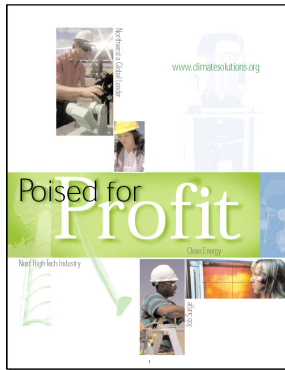

POISED FOR PROFIT II:
PROSPECTS FOR THE FUEL CELL SECTOR IN
THE PACIFIC NORTHWEST

January 2004

TABLE OF CONTENTS

Preface	3
Poised for Profit: Promoting a Northwest Clean Energy Industry.....	3
About the Partners	4
About Climate Solutions	4
About The Athena Institute and The Center for Smart Energy.....	4
Acknowledgements.....	5
Executive Summary	6
Market Potential	9
Powerful Market Drivers Are Influencing Growth	9
Significant Market Barriers Remain	11
Five Market Segments Are Emerging.....	15
Five Customer Segments Are Key to the Market.....	26
Regional Potential	28
Fuel Cells Will Drive Significant Opportunities... Eventually	28
The Northwest Has Major Fuel Cell Assets.....	30
The Northwest Is a Logical Venue for Many Fuel Cell Activities.....	37
The Northwest Faces Challenges	37
Near-Term Opportunities	41
The Northwest Has Significant Potential in Four Important Niches	41
The Northwest Has at Least Three Moderate Opportunities	44
Initiatives To Improve Fuel Cell Prospects in the Northwest	45
Cross-Border Collaboration	45
A Permanent Fuel Cell Advocacy Organization.....	45
Coordination of Research Efforts	45
A Defined Path to Commercialization.....	46
Education and Outreach	47
Appendix A: Technology Overview	49
Fuel Cell Definition.....	49
Fuel Cell Approaches.....	50
Fuel Cell Benefits	52
Fuel Cell Value Chain	54
Appendix B: Project Overview	56
The Methodology	56
About Climate Solutions	58
About The Athena Institute and The Center for Smart Energy.....	58
About the Analysts.....	58

POISED FOR PROFIT: PROMOTING A NORTHWEST CLEAN ENERGY INDUSTRY



In 2001, eight economic development and energy agencies from Oregon, Washington, and British Columbia commissioned a study: *Poised for Profit: How Clean Energy Can Power the Next High-Tech Job Surge in the Northwest*. The resulting report revealed that the clean energy sector could be twice the size of the aircraft industry within 20 years. What's more, it could generate as many as 30,000 new jobs. That first report is available at www.climatesolutions.org. A new partnership has come together to fund *Poised for Profit II*, follow-on research to support a world-class clean energy industry in the Northwest. Through the work of The Athena Institute, the project has produced a series of reports containing critical information for investors, entrepreneurs, and policymakers. These tools include:

- Research and analysis to pinpoint the largest and best opportunities
- Surveys of investor and utility plans
- Directories to research reports, related companies and helpful resources

This document is part of a research module called the Preliminary Analysis of Near-Term Opportunities. It reports on the market opportunities for fuel cells. Other documents in the module cover near-term prospects in wind, solar and Smart Energy.

The Athena Institute was asked to identify near-term market opportunities for selected energy technologies. At the direction of the Steering Committee, we focused on opportunities that could see commercial success within five years, with emphasis on “cluster opportunities” that could have positive economic impact for Oregon, Washington, and British Columbia. Throughout this report, when we refer to *Pacific Northwest* or *the Northwest*, we are referring to those three territories.

The Milken Institute defines clusters as “agglomerations of interrelated industries that foster wealth creation in a region.” (For example, Washington’s King County is known for its aerospace and software clusters.) This report relates to the prospects for regional cluster success. It does not address the prospects for individual companies or the economic benefits related to constructing and operating clean energy facilities. Please turn to “Appendix B: Project Overview” on page 56 for more details on the scope and methodology.

ABOUT THE PARTNERS

Poised for Profit II was jointly funded and guided by the following organizations and members of the Poised for Profit Steering Committee:

- **BC Hydro:** Karen Leach and Bruce Sampson
- **Bonneville Power Administration:** Mike Hoffman, Kevin O’Sullivan and Mike Weedall
- **City of Portland:** Jeff Cogen and Curt Nichols
- **NW Energy Technology Collaborative:** Lee Cheatham and Jeff Morris
- **Oregon Institute of Technology:** Howard Thurston
- **Oregon Office of Energy:** Mark Kendall
- **Leading Edge British Columbia:** Anton Kuipers
- **Pacific Northwest National Laboratory:** Mike Lawrence
- **Portland Business Alliance:** Molly Moore
- **Portland Development Commission:** Ann Griffin
- **Portland General Electric:** Joe Barra
- **Seattle Office of Economic Development:** Ben Wolters
- **Washington Office of Trade and Economic Development:** Tony Usibelli and Tim Stearns

ABOUT CLIMATE SOLUTIONS

The *Poised for Profit* initiative is managed by Climate Solutions, a public interest group that works to make the Pacific Northwest a global warming solutions leader. Since 1998, the group has targeted development of a Northwest clean energy technology industry cluster as a globally significant contribution the Pacific Northwest can make to reduce greenhouse emissions. Climate Solutions generates leading-edge information and knowledge on clean energy technology and the economic opportunities it presents. The organization issues reports, organizes conferences and builds cross-cutting alliances to further the goal of rapid energy transition.

ABOUT THE ATHENA INSTITUTE AND THE CENTER FOR SMART ENERGY

The Athena Institute is a research organization that helps executives and organizations find success in emerging markets. Its methodologies and insights have been implemented by many organizations, ranging from Fortune 1000 corporations to public policy agencies. Athena manages the **Center for Smart Energy** (www.centerforsmartenergy.com), the industry's guide to the value chain. The Center is dedicated to making North America the leader in energy innovation.

The Center's research and acceleration programs help businesses and investors pursue their strongest opportunities.

ACKNOWLEDGEMENTS

The Athena Institute would like to recognize the following companies and individuals for their contributions to the *Poised for Profit* initiative in general and this report in particular.

For catalyzing the project and providing oversight, we acknowledge Climate Solutions, with special recognition to Rhys Roth.

For expert comments and research materials, we wish to thank:

- Clay Braziller, Canadian Institute for Market Intelligence
- Ron Britton, Fuel Cells Canada
- Denis Connor, Angstrom Power
- KC Golden and Patrick Mazza, Climate Solutions
- Steve Hauser, Utility Automation, Inc.
- Subhash Singhal, Pacific Northwest National Laboratory
- Wal Van Lierop, Chrysalix Energy

We are especially appreciative of the co-funders and members of the Steering Committee, who provided ongoing advice and assistance.

EXECUTIVE SUMMARY

A fuel cell is an electro-chemical device that combines hydrogen and oxygen to create electricity -- without combustion and without harmful emissions. Could this exciting technology create significant near-term economic growth for the Pacific Northwest (Oregon, Washington, and British Columbia)? Could it form the basis of a new economic cluster similar to software, aerospace, or biotech? This report set out to answer those questions.

Viewed in the long term, powerful forces are at work in favor of fuel cells. The world has a steadily growing need for high-quality electricity. At the same time, it needs to reduce greenhouse gases and dependence on dwindling coal, oil, and natural gas reserves. Fuel cells hold the promise of producing premium-quality electricity with less damage to the environment and more efficient use of fossil fuels.

Despite the forces in favor of fuel cells, significant barriers remain. Today's fuel cells are 10-100 times more expensive than the technologies they replace. We believe fuel cells will follow the typical high-tech growth curve. They will catch on first in niche markets where buyers can cost-justify a premium price. They will gradually penetrate other markets, eventually dropping in cost and achieving mass-market success. Below are the five main categories, in the approximate order they will become commercially viable.

- **Backup and portable power** -- for standby electricity or off-grid use, which could reach \$2B in sales by 2013
- **Micro fuel cells** -- for laptops and other digital devices, which could reach \$3B in sales by 2013
- **Stationary power** -- for commercial, industrial, residential, and remote buildings, which could hit \$6B in a decade
- **Transportation** -- auxiliary power for on-board electronics and primary power for cars, trucks, military vehicles, boats, and ships, which together could generate \$8B in sales by 2013
- **Hydrogen infrastructure** -- produce, transport, store and dispense hydrogen

The overall fuel cell market was approximately \$500M worldwide in 2002. Athena predicts it could grow to \$19B by 2013.

Five customer segments are the keys to the future of fuel cells. In the order of their likely adoption of fuel cells, they are: Military, Government, Commercial, Industry, and Consumer. Based on these markets and customer segments discussed above,

Athena uncovered four niche markets with especially high potential for the Northwest. They are:

- **Backup and portable power**, where Spokane's Avista Labs and Vancouver's Ballard Power Systems are already making inroads
- **Balance of plant**, where Vancouver's Xantrex is a world leader in the power electronics portion
- **Auxiliary power**, where we house two of the world's largest heavy truck manufacturers, who are likely to be early customers
- **Micro fuel cells**, where we have several promising startup companies

The Northwest has several important assets that strengthen its chance for success as a leader of this emerging industry. The chief is the emerging Vancouver fuel cell cluster, arguably the world's highest concentration of fuel cell talent, research, and companies. The Vancouver area has a strong anchor tenant (Ballard Power Systems), numerous research institutions, and the entire ecosystem of related suppliers and service providers.

Oregon and Washington also have some notable research assets, including Pacific Northwest National Laboratory, the Oregon Institute of Technology, and the University of Washington. Beyond that, however, those two states have few of the other ingredients for cluster success. With barely two dozen fuel cell companies scattered widely about the region, they certainly do not have critical mass. And they are far behind regions such as California, Connecticut, Michigan, and Japan, which have already begun multi-million dollar initiatives to attract fuel cell jobs.

In summary, then, the cluster prospects for British Columbia are very good. The region has all the necessary ingredients with the exception of strong local demand. Although we believe current projections are overly optimistic -- 30,000 fuel cell jobs in British Columbia by the year 2020 -- we have no doubt that the fuel cell industry will experience major growth and that British Columbia will be a primary beneficiary.

The case for Oregon and Washington is more problematic. Those two states lack most of the ingredients for near-term cluster success. They have no anchor tenant, no critical mass, no concentration, and little interest or awareness of fuel cells as a possible source of growth. Although we expect individual companies to be successful, we find little to support the idea that a fuel cell cluster could emerge in Washington or Oregon.

If Oregon and Washington want to become significant players in fuel cells, they must join forces with British Columbia. They must come to see that province as a source of intellectual property and commercial products. British Columbia, for its

part, must come to see Oregon and Washington as providers of essential services, as conduits to important research and demonstration projects, and as gateways to the larger markets of the United States.

Cross-border collaboration would have the greatest prospects for success if it incorporated:

- A permanent fuel cell advocacy organization
- Coordination of research efforts to avoid duplication and to bring large projects to the region
- Creation of a well-defined path to commercialization
- Education and outreach to let investors, entrepreneurs, and other nations know of the region's advantages

If this partnership fails to materialize in the next few years, we think it likely that British Columbia will leapfrog Oregon and Washington on its way to the lucrative markets of California and the eastern seaboard. We also believe British Columbia will turn increasingly to China and Japan for partnerships and the two U.S. states will lose out on a role in those trade, manufacturing, and shipping relationships.

If the collaboration takes place, then the three areas have the opportunity to build a combined reputation for sustainable development in general and fuel cells in particular.

MARKET POTENTIAL

Key fuel cell products have moved from prototype to commercial shipment, with more coming online over the next few years. Government support is growing. Public attention is increasing. As the economy continues to recover in 2004 and 2005, several niche fuel cell markets are poised for growth. Other segments will follow at the end of the decade or shortly thereafter.

Despite the powerful political and market forces in favor of fuel cells, the sector faces obstacles as well. These obstacles will prevent fuel cells from entering the mainstream until the next decade. In the meantime, the opportunities will be in selected niches.

This section explains the key market drivers, reveals the five major fuel cell markets, and comments on the worldwide market potential.

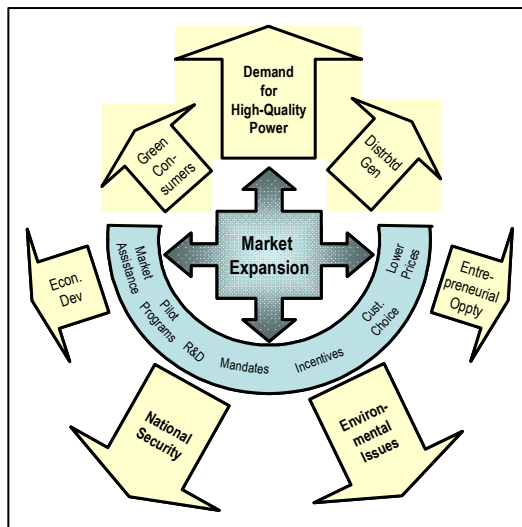
POWERFUL MARKET DRIVERS ARE INFLUENCING GROWTH

Fuel cells are the “microchip of the hydrogen age” -- the core technology that makes everything else possible. There is wide consensus, in this country and abroad, that fuel cells are central to a safer, more reliable, more prosperous energy future. For a detailed explanation of fuel cell technology, turn to “Appendix A: Technology Overview” on page 49.

Powerful forces are converging to stimulate the fuel cell market, including at least three direct and four indirect drivers. (See Figure 9.) A “direct” driver stimulates customer demand. An “indirect” driver stimulates government incentives or market forces, which then motivate customers.

*Figure 1
Fuel Cell Market Drivers
The three drivers at top act
directly on the market to
stimulate demand for fuel cells.

The four drivers at bottom act
indirectly, by stimulating
government programs, customer
choice and lower prices.*



Direct Drivers of Demand

These three forces act directly to influence customer decisions. They are:

1. A rising demand for power, especially high-quality power. The demand for electricity will nearly double in the next 20 years. And not just any power will do. High-quality, high-reliability power is becoming an economic necessity in our connected, digital economy. (See Table 1.) It operates from the top to the bottom of the market, from the UPS needs of individual computer users to the power needs of small cell phone towers to the massive requirements of a major brokerage.

