio's Third Frontier fuel cell development initiative will commit $103 million over three years to financing, research, development and demonstration and training.[35]

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[30] California Air Resources Board, "Zero-Emission Vehicle Program," http://www.arb.ca.gov/msprog/zevprog/zevprog.htm. (Last visited August 11, 2002.)
[31] Interview with Steve Pratt, U.S. Environmental Protection Agency, August 21, 2002.
[32] Fuel Cell Initiative Advisory Committee, Incentives Team working paper – Stationary Applications, May 2002, p. 10.
[33] Alejandro Bodiop-Memba, "Michigan Vs. Ohio: States Compete to be the Fuel Cell Capital," *Detroit Free Press* (June 26, 2002).
[34] Fuel Cell Initiative Advisory Committee, Incentives Team working paper – Stationary Applications, May 2002, p. 9.
[35] Office of the Governor of Ohio, "Governor Announces Ohio Fuel Cell Initiative", *News Release* (May 9, 2002).

Emission Reduction Credits

The use of tradable emission reduction credits (ERCs) could encourage the use of fuel cells to reduce pollution through alternative market-based mechanisms.

The federal Clean Air Act allows states to create ERCs as a way to ensure that no net increase of emissions results when a new source is approved for operation. Under an ERC system, when an existing source of pollution reduces its emissions of certain pollutants (such as NOx, particulate matter, carbon monoxide and reactive organic gases) to a level below that required by existing rules and regulations, its "surplus" reductions are converted into ERCs, economic commodities that can be bought and sold. In a system of tradable ERCs, facilities that can reduce emissions cheaply have an incentive to accumulate surplus emission credits that then can be sold to facilities that find emission reductions more costly. A system with tradable ERCs allows states to achieve total emission reductions at the lowest cost to business. States can choose to make ERCs permanent or limit them by volume and time.

Fuel cells can create ERCs directly when used to replace older, more polluting technologies such as diesel generators, heaters and boilers. Indirect emission reductions occur whenever electricity generated by a fuel cell offsets the need to generate electricity at a more polluting power plant. At this writing, however, no state or region has been able to satisfy the federal criteria to issue credits for indirect emission reductions.

Texas Efforts

Texas has some limited programs to further the development of fuel cell technology. For instance, the Higher Education Coordinating Board receives appropriations for its Advanced Research and Advanced Technology projects, which provide grants for research and for technology development. For the 2001-02 biennium, the Legislature appropriated $59 million for these programs. Fuel cell related projects have received some funding through these programs but could be targeted for more.

The 2001 Legislature created the Texas Council on Environmental Technology to fund the research and development of clean technologies; the group has considered some fuel cell projects, but has funded none to date.

Texas universities and research institutions such as Texas A&M University, the University of Texas, the Houston Advanced Research Center and Southwest Research Institute have developed programs designed to bring fuel cell technology to the marketplace, and more by other entities are being proposed.

Thus far, however, there has been little movement toward creating technical and degree programs for fields related to fuel cell technology. Representatives of Texas A&M University and the University of Texas have proposed the formation of a Texas

Consortium for Advanced Fuel Cell Research, and with the help of the FCIAC have taken steps to do so. This consortium would work to develop these technical and degree programs as well as attract research funding.

Texas ERC Program

Texas has established a market for pollution emission reduction credits. The ability of fuel cell users to generate ERCs—particularly in the Houston/Galveston area, where an ERC for a ton of NOx currently sells in a lively market for anywhere from $4,250 to $17,500—should greatly enhance the technology's market penetration.[36]

As with other states' programs, Texas could award fuel cells with ERCs only if they directly replace an emission source. TCEQ is attempting to develop mechanisms to compensate fuel cell operators for *indirect* reductions of harmful emissions, but these would require the EPA approval that thus far has eluded other states' efforts.

[36] Houston Advanced Research Center and Gladstein & Associates, *Market Mechanisms to Comptensate Fuel Cells for their Contribution to Air Quality,* (August, 2002) p. ii.

