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This report explains the current state of the art in fuel cell development for transportation and presents industry goals and opinions regarding when it may become commercially feasible. It discusses consumer acceptance and future implications for transportation departments. The report also provides sources for ongoing information about fuel cells.

Large companies are investing funds into prototype development of fuel cell vehicles and into size, weight, cost, and performance solutions. Much progress has been made in those areas. The fact that methanol or gasoline can be reformulated into hydrogen on board the vehicle makes it a more viable technology. A few fuel cell buses already are on the streets. Time estimates for the on-the-road use of a significant number of fuel cell vehicles vary from 2010 to 2025.

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FUEL CELLS IN TRANSPORTATION

Final Report

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Chapter 1: Introduction

Environmentally friendly fueling systems have been making a lot of news in the automotive world lately. Especially in the wake of the recent United Nations conference on global warming in Kyoto, Japan, major auto companies seem to be in a race to produce "green" cars. Battery-powered electric cars, fuel-cell powered electric cars, and "hybrids" that use both batteries and fuel cells or both gasoline and batteries are all in the running. Drawing particular attention are the vehicles that use fuel cells. At the 57th International Motor Show (Frankfurt, Germany, September 11-21, 1997) Daimler-Benz, maker of Mercedes Benz, made big news by unveiling a fuel-cell version of its new A-class model subcompact. Toyota displayed a sport utility vehicle that was a hybrid electric vehicle powered by a fuel cell. Then Chrysler showed its LHX fuel cell concept car at the North American International Auto Show in Detroit in January, 1998.

Now, articles about fuel cells are showing up not only in the trade journals, but in the general news magazines as well. They are being heralded as a clean, efficient technology that may revolutionize the automobile. Claims are being made that the internal combustion engine may finally have a serious competitor.

Fuel cell technology has been identified as an issue that has the potential to impact the Minnesota Department of Transportation (Mn/DOT). For example, if fuel cells really were to replace gasoline engines in a large number of cars, trucks, and buses in the next few years, there would be major changes in the entire fuel delivery infrastructure. The revenue that we currently receive from gas taxes would be dramatically reduced, making it necessary to have alternative funding mechanisms in place.

This paper will explain the current state of the art in fuel cell development for transportation, and will present industry goals and opinions regarding when it may become commercially feasible. It will discuss consumer acceptance, and future implications for transportation departments. Finally, it will provide sources for ongoing information about fuel cells, so that Mn/DOT can monitor the issue and act accordingly.

Chapter 2: What are fuel cells?

Fuel cells convert hydrogen and oxygen into electricity, creating a byproduct of water. Unlike batteries which store their energy within and must be recharged when they run down, fuel cells act like batteries with an external energy source that continually recharges the cell to produce electricity. The electricity can then be used to power an electric motor. The fuel cell was invented in 1839, and has been used for non-automotive applications, but never made it far in the automobile world because of a number of technical barriers that will be detailed in a later section. Their biggest transportation use has been in the space program, in the Gemini and Apollo spacecraft. Right now, the two major applications for which fuel cells are being developed are stationary electric utility power plants and motor vehicles.

The pace of research and development efforts to make them commercially feasible for motor vehicles has picked up considerably in the past couple of years, and several large auto companies are putting millions of dollars into the effort. At least one of them is aiming to have fuel-cell powered automobiles on the market by 2004.

Chapter 3: Who is developing them?

Here's a look at some of the companies involved in this effort and the progress they have made:

Daimler-Benz

Karl Benz has been cited as the inventor of the car and Gottlieb Daimler as the developer of the first gasoline engines suitable for automotive use. They each built their first automobile in 1886. The companies they each founded merged in 1926 to form Daimler-Benz. Their cars would be called Mercedes-Benz. Daimler, Benz, and the companies they founded also designed the first motorcycle, first gasoline-powered motorboat, first airship and airplane engines, and first diesel automobiles.[1] Now, the company that brought us gasoline-engine-powered vehicles is poised to be the first to replace them with the next major technology. And they have put their money on fuel cells to be that technology.