Table 1 -- The Cost of Power Outages

INDUSTRY	HOURLY COST
Cellular Communications	\$41,000
Telephone Ticket Sales	\$72,000
Airline Reservations	\$90,000
Semiconductor Manufacturing	\$2,000,000
Credit Card Operations	\$2,580,000
Brokerage Operations	\$6,480,000

Source: American Power Conversion

2. Growing interest in distributed generation. More and more utilities are considering distributed generation (DG) -- placing small power plants near the customer. DG minimizes construction time and construction costs, since plants can be up and running in months, not years. It also reduces the need for new transmission lines. Beyond utilities, large industrials and even a small fraction of residential consumers are also adopting distributed generation. Fuel cells are one of several technologies suitable for distributed generation.

3. Modest consumer interest in lessening environmental and noise pollution. As discussed below, environmental issues are more powerful as indirect drivers of demand, where they stimulate government intervention. However, a small group of consumers now seeks out green products. Even amongst this group, the desire for quiet power may be a more powerful fuel cell purchase motivator than a desire for green power.

Indirect Drivers of Demand

These four forces, listed here in approximate order of importance, work through various agencies to influence the market.

1. National security concerns. The U.S. government has identified fuel cells as a way to reduce dependence on foreign oil. It also sees distributed generation -- where fuel cells are one of several approaches -- as a way to reduce the vulnerability of the grid to terrorist attack. Widely dispersed generation would make it much harder to bring down military bases and essential business operations by attacking a single central facility. Meanwhile, the military has deemed fuel cells vital to defense interests to supply quiet, high-quality power for the battlefield of the future. Together, these national security concerns are leading to billions of dollars in research, development, pilot programs and market incentives.

2. Environmental regulations and incentives. Fuel cells have not benefited from environmental concerns to the same extent as wind and solar. Nonetheless, the promise of emissions-free electricity is a chief selling point for fuel cells -- even though fuel cells are not truly “green” if the hydrogen has been refined from a fossil fuel, as is typically the case. Even with that drawback, fuel cells are cleaner and more efficient than coal, gas, and internal combustion engines.

3. Entrepreneurial opportunity. The same forces that earlier created opportunity in computers, telecomm and airlines are now at work in the energy sector. They include digital technology, interactive networks, and a gradual shift from vertically integrated companies to open markets. As more entrepreneurs enter the field, they create consumer choice and price competition, stimulating the market.

4. Economic development efforts. At least a dozen regions have chosen fuel cells as an engine for economic growth, including important centers in the U.S., Canada, Germany, Japan, and the UK. These regions are investing tens of millions in research facilities, incubators, investment programs, and other mechanisms to accelerate commercial success.

SIGNIFICANT MARKET BARRIERS REMAIN

To reach its full potential, the fuel cell market must overcome significant barriers in technology, cost, fuel, infrastructure, and finance.

Transportation is the most stringent fuel cell market, posing the greatest technical challenges. The Department of Energy currently lists these four problems as major barriers:

- Reducing the initial cost by two orders of magnitude. Fuel cells will be viable for mainstream transportation when they cost \$50 per kW. (Today’s units are \$5000 per kW or higher.)

- Extending the useful life of fuel cells. Automobile manufacturers need fuel cells that last 5,000 hours or longer. (Today's units typically last 1,000 before needing overhaul or replacement.)
- Storing enough hydrogen on board to travel 300 miles. (Current demo projects typically have half that range.)
- Reducing the cost of hydrogen to the equivalent of today's U.S. gas prices, or \$1.50 to \$2.00 per gallon. (In the necessary purity, hydrogen can be two or three times that price today.)

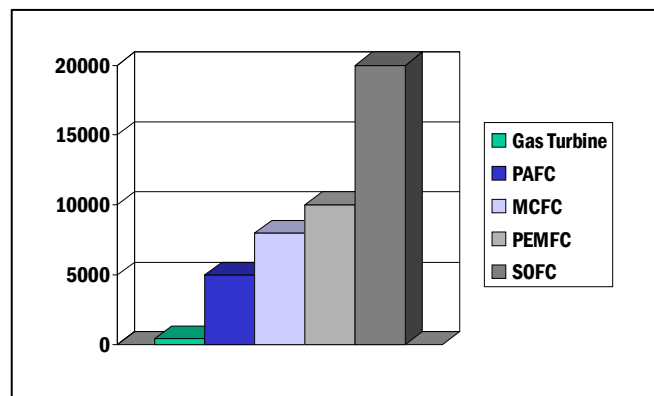
Technology Barriers

Fuel cells still face significant development barriers before they can achieve high production volumes and low costs. Some end use categories still require fundamental breakthroughs to achieve practicality and commercial possibility. Other categories have the fundamentals in place but have not yet moved to mass production. *Scaling up to mass production often proves very difficult.* It is relatively easy to produce a cost-is-no-object prototype. It is much harder to devise materials and manufacturing strategies to bring down costs to mass-market levels.

Cost Barriers

Fuel cells compete with highly developed, highly reliable, widely available internal combustion engines and microturbines. Internal combustion engines cost \$25-\$50 per kW for transportation uses. Natural gas turbines can be built for \$450 per kW. By contrast, phosphoric acid fuel cells have plateaued at \$5000 per kW. Other fuel cell technologies are slowly improving, but molten carbonate fuel cells are still at \$8,000, proton exchange membrane at \$10,000 and solid oxide at \$20,000 per kW. (See Figure 2.)

*Figure 2
Initial Cost.
Natural gas turbines (far left) are far less expensive than the four different kinds of fuel cells shown here. Capital costs must drop dramatically before fuel cells become competitive. Source: Reed Global Advisors, September 2002*

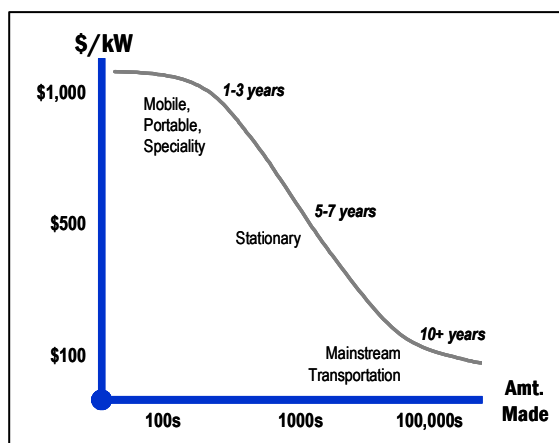


Some companies claim they will soon be able to build stationary fuel cells for power generation at \$4000-\$10,000 per kW. Yet even those figures are too high. The National Fuel Cell Research Center (NFCRC) believes fuel cells could become competitive for stationary power "if they reach an installed cost of \$1,500 per kW

or less.” But the NFCRC cautions that “in the automobile sector, a competitive cost is on the order of \$60-100 per kW, a much more stringent criterion.”

These cost figures help to explain why Athena predicts early growth will come in segments where customers already pay a premium, such as portable, backup, and micro fuel cells. For instance, today’s small batteries and photovoltaic strips cost about \$4,000-10,000 per kW. (See Figure 3.)

Figure 3
Cost vs. Volume.
Mobile and other specialty applications can justify a high cost per kW. Other applications are more price sensitive. They will not switch to fuel cells until manufacturing volumes climb, thereby lowering costs.
 Source: Center for Automotive Research at ERIM, Inc., 2001



Fuel Barriers

Most fuel cells run on hydrogen, which can be obtained through a variety of methods. *Electrolysis* splits water into hydrogen and oxygen. *Reforming* converts fuels such as natural gas, propane, methanol, and gasoline. *Onboard reforming* converts fuels internally. *External reforming* refers to hydrogen produced elsewhere, then piped to the fuel cell or stored in a pressure tank.

During fuel cells’ “honeymoon phase” in the late 90s, analysts largely ignored the issue of fuel. Some assumed it would be reformed from fossil fuels. Others thought that methanol would be the fuel of choice. Still others assumed that hydrogen would soon be available from renewable methods. All of them apparently believed that, whatever the fuel, it would magically become available all across the country.

Those assumptions were wrong. Today fuel looms as the biggest unsolved issue on the way to the hydrogen economy. The first problem is obtaining hydrogen. There are large obstacles in obtaining hydrogen from fossil fuels, including cost, transport, and emissions. The obstacles to producing it from water through electrolysis are even larger.

Next comes the problem of transporting, storing, and dispensing the hydrogen. There are few hydrogen pipelines in the U.S. Building a suitable pipeline infrastructure would cost many billions. Former BPA executive Jack Robertson estimates that 25% of the nation’s 180,000 service stations would need to be

converted to hydrogen to have a workable infrastructure for hydrogen-powered automobiles. At his estimate of \$1M per station, that is a total price tag of \$30B.

For these reasons and more, the U.S. Department of Energy believes the North American public won't be able to obtain pure hydrogen through a mass infrastructure until 2030.

Some experts argue that the so-called "hydrogen economy" is a pipe dream. "The hydrogen economy is about creating the infrastructure to produce, store and deliver pure hydrogen," explains Patrick Mazza, Research Director of Climate Solutions. "The multiple inefficiencies involved in pure hydrogen can easily cancel out any efficiency advantage fuel cells have."

"The growth of fuel cells is not contingent on the development of a vast new infrastructure to produce pure hydrogen," he continues. "They can win on their own merits – on their capabilities for supplying on-site premium power and their potential for combined heat and power -- using currently available fuelling options."

Institutional and "Psychological" Barriers

Like most emerging markets, the fuel cell industry faces numerous issues around codes, standards, interconnection, certification, and industry cooperation. It also faces resistance from incumbents, including certain utilities, oil companies, and automotive manufacturers.

Indeed, there are growing signs of a "hydrogen backlash" in the expert community. A 2003 study from the California Institute of Technology claimed that hydrogen was likely to leak from storage and could deplete as much as 10% of the ozone layer. Other scientists claim the amount of energy to make hydrogen from electrolysis is more than the power produced from it inside fuel cells. Still others warn that reforming hydrogen from fossil fuels releases pollutants.

"Now it's time to awaken from our hydrogen hallucination and devote attention to the real solutions of improved efficiencies and sustainable sources," says Mark Sardella, co-founder, Southwest Energy Institute. "Although hydrogen makes for fun science projects, it does not provide a solution to the energy problems we face today and in all likelihood it won't in the future." While there are many scientific voices in favor of hydrogen, the growing number of opposing views poses a barrier to rapid, wide-scale adoption of hydrogen.

Financial Barriers

Sufficient investment could overcome many of the barriers discussed above. Unhappily, that money is in short supply. Notwithstanding the U.S. government's

enthusiasm for fuel cells and the hydrogen economy, publicly owned fuel cell companies have suffered a massive loss of equity. PriceWaterhouseCoopers' *2003 Fuel Cell Industry Survey* reported a "dramatic fall in market capitalization and a paucity of financings."

The financing challenge is particularly acute in British Columbia according to some experts. On one hand, the area has more fuel cell-savvy venture capitalists than any region in the world. On the other, according to Ron Britton, President and CEO of Fuel Cells Canada, "Canadian companies have a particular challenge with mezzanine financing due to structural issues. There isn't as much available in Canada. And if they access U.S. money, they can lose the right to use important tax incentives such as the Scientific Research and Experimental Development Program, which requires a certain percentage of Canadian control."

Competitive Barriers

President Bush has called fuel cells "the wave of the future," proposing funding of \$1.7B over five years via a variety of programs. And Canada -- particularly British Columbia -- has been a leader for years. Even so, the competition is increasing. Other countries are aggressively pursuing fuel cells as an engine of growth. For instance, Japan far outstrips the U.S. in combined private and public funding for fuel cell research. The European Commission provides as much as \$70M per year on top of funding from individual countries. Korea, Australia, and Singapore are significantly increasing their fuel cell investments.

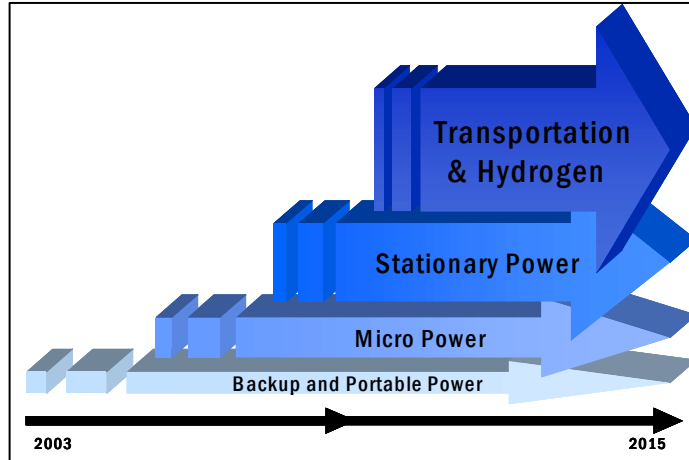
FIVE MARKET SEGMENTS ARE EMERGING

Athena categorizes fuel cells into four application areas, plus a fifth related area, the hydrogen infrastructure. We list them below in the approximate order we expect them to become commercially viable. (See Figure 4.)

- **Backup and portable power** -- for standby electricity or off-grid use
- **Micro fuel cells** -- for laptops and other digital devices
- **Stationary power** -- for commercial, industrial, residential, and remote buildings
- **Transportation** -- auxiliary power for on-board electronics and primary power for cars, trucks, military vehicles, boats, and ships
- **Hydrogen infrastructure** -- produce, transport, store and dispense hydrogen

*Figure 4
Fuel Cell Roadmap.
Backup and mobile uses will lead
the fuel cell sector.
Transportation will catch on more
slowly, but will eventually be
much larger. The hydrogen
infrastructure will develop in
parallel with transportation.*

*Source: Athena
consensus estimate*



Success will come first to areas where a) the cost per kilowatt is already high -- as with remote power, backup power and battery power today-- and b) the cost per kilowatt (kW) is not the major purchase factor -- as with military applications, financial clearinghouses, hospitals and voltage-sensitive manufacturing.

Some fuel cell projections are more optimistic. On the other hand, recent reports to Congress and from the Department of Energy are even more pessimistic. When it comes to transportation, the DOE's hydrogen program currently pegs 2010 as the beginning of the market transition phase, 2015 as the beginning of the expansion phase and 2025 as the beginning of full realization.

We believe the roadmap shown in Figure 4 strikes the right balance. It recognizes the difficulty and length of time necessary to build a full-scale hydrogen economy. But it also recognizes the many niche opportunities that will fuel industry growth along the way (including niche transportation applications discussed later).

Backup and Portable Power Could Reach \$2B in a Decade

Fuel cell products in this segment typically replace battery banks or small generators.