VII. Commercialization Acceleration Timeline

To help achieve competitive pricing and industry self-sufficiency, the FCIAC has suggested that Texas set a goal of 1,000 MW of fuel cell capacity to be installed by 2010, with intermediate goals as follows:

- 50 MW by December 31, 2004
- 200 MW by December 31, 2005
- 400 MW by December 31, 2006
- 600 MW by December 31, 2007
- 800 MW by December 31, 2008
- 1000 MW by December 31, 2009

This timeline implies a volume of sales that, with equal growth across the total fuel cell market, would provide the fuel cell industry with the capital it needs to conduct R&D and improve its manufacturing techniques. Any legislative incentives could be phased out by the end of this schedule.

Such a goal is similar to Texas' successful Renewable Energy Portfolio Standard(RPS), which calls for the construction of 2000 new megawatts of renewable electricity generating capacity by 2009. Electric providers have embraced the RPS and are even buying more renewable energy than required under the law. As a result, after only three years more than half the goal is satisfied and new projects continue to be announced.

VIII. Summary Observations

The fuel cell industry is caught in a classic bind common to new industries. To reduce the costs of its products to commercially acceptable levels, it needs capital for R&D and improved manufacturing techniques; only then can it increase sales and enhance its capital investments. The attainment of FCIAC's fuel cell goal for Texas would require state participation in and stimulation of the early market.

Government's Role

As noted above, the federal government has invested in fuel cell technology and purchased the resultant products primarily for specific, limited uses; only recently has it broadened its focus to include programs intended to bring fuel cells into wide commercial use. States have made (mostly modest) investments in the technology and supported some demonstration projects, with funding derived largely from air-quality programs.

Fuel cells promise to improve America's air quality, but dramatic benefits will not be realized until they are in widespread use in cars and trucks, and by all accounts this development is at least 10 years away.

But Texas could realize other important benefits by stimulating the early market. By becoming an early market participant, Texas could:

- provide objective performance data to the marketplace;
- identify infrastructure needs;
- identify code and regulatory hurdles;
- create market demand;
- stimulate capital investment; and
- manage consumer expectations.

State government can "prime the pump" of the early market by using fuel cells in a wide variety of applications. Fuel cells could provide heat and power for state facilities and backup power for core data systems. Portable applications could power remote highway signs or rest stops and provide emergency backup power for small-scale stationary applications. Micro fuel cells could power many electronic devices used by government workers.

Standardized state and local codes and regulations would enhance the industry's ability to reduce costs and meet demand. Certain laws, such as those regulating the distribution and storage of hazardous materials, should be reviewed and amended to ensure their compatibility with this new technology. Training and education are needed as well.

Of course, events beyond Texas' borders will be crucial to the success of the early market, but state government can help there as well. By working with national organizations such as the Hydrogen Codes and Standards Coordinating Committee, the

National Fire Protection Agency and the Institute of Electrical and Electronic Engineers, among others, the state can help craft national codes and standards that help minimize market risk by limiting uncertainty among manufacturers and consumers. The state also could participate in regional research consortiums to encourage technology development.

Stakeholder Participation

Texas needs an entity to oversee the development of fuel cell policy and plan for its implementation.

The Legislature recently created the Texas Council on Environmental Technology (TCET) to evaluate new clean energy technologies; its members have both technical and marketing experience, making it the logical body to oversee the activities of various public and private partners in developing and executing a state fuel cell policy.

Another hurdle is the ownership of intellectual property and other proprietary interests; a Texas effort would rely on cooperative information-sharing among private and public participants. Performance data, manufacturing capabilities, the status of available technology and similar data are important for policy making, and the lack of such data is due in part to the secrecy surrounding proprietary information on fuel cell technology.

While the reluctance of private companies to share such information is understandable, government still should work with them to obtain, verify and disseminate better data, and find ways to encourage the industry to be forthcoming with information in exchange for public assistance.

IX. Policy Recommendations

FCIAC developed a number of recommendations that would aid in the acceleration of commercialization; public input and SECO provided others. These recommendations support one another, making it important that they be implemented as a group. An incentive for purchasing a fuel cell, for instance, is of no value if the consumer can't get it installed, serviced or insured.