Daimler-Benz has built four fuel-cell demonstration vehicles so far: the NECAR I (new electric car) full-size van in 1995; NECAR II minivan in 1996; NEBUS (new electric bus) city bus in 1997; and NECAR III, Mercedes A-class subcompact unveiled at the 57th International Motor Show in Frankfurt, Germany, in September,1997. They have publicly proclaimed their goal of having fuel-cell cars available for sale by 2004. In order to accomplish that, they have been forging partnerships with other major players in the fuel cell business.

Ballard Power Systems

Ballard Power Systems of Vancouver, British Columbia, is a leading developer and producer of proton exchange membrane (PEM) fuel cells, the type that is thought to be the best suited for vehicle use. Daimler-Benz and Ballard have been collaborating since 1993 in the development of fuel cells for automotive use. Ballard is also developing fuel cells to be used for stationary power plants.

Ford Motor Co.

In December, 1997, an agreement of understanding was signed between Ford, Ballard, and Daimler-Benz to form an alliance to develop fuel cell technology for automotive use. After all of the investment arrangements are completed, Ford will own 15.1% of Ballard common stock, and Daimler-Benz will own 20%. The three companies will also own DBB Fuel Cell Engines, Ford 23.3%, Ballard 26.6% and Daimler-Benz 50.1%. In addition, Ford will be the managing partner in a new subsidiary being formed to further develop and commercialize electric drive trains. Ford will concentrate on electric drive systems, Daimler-Benz on fuel cell systems, and Ballard on the fuel cells themselves. Ford's expertise in low-cost mass production is expected to be useful to the alliance.[2]

Chrysler

Daimler-Benz's latest alliance is with Chrysler Corp. On May 7, 1998, the two companies announced that they have agreed to merge their businesses to become DaimlerChrysler. DaimlerChrysler will be the fifth largest producer of cars and light trucks in the world. Chrysler had already been involved in fuel cell research, related to how the hydrogen fuel is produced. Hydrogen tanks are bulky to transport in automobiles, and there are safety concerns due to the explosive nature of hydrogen. There is also the problem of developing a new storage and dispensing infrastructure to supply hydrogen to travelers. Chrysler is involved in the development of a technique for on-board processing of gasoline into hydrogen to power the fuel cells. This technique could make use of the nation's existing fueling infrastructure, which would solve the problem of how to supply hydrogen to fuel cell vehicles.

Chrysler may benefit from the merger with Daimler-Benz by having more research money available, which could speed up the fuel cell research. A newswire story quoted Canadian Auto Workers union president Buzz Hargrove as saying that the merger would be "complimentary; a pooling of resources which would strengthen both to have greater capital available for research, development and bringing new products on stream."[3] The *Star Tribune* article that reported the merger stated that it "offers Daimler-Benz an opportunity to learn from Chrysler's envied process of making decisions quickly and bringing new vehicles to market promptly…." [4] That also could speed the development of fuel cell vehicles.

Partnership for a New Generation of Vehicles

The **U.S. Department of Energy** and the **Big Three** automakers formed the Partnership for a New Generation of Vehicles (PNGV) in 1993. Their research has investigated alternative propulsion systems, lightweight materials, and alternative fuels, including fuel cells. It was as part of that program that the **Arthur D. Little** technology firm worked with the **Los Alamos National Laboratory** to develop a process for extracting hydrogen on board a vehicle from a variety of fuels, as mentioned above. **Chrysler** is working on taking that process out of the lab and putting it into fuel cell vehicles. This is considered an important development.