1. Backup applications provide standby electricity when the primary power source fails. (Because fuel cells typically take five or more minutes to come up to full power, they must be combined with small batteries for uninterruptible applications.) "Emergency back up/UPS products that target commercial, residential, or utility customers have a legitimate chance to commercialize within the next couple years," confirmed Reed Global Advisors in September 2002.

2. Portable power applications provide temporary standalone power to a location not connected to the electric grid (see Figure 5). Examples include construction sites, camping, recreation and developing countries without a reliable grid. In the

future this list may expand to include on-board power for electric wheelchairs, camping lanterns, variable message signs, medical devices, lawnmowers, remote navigational aids and more.

*Figure 5
Introduced in December 2002,
the Air Gen fuel cell generator
was one of the earliest examples
of a portable power source
based on fuel cells.*

Courtesy Ballard Power Systems



The backup and portable power market is relatively price-insensitive. Current battery solutions supply power for short durations only and cost \$4,000-\$10,000 per kW, putting fuel cells in striking distance. Gasoline and diesel generators are much cheaper than fuel cells, but they emit high levels of noise and pollution.

The needs of this segment -- high-quality, high-reliability, low-maintenance power -- mesh nicely with the strengths of fuel cells. In addition, many portable and backup applications require low emissions and low noise, again playing to the strengths of fuel cells. With commercial products shipping already, the growth of this segment will pick up rapidly as soon as prices begin to come down.

According to Allied Business Intelligence, global portable fuel cell shipments will reach 200M units by 2008. *Fuel Cell Today* claims “portable power promises to be the first truly commercial market for fuel cell technology. This sector is growing faster than any other.” We believe shipments will ramp up quickly in 2005. We estimate this market could hit \$2B by 2013.

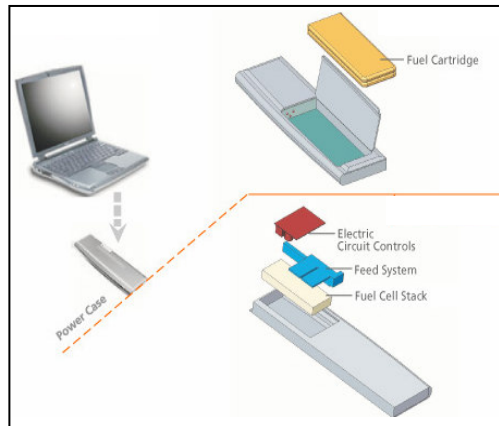
Micro Fuel Cells Could Hit \$3B by 2013

Products in this niche provide up to 50 watts of power for laptop computers, cell phones, video cameras and other electronic devices. In theory, micro fuel cells can operate for days and be “recharged” instantly just by slipping in a new fuel cartridge. (See Figure 6.)

Micro fuel cells are likely to become the second category to reach commercialization. Part of the reason for optimism is the low quality of competing battery technologies, which exhibit poor performance, low power density (power to weight ratio), long recharge times and a high price per kW.

Figure 6
Micro Fuel Cells
Micro fuel cells could soon replace batteries in laptops, cell phones and other electronic devices, providing longer duration and quick “recharging” via a sealed fuel cartridge.

Courtesy Neah Power



Although several companies are now shipping micro fuel cell prototypes, much remains to be done. The industry still has no standards for size, interconnection, power output, or fuel cartridges. Even the market leaders have yet to prove they can manufacture in quantity at low cost or develop significant distribution partnerships.

“An aspect that most micro fuel cell developers still seem to be unaware of is the complexity of possible government regulations,” warns Atakan Ozbek, Director of Energy Research for Allied Business Intelligence. “It may take anywhere from six months to two years to get codes and standards from the Department of Transportation and Federal Aviation Administration to allow commercial products on board aircraft.”

If progress occurs quickly, the micro fuel cells category could outpace portable and backup power. More realistically, it will trail by a year or two. Athena believes many analysts are underestimating several key challenges:

- agreeing on standard sizes, power output, fuel and fuel cartridges
- gaining national distribution
- gaining approvals (to bring fuel cartridges onto planes, to get safety certifications, etc.)
- educating consumers

The last point -- consumer education -- is largely ignored by analysts, yet it could present a formidable obstacle. Today’s battery costs are built into the overall cost of the device (the laptop, cell phone, portable game player). Recharging the battery seems to be free. In reality, of course, consumers pay a small amount for the electricity coming through the wall socket, but the perception is that recharging is free, especially since it’s often done at a hotel or office at someone else’s expense.

Washington Startup Takes Aim at Micro Fuel Cells



A Washington State startup claims it has developed a way to make fuel cells from silicon, paving the way for increased performance and decreased manufacturing costs. Bothell-based Neah Power Systems says it has a "breakthrough approach for producing direct methanol fuel cells for portable electronic products. The company's silicon-based design leverages years of experience in semiconductor manufacturing.

Neah intends to develop micro fuel cells that operate at up to 200 watts. It is aiming for operating times two or three times greater than similarly sized lithium-ion batteries. The refueling procedure to continue operation can take seconds as compared to the hours required to recharge a conventional battery.

So far the 30-person company has raised nearly \$10M from venture investors. The company doesn't expect to release a mainstream product until 2007. It faces competition from micro fuel approaches under development in British Columbia, Germany, Japan and elsewhere in the U.S.

We question whether consumers will be willing to pay \$10, \$20 or even more for a "recharge" via a fuel cartridge, when current recharges are "free" -- even if the fuel cell "recharge" does last a little longer.

Once this segment gets past these obstacles, it could become a large one. The global market for batteries was \$11.4B in 2002 according to research from Business Communications. Reed Global Advisors predicted in 2002 that micro fuel cells could be a \$1B market by 2005 or 2006. Athena projects \$3B by 2013.

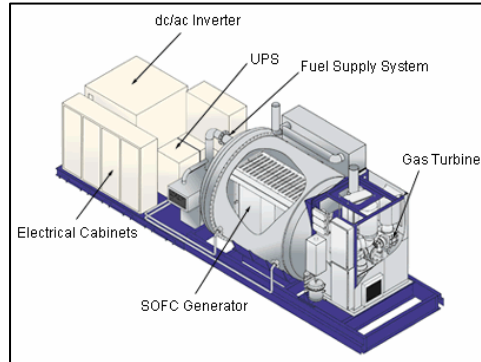
Stationary Power May Reach \$6B in 10 Years

Products in this category produce power for industrial, commercial, and residential buildings. Four areas will lead the stationary power segment: 1) premium power, 2) combined heat and power, 3) remote power and 4) distributed generation. Although there is significant overlap between categories -- a remote user may also need premium power, for instance -- these four distinctions describe the primary purchase motivator.

Premium power delivers high- quality, high-reliability power for locations that cannot tolerate power fluctuations or interruptions. Examples include server farms, Internet hosting, telecommunication nodes, financial data centers, and power-sensitive manufacturing. Many of these businesses cannot tolerate even minor fluctuations, much less outages. These companies already buy diesel and microturbine generators to protect themselves from disturbances. They will value fuel cells for their pure, unvarying output.

Combined heat and power (CHP) applications provide both electricity and heat by using the exhaust heat from a high-temperature fuel cell to heat water, run a turbine or provide heat to a heat exchanger for absorption chillers. Applications include boilers for large buildings, space heating loops, domestic hot water, swimming pools and absorption cooling. (See Figure 7.)

*Figure 7
Combined Heat and Power Fuel Cell
High-temperature fuel cells can use waste heat to heat water or power a turbine, raising total efficiency as high as 85%.
Source: Siemens Westinghouse*



Remote power includes buildings not attached to the grid, such as remote communications facilities where it is too expensive to run power lines. There is some overlap between this segment and portable and backup power. Remote power is typically a permanent installation requiring higher levels of power. Wind and solar are intermittent, requiring large battery banks. Assuming sufficient storage for hydrogen, a fuel cell is quieter, cleaner, and more reliable than a diesel generator. Although there are remote power applications in North America, the bulk of the growth will occur in developing countries with an inadequate national grid.

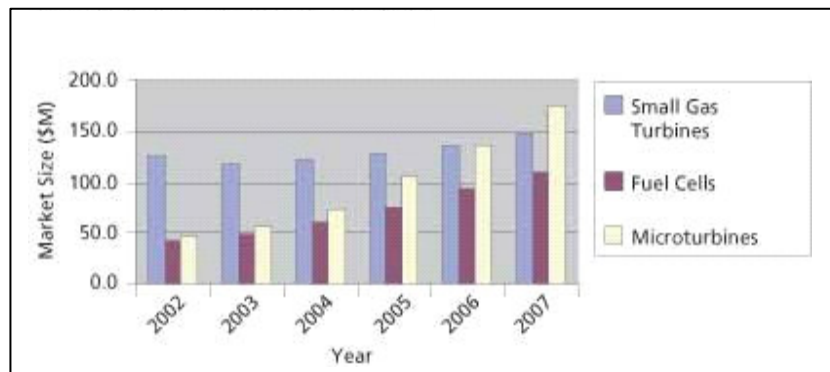
Distributed generation provides small-scale power (typically less than 25 MW) located close to the customer. Distributed generation (DG) provides all or most of the power for a factory, building, office park, or military base. Today, gas turbines or diesel generators are typically used for DG, but fuel cells may be a future choice.

Sidebar 1 -- Long Island Power Authority Buys 45 More Fuel Cells for Distributed Generation	
<p><i>February 27, 2003.</i> The Long Island Power Authority (LIPA) announced it will buy an additional 45 fuel cell systems in 2003. The units will be installed across Long Island including, for the first time, in homes.</p> <p>Twenty-five units will be installed in LIPA's demonstration site where they will feed power directly to the grid. The remainder will generate on-site heat and power for single or multi-family residential units.</p>	<p>Funding for the project is provided under LIPA's Clean Energy Initiative, a five-year, \$170M program originally proposed by Governor Pataki of New York. LIPA has previously placed fuel cells at various commercial locations.</p> <p>All of the 5 kW systems are from Plug Power. In 2002, Plug Power delivered 121 fuel cell systems generating approximately 1.6M kW hours, much of it on Long Island.</p>

Placing the fuel cells near the customer saves on transmission costs. These savings help make up for the higher costs to build and the higher costs per kW versus coal, natural gas and diesel alternatives. In the long-term, fuel cells must be delivered at an initial cost of \$400-600 per kW -- less than one-tenth current costs -- to be viable for distributed generation. Despite that challenge, many experts believe fuel cells will ultimately play a significant role in distributed generation, though it may be the end of the decade before the numbers become significant. (See Figure 8.)

Figure 8
Fuel Cells for Distributed Generation
As distributed generation gradually becomes a reality in North America, fuel cells and microturbines will increase their market share versus traditional gas turbines.

Source: Venture Development Corporation



Strong demand for fuel cell stationary power is at least three to five years away:

- *Fuel Cell Today* predicted in late 2002 the market for stationary units greater than 10 kW would grow by 12% per year (from a very small base).
- Wintergreen Research says the stationary fuel cell market was \$45.2M in 2001 and will reach \$11.4B by 2007.
- Allied Business Intelligence believes the stationary market was \$40M in 1999 and will reach \$10B by 2010.
- Principia Partners pegs stationary fuel cell power generation at \$3B by 2005.
- Business Communications Company tags the 2002 market for large-scale fuel cells at \$251M. It expects an average annual growth rate of 20.7% for a market of \$642M by 2007.

Athena believes significant obstacles remain with costs, with grid interconnection issues, with the distribution channel and with the financial disarray of the utility sector. We believe utility involvement is essential for the growth of distributed and district generation. Utilities are unlikely to conduct any market experiments until they solve their current financial crisis. Our consensus estimate is therefore on the lower side. We expect sales of \$6B by 2013.

Transportation Could Generate \$8B in 10 Years

Transportation is a vast and misunderstood segment. Most analysts pay attention only to the mainstream passenger market. In fact, Athena believes passenger vehicles will be the last transportation segment to experience growth, with mainstream success at least 10 years away.

“Although the future fuel cell vehicle (FCV) market appears promising, initial market estimates are over-optimistic,” warned Reed Global Research in a November 2003 report entitled *Application and Market: Fuel Cell Vehicles*.” The report cites predictions ranging from 1.5-8M vehicles by 2011 and 10-30M by 2020. In reality, “it is hard to conceive of an annual FCV market exceeding 100,000 units in the U.S. before 2011,” the report concludes.

The overemphasis on passenger cars has led most observers to ignore the prospects in other transportation sectors. We predict the transportation segment will find commercial success in approximately the following order:

- Military vehicles
- Bus, government, delivery, and taxi fleets
- Industrial and campus applications (forklifts, utility vehicles, campus vehicles, airport tugs and ground support, golf carts and small-scale people movers)
- Auxiliary power for trucks, RVs, boats, ships, and luxury autos
- Scooters, Segways and fuel cell bicycles
- Passenger vehicles and light trucks
- Heavy trucks and RVs

We believe fuel cell hybrid vehicles (FCHVs) will find success much sooner than “pure” fuel cell vehicles. FCHVs use a fuel cell to help recharge the batteries and extend the range of electric vehicles.

The military vehicles segment may grow faster than expected. Fuel represents 70% of the weight of materials moved in a military operation. “Increased concern of the logistical burden of fuel supply for internal combustion vehicles has resulted in new initiatives through the DOD,” confirms energy consultancy Green Strategies.

Many of those initiatives focus on fuel cell vehicles, which are not only efficient, but quiet. When we say “vehicles,” we do not mean cars and trucks alone. The DOD is actively researching fuel cell power for tanks, transports, ships, submarines and unmanned aircraft.

Sidebar 2 -- GM Unveils Military Truck Featuring Fuel Cell Auxiliary Power



January 9, 2003. General Motors Corp. and the U.S. Army revealed a diesel hybrid military pickup truck equipped with a fuel cell auxiliary power unit (APU) that could become the model for the Army's fleet of 30,000 light tactical vehicles.

The diesel hybrid military pickup truck is equipped with a 5 kW PEM fuel cell auxiliary power unit (APU) from Hydrogenics. When the vehicle is driven, the PEM electrolyzer uses electricity provided by the diesel engine to separate water into hydrogen and oxygen, with the hydrogen stored for future use.

The APU would replace the loud engine- and battery-based stationary generators the Army now uses for field power, thus enhancing the Army's "silent watch" capability.

Silent Watch is the ability to operate undetected by the enemy. Fuel cells are much quieter than generators and do not give off as much heat, making them less likely to be picked up by enemy sensors.