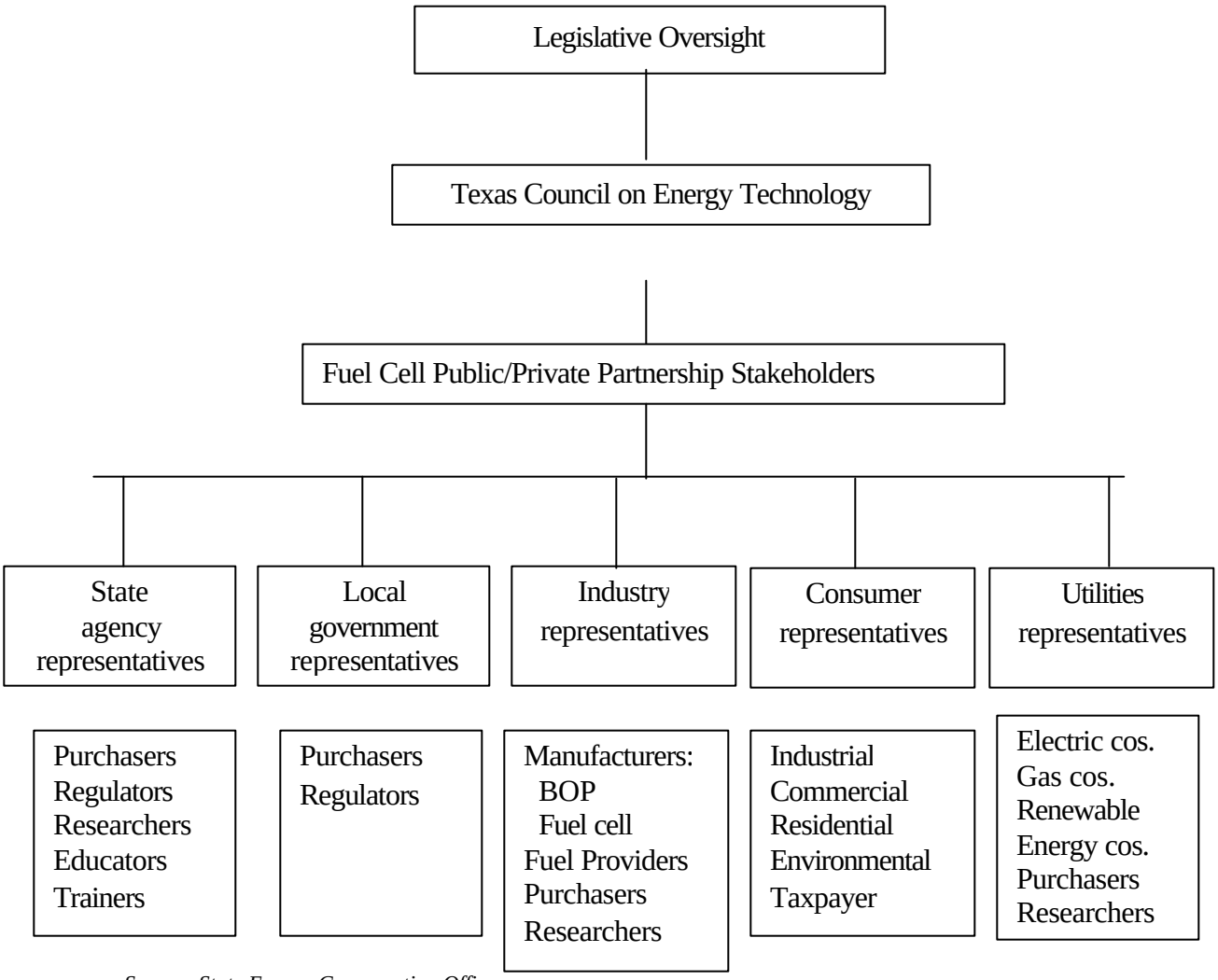
Recommendation 1: Texas should create a public/private partnership, overseen by the Texas Council on Environmental Technology, to encourage the commercialization of fuel cell technology and the growth of a fuel cell industry in Texas.

With proper support, TCET is capable of taking on this task as a part of its current mission.

TCET could be responsible for implementing FCIAC recommendations; identifying and resolving barriers to commercialization; coordinating projects and programs; periodically reviewing policy effectiveness; and evaluating the technology and market factors it deems necessary for planning its future actions. It also could oversee the funding of fuel cell technology and infrastructure development and interstate cooperative efforts.