Other Auto Companies

Toyota has been building "hybrid" electric cars that use an internal combustion engine for use on the open road and an electric battery for city driving. The car that Toyota displayed at the Tokyo Motor Show in October, 1997, had a small fuel cell together with a battery and a system for "regenerative" braking, so that when the brakes are on, the electric motor generates power to be stored in the battery. **General Motors** is working on fuel cells, hybrids and battery-electric cars. Their first fuel cell prototype van was announced in the

April, 1998 *Hydrogen & Fuel Cell Letter*. They hope to have a vehicle ready for production by 2004. **Mazda** is working on a fuel cell vehicle based on their small station wagon. **BMW** has plans to enter fuel cell development as well. **Renault** is heading a French-Italian-Swedish team in developing a fuel cell hybrid station wagon which runs on liquid hydrogen and uses a battery for energy buffer storage and to help during startup.

Fuel Cell Transit Bus Program

This is a program supported by a grant from the Federal Transit Administration. As part of that program, Georgetown University introduced a fuel cell bus at the American Public Transit Association's Bus Operations Conference in May, 1998. It extracts hydrogen from liquid methanol using an onboard reformer, and uses the type of phosphoric acid fuel cell that stationary electric power plants use, manufactured by **International Fuel Cells**. Most motor vehicle applications use another type of fuel cell, the proton exchange membrane (PEM) fuel cell.

Chapter 4: What are the advantages of fuel cells?

What advantages do fuel cells have over the conventional engine? 1)They are cleaner. They do not produce combustion byproducts, so do not contribute to air pollution or to the greenhouse effect. The only by-product if pure hydrogen is used as fuel is water. If fuels such as gasoline or methanol are processed into hydrogen on board the vehicle, emissions that include carbon dioxide are produced. But even if the vehicle puts out as much CO2 per gallon as a conventional engine, the hydrogen generated from the gasoline provides more power, so that a fuel cell car could get about 80 miles per gallon of gas, resulting in a significant net reduction in greenhouse emissions.[5]

2)They are efficient. In the internal combustion engine, after losses to wasted heat, mechanical friction, and incomplete burning, only 15 to 20 percent of the possible energy in the fuel ends up moving the vehicle. A fuel cell converts 30 percent of the energy in its fuel into useful work, making them 30-50 percent more efficient.[6] Fuel cell-powered electric motors are also expected to require less maintenance over the life of the vehicle.

3)They save oil. They could cut the use of petroleum products significantly if they were in widespread use, thus reducing our dependence on oil. We are not currently suffering from a shortage, and many researchers expect that world oil reserves will continue to increase. But that expectation is not unanimous. The authors of an article in the March, 1998, issue of *Scientific American* predict that the world's supply of oil will reach its peak and begin a decline by 2010.[7]

4)They could conceivably power both our vehicles and our buildings. An intriguing article in *Transportation Research Part D: Transport and Environment* analyzes the potential benefits of tapping electric vehicles when not on the road as power resources for electric utilities. The authors envision a future utility system that is integrated with the electric vehicle fleet, in which electricity customers are also vendors of storage and generation resources. The article fully analyzes battery-operated vehicles rather than fuel cells, but does say that fuel cell vehicles could be used cost-effectively for power generation. It cites a conference paper from 1995 titled "Why not plug your house and workplace into your fuel cell vehicle?"[8]

Chapter 5: What are the barriers to fuel cell use, and how are they being addressed?

What are the difficulties, both technical and human factors, that will have to be overcome or greatly minimized before fuel cell cars can become successful? And how are the major players working to overcome these difficulties?

Cost

A fuel-cell car would currently cost about 10 time as much as a gasoline engine car. But ten years ago, it would have cost 100 times as much. Progress has been made in cutting back, for example, on the amount of expensive platinum (used as a catalyst on the electrodes of a fuel cell) that is necessary. In 1984 it would have taken $33,000 worth of platinum for one fuel cell; the current figure is variously reported as being from $140 to $500. It is also expected that the cost of fuel cells will drop sharply once they can be produced in high volume.