Auxiliary power is the sleeper in the transportation category. From power locks to climate control to sophisticated GPS devices, motor vehicles are dramatically expanding their need for electricity. Long before vehicles have fuel cells in place of engines, they will have fuel cells for auxiliary power. Auxiliary power units (APUs) allow for full climate control and on-board power while the engine is off.

Military vehicles are the leading candidates for early adoption. They often carry sophisticated electronic equipment. In addition, they often provide field power while parked.

Long-haul trucks also present a mid-term opportunity. Today, diesel trucks idle their 600-hp engines while parked to provide the power they need. That power demand is growing, with many trucks now carrying computers and GPS units in addition to CBs, radios and televisions. Fuel-cell APUs could reduce total emissions up to 45% for long haul vehicles while also lowering fuel consumption. Both are increasingly important as trucks approach the new emissions standards for 2007, which will force truck manufacturers to make hard choices.

Related market segments will follow quickly, including APUs for refrigeration trucks, ships, boats, ferries, trains, helicopters, small airplanes, and luxury autos. Marine applications have particularly strong potential for the Northwest with its legacy shipyards and boat-building operations.


Allied Business Intelligence believes the automotive market will achieve \$9B by 2007. Reflecting a more realistic outlook, Wintergreen Research predicts the transportation fuel cell market will be only \$40.5M in 2005, climbing to \$8.5B by

2011. The Athena consensus estimate is more conservative, and takes into account recent reports to Congress and to the DOE that predict a longer-than-expected ramp up to mass acceptance. We predict \$8B by 2013.

Prospects for the Hydrogen Infrastructure Are Unclear

To this point, we've considered the four key fuel cell application areas. A fifth area of potential jobs and growth is the hydrogen infrastructure -- the business of making, transporting and dispensing hydrogen as fuel.

No one yet knows how, whether or when the hydrogen infrastructure will arise. Its success is interdependent on the adoption rates of other fuel cell applications. And, as discussed elsewhere, some experts believe future fuel cells will run on methanol and bio-fuels and that we will never have a full-scale hydrogen infrastructure. This uncertainty makes it nearly impossible to generate reliable projections of growth of the hydrogen infrastructure.

Sidebar 3 -- QuestAir Gas Purification Contributes to Hydrogen Infrastructure	
 <p>Fuel cells need hydrogen to operate, and a British Columbia company is contributing to the infrastructure needed to produce hydrogen for stationary and automotive fuel cells. QuestAir's compact gas purification technology is used to improve the quality of hydrogen produced for industrial fuel cell applications.</p>	<p>QuestAir's compact hydrogen purification technology removes carbon dioxide and other impurities. The company has sold several of its first generation HyQuestor® units to the operators of hydrogen refueling demonstrations. It also sells to customers in the industrial gas, oil refining, and chemical industries. QuestAir employs approximately 100 engineers, scientists, technicians, and support staff with principal facilities in Burnaby, BC.</p>

Given the very early state of the hydrogen infrastructure, it does not represent a near-term source of economic growth. We do note, however, that the Northwest has a number of initiatives underway that could, in theory, bring hydrogen leadership to the region over time. First is the existence of General Hydrogen in Vancouver, B.C. Begun by Dr. Geoffrey Ballard, also the founder of Ballard Power Systems, it has as its goal to be to hydrogen what General Motors is to cars and General Mills is to breakfast food. It is unclear how much benefit B.C. businesses will create in Washington and Oregon, but we recognize the possibility.

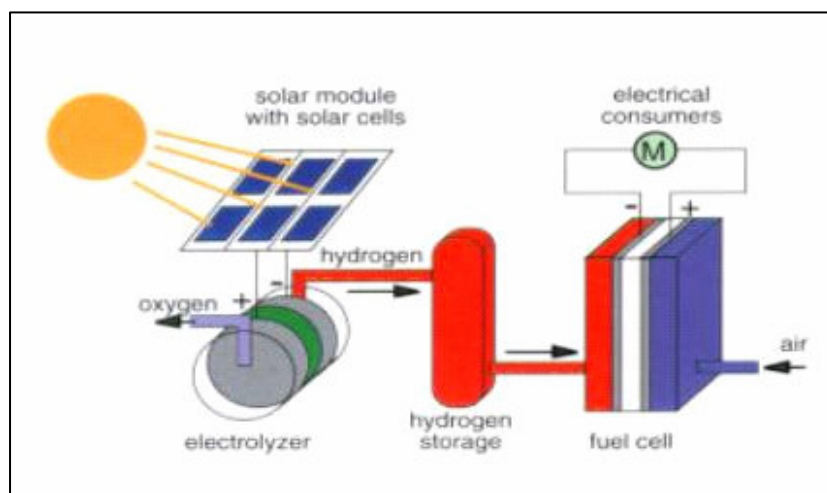
Numerous public and private research efforts are underway as well. PNNL has several fuel-related projects, including attempts to find better, cleaner ways to recover hydrogen from fossil fuels and a micro-sized reformer. IdaTech of Bend, OR, has made fuel processing a core competency with an onboard processor that can operate on a variety of fuels. Genesis Fueltech of Spokane makes reformers that produce hydrogen from methanol. And Hydro Environmental Resources of

Vancouver, WA, is in the early development stage of a hydrogen “reactor” that operates at normal pressure at relatively low temperatures.

We also note that the Northwest has been mentioned as a possible site for (See Figure 4) using renewable power to generate hydrogen. Hydroelectric dams often generate “throw-away” power late at night, when demand is low. Theoretically, that power could be tapped for electrolysis. Likewise, the eastern halves of Washington and Oregon have robust solar resources, with more than 300 sunny days per year. In theory, that sunlight could be used to create hydrogen. (See Figure 9.)

*Figure 9
Solar PV for Hydrogen
Production
Some experts believe we can tap
wind, solar and hydroelectric
power to generate hydrogen and
have suggested the Northwest
as a place to experiment. As
yet there is no evidence that
such an approach would
be economically viable.*

Source: DOE



The Overall Market Could Reach \$19B by 2013

The overall market projections discussed in this section ignore several categories, most notably figures for the hydrogen infrastructure and for space applications. They also do not include guesses about new, yet-to-be-invented devices that may drive demand even higher.

- Clean Edge pegs the market at \$500M in 2002 and expects the overall market to hit \$12.5B by 2012.
- Mark Williams of the National Energy Technology Laboratory expects the total worldwide fuel cell market to grow from \$500M in 2001 to \$20B by 2010.
- According to the Freedonia Group, the world fuel cell market will triple through 2005 to US\$8.5 billion, and exceed US\$23 billion by 2010.
- Allied Business Intelligence predicted in May 2003 that the global fuel cell industry would generate \$18.6B in 2013 (and could hit twice that if automotive fuel cells catch on faster than expected).

Athena believes the estimates at the high end of the range cannot be supported. They assume annual growth rates of 50% per year, sustained for a decade. They also ignore the many barriers to mass adoption and the fuel cell industry’s 20-year

history of less-than-expected growth. Athena believes the fuel cell industry will grow to approximately \$19B by 2013, from about \$0.5B today, distributed in these segments:

- Backup and portable -- \$2B
- Micro fuel cells -- \$3B
- Stationary -- \$6B
- Transportation -- \$8B

For these figures to be realized, the hydrogen infrastructure will also have to experience success. At this point, there is too little data to predict how that market will evolve and what kind of revenues it will generate. But it will certainly need to grow to multi-billion-dollar proportions to support the other markets described above.

FIVE CUSTOMER SEGMENTS ARE KEY TO THE MARKET

Five customer segments are the keys to the future of fuel cells. In the order of their likely adoption of fuel cells, they are: Military, Government, Commercial, Industry, and Consumer.

Table 2 summarizes key customer segments in the Northwest. The military and government segments are particularly important, since we believe they will represent the bulk of early sales.

Table 2 -- Fuel Cell Customer Segments and Representative Examples

Segment	Applications	Comments	Regional Issues
Military	Bases and Installations	Already piloting fuel cell and other alternative power sources to ensure reliability and independence from the grid.	Washington State is home to numerous military facilities at cities such as Bangor, Bremerton, Everett, Oak Harbor, Spokane, and Tacoma.
	Military vehicles	Already deep into planning for fuel cell-powered vehicles, transports, tanks and unmanned planes.	Historically, other regions have supplied these vehicles. Boeing's unmanned planes are produced in California.
	Soldier of the Future Project	Deep interest in fuel cells for laptops, handhelds, GPS positioning devices and supply chain power.	Both PNNL and WSU are doing research in this area.
Government	Buildings	The U.S. and Canadian federal governments have already embarked on programs to make their facilities and offices leaders in energy efficiency. Several states have similar programs.	Through BPA and regional DOE operations, the region has a history of government leadership in energy efficiency. Both state governments have also committed to lead by example.
	Government vehicles	Leadership in a fuel cell-powered fleet could come from federal, state and provincial governments, or from the Post Office. No programs announced at this time.	Vancouver, B.C. is home to a new program to construct a lightweight fuel cell vehicle. Regional leaders have proposed a fuel cell corridor along key interstate highways.
Commercial	Office buildings	Office parks and high-rises are an obvious early choice to install CHP. However, building owners have been slow to adopt other energy programs, even those with a rapid payback.	Our relatively low power rates make alternative energy less economically viable here than in other parts of the U.S and Canada or overseas.
Industry	Telecommunications	Fuel cells could become a technology of choice for cell towers, call centers, etc.	Washington State is home to a significant wireless cluster, although most equipment is manufactured outside the region.
	Manufacturing	Some kinds of manufacturing are sensitive to power fluctuations and would be good candidates for fuel cell power or backup.	The Portland area is the center of a cluster of semiconductor manufacturers and support services.
Consumer	Mobile devices	Both business and consumers are likely to be eager customers for products that extend the working time of digital devices.	Neither the traditional battery industry nor the consumer electronics industry has much presence in the region. However, our software companies have strong relationships with overseas manufacturers of digital devices.

REGIONAL POTENTIAL

In the previous section, we examined the global market for fuel cells. In this section, we consider regional assets and challenges with respect to a fuel cell industry. With that as background, we examine three fuel cell opportunities with significant near-term potential for the region and four more with moderate potential.

FUEL CELLS WILL DRIVE SIGNIFICANT OPPORTUNITIES... EVENTUALLY

Fuel cells will eventually generate meaningful employment and export gains. Indeed, numerous states, provinces, and national governments are targeting fuel cells for support and investment, as documented in the fall of 2003 by the State Science & Technology Institute: “With the growing need to identify cleaner sources of power . . . many state are targeting science and technology investments toward fuel cells. California, Connecticut, Michigan, Massachusetts, and New York all have made investments in fuel cell research demonstration or commercialization projects through energy related research funds.”

Economic Development Opportunities

According to a survey by the U.S. Fuel Cell Council, fuel cell jobs in the U.S. reached 3,273 in 2002. The Breakthrough Technologies Institute believes the number was higher. It pegs worldwide fuel cell employment at 13,000 in 2002, with 4,500-5,500 of those jobs in the U.S. It projects future worldwide employment at 47,000-75,000 by 2021 (plus another 70,000-113,000 indirect jobs).

Fuel Cells Canada believes the technology represents Canada’s single greatest opportunity for job growth. It currently attributes more than 1,200 jobs to fuel cells in British Columbia alone. It projects that number at 10,000 by 2010 and 30,000 by 2020.

We think those numbers are laudable as a goal, but unlikely as a forecast. They presume a compound annual growth rate of more than 35% year after year. It is also important to realize two factors that may limit the number of eventual jobs. First, many early jobs -- in B.C. and elsewhere -- are research and development positions dependent on fickle government grants. Those jobs can dry up quickly with a change in government emphasis.

What’s more, not all jobs will stay in the region. “Once in a great while, technology commercialization by one company, such as Microsoft or Dell, can provide enormous direct job benefits to a region, but this is the rare exception rather than the rule,” warns *Technology Transfer and Commercialization: Their*

role in economic development, a 2003 report prepared for the U.S. Department of Commerce's Economic Development Administration. "In this age of geographically dispersed corporate functions and outsourcing . . .the direct employment benefits may be spread across many locales."

"In the early days, manufacturing will stay near headquarters," agrees Ron Britton, President and CEO of Fuel Cells Canada. "Over the long-term, it will migrate to China and other low-cost centers. You have to be sure you are figuring out where the value-added jobs are."

By rough estimate, Washington and Oregon have some 250 fuel-cell-related jobs today. With steady market progress, that number could grow to 1,200 in five years. If the market achieves a surprise breakthrough, or if the Northwest undertakes some of the initiatives laid out at the end of this report, that number could double or even triple.

Export Opportunities

Because of their complexity and their high value-to-weight ratio, most fuel cell components could be manufactured in this region for export. Even in the case of transportation applications -- where final assembly is likely to occur near the major automakers -- R&D and pilot manufacturing could easily remain in the Northwest.

In fact, export may be an early requirement for success. In the near- to mid-term, Japan and Europe will have higher demand for fuel cells than the United States. They have higher electricity prices and higher emissions standards, both of which make fuel cells easier to justify.

Sidebar 4 -- Spokane Fuel Cell Maker Signs Italian Distribution Agreement



October 2002. Spokane-based Avista Labs announced an agreement with SGS Future for distribution of Avista's fuel cells in Italy. SGS Future markets systems for the production of electrical energy at low environmental impact. SGS Future will purchase Avista Labs' fuel cell products and resell them to customers in Italy.

SGS committed to purchase 13, one-kilowatt, Independence 1000™ fuel cell systems in 2002. The company will also purchase 200 kilowatts of Independence products of various sizes in 2003.

Avista Labs, a wholly owned subsidiary of Avista Corp., is a leader in PEM fuel cells. The company markets a variety of commercially available fuel cells using its patented Modular Cartridge Technology.

In the long-term, much of the growth in electricity demand will come from the developing world. Most of those countries have inadequate power grids, plus high electricity costs and severe issues with congestion and pollution -- factors favoring fuel cells once prices come down.

Northwest fuel cell companies are already exploring these opportunities. For instance, Bend, OR-based IdaTech has a long-term partnership in Japan with Tokyo Boeki. Spokane's Avista Labs has a distribution agreement in Italy and is actively seeking partners in other countries. And Vancouver, B.C.'s Ballard Power Systems, the worldwide leader in PEM fuel cells, has long-standing agreements with automakers in the U.S., Europe, and Asia.

THE NORTHWEST HAS MAJOR FUEL CELL ASSETS

Our region has several advantages that accrue to fuel cell businesses, including the Vancouver fuel cell cluster, our research institutions, our entrepreneurial and export experience and several existing industries with strong synergies.