The partnership's members should include representatives of the Texas Consortium for Advanced Fuel Cell Research, when it becomes active (see Recommendation 3). The partnership would meet periodically to share information and update one another in their areas of specialty (Exhibit 6).

Exhibit 6: Fuel Cell Policy Implementation: Organization



Source: State Energy Conservation Office.

The partnership's responsibilities should include:

- proposing options for coping with intellectual property and proprietary issues that may arise during the collaborative effort;
- funding fuel cell technology and research projects;
- serving as project manager for these projects;
- setting policy for and directing the activities of the members of the partnership;
- conducting periodic reviews of fuel cell technology, the fuel cell market and stakeholder activities;
- reporting to the Legislature on the viability of continuing fuel cell technology and market development, based on the above review;
- observing and managing progress toward FCIAC's 1000 MW goal , or any new goal;

- identifying government niche markets and working with industry and state agencies to place fuel cells in those markets;
- identifying and developing public and private-sector demonstration projects;
- identifying additional barriers to fuel cell commercialization;
- acting as a clearinghouse for fuel cell technology and market information;
- preventing duplication of projects funded with public dollars;
- discouraging duplication of private-sector efforts;
- maximizing any public capitalization of infrastructure by preventing the duplication of effort by the public and private sectors, and by ensuring at least equal funding participation by private industry;
- identifying funding sources for research into and the purchase of fuel cell technology; and
- identifying ways to implement the remaining recommendations of this report.

Recommendation 2: Texas should adopt concrete goals for fuel cell development.

As noted above, FCIAC recommended a goal of 1,000 MW of fuel cell-generated power in Texas by 2009. According to the committee, this level would allow manufacturers to begin reducing the costs of fuel cells.

This goal should be adopted unless the public/private partnership overseen by TCET suggests another. The adopted goal should be reviewed periodically and updated as necessary.

Recommendation 3: Texas should encourage and assist in the formation of a Texas Consortium for Advanced Fuel Cell Research.

As part of the public-private partnership, a multi-location consortium would enhance the state's ability to attract research grants and provide additional research capability for its fuel cell industry. Numerous state research and academic institutions, anchored by the University of Texas and Texas A&M University systems, have expressed interest in such a consortium and already have conducted exploratory meetings. These institutions should offer appropriate resources to the project, but the state should consider providing any additional resources needed as well.

Recommendation 4: The state of Texas should become an "early adopter" of fuel cell technology.

This would allow the state to generate objective information for the marketplace while providing benefits to the taxpayers in the form of improved air quality and lower government energy bills.

The public/private partnership overseen by TCET should identify uses for fuel cells

unique to public facilities or operations and work with industry and public research institutions to place fuel cells in these roles. For economic development purposes, the partnership should conduct similar research for the private sector as well, to further encourage early adoption of the technology.

State agencies soon will begin participating in a legislatively mandated energy and water efficiency program for all state facilities. This effort may create an opportunity for a large agency to install fuel cells, particularly if it can replace boilers with fuel cell-generated heat and electricity in its facilities or those of other agencies.

Recommendation 5: Texas should purchase fuel cell power through "off-take" utility contracts.

"Off-take" contracts are long-term arrangements that obligate the buyer to purchase a minimum quantity of power over a specified period of time at an agreed price. A fuel cell owner could then use this contract to help secure financing for the equipment. The state could offer long-term, fixed-price contracts to vendors for electricity generated from fuel cells to meet a portion of its power requirements. This should help Texas reach its 1,000 MW goal power goal (or any other goal subsequently adopted).

Recommendation 6: Texas should develop and fund fuel cell demonstration projects.

Such projects would provide objective information needed to stimulate research and consumer and investor interest.

Recommendation 7: The Legislature should reserve a percentage of current state research funding to serve as matching funds for federal grants related to fuel cell systems.

This funding would come from appropriations for the Higher Education Coordinating Board's Advanced Research Project and Advanced Technology Project programs.

Recommendation 8: The public/private partnership should assist the development of a wide variety of fuel cell training and education.

The public/private partnership overseen by TCET should develop degreed and vocational fuel cell technology programs. The state should assist public and private institutions with the preparation and dissemination of educational information to be incorporated into classroom instruction at all levels, as well as information for general public consumption.