Industry writers frequently refer to the cost per kilowatt of producing the 80 kilowatts necessary to power an electric car. That is another cost that must come down considerably for fuel cell vehicles to be successful. In 1990, the cost per kilowatt was about $5,000 for a fuel cell. I have seen figures for current cost of from $250 to $500. That still makes it at least $20,000 per car just for the fuel cell. Auto companies are giving $25 to $35 per kilowatt as their target, to make the price similar to that of traditional engines.[9]

Another problem is warm-up time. It takes ten minutes to warm up a fuel cell processor. Until then, the vehicle has to run on a nickel-metal-hydride battery, which to run a car for ten minutes would weigh five hundred pounds and cost $20,000. If the warm-up time can be shrunk to one minute or less, then a lighter, less costly battery would suffice.[10]

Public Acceptance

Even if the cost continues to come down, there is the question of how much of a market there will be for fuel cell cars. Right now, the cost of gas is low, and fuel economy is not a consumer priority. Large vehicles are best-sellers and gasoline consumption is way up. The *Star Tribune* reported on a survey in which about seven out of ten Americans said that the cost of gasoline would have to rise to $2.09 per gallon before they would switch to more fuel-efficient vehicles.[11] As an example, someone who drives 15,000 miles per year, gets 20 miles per gallon, and pays $1.25 per gallon would pay a total of $937 per year for gasoline. If their vehicle were to get 80 miles per gallon, they would spend $234 per year on gas, a savings of about $700 per year. If they kept their vehicle for seven years, the savings over the life of the vehicle for them would be just under $5,000, so that's the maximum you could expect them to pay extra for the vehicle that gets the super mileage.[12]

The head of the fuel cell program at Daimler-Benz, Ferdinand Panik, is realistic about customer priorities. He knows that people aren't going to buy these cars just for the low emissions. He said, "Fuel cell cars will succeed when their efficiency, cost and performance matches conventional fossil fuel engines."[13] People are not going to buy cleaner cars if they are more expensive and offer poorer performance then conventional vehicles. In fact, Chrysler Corp. claims that fuel economy ranks 19th among buyers' criteria in picking cars – right after "quality of the air conditioning."[14] So the auto companies have the challenge of making fuel cell electric cars not only work, but work as well as what we are used to, and cost about the same as what we are used to, in order to gain consumer acceptance. The environmental benefits will satisfy government regulations (and benefit our atmosphere and our health), but will not be the selling points.

In fact, one article points to state and federal regulations as the primary driver behind alternative fuel research at this point.[15] The Big Three automakers agreed in February to make all U.S. vehicles meet emissions specifications as tough as those being mandated in California, drawing praise from the Environmental Protection Agency. The number of companies involved in electric, fuel cell, and hybrid programs continues to grow. But the movement is not consumer-driven. If there were oil shortages and the cost of gasoline doubled, the story might change.

Hydrogen

Hydrogen is difficult to store in a motor vehicle in sufficient quantities. There are concerns about leaks and the potential for explosions. Hydrogen tanks are bulky and heavy. The NECAR II was a minivan with hydrogen tanks mounted on the roof. They would not fit easily inside a sedan. And there is no infrastructure in place for the delivery of hydrogen as fuel.

A goal of the Partnership for a New Generation of Vehicles (PNGV) program has been to develop what they are calling 3X vehicles, light-duty vehicles that can get up to three times the fuel economy of today's vehicles. One way to do that is through alternative fuels. A study was conducted at Argonne National Laboratory to investigate the the economic impacts of four alternative fuels on the fueling infrastructure (methanol, ethanol, dimethyl ether, and hydrogen.) The study included capital needs for producing and distributing these fuels, and estimation of energy use and emissions of 3X vehicles using the different fuels. The cost was substantial in all cases, but the costs for hydrogen were found to be at least five times as much as for any of the others. However, hydrogen use achieved the largest energy and emissions benefits among the four alternative fuels.[16]

One potential solution for the lack of hydrogen fueling infrastructure that was mentioned in a previous section, is that it is now possible to use an onboard reformer to extract hydrogen from methanol, natural gas, ethanol or gasoline. This was announced last fall as a technological breakthrough that could speed the development of fuel cell powered cars. The reformer technology was also developed as part of the PNGV program. The U.S. Department of Energy initiated research efforts with Arthur D. Little, a technology-based consulting firm. Then Chrysler teamed with Arthur D. Little and the DOE to refine the process and develop operating hardware.