The Vancouver Fuel Cell Cluster

Vancouver, B.C. has emerged as one of the world's most significant fuel cell clusters. It boasts fuel cell companies, component manufacturers, skilled labor, skilled management, and informed capital. Relevant organizations include:

- Manufacturers such as Ballard Power Systems, Cellex Power Products, Palcan Fuel Cell Company, Polyfuel, and Xcellsis Fuel Cell Engines
- Makers of power electronics such as Xantrex
- Infrastructure providers such as General Hydrogen and Questair
- Makers of testing and support equipment such as Greenlight Power Technologies
- Suppliers of methanol such as Methanex
- Venture capital funds with extensive fuel cell experience, including Ventures West and Chrysalix
- Research facilities such as Powertech Labs, the National Research Council Innovation Centre, and the University of Victoria's Institute for Integrated Energy Systems
- A cooperative utility -- BC Hydro -- willing to field test fuel cells

Sidebar 5 -- Ballard Systems Continues Progress in Fuel Cell Buses



December 18, 2003, Vancouver, Canada - Ballard Power Systems announced it will provide three of its latest generation heavy-duty fuel cell engines to EvoBus for integration into Mercedes-Benz Citaro buses for the public transport system in Perth, Western Australia. Ballard will deliver the 205 kW heavy-duty fuel cell engines in the first half of 2004 and the buses will be placed in routine transit operation in the second half of 2004 as part of a two-year demonstration program.

Perth becomes the twelfth city committed to demonstrating Ballard fuel cell engines in transit buses. Since 1993, Ballard has produced and tested five generations of heavy-duty fuel cell bus engines.

Ballard is the recognized world leader in proton exchange membrane fuel cells and anchors the Vancouver fuel cell cluster. In addition to fuel cells for portable and stationary uses, Ballard is commercializing fuel cell engines and electric drives. It has also developed power electronics to convert power generated by photovoltaics, fuel cells, and microturbines.

Michael Porter, the leading authority on cluster theory, described clusters as "critical masses in one location with unusual competitive success in specific fields." Successful clusters almost always have at least one anchor tenant. The Vancouver cluster developed from the early activities of Ballard Power Systems. (See Sidebar 5.) Founded in 1982, the company has approximately 800 employees in the province (and several hundred elsewhere). Some employees from Ballard Power Systems have moved on to found new corporations.

Vancouver has the entire ecosystem in place. Figure 10 shows the hydrogen "playground" as defined by Chrysalix Energy Limited Partnership, a Vancouver-area venture capital firm focusing on fuel cell & related companies.

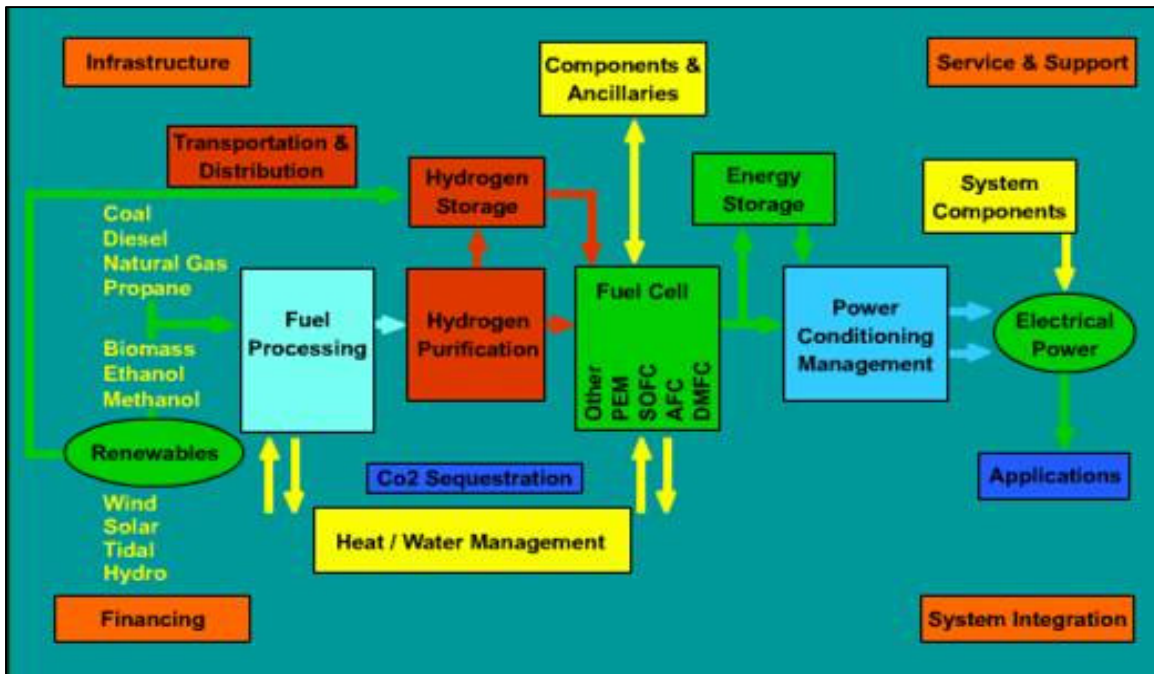


Figure 10: Vancouver's fuel cell cluster contains virtually the entire "ecosystem." Source: Chrysalix Energy Limited Partnership

Equally important, the province -- indeed all of Canada -- is thoroughly committed to the fuel cell sector. One example is the Canadian Transportation Fuel Cell Alliance, a \$23M initiative to demonstrate and evaluate fueling options for fuel cell vehicles. Another is Fuel Cells Canada (FCC), a national nonprofit association established to advance Canada's fuel cell industry. In a few short years, FCC has developed six new fuel cell research facilities in B.C., including the Fuel Cell Technology Centre on the campus of the University of British Columbia.

British Columbia has the fuel cell religion. Says FCC President Brian T. Josling: "We believe that the fuel cell industry is the greatest opportunity for Canada in terms of job creation, both knowledge-based and manufacturing."

Strong Research Facilities

The Northwest has many research institutions with programs relevant to fuel cells. We've listed several of the most notable programs below.


The Boeing Company has extensive experience in fuel cells for space and terrestrial applications. The company is currently researching fuel cells for unmanned electric planes and as auxiliary power units on commercial planes. Much of the research is conducted in Europe with partners. However, the Commercial Airlines group, headquartered in Seattle, is studying fuel cells to replace aircraft auxiliary power units. In addition, Boeing's Energy Systems Division is developing fuel-reforming technology called BOSH2 -- the Boeing One Step Hydrogen generator.

BC Research Inc. is a private company that provides contract research and research facilities in chemical and biological sciences, including fuel cell-related disciplines. It operates the BC Research Complex on 10-acres on the University of British Columbia South Campus, consisting of laboratories, offices, pilot plant facilities, a library, cafeteria, and an auditorium. The company also provides acceleration services to transform early stage technologies into viable commercial opportunities.

The British Columbia Institute of Technology near Vancouver, BC delivers certificates, diplomas, and degrees in technologies and trades. It also conducts applied research. Although most of its past energy efforts have centered on solar photovoltaic, it has begun to offer classes and research for fuel cells. Its Venture Development Centre provides advice and guidance in product commercialization and business development.

The Institute for Integrated Energy Systems at the University of Victoria hosts graduate and undergraduate programs in fuel cell modeling and fuel cell diagnostics. In addition, UVic's Innovation and Development Corporation helps

researchers develop the commercial potential of their ideas (including fuel cell-related ideas). In 2001, for instance, it assisted 18 UVic spin-off companies and filed patents for 45 new inventions based on UVic research. (See Sidebar 6.)

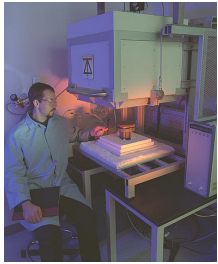
Sidebar 6 -- Institute for Integrated Energy Systems	
	<p>IESVic is widely known for its work in fuel cells, IESVic also researches energy systems and energy policy. The former includes work with industrial partners to provide access to specialized knowledge and equipment as well as work on how to integrate alternative energy into the power grid. The latter includes work with government partners to support policy and decision making.</p> <p>Research capabilities include product design and manufacturing; materials testing; engineering mechanics; market analysis; and socio-economic studies.</p> <p>The Institute also promotes energy systems education at all levels, formally and informally, to convince the world of the critical need for new and sustainable energy systems.</p>
<p>The Institute for Integrated Energy Systems at the University of Victoria researches new technologies for sustainable energy.</p>	

The National Research Council Institute for Fuel Cell Innovation (NRC-IFCI) in Vancouver, BC, is home to the NRC Fuel Cell Program. In collaboration with industry, universities, and other government agencies, the program provides research and innovation support in areas such as fuels research, system integration, manufacturing, and component development. NRC has also funded hydrogen-safe labs and testing facilities. Infrastructure includes demonstration facilities for new technology and incubation space for startups.

The Oregon Institute of Technology houses the Oregon Renewable Energy Center, which investigates many different energy technologies, including fuel cells. For instance, Professor Bob Rogers uses fuel cells manufactured by BC's Ballard Power Systems to demonstrate innovative uses of fuel cells to the public (including a single-person prototype vehicle powered by a fuel cell).

Pacific Northwest National Laboratory (PNNL) has a major facility in Richland, WA, plus offices in Seattle, WA, Tacoma, WA, and Portland, OR. Gary McVay manages many of PNNL's fuel cell programs "We take a multi-disciplinary approach to projects," he said in a December 2003 article in *Fuel Cell Magazine*. "We have chemists, material scientists, computer scientists, and a host of other resources. Our capabilities are not widely replicated in industry or academia." Those capabilities include expertise in materials, manufacturing, modeling, simulation, fuel reformation, and thermal management.

The laboratory partners with numerous organizations on fuel cell-related research. For instance, PNNL co-leads the Solid State Energy Conversion Alliance, a public-private partnership devoted to bringing solid oxide fuel cells to the mass market. As part of that initiative, PNNL scientists are developing improved cathodes, anodes, interconnections, and seals. (See Sidebar 7.)

Sidebar 7 -- PNNL Establishes Role as National Center for Fuel Cell Research	
 <p>Pacific Northwest National Laboratory in Richland, WA has been researching fuel cells for more than 15 years. Now it is expanding to include design and fabrication of complete Solid Oxide Fuel Cell systems. Programs include portable power generators, auxiliary power units, and fuel reforming.</p> <p>PNNL continues to plan expansions to its facilities, including a sophisticated fuel cell observatory. It has established a High-Temperature Electrochemistry Center with Montana State University to perfect the clean use of fossil fuels in fuel cells.</p>	<p>In 1999, PNNL teamed with the National Energy Technology Laboratory to form the Solid State Energy Conversion Alliance (SECA). The group includes agencies, universities, laboratories, automobile manufacturers and others. The shared cost research program has as its goal to bring cost-effective SOFCs to market in 10 years or less.</p> <p>Along with the Bonneville Power Administration, PNNL is also a leader in research on interconnection issues, many of which apply to the use of fuel cells for stationary power. It also has collaborations in place with Siemens Westinghouse, FuelCell Energy, the DOE Energy Efficiency and Renewable Energy program, and others.</p>

Oregon State University hosts several programs of direct relevance to the fuel cell industry. For instance, its micro technology initiative involves 17 faculty members from three different colleges. Work in progress includes micro channel reactor-based chemical fuel processors for residential and portable fuel cells. The university's School of Electrical Engineering and Computer Science hosts a well-regarded Power Electronics program that studies a wide range of applications, including power supply converters for fuel cell vehicles.

Simon Fraser University has three campuses in the Vancouver, BC area. The university offers graduate and undergraduate programs to approximately 25,000 students. Relevant research includes work on the polymer science and electrochemistry of Proton Exchange Membrane fuel cells.

The University of British Columbia conducts more than 4,000 research projects and attracts upwards of \$200M in research funding annually from government, industry, and non-profit foundations. UBC hosts the NRC Institute for Fuel Cell Innovation (see above) and conducts numerous other research programs relevant to fuel cells. For instance, the Chemical and Biological Engineering department is actively developing fuel cells as a cleaner, more efficient energy source.


The University of Washington includes fuel cell topics in its engineering and chemistry curricula and has research efforts in both PEMFCs and SOFCs. It hosts

an undergraduate fuel cell research team conducting research into bipolar plates, catalyst printing, test stand design, and fuel cell use in transport applications. **The Washington Technology Center**, located on the University of Washington campus, has a 15,000 sq. ft. microfabrication facility open to industrial and academic users.

Entrepreneurial Experience and Infrastructure

Washington State ranks high in most measures of entrepreneur energy and infrastructure. Oregon typically ranks in the top third. British Columbia is also well served. It has several significant “fuel-cell-centric” venture capital firms, as well as fuel cell-savvy offices of many leading accounting and law firms. Overall, the Northwest is well-served by angel investors, venture capital firms, law firms, accounting firms, banks, trade associations and serial entrepreneurs. Although this infrastructure is concentrated near Seattle, Portland, and Vancouver, BC, nearly all communities of any size have access and local economic development organizations to assist.

The Northwest also has a “green” reputation as a community that favors environmental responsibility. This reputation is a positive factor in attracting alternative energy entrepreneurs, most of whom share those values. Likewise, our region’s high quality of life is a major plus when attempting to recruit workers.

Sidebar 8 -- PEM Technologies	
 <p>Wei, Ph.D., previously served as Research Manager at Ballard Power Systems and Nexcel Power Systems.</p>	<p>PEM Technologies Inc. of Richmond, BC was founded in 2001 around a core group of scientists experienced in polymer chemistry and fuel cell gas management. The company makes fuel cell systems in the 100W to 5kW range. Founder Jim</p> <p>In the process of making its own stacks, PEM Technologies has developed advanced fuel cell components, including membranes and electrode assemblies, which it now sells separately to other companies. PEM Technologies is also notable for building working prototypes of several small fuel cell-powered vehicles, including the fuel cell motorcycle shown here.</p> <p>The venture-backed business completed a second round of funding in March 2003 and is currently seeking a third round.</p>

Export Experience and Infrastructure

Washington often ranks at the top of all U.S. states in exports per capita. Vancouver ranks #2 in total foreign exports in North America. Oregon has made progress in recent years with the advent of semiconductor manufacture and other high-tech businesses. The Northwest has outstanding port facilities and wide expertise in export issues.