Recommendation 9: The Legislature should provide financial incentives to support its goals for fuel cell development.

The private sector could be encouraged to help the state meet its goals through incentives

such as emissions reduction credits, property and sales tax relief and reductions in permitting and licensing fees.

Recommendation 10: The Legislature should allow power transmission and distribution companies to own fuel cells.

As a result of deregulation, state law currently forbids power transmission and distribution companies to own generating capacity. Allowing these companies to invest in fuel cells would have an immediate public benefit in the Dallas/Fort Worth Metroplex, which otherwise will not be able to meet its near-term future power needs without a major investment in conventional generation, transmission and distribution facilities.

Given the extreme difficulty of building new power plants in the area, and of moving enough power to the region from elsewhere in the state, Metroplex utilities and consumers may find that fuel cells are cost effective when weighed against the alternatives. Fuel cell capacity would relieve generators of the necessity for intensive capital investment in more capacity.

This recommendation would help keep the consumer cost of electricity from spiraling upward. Of course, any significant use of fuel cells may create its own set of challenges, such as liability, safety and interconnection issues. These issues should be addressed and resolved by the public/private partnership overseen by TCET.

Recommendation 11: The Legislature should amend or create other state laws, regulations and permits as needed to accommodate the use of fuel cells.

State purchasing laws may need amendment to allow agencies and local governments to purchase fuel cells, since they cannot yet compete with traditional forms of energy in terms of cost. Environmental regulations may need changes as well, to accommodate the handling, transport, storage and disposal of hazardous materials used in fuel cell systems. Fire and safety laws may need amendment to allow the personal use of fuels such as hydrogen.

Furthermore, the Public Utility Commission should make any adjustments to Texas' current "net metering" rules needed to allow consumers using fuel cells to sell excess power back to the grid. Fuel cells are most efficient when running at or near capacity all of the time. Residential and many commercial loads would not be constant for 24-hour periods, so allowing fuel cell owners to sell excess power would help to further justify the costs of the systems. The public/private partnership also should explore the idea of "fuel cell cooperatives" that could sell power to the grid in larger quantities.

Recommendation 12: The Texas Commission on Environmental Quality should continue its efforts to ensure that fuel cells can generate both direct and indirect emission reduction credits.

TCEQ is working with EPA to gain credit for indirect emission reductions; it should ensure that fuel cells qualify as well. This would encourage the use of fuel cells to help Texas meet federal clean air mandates.

Recommendation 13: Texas should support and pursue the adaptation of national codes and standards to accommodate the use of fuel cells.

Industries often adopt national codes and standards, so interstate cooperation would be necessary. For instance, the Institute of Electrical and Electronic Engineers is working on power grid interconnection issues; Texas representatives should participate in these discussions.

Recommendation 14: Texas should participate in regional and national consortiums and partnerships related to fuel cells.

By forming and/or partnering in regional and national organizations related to fuel cells, Texas could increase its visibility in the industry and aid efforts to bring fuel cells to widespread use. In addition, working with groups now formulating national fuel cell policy would help Texas ensure that it protects the interests of its own fuel cell industry.

Recommendation 15: When they become available, Texas should seek federal permission to allow fuel cell-powered vehicles to use high-occupancy vehicle lanes on Texas highways, regardless of their number of passengers.

This would provide one more incentive for consumers to purchase fuel cell vehicles when they become available. At present, such an action could jeopardize federal highway funding; the Legislature should work with the Texas Department of Transportation and federal officials to ensure the viability of this funding before implementing this recommendation.