This technology stores gasoline in a fuel tank, and then an onboard processor reforms the gas into hydrogen in a multi-stage chemical reaction. The hydrogen is delivered to the fuel cell stack, which creates electricity to power the electric motor that drives the vehicle. A goal is to make the system small enough to fit into a conventional automobile. Vehicles powered this way would not be zero emissions vehicles; the reformer would emit carbon dioxide. But you would only need about half the fuel per mile as in an internal combustion engine, so it would still reduce pollutants. And, drivers could use the same fueling facilities that are now in place. It may even be possible to switch fuels at will, and refuel the same vehicle on different fuels in different locations. Chrysler has been focusing on gasoline. The Daimler-Benz NECAR III uses methanol; Toyota's hybrid fuel cell electric vehicle also uses methanol. According to one large methanol producer and supplier, it would cost only about $5,000 to add a methanol tank and dispensing facilities to a U.S. gas station. [17]

No one seems to think that the United States will be ready any time soon to switch to a "hydrogen economy." That is why it is important that the nation's current fueling infrastructure could still be used for fuel cell vehicles. But Iceland is moving ahead with plans to do just that, become a laboratory for hydrogen energy technology. And Ballard and Daimler-Benz are their partners. The goal is to convert Iceland to a hydrogen economy in fifteen to twenty years, starting with hydrogen buses. They will study the feasibility of converting the country's fishing fleet to hydrogen, and of gradually converting the car, bus and truck fleets to methanol and hydrogen. They will also study the prospect of exporting locally produced hydrogen to other countries.[18] The success of Iceland's experiment may have a bearing on how quickly the technology is taken up in the U.S. and other countries.

Chapter 6: What is the projected timeline?

When might we start seeing fuel-cell powered vehicles on the road? You already may if you ride the bus in downtown Chicago. The Chicago Transit Authority took delivery of three Ballard Commercial Prototype Fuel Cell buses in 1997. They are running on downtown routes in a two-year demonstration program. Three more Ballard buses will be delivered to British Columbia Transit for use in Vancouver this year. Buses, because of their size, have more room in which to fit the bulky fuel cells. The transit authority is also able to maintain its own hydrogen fueling station.

When will the challenges of bulk, cost, and fuel be met so that we see fuel cell cars and vans on the road? Estimates vary. Daimler-Benz wants to have commercially viable vehicles by 2004. Reports on the numbers that they hope to be selling range from 40,000 units by 2006 to 100,000 units by 2008. Other companies, including Ford and General Motors, have said that they also hope to have fuel cell vehicles ready to launch by mid-decade, but admit that they are currently a long way from a high-volume vehicle that is affordable. A Chrysler technology specialist doesn't see mass production of fuel cell cars before 2010. The director of the L.W. Schatz Energy Research Laboratory at Humboldt State University in Arcata, California, an avid supporter of fuel cells, doesn't see mass production being economically feasible until 2020 or 2025.[19] The Schatz Energy Research Center, incidentally, recently funded the design of a hybrid-electric half-ton pickup truck powered by a fuel cell manufactured in Italy. It operates on pure hydrogen, and can use its fuel cell to power tools at remote work sites.

Some believe that the new technology allowing on-board reforming of gasoline or methanol into hydrogen will speed the whole process up by as much as ten years. The automotive trade journals tend to see the transition to fuel cells as more of an evolution. We won't go from gas-guzzling sport/utility vehicles to fuel cells overnight, they say. The internal combustion engine will go through some changes first. The most commonly predicted changes are direct-injection diesel using purer forms of diesel fuel, and direct-injection using reformulated gasoline.[20] The PNGV research in quest of 3X vehicles includes study of reformulated gasoline and low-sulfur diesel. Cleaner diesel is at present considered a more cost-effective method for reducing emissions from transit buses than alternatives such as compressed natural gas or fuel cells. Most of the authors that I read believe that eventually the transition will be made, but the timing is not certain.