The Northwest's location makes it a natural gateway to the Asia-Pacific region. In addition, Vancouver has had many historical and ethnic ties to Japan and Hong Kong, and, of course, to the U.K. and the rest of the British Commonwealth. As noted in the original *Poised for Profit* study, Europe is the most important international market for energy products such as fuel cells in the short term.

Synergistic Industries

Many of the Northwest's traditional industries have relevance to fuel cells:

Aerospace. Boeing was an early sponsor of fuel cell research for space and aerospace applications. It continues to investigate their application to unmanned aerial vehicles, spacecraft, and auxiliary power for aircraft, although much of the work is outside the region and much of it is classified for military reasons. Boeing also has extensive experience with fuel reforming, turbine design, and emissions reductions.

In addition, Boeing and its suppliers have decades of experience in fields with direct application to fuel cell research and manufacture, including control electronics and advanced materials fabrication.

Power electronics. Xantrex, a British Columbia firm, is generally regarded as the world leader in power inverters. The company maintains facilities in BC and in Washington State. The Northwest is also home to several other firms with international reputations in power electronics, battery technology, and related fields.

Utilities and related organizations. The Northwest has a number of organizations that have made significant contributions to both the traditional and the alternative energy industries.

- Forward-thinking utilities such as Puget Sound Energy, BC Hydro, PGE and Avista
- Bonneville Power Administration, a U.S. leader in power planning. BPA has done pilot testing of fuel cells with partner utilities. It also promotes its Energy Web concept, which foresees decentralized energy such as fuel cells.
- Northwest Energy Efficiency Alliance, which boasts a track record in successful market transformation

Heavy truck manufacturing. We expect long-haul trucks to be an early market for fuel-cell-based auxiliary power. The Northwest is home to two of the world's largest truck manufacturers, Paccar and Freightliner, and to the Northwest Alliance for Transportation Technologies. It also houses programs in advanced

transportation technologies at the University of Washington, the University of Idaho, and PNNL.

THE NORTHWEST IS A LOGICAL VENUE FOR MANY FUEL CELL ACTIVITIES

The Northwest is unlikely to gain a significant role in fuel cell chemicals and raw materials. Our region is, however, well positioned for most other aspects of the fuel cell value chain. Virtually all of these activities coincide nicely with Northwest strengths and create high-skill, high-pay jobs.

In terms of the fuel cells themselves, the Northwest has strong opportunities in development, testing, fuel stack manufacture, and integrated fuel systems assembly. In terms of the *balance of plant* products (the other components needed to make a fully operational fuel cell), the Northwest could easily become a center of excellence. Examples include power electronics, control electronics, fuel reformation, fuel storage, electric engines, and electric drive trains. Many of these ancillary products will also be important to other clean energy technologies such as solar and wind.

THE NORTHWEST FACES CHALLENGES

To become a dominant player in fuel cells, the Northwest must overcome numerous hurdles. Although most of those challenges are the same ones that face the fuel cell industry around the globe, some of them are unique to this region.

Two regional challenges seem particularly troublesome. The first is limited interest and awareness in Oregon and Washington. The second is lack of geographical proximity. The region must find a way to overcome those obstacles if it wants to reap the full rewards of the fuel cell opportunity. Despite its impressive progress and promising future, BC's fuel cell industry cannot develop as quickly and completely without access to the markets and partnerships of Oregon and Washington. The reverse is even more true. Unless Oregon and Washington access British Columbia's tremendous research, technical, and product resources, they are highly unlikely to develop a significant fuel cell cluster.

Lack of Awareness

Vancouver is a world thought leader in fuel cells. Once you cross the border to the south, however, the situation is dramatically different. Although there are individuals in both Washington and Oregon who believe in the promise of a fuel cell industry, most residents are unaware of fuel cells as a source of economic development. This "awareness gap" is particularly acute with Oregon and Washington investors. Oregon and Washington venture capitalists traditionally focus on software. They have to date largely ignored other regional strengths (such

as aerospace and semiconductor manufacturing), other regional opportunities (such as Boeing spinouts), and other sectors (such as fuel cells and energy technologies).

This is certainly understandable, as venture capitalists' investment charters are aligned with their expertise. With a few exceptions, Oregon and Washington VCs have little experience beyond software and related categories. It's not surprising that they pay less attention to opportunities from the energy space. However, their "software blinders" do mean less capital for fuel cell startups.

Lack of Advocacy

Most regions that are experiencing early success in fuel cells have had a high-profile individual or coalition leading the way, from the California Fuel Cell Partnership to Michigan's NextEnergy coalition. Although state officials and public-private partnerships have provided strong leadership in other sectors -- aerospace, semiconductors, biotech and more -- fuel cells are not on the radar screen as a significant source of economic growth for Washington and Oregon. By contrast, fuel cells as an engine of growth is practically a religion in British Columbia. The Province houses several important organizations, notably Fuel Cells Canada and the Institute for Fuel Cell Innovation. No such leaders have stepped forward in Washington and Oregon.

Geographical Distance and Regional Rivalry

The economic development literature makes it very clear that truly explosive growth comes from "clusters" -- agglomerations of related businesses. The Northwest's own history bears that out, with examples ranging from timber to aerospace to software to biomedical. Although British Columbia has a fuel cell cluster, the same is not true south of the border, where fuel cell businesses are few and -- quite literally -- far between. Oregon and Washington have barely two dozen fuel cell companies between them, scattered from Bend to Spokane to Seattle and beyond.

Like all locales, the Northwest also has a history of regional rivalries. Seattle, Portland, and Tacoma compete more often than they cooperate. Cross-border economic development cooperation is even more uncommon, despite several groups devoted to the cause and events sponsored by the Canadian Consulate and the Pacific Northwest Economic Region to bring the two groups together. U.S. businesses rarely look north for ideas and partners. And Canadian companies and investors are much more likely to look for opportunities 2,000 miles away in Toronto than 100 miles away in Seattle.

Cross-border initiatives are certainly possible. But despite the best of intentions on both side, cross-border partnerships have been difficult for a host of reasons,

including distance, ignorance, regulations, historical alliances, currency exchange rates, and suspicion.

Sidebar 9 -- Michigan Launches Bid to Take Leadership in Fuel Cells and Power Electronics



December 10, 2002. Michigan Governor John Engler joined city and industry leaders in a groundbreaking for the NextEnergy Center at Wayne State University in Detroit.

Combined with other components of the NextEnergy initiative, the Center “will significantly expand Michigan’s leadership in alternative energy research and manufacturing,” Engler said.

The center will develop educational programs, provide laboratory space, serve as a clearinghouse, and establish industry accelerator and support programs.

Michigan is spending more than \$40M to launch the NextEnergy initiative, which has as its goal to make Michigan a global center for fuel cells, power electronics, and other clean energy technologies.

Late to Compete

Although Vancouver, BC is arguably the world’s most important fuel cell cluster, Oregon and Washington have fallen far behind other regions, which have demonstrated a stronger understanding of the fuel cell opportunity and a greater funding commitment. The list below gives a sense of the competition the Northwest faces just in the U.S.

- **California** has some of the world’s most ambitious fuel cell initiatives in place. The California Fuel Cell Partnership is a collaborative of auto manufacturers, energy companies, fuel cell companies, and government agencies. The National Fuel Cell Research Center at the University of California Irvine is managing numerous research efforts and demonstration projects.
- **Connecticut** is constructing a new fuel cell research facility at the University of Connecticut and has earmarked millions for investment in regional fuel cell companies. For instance, its Clean Energy Fund is investing \$6M for fuel cell commercial applications. The fund is capitalized by a surcharge on utility bills and is expected to grow to \$120M by 2005. In March, 2003, Connecticut hosted a high-level fuel cell investment summit.
- **Massachusetts** has been promoting commercial fuel cells since 2001 through the Premium Power Program of the Massachusetts Renewable Energy Trust.
- **Michigan** introduced the NextEnergy initiative in April 2002 to a position to capitalize on the growing alternative energy market. It is constructing the NextEnergy Center to provide laboratory space and business incubator space for energy companies. It is also producing educational programs in power electronics, fuel cell technology, and related disciplines. The initiative also

provides tax incentives for companies involved in new alternative energy research, development and manufacturing.

- **New York** has made numerous investments into fuel cell pilots through the New York State Energy Research and Development Authority and other organizations.
- **New Mexico** has declared itself “the Hydrogen State” and has a committee at work to determine the best ways it can become a leader in the field.
- **Ohio** may spend as much as \$100M in a strategic initiative to secure a prominent position in the fuel cell industry, including expanding research facilities, participating in demonstration projects, training workers, and attracting fuel cell companies.

Colorado, Pennsylvania, Texas, Japan, Germany, and Korea are some of the other regions in active pursuit of the fuel cell opportunity.

Sidebar 10 -- California Fuel Cell Partnership	
The California Fuel Cell Partnership is a public-private consortium of automakers, energy providers, fuel cell companies, and government agencies. In 2002, the Partnership put 20 fuel cell vehicles on the road and activated four fueling stations. It promises even greater progress in 2003.	The program includes a plan to establish fuel cell-friendly model communities throughout the state, complete with test vehicles and hydrogen refueling stations. In addition, four California universities have major fuel cell research programs. Leading automotive companies from around the world donate millions to these programs each year.

NEAR-TERM OPPORTUNITIES

With our previous discussions as background, we are ready to consider where and whether the Northwest has near-term opportunities in the fuel cell space. Our preliminary research has uncovered at least three strong prospects and at least four more with moderate potential.

THE NORTHWEST HAS SIGNIFICANT POTENTIAL IN FOUR IMPORTANT NICHES

At this early stage, the Pacific Northwest could still gain a leading stake in the fuel cell sector. Our research uncovered four areas that combine a) near-term growth prospects with b) regional strengths. Table 3 lists these opportunities along with their associated issues. We provide a preliminary discussion of each one below.

Table 3 -- Strong Opportunities for Northwest Fuel Cell Growth

Opportunity	Assets	Challenges	Organizations
Backup and Portable Power	<ul style="list-style-type: none"> ▪ Spokane's Avista Labs shipping now ▪ B.C.'s Ballard Power Systems shipping now 	<ul style="list-style-type: none"> ▪ Few synergies between U.S. and Canada despite proximity 	<ul style="list-style-type: none"> ▪ Avista Labs ▪ Ballard Power Systems (B.C.)
Auxiliary Power	<ul style="list-style-type: none"> ▪ Home to two of world's largest truck manufacturers ▪ PNNL leads related SECA initiative ▪ Strong aerospace expertise ▪ Legacy shipbuilding 	<ul style="list-style-type: none"> ▪ Theory only. No regional company attempting to commercialize ▪ Still not recognized as an important opportunity by fuel cell startups 	<ul style="list-style-type: none"> ▪ Freightliner ▪ Northwest Alliance for Transportation Technology ▪ Paccar ▪ PNNL SOFC research and its SECA initiative
Balance of Plant	<ul style="list-style-type: none"> ▪ Power electronics legacy ▪ Legacy expertise in related systems integration (solar) ▪ Aerospace and missile electronics expertise ▪ Applies to all types of fuel cells and to other alternative energy technologies 	<ul style="list-style-type: none"> ▪ Xantrex, moving manufacturing overseas ▪ Applied Power purchased by Schott, moving many operations to CA ▪ Software blinders by investors 	<ul style="list-style-type: none"> ▪ Aerojet ▪ Alpha and Argus ▪ Boeing ▪ Outback ▪ Power ▪ Schott Applied ▪ Xantrex
Micro Fuel Cells	<ul style="list-style-type: none"> ▪ Region's "gateway to Asia" status could give access to Asian manufacturers ▪ Regional wireless, telecom, and gaming software companies have relationships with device makers 	<ul style="list-style-type: none"> ▪ Most major distributors, partners and customers are located elsewhere 	<ul style="list-style-type: none"> ▪ Lilliputian Systems ▪ Neah Power ▪ Polyfuel ▪ PNNL research WTC Micro-fabrication Lab

Backup and Portable Power

Backup power provides electricity for standby needs when the primary power source fails. Portable power provides electricity to a location not connected to the electric grid. Typical amounts are 500 -4,000 watts. Applications include construction sites, camping, remote lodges and towns, as well as business uses that need a transportable solution.

The first success in this category will come in the so-called “premium power” niche -- those sites that must have high-quality power 24 hours per day, 365 days per year. Examples include substations, telecommunications sites, cellular towers, financial services centers, computing centers, pipeline-monitoring stations, etc.

In this space, the Northwest’s opportunities lie in its vendors. Avista Labs is in commercial production of transportable power units for premium power. Oregon’s IdaTech is close to commercial shipment of a unit that could play in this market niche. Across the border in British Columbia, Ballard Power Systems is also selling a portable power product. Early in 2004, BC Hydro will field test 1Kw Ballard fuel cells as replacements for batteries, which currently provide emergency power at more than 600 sites.

Auxiliary Power

Auxiliary power units (APUs) handle the growing need for electricity on board trucks, recreational vehicles, boats, trains and planes. We think this segment may find significant growth while flying “under the radar” of traditional analysts. We also believe it has numerous Northwest synergies.

Some of those synergies relate to ongoing work at Pacific Northwest National Laboratories. PNNL is a founding member of the Northwest Alliance for

*Figure 11
PNNL has partnered with truck makers, auto makers and Northwest aluminum producers to study advanced vehicle materials and emissions technologies.*

Source: PNNL.




Transportation Technology, which is conducting research on lighter vehicles and on fuel cells (See Figure 11). It is also a co-leader of the Solid State Energy Conversion Alliance. This national organization has an ambitious and well-funded program to accelerate the commercialization of solid oxide fuel cells.

PNNL is also working on ways to put fuel reformers on vehicles, so various kinds of fuel, including diesel, can be converted into hydrogen for fuel cells.

Eventually, auxiliary power may become standard equipment on luxury autos. The APU would replace the alternator, producing more power without requiring the engine to be running. PNNL has already completed a successful demonstration with Delphi and BMW.

The auxiliary power segment seems especially promising because the Northwest has excellent access to early markets. Large trucks may be amongst the first to adopt fuel cells for auxiliary power, and the Northwest is home to two of the world's largest heavy truck manufacturers.