Appendices

Appendix 1
Fuel Cell Initiative Advisory Committee

Name	Personal Information	Company Information
Mr. Larry Alford Manager, Distributed Generation Austin Energy Austin, Texas	Mr. Alford has 30 years of experience in electric power generation and is responsible for the evaluation, development, operation and maintenance of distributed generation projects.	Austin Energy is a municipally owned and operated electric service serving the Austin community, including many state facilities.
Ms. Carol Bailey Market Development Manager ChevronTexaco Technology Ventures Bellaire, Texas	Carol J. Bailey, market development manager for ChevronTexaco Technology Ventures, is primarily responsible for market development, product development and strategic planning, as well as customer relations concerning the company's advanced energy technologies.	Chevron Texaco is involved in the development and commercialization of several advanced energy technologies such as fuel cells, hydrogen storage and gas-to-liquid processes.
Mr. Hugh Baker Vice President Hunt Power Dallas, Texas	Hugh Baker is responsible for finding and evaluating new business opportunities in the power and telecommunications industries. Prior to joining Hunt Power, Mr. Baker, a professional engineer, was president of Capstone Energy, Inc. He also spent several years in energy marketing and trading.	Hunt Power functions as a project development organization, seeking out and taking advantage of opportunities in the utility marketplace. Hunt Power also provides utility-related consulting services to other entities in the Hunt Consolidated family of companies, and to third parties on a selective basis.
Ms. Heather Ball Director, Marketing And Public Education, Alternative Fuels Research And Education Division Texas Railroad Commission Austin, Texas	Heather Ball has directed Marketing and Public Education for the Texas propane check-off program (AFRED) since 1992. She has worked in the energy industry for more than 20 years and conducted some of the early market research on fuel cells for small-scale applications.	
Ms. Jannee Briesemeister Consumers Union Austin, Texas		
Mr. Gerry Conway Plug Power Latham, New York		

Name	Personal Information	Company Information
Mr. Tom Coulbourn Regional Manager, Southern U.S. UTC Fuel Cells South Windsor, Connecticut	As a regional manager for UTC Fuel Cells, Tom Coulbourn is responsible for the business development and sales activities in the southern United States. Mr. Coulbourn has developed fuel cell projects around the world and most recently managed the design and installation of a PC25 unit in Austin, Texas for Austin Energy.	UTC Fuel Cells, a unit of United Technologies Corporation, is the world leader in fuel cell production and development for commercial, transportation, residential and space applications. One of the largest companies in the world solely devoted to fuel cell technology, UTC Fuel Cells has more than 40 years of experience in the field.
Malcolm Jacobson Marketing, Market Development Fuel Cell Energy, Inc. Headquarters: Danbury, Connecticut Southern Regional Office: Houston	Malcolm Jacobson has 18 years of experience in the energy industry, with a particular focus on advanced technologies. In his current role at FCE, he is responsible for identifying and developing early adopter markets to support the commercial launch of FCE's Direct FuelCell™ technology. Malcolm holds an Engineering degree from Texas A&M and an MBA from the University of Houston.	FuelCell Energy, Inc. is a recognized leader in the development and commercialization of high-efficiency fuel cells for stationary power generation. The company offers the only "megawatt class" fuel cell in the world and is introducing its Direct FuelCell™ power plants for large commercial, industrial and utility applications. These units are ultra-efficient, non-polluting and are fueled directly with hydrocarbon fuels such as natural gas.
Mr. Don Lewis Fleet Manager Texas Department of Transportation Austin, Texas	Donald J. Lewis is fleet manager and coordinator of the Alternative Fuels Group for the Texas Department of Transportation. The Alternative Fuels Group has been established within the General Services Division to assist in the development and implementation of an alternative fuel strategy for the department.	
Mr. Jim McBride Managing Director Fleet Corporate and Investment Banking Houston, Texas	Jim McBride is managing director of the Houston Energy office for FleetBoston Financial. Mr. McBride has more than 25 years of energy industry and energy finance experience.	FleetBoston Financial is the seventh-largest financial holding company in the United States, with assets of $191 billion. The company's principal businesses, Personal Financial Services and Wholesale Banking, offer a comprehensive array of innovative financial solutions to 20 million customers. Fleet's Wholesale Banking Division offers commercial banking, commercial finance, capital markets and global processing services.