Chapter 7: What might the impact be for us?

If the future of the motor vehicle does lie with fuel cells, what will that mean for the Department of Transportation? If vehicles use little or no gasoline and produce little or no pollution, will miles driven increase ever more sharply, increasing congestion as well as wear and tear on the highways? More importantly, if vehicles are fueled with pure hydrogen, or with methanol or only small quantities of gasoline, what will happen to the whole fuel production and distribution infrastructure? What will replace the funds that the gas tax currently provides? In fiscal year 1996 the State of Minnesota collected $514,415,000 in tax revenues from highway fuels.[21] Will we be prepared with alternatives?

Chapter 8: Has there been research on the funding issue?

National Cooperative Highway Research Program (NCHRP) project 20-24(7), "Alternatives to Motor Fuel Taxes for Financing Surface Transportation Improvements" concludes that motor fuel taxes will remain an important source of revenue for the next three decades, but that agencies should seek a smooth transition to alternative sources by phasing in promising new revenue sources. It presents a framework for evaluating revenue sources, a method for developing scenarios of importance to the choice of revenue sources, and recommends an approach to financing surface transportation in the future.[22] Francis Francois, Executive Director of the American Association of State Highway and Transportation Officials (AASHTO), referred to the NCHRP study in a talk that he gave in 1996. One of his personal recommendations was that "over the next decade, alternatives to the motor fuel tax should be explored and implemented."[23]

Chapter 9: Are other states acting on this issue?

The Ohio Department of Transportation's Division of Finance was required by their last budget to conduct a study on the potential impact of alternative fuels. The study was to determine the kinds of fuel currently being consumed to operate motor vehicles that are not subject to taxation, and to estimate the quantities of each kind of fuel being used. Two types of fuels not subject to taxation are currently being used in Ohio: compressed natural gas and electricity. They use "gasoline equivalent gallons" to determine estimated tax losses from the use of alternative fuels. The tax loss from electric vehicles is at present very small. However, an Energy Information Administration table of estimated number of alternative-fueled vehicles in use in the United States is included in the report, and shows the number of electric vehicles increasing nationwide, from 2,860 in 1995 to 3,925 in 1997.[24]

The State of Pennsylvania passed a law last year which created a tax on alternative fuels, including electricity, hydrogen, natural gas, liquid propane gas and others. They also use "equivalent gallons," defined as the amount of any alternative fuel as determined by the department to contain 114,500 BTU's. In fiscal year 1998, Pennsylvania collected $564,369 in revenues from this tax. Although that is a small amount compared to current revenues from the gas tax, it puts Pennsylvania in a position to avoid future revenue losses caused by the increasing availability and use of alternative fuels.[25]

Chapter 10: Summary

Very large companies are putting huge quantities of money into developing prototype fuel cell vehicles, and into solving size, weight, cost and performance issues in order to make vehicles that the public will buy. A lot of progress has already been made in those areas. The fact that methanol or gasoline can be reformulated into hydrogen on board the vehicle makes it a more viable technology than if pure hydrogen had to be supplied and carried on board. A few fuel cell buses are already on the streets. Those are all indications that the technology is indeed feasible.

Estimates for when there will be significant numbers of fuel cell vehicles on the road vary. An optimistic prediction is 2010; a more conservative prediction is 2025. We could start seeing the first few by 2005. That is assuming that the conditions driving the technology remain about the same. If an oil crisis made it more of a national priority to reduce dependence on petroleum products, for example, the timeline could be speeded up.

As the availability and interest in clean, fuel cell (or other alternatively fueled) vehicles increases, so will the potential impact on transportation departments. Mn/DOT may wish to participate in some way in fuel cell research. We may choose at some point to lead the way in using fuel cell vehicles in our fleet. But most of all, we will need to be prepared for a loss of gas tax revenue, and have alternative funding plans in place. Other state Departments of Transportation, the NCHRP, and AASHTO have begun to pay serious attention to the need for alternatives to the gas tax. Their research, and the sources listed below, should be of use as Mn/DOT responds to the issue.