Sidebar 11 -- Oregon Fuel Cell Maker Gets Contract for Demonstration Military Vehicles	
	<p>The 2 kW systems will provide on-board power for "silent watch" field exercises in which quiet operation is essential.</p> <p>The Army's Communications - Electronics Command (CECOM) is also field-testing IdaTech's FCS 1200, a self-contained fuel cell system</p> <p>IdaTech is a Bend, OR, developer of fuel processors and PEM fuel cells. Its core capability is its patented fuel processing technology.</p>
<p>October 2002. The U.S. has contracted with IdaTech to develop 2 kW fuel cell systems to power electronic equipment on a High Mobility Multipurpose Wheeled Vehicle (HMMWV - pronounced HumVee).</p>	

The Northwest also has a legacy shipbuilding business that offers a prime opportunity. Washington State's once-dominant position in power inverters (since co-opted by British Columbia) arose because area shipbuilders were searching for solutions to their marine power needs. The region's high-profile industry could once again lead the way in this new category.

Finally, we expect the military to be the single largest purchaser of most fuel cell types during the early years. Washington State has numerous military facilities that could provide fertile ground for pilot projects and early sales. This is by no means a small opportunity. The U.S. army alone maintains a fleet of 30,000 light vehicles, plus thousands of tanks and heavy trucks. Virtually all of them are candidates for APUs.

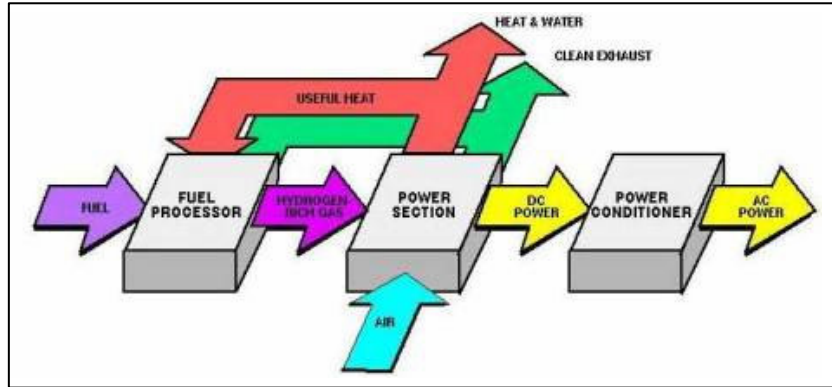
Balance of Plant

A complete fuel cell system includes several components in addition to the fuel cell itself. These components are known collectively as *balance of plant*. They may include a fuel processor or fuel reformer, fuel storage, power conditioning (such as inverters and voltage controls), motors, compressors, blowers and fans, valves and piping, even conventional batteries complementary to the fuel cell stack. (See Figure 12.) This segment may not be "sexy," but we expect it to exhibit strong, steady growth. Part of its strength lies in the fact that many of the components can be adapted from existing Northwest competencies. They can also be adapted to other industries, including solar and wind, giving them a larger potential market. In addition, Vancouver, B.C.-based Xantrex, a maker of power electronics and other balance of system components, is approaching \$150M in annual sales and

Figure 12
Balance of Plant

A typical fuel cell system includes a fuel processor, a fuel cell stack (labeled power section in this drawing), and balance of plant components including power conditioning, thermal management and water handling.

Source: National Fuel Cell Research Center



still maintains several facilities in Washington State. Other regional players include Alpha Technologies, Argus Technologies, and Philtek Electronics.

THE NORTHWEST HAS AT LEAST THREE MODERATE OPPORTUNITIES

Our early research has uncovered at least three market segments with moderate near-term potential. Table 4 lists and explains our findings.

Table 4 -- Moderate Opportunities for Northwest Fuel Cell Growth

Opportunity	Assets	Challenges	Organizations
Stationary Power	<ul style="list-style-type: none"> ▪ Military bases and federal installations that could become pilot customers ▪ Forward-thinking utilities that might pioneer sales ▪ Region is leader in building codes and interconnection standards 	<ul style="list-style-type: none"> ▪ Low cost of power provides little financial incentive to explore alternative energy -- early growth will be elsewhere ▪ Only one regional fuel cell company focused on stationary power (IdaTech) 	<ul style="list-style-type: none"> ▪ Avista Utilities ▪ BPA ▪ Idatech ▪ PGE ▪ PNNL ▪ PSE
Marine Transportation	<ul style="list-style-type: none"> ▪ Seattle and Vancouver remain major ports and marine-industry hubs with legacy boat-building operations ▪ Everett, Bremerton, and Bangor Naval facilities ▪ PNNL researching SOFCs, a prime candidate 	<ul style="list-style-type: none"> ▪ Sector unlikely to see strong growth for several years, except pilot projects for the military 	<ul style="list-style-type: none"> ▪ Numerous small shipyards ▪ Naval bases and facilities ▪ PNNL
Truck Transportation	<ul style="list-style-type: none"> ▪ Home to two of world's largest truck manufacturers ▪ Vancouver, BC electric car and fuel cell bus efforts ▪ Aerospace expertise in materials fabrication, control electronics 	<ul style="list-style-type: none"> ▪ Auxiliary power will be an early market. Primary power will be much longer to develop for trucks, perhaps more than a decade away. 	<ul style="list-style-type: none"> ▪ Freightliner ▪ Paccar

INITIATIVES TO IMPROVE FUEL CELL PROSPECTS IN THE NORTHWEST

The Northwest can take steps to improve its advantages and minimize its barriers. We mention four key steps below. Each one has individual merit. The greatest progress, however, would come from combining all four into a coordinated, cross-border initiative.

CROSS-BORDER COLLABORATION

The region's single biggest opportunity is to join forces to form a "super-cluster." Emerging technology sectors are "winner-take-most" markets. By combining forces, we stand to gain in stature and visibility -- precisely the factors that attract more investment, more entrepreneurs, and more relocations. It becomes a self-fulfilling prophecy. Cross-border collaboration could also cut the price tag by reducing duplication and allowing shared cost efforts. To succeed, cross-border collaboration should include:

1. An organization to oversee the joint effort and synchronize the many different agencies and efforts already underway
2. Coordination of research efforts
3. Creation of a commercialization path
4. A joint campaign of outreach and education to increase the acceptance of fuel cells and the visibility of the Northwest as an epicenter

A PERMANENT FUEL CELL ADVOCACY ORGANIZATION

At least 10 other regions around the world have public or public-private organizations with a full-time mission of advancing fuel cell prospects for their region. Fuel Cells Canada, which is headquartered in British Columbia, fills that role for Canada. Oregon and Washington have no such group. To contend in this increasingly competitive arena, those two states must find a way to fund such a group or to join forces with a BC organization. An umbrella organization could coordinate the different groups and initiatives underway already and provide a cohesive voice. Ideally, it can also join forces with a) existing cross-border efforts such as the Pacific Northwest Economic Region and b) the larger sustainability movement that seeks to define the Northwest as the "Sustainability Cluster."

COORDINATION OF RESEARCH EFFORTS

First, the Northwest needs to coordinate its research to avoid duplicating efforts. Second, it needs to attract even more R&D.

One of the first efforts of any regional fuel cell organization should be to normalize the region's research efforts. Fuel Cells Canada estimates that the world's governments currently spend \$1B to \$1.5B each year on fuel cell research (the tab for private research is even higher). Of that, more than 50% is duplication, according to the agency. In a similar fashion, much of the fuel cell-related economic development work is duplicative. Regional coordination could reduce that overlap while filling in the gaps that remain.

Whether jointly with Canada or on its own, the Northwest can raise its fuel cell prospects by aggressively pursuing the growing number of research opportunities funded by government, military, and private industry. To date, most U.S. fuel cell research dollars are flowing to California, although Connecticut, Michigan, and Texas are also pulling in significant amounts. Most of the new facilities and relocations have gone to California, Pennsylvania, Connecticut, and Michigan.

The Pacific Northwest could make up lost ground through an organized, concerted effort to compete for future fuel cell research projects and laboratories. It would seem that BC fuel cell firms have an incentive to seek US partnerships that would allow them to pursue US FreedomCAR and FreedomFUEL funds.

A DEFINED PATH TO COMMERCIALIZATION

As part of its strategic plan, a cross-border initiative should define a path to commercialization. That path should include the necessary steppingstones to take the industry from its current embryonic stage to mainstream success, including:

- Competing for research projects (see above)
- Creating pilots and demonstration projects
- Collaborating on market transformation activities to create regional demand

Pilots and demonstration projects. Working together, the Northwest has many opportunities to create pilots and demonstrations that would give fuel cells a leg up. For instance, British Columbia's "Hydrogen Hy-Way" is a proposed fuel cell-friendly corridor from Vancouver to Whistler, site of the 2010 Winter Olympics. The highway encompasses regular refueling stops, demonstration fleets, fuel cell buses, and other efforts to make it easy to travel back and forth between the two cities using fuel cell vehicles.

Extending the Hydrogen Hy-Way to Seattle and Portland would give it even more prominence and could be the kind of symbolic effort that cements our region's place as a global leader. Likewise, the Hydrogen Village contemplated for eastern Canada would be an ideal demonstration activity for the Northwest.

Bonneville Power Administration's Non-Wire Alternatives program -- an initiative to seek alternatives to building new transmission lines -- could potentially make a place for fuel cells as a distributed generation option.

Washington State also has many military installations and federal buildings that can act as staging grounds for government programs. For instance, the U.S. Army has a large program in place to assist commercialization of fuel cells so it can procure them at lower cost for military purposes. The U.S. Department of Energy, to name another example, has a program underway to encourage combined heating and power installations (a natural for fuel cells.) Dozens of other pilot opportunities exist.

Market transformation. In April 2003, Fuel Cells Canada released a commercialization roadmap for the Canadian fuel cell industry. It noted one of the four key steps as "stimulating market demand rather than relying on technology pull." Fortunately, the Northwest has an excellent record of such transitions, particularly in areas with environmental implications. The Northwest was one of the first regions to implement recycling successfully, for instance. Likewise, the Northwest Energy Efficiency Alliance is recognized around the world for its success in accelerating market acceptance for products such as compact fluorescents and Energy Star appliances. Similar programs on behalf of fuel cells could make the Northwest that much more attractive as a place to start and grow fuel cell-related businesses.

EDUCATION AND OUTREACH

Finally, the Northwest could greatly benefit from a campaign of education and outreach. The education could help investors, entrepreneurs, and policymakers understand why and how to invest in the future of fuel cells. The outreach could raise the Northwest's profile around the world.

Any such campaign should begin with an effort to define a regional brand or slogan that can act as an umbrella for all of the region's fuel cell efforts. Branding works for corporations and it works for regions too.

The education portion should include investors, entrepreneurs, and policymakers. Typical activities include venture forums, conferences, road shows, trade missions, and investor-oriented newsletters.

A short-term promotion and publicity campaign could raise the Northwest's profile around the world. This effort would also help to solve some of the region's other challenges as well. For instance, venture capitalists are strongly attracted to emerging clusters that can show early success stories. Likewise, companies

shopping for new branch locations prefer regions that can supply customers and skilled workers. Skilled workers, meanwhile, gravitate to “thick” employment markets -- regions with many companies and many jobs in the same sector.

Such promotional efforts do not need to be costly. It is far more effective -- and far less expensive -- to get positive articles in respected publications than to purchase advertisements or send delegations on expensive visits. Promotional campaigns undertaken by organizations such as Michigan’s NextEnergy and Austin’s Clean Energy Incubator can provide templates for success.

The Opportunity -- and the Challenge

The Pacific Northwest has many of the assets necessary to gain an important role in the hydrogen economy -- and the resulting economic development benefits. Those benefits will not come easily or automatically. Dozens of different regions have taken aim at the fuel cell sector. They are collectively pouring hundreds of millions into attracting and accelerating fuel cell businesses. Even with its assets and advantages, the Northwest will lose ground to those other regions unless it takes action.

APPENDIX A: TECHNOLOGY OVERVIEW

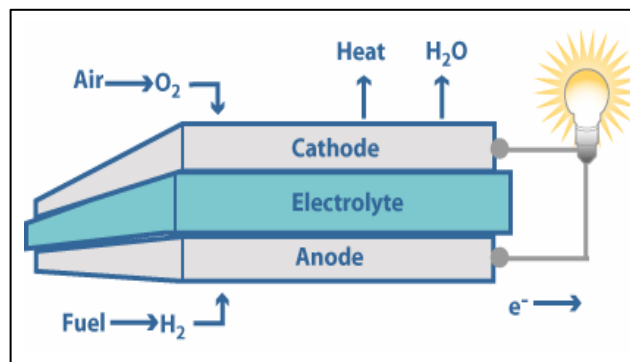
FUEL CELL DEFINITION

Fuels cells combine a fuel (usually hydrogen) with oxygen to produce electricity. They do so without combustion through an electrochemical process that produces water and heat as byproducts.

Fuel cells have two conducting plates called *electrodes*. Sandwiched in between is an *electrolyte* coated with a *catalyst*. (See Figure 13.)

*Figure 13
Fuel Cell Schematic.
Fuel enters at bottom where a catalyst strips off the electrons.
The resulting ion migrates through the electrolyte.
The electrons flow through a wire to the other side,
creating a current.*

*Source: National Fuel Cell
Research Center*



In most fuel cells, the catalyst induces the hydrogen to give up its electron. The hydrogen ion (a proton) migrates to the other side, leaving the electrons behind. Connecting the electrodes with a wire allows the electrons to stream to the other side, creating an electric current. Once on the other side, the electrons combine with the hydrogen ions and with oxygen to create water. The current continues as long as fresh hydrogen is fed into this process.

A single fuel cell generates very little power. However, like batteries, individual fuel cells can be combined into stacks of virtually unlimited size.

Feeding the Fuel Cell

Most fuel cells run on hydrogen, which can be obtained through a variety of methods. *Electrolysis* splits water into hydrogen and oxygen. *Reforming* converts fuels such as natural gas, propane, methanol, and gasoline. *Onboard reforming* converts fuels internally. *External reforming* refers to hydrogen produced elsewhere, then piped to the fuel cell or stored in a pressure tank.

FUEL CELL APPROACHES

Fuel cells come in many types with widely varying characteristics such as operating temperature, power density, tolerance of impurities, ease of manufacture and cost of materials. Those differences determine which types are suitable for which applications.

Table 5 shows the seven fuel cell technologies currently receiving the most attention. At least a dozen other approaches are actively being researched.