Name	Personal Information	Company Information
Mr. Oliver Murphy President Lynntech, Inc. College Station, Texas	Oliver J. Murphy is a co-founder and president of Lynntech, Inc. Dr. Murphy developed the vision of the company and directs its technology commercialization operations, including the company's intellectual property strategy.	Lynntech, Inc. was incorporated in 1987 and initiated full-time business activities in 1990. The mission of Lynntech, Inc., under the leadership of Dr. Murphy, is to develop proprietary technologies, in particular proton exchange membrane fuel cells and electrolyzer technologies, for commercialization through strategic alliances and licensing agreements. The company also manufactures specialty fuel cell test and measurement equipment as well as components for electrochemical systems manufactured by others, including licensees
Mr. Bruce Rauhe Houston Advanced Research Center The Woodlands, Texas		
Mr. Tim Rebhorn Strategic Advisor Nuvera Houston, Texas	Tim Rebhorn is managing director and partner of Resolutions Management, a consulting firm supplying risk management, strategic negotiation and analytical services to the steel and energy industry. Mr. Rebhorn currently advises Nuvera Fuel Cells of Cambridge	Resolutions Management supplies risk management, strategic negotiation and analytical services to the steel and energy industry.
Mr. Joe Redfield Group Leader, Fuel Cell Systems Southwest Research Institute San Antonio, Texas	Joe Redfield, with 19 years of R&D development, leads a team of scientists and engineers in the development of advanced energy technologies for the military and industry. He is currently managing programs in development, demonstration and testing of fuel cell systems and subsystems used in stationary and transportation applications.	Southwest Research (SwRI) is an independent nonprofit research and development firm. SwRI is world-renowned for its contribution to technology development for both government and industry. SwRI has major R&D and commercialization programs under way in fuel cell-related technologies.
Ms. Katie Schmidt de Fernandez Vice President DCH Technology		
Mr. Tom Smith State Director Public Citizen – Texas Austin, Texas		
Mr. Dick Snyder President Reliant Energy Power Systems Houston, Texas	Dick Snyder is president and chief operating officer of Reliant Energy Power Systems. Mr. Snyder has primary responsibility for the commercialization of Reliant's proprietary proton-exchange-membrane fuel cell technology. In this capacity, he provides overall management and guidance for the introduction of Reliant's fuel cell into the market.	Reliant Energy Power Systems is a wholly-owned subsidiary of Houston-based Reliant Energy, Inc.

Name	Personal Information	Company Information
Mr. Mike Williams President/CEO Texas Electric Cooperatives Austin, Texas		
Mr. Bob Wright Government Relations Methanex Nevada, California		

Appendix 2:
FCIAC Working Teams

While originally dividing into 8 teams, the committee members eventually consolidated those into the following 6 teams. Some members(*) were unable to participate in final team deliberations.

1. Applications:
   Hugh Baker (Team Leader)
   Gerry Conway
   Bruce Rauhe*
   Malcolm Jacobson

2. Barriers
   Dick Snyder (Team Leader)
   Bob Wright
   Bruce Rauhe*

3. Benefits
   Jim McBride (Team Leader)
   Heather Ball
   Jannee Briesemeister*
   Dick Snyder
   Bruce Rauhe*
   Joe Redfield
   Tom Smith

4. Demonstrations
   Don Lewis (Team Leader)
   Larry Alford
   Hugh Baker
   Malcolm Jacobson
   Tim Rebhorn
   Tom Coulborn
   Susan Ghertner*