Chapter 11: Sources for continuing information on fuel cells

There is a large quantity of information available on fuel cells. Here are some sources for keeping up with current developments on the topic.

Internet World Wide Web sites

- **Yahoo:** http://pb.yahoo.com/science/energy/fuel_cells

The Yahoo subject directory has a fuel cell section containing links to sites with fuel cell information. As of this writing, the following links from Yahoo were active and contained useful information:

- Companies@: lists companies in the fuel cell industry with hot links to the companies' home pages. The list includes **Ballard Power Systems**, http://www.ballard.com. The Ballard "Products" section contains detailed information about fuel cells. Of particular interest is the "Transportation Applications" section, covering applications for both buses and automobiles.

- **1998 Fuel Cell Seminar**, http://www.fc98.com, to be held November 16-19, 1998 in Palm Springs, California. The site includes preliminary program and registration information. Sponsors of the seminar include the U.S. Dept. of Energy, Federal Transit Administration, and others.

- **Canadian Fuel Cell Home Page**, http://www.engr.uvic.ca/~dbryan/fuelcell.html, gives history and general information on fuel cells, and some additional links, but most of the links are inactive or outdated.

It includes a report completed in July, 1995, called "Estimated Economic Impact and Market Potential Associated With the Development and Production of Fuel Cells in British Columbia" that is interesting for the predictions that it made. It predicted that the evolution of fuel cell usage was likely to begin with transit and fleet vehicles, with North America being the primary market initially, and then evolve to automobiles. It also predicted a boon to the Canadian economy from having a large fuel cell industry there (Ballard), and predicted significant growth in demand for low emission and zero emission vehicles between 1998 and 2010. It will be interesting to see how accurate those predictions turn out to be.

- **2nd International Fuel Cell Workshop**, http://www.ab11.yamanashi.ac.jp/ifcw2/index.html, to be held September 19-20 in Yamanashi, Japan. Sponsored by the Fuel Cell Division of the Electrochemical Society of Japan and the Energy Division of the International Society of Electrochemistry.

- **Fuel Cells 2000**, http://www.fuelcells.org, (**EXCELLENT SOURCE OF INFORMATION**), a private, nonprofit educational organization providing information to policy makers, the media and the public and supporting the early utilization of fuel cells by such means as pilot projects and government purchases. The site contains lots of information and links to related sites. There is also a bibliography of books, papers, government studies, articles and online publications. They cover both transportation applications and power plant applications, and some of the publications are from several years ago, but recent material is there, too. The people at Fuel Cells 2000 were very helpful about answering questions and sending me material. They have a newsletter, *Fuel Cell Quarterly*, available for subscription at $20.00 per year.

- ***Hydrogen and Fuel Cell Letter***, http://www.mhv.net/~hfcletter, provides the table of contents for each monthly issue of this newsletter, and the full text of the lead article only. The newsletter reports on industry news and developments, and is available for subscription for $195.00 per year.

Literature Searches

Online databases in business & industry have hundreds of articles concerning fuel cells and other alternative fuels. The library can provide literature searches on specific aspects of the topic at any time. The library's Information Profiles service allows you to set up a specific search and have it run automatically each month so that you receive abstracts of new articles or reports on the topic coming in on a regular basis.

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22. Arlee T. Reno and Joseph R. Stowers, *Alternatives to Motor Fuel Taxes for Financing Surface Transportation Improvements,* NCHRP Report 377 (Washington, D.C., Transportation Research Board, National Research Council, National Academy Press, 1995).

23. Francis B. Francois, "Highway Finance – Entering the Second Century," in *1996 Semisesquicentennial Transportation Conference Proceedings* (Ames, Iowa: Center for Transportation Research and Education, Iowa State University, 1996), 218-221.

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25. Michael Sandusky, Bureau of Fiscal Management, Pennsylvania Department of Transportation, faxed this information to me, July 9, 1998.