5. Education/Public Outreach
   Elizabeth Selig (Co-Team Leader)*
   Susan Ghertner (Co-Team Leader)*
   Oliver Murphey

6. Incentives
   Tom Coulbourn (Team Leader)
   Gerry Conway
   Malcolm Jacobson
   Tim Rebhorn
   Bob Wright

Appendix 3
Acknowledgement List

Mr.	Robby Abarca	Texas Public Utility Commission
Dr.	David Allen	Texas Council on Environmental Technology
Mr.	Israel Anderson	Texas Commission on Environmental Quality
Mr.	Greg Brady	Alamo Area Community College District
Mr.	Dan Eden	Texas Commission on Environmental Quality
Dr.	N. Enjeti	Texas A&M University
Mr.	Frank Falkstein	Lower Colorado River Authority
Mr.	Bill Fry	H-E-B, San Antonio
Ms.	Susan Ghertner	Texas General Land Office
Dr.	Valerie Harris	City Public Service, San Antonio
Dr.	Kristin Heinemier	Brooks Energy and Sustainability Laboratory, San Antonio
Ms.	Rhonda Henderson	Texas Department of Economic Development
Dr.	Jo Howze	Texas A&M University
Dr.	David Hurlbut	Public Utility Commission of Texas
Mr.	Dan Kelly	Texas Railroad Commission
Mr.	Tom Knutsen	Lower Colorado River Authority
Dr.	Alan C. Lloyd	California Air Resources Board
Commissioner	Ralph Marquez	Texas Commission on Environmental Quality
Ms.	Amy Mazeika	American Airlines
Mr.	Al Notzen	Alamo Area Council of Governments , San Antonio
Mr.	Mani Palani	University of Texas Health Science Center
Ms.	Patrice Parsons	Houston Advanced Research Center
Mr.	Doug Peck	VIA Metropolitan Transit
Mr.	Steve Polunsky	Texas Department of Transportation
Mr.	Steve Pratt	U.S. Environmental Protection Agency
Mr.	Gene Richards	Texas Department of Economic Development
Ms.	Mary-Jo Rowan	State Energy Conservation Office
Mr.	Dub Smothers	Citizen
Mr.	Sam L. Williams	Texas State Technical College
Mr.	Jim Yarbrough	U.S. Environmental Protection Agency
Mr.	Ken Zarker	Texas Commission on Environmental Quality

Appendix 4
House Bill 2845

1-1 AN ACT
1-2 relating to the creation of an initiative to promote the
1-3 commercialization of fuel cell technologies.
1-4 BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF TEXAS:
1-5 SECTION 1. DEFINITION. In this Act, "energy office" means
1-6 the State Energy Conservation Office.
1-7 SECTION 2. FUEL CELL COMMERCIALIZATION INITIATIVE. (a) The
1-8 energy office shall develop a statewide plan for the coordinated
1-9 acceleration of the commercialization of fuel cell generation in
1-10 this state. The plan must explore and draw conclusions about the
1-11 availability and efficacy of alternative mechanisms that might be
1-12 created in cooperation with the private sector, utilities, and
1-13 other agencies to accelerate the commercial availability and
1-14 economic viability of fuel cells for use in this state. The plan
1-15 must consider, at a minimum, the use of:
1-16 (1) funds available to the energy office or additional
1-17 funding from other state, federal, or private sources for programs
1-18 of research and development, particularly incentives for commercial
1-19 installation of cells by residential, commercial, or industrial
1-20 utility customers;
1-21 (2) utility-administered incentive funds, consistent
1-22 with programs established under Chapter 39, Utilities Code;
1-23 (3) market mechanisms that might be created to assure
1-24 that clean emerging technologies may be compensated for their
2-1 contribution to the reduction of harmful emissions; and
2-2 (4) tax or other economic incentives.
2-3 (b) In developing the plan and proposed rules, guidelines,
2-4 and operating procedures, the energy office shall seek the
2-5 assistance and support of, as appropriate, the Texas Natural
2-6 Resource Conservation Commission, the Public Utility Commission of
2-7 Texas, and other state or local agencies. The plan must consider
2-8 the impact of the use of fuel cell technologies in areas of the
2-9 state that the energy office determines:
2-10 (1) are designated as nonattainment areas under
2-11 Section 107(d) of the federal Clean Air Act (42 U.S.C. Section

7407); or

(2) have a high probability of being so designated in the near future.

(c) Not later than September 15, 2002, the energy office shall issue to the House Energy Resources Committee and the Senate Business and Commerce Committee a report of its findings and recommendations for development of the fuel cell commercialization initiative, including:

(1) the state of the industry or of specific components of the industry;

(2) alternative programs to accelerate the commercial availability of fuel cells, including similar efforts by other states;

(3) programs considered to encourage the industry to locate manufacturing, system integration, or related component parts or services in this state; and

(4) program recommendations, including how proposed programs would work, the impact anticipated on industry development, program costs and sources of funding, and proposed measures of performance.

(d) The energy office shall appoint a fuel cell initiative advisory committee to advise the energy office regarding development of the plan and to assist the energy office in meeting the goals of this Act. The energy office shall appoint to the advisory committee representatives of:

(1) the fuel cell industry;

(2) energy services providers;

(3) electric transmission and distribution utilities;

(4) retail providers of electric energy;

(5) small electric energy consumers;

(6) electric cooperatives; and

(7) municipally owned electric utilities.

SECTION 3. EFFECTIVE DATE. This Act takes effect September 1, 2001.