Table 5 - Fuel Cell Technologies

Type	Operating Temp, F	Efficiency	Typical Applications	Comments
Phosphoric Acid (PAFC)	200-220	40-45%	Large-scale stationary power	One of the earliest technologies to achieve commercial sales, now falling out of favor.
Alkaline (AFC)	300-400	60%	Space, military, transportation	Used by NASA for space missions. Generally considered too expensive for mass markets, though some companies continue to experiment.
Molten Carbonate (MCFC)	1200	45-60%	Large-scale stationary power	High temperature allows combined heat and power and on-board reforming.
Solid Oxide (SOFC)	800 -1800	50-65%	Stationary power, transportation	High temperature allows combined heat and power and on-board reforming. Can use semiconductor manufacturing techniques to lower costs.
Proton Exchange Membrane (PEMFC)	175	30-60%	Backup and remote power, portable power, transportation	Low temperature and high efficiency make this the leading candidate for transportation.
Direct Methanol (DMFC)	120-190	40%	Mobile devices	A form of PEMFC that uses methanol directly for fuel.
Porous Silicon	n/a	n/a	Mobile devices	A form of DMFC that uses silicon instead of a polymer membrane in hopes of getting lower manufacturing costs and higher power density.

Source: www.fuelcells.org and various company press releases

Phosphoric Acid

Capable of producing 200-1000 kW, PAFCs are the only commercially available fuel cells that has shipped in any significant volume as of this writing. However, PAFC technology is limited in its applications and in its potential for cost reduction. Suppliers are switching away from this technology.

Alkaline

Used extensively in space applications, alkaline fuel cells are efficient, compact and reliable. However, they are so expensive that most people consider them impractical for civilian applications.

Molten Carbonate

MCFCs are capable of producing 250-3000 kW in stationary power applications. They operate at a high temperature --1112 degrees Fahrenheit -- which allows them to produce hydrogen with onboard reforming. They offer greater fuel flexibility and efficiency than low-temperature fuel cells. The high temperature also suits them for combined heat and power applications, where they can reach combined efficiencies of 85%.

Unlike most other fuel cell technologies, MCFCs do not require expensive platinum catalysts or rare earth metals. This increases the chances for significant cost reduction. On the other hand, they can be costly and difficult to operate. The caustic molten electrolyte degrades, requiring replacement after several years.

Solid Oxide

A SOFC uses mixtures of ceramics and metals to create a solid-state cell. The stability and reliability of their-solid-state ceramic construction raises the possibility for low-cost mass production.

SOFCs are capable in theory of producing 1-3000 kW. They operate at high temperatures -- 800 - 832 degrees Fahrenheit -- which makes them unsuitable for many uses but excellent for combined heat and power. Like MCFCs, they offer the possibility of onboard reforming and fuel flexibility.

SOFCs do not suffer the degradation of molten carbonate. The leading producer, Siemens Westinghouse Power Corporation, claims PEMFCs have a life of 15,000 hours, MCFCs 30-50,000 hours and SOFCs 50-100,000 hours

SOFCs also benefit from the DOE's Solid State Energy Conversion Alliance (SECA). Under this program Siemens Westinghouse and several other industry teams are developing SOFC systems for remote, residential and transportation application. The long range goals of the program include reducing the initial cost to the \$400 per kW range (about 1/10th the current cost).

The leaders in solid oxide fuel cells are beginning to design and build automated factories using techniques from the semiconductor industry. Although prices are high now, this technology is a strong long-term bet for stationary and auxiliary power applications.

Proton Exchange Membrane

PEMFCs are the most versatile technology, capable in theory of producing 3-300 kW. They offer several advantages. They start more quickly than most other types. They have the cost reduction potential to make them much less expensive. And their lower operating temperature -- as low as 122 degrees Fahrenheit -- suits them for transportation and portable power.

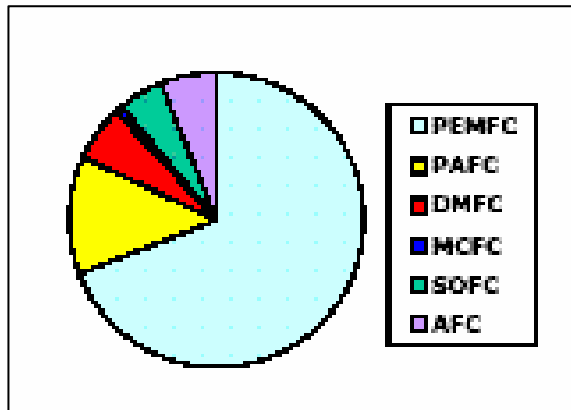
However, the low temperature is a disadvantage for combined heat and power and requires a separate, external hydrogen reformer, leading to issues with transport and storage of the hydrogen fuel. PEMFCs are also more sensitive to contaminants and must use pure hydrogen.

PEMFCs currently get the bulk of the press attention, the research dollars and the purchases, representing about 2/3 of all fuel cells in operation today according to *Fuel Cell Today*. (See Figure 14.)

Figure 14
Installed Base

Worldwide fuel cell installed
base by technology type.

Source: *Fuel Cell Today*,
November 2002



Direct Methanol

This technology is a form of PEMFC that uses methanol without the usual step of reforming it into hydrogen. This technology is best suited for mobile devices that require less than 1 kW.

Porous Silicon

Porous silicon is a direct methanol variant that substitutes silicon in place of a polymer membrane. The inventor, Neah Power of Bothell, WA, argues that silicon enables higher power density and more efficient operation. The company also believes it can be manufactured at low cost by taking advantage of the decades of research into silicon and semiconductor manufacture.

FUEL CELL BENEFITS

Fuel cells offer numerous advantages, including:

- **High Efficiency** -- up to 60% in standalone applications, up to 85% in combined heat and power
- **Lower Emissions** -- fewer pollutants, fewer greenhouse gases
- **Modularity and Flexibility** -- power from a few watts to hundreds of watts using a wide range of fuels and operating at a wide range of temperatures
- **High Power Density** -- excellent power to weight ratio
- **High Power Quality** -- as required by modern digital equipment

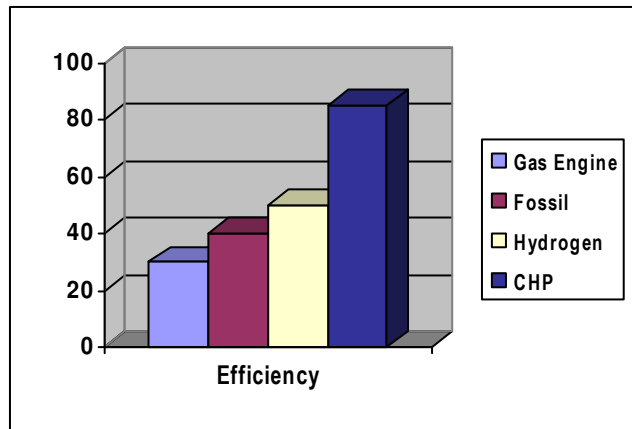
High Efficiency

Traditional power sources typically range from 20-40% efficiency. For instance, a typical internal combustion engine operates at 25% efficiency. On their own, fuel cells typically achieve 40-60% efficiency. That number can exceed 80% when the excess heat is captured for combined heat and power. (See Figure 15.)

*Figure 15
Efficiency Comparison.*

Fuel cells are inherently efficient. When powered by fossil fuels they achieve 40% efficiency. When powered by pure hydrogen, the figure rises to 50%. When their excess heat is captured for combined heat and power, total efficiency can exceed 85%.

Source: Breakthrough Technologies Institute



Low Emissions

Under best-case circumstances, fuel cells have near-zero emissions. They convert energy directly without combustion, and therefore produce no pollutant emissions. According to United Technologies, a fuel cell creates less than one ounce of pollution per 1,000 kilowatt-hours. In contrast, internal combustion systems generate 400 ounces of pollution (25 lbs).

However the fuel cell figures refer only to operation on pure hydrogen, not to the process of producing that hydrogen, which can generate emissions. The degree of “cleanness” depends on the fuel source. Fuel cells powered by hydrogen from renewable sources (for instance, solar-powered electrolysis) are very clean. But when the hydrogen comes from fossil fuels, the reformation process introduces pollutants and greenhouse gases. Even in that case, however, fuel cells represent an improvement over internal combustion engines.

Some scientists also warn against “fugitive emissions.” They believe that hydrogen is such a lightweight gas that it will leak from storage tanks and pipelines much

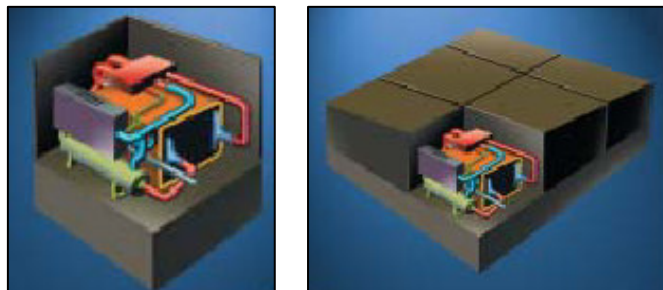
more easily than natural gas. Those fugitive emissions could become a problem if the world were to transition to a hydrogen economy with an extensive hydrogen infrastructure.

Modularity and Flexibility

Because fuel cell stacks can be mixed and matched to suit power needs, they offer unparalleled flexibility. Customers can start small and build up in small increments as needed, minimizing upfront costs and postponing additional investments as long as possible. (See Figure 16.)

*Figure 16
Fuel Cell Modularity*

Fuel cells can be constructed as small modules, then mixed and matched as needed to suit the customer's power needs.



Source: SECA

Fuel cells also offer a fast response to changing needs. Installing a fuel cell is much faster than constructing a large central station and the necessary high-voltage transmission lines. They are easy to site, so the quiet, clean units can be placed near the customer, reducing transmission costs. They are also easy to site in locations not served by the grid.

Finally, fuel cells also offer fuel flexibility. They can operate on natural gas, gasoline, diesel fuel, alcohol fuels, coal-derived gases and biomass gases.

High Power Density

Fuel cells offer more power for less weight, especially when compared to batteries.

High-Quality Power

Fuel cells can be configured to provide “digital-grade” power, offering freedom from troublesome frequency variations, voltage transients, dips and surges. Most fuel cell technologies can be configured to provide 99.9999+ uptime. This makes them an attractive alternative to expensive uninterruptible power supplies, power-line filters and battery backups.

FUEL CELL VALUE CHAIN

Figure 17 (below) shows a high-level view of the fuel cell value chain. Finding the best regional opportunities involves examining each niche to discover which ones have an intersection between market demand and regional strengths -- that is, to find the areas of rapid growth where the Northwest has a competitive advantage.

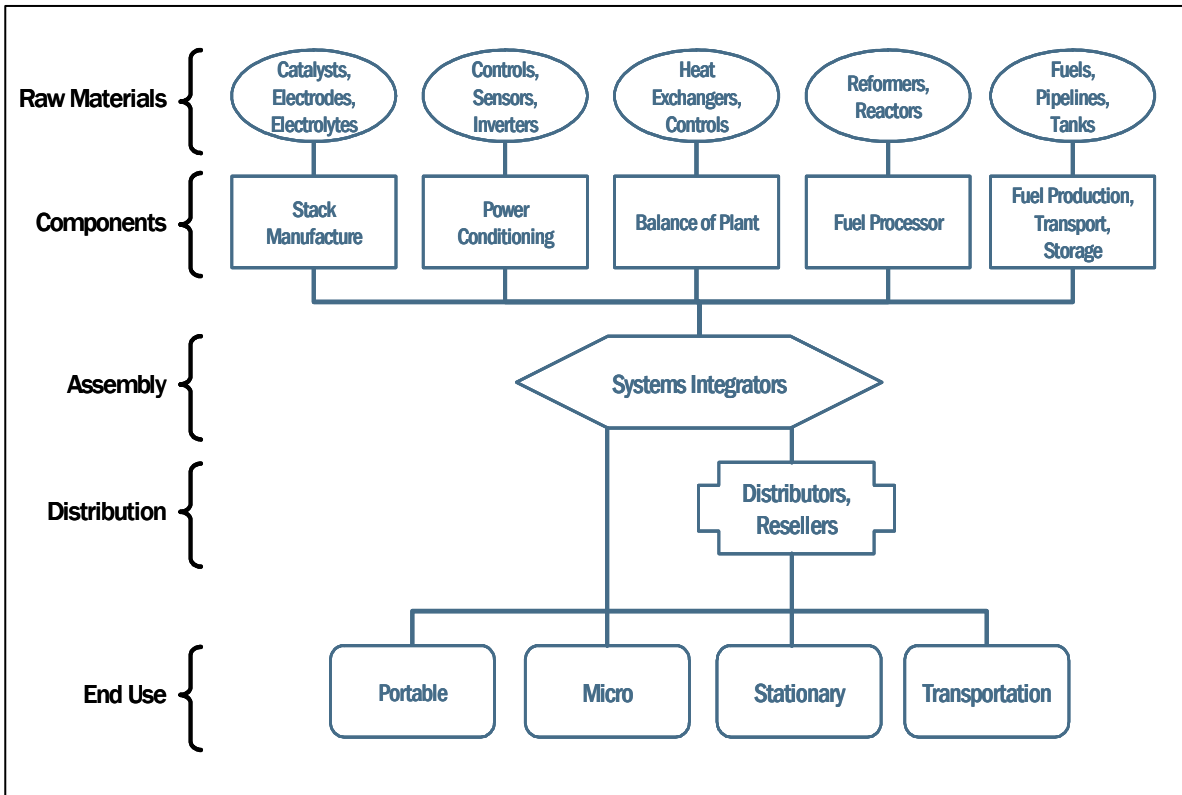


Figure 17: Fuel Cell Value Chain. Source: DOE, Allied Business Intelligence

APPENDIX B: PROJECT OVERVIEW

This report is focused narrowly on near-term market opportunities. As used in this report, a “near-term opportunity” is a market niche that can generate thousands of high-quality local jobs and millions in new revenues within the next three to five years. In addition, that niche must create significant export opportunities, significant growth prospects for current companies and significant reasons for “latent entrepreneurs” to start up related businesses. As you read through this report, please note that:

- **This report discusses regional cluster prospects.** This report does not relate to the prospects for success for individual companies, which may prosper whether or not a cluster emerges.
- **This report focuses on near-term prospects.** A market niche with little short-term potential could still become a major opportunity later in the decade. The goal of this study was to find sectors that could see significant market growth within five years. Sectors with longer time horizons were not appropriate for inclusion.
- **This report focuses on cluster potential rather than clean energy potential.** Comments relative to alternative energy speak only to its cluster potential, not to its value as a cleaner way to generate power. Nor does it include the economic benefits related to constructing and operating clean energy facilities such as job creation from wind farms or the economic benefits of spending less on imported energy.
- **This report includes generally accepted consensus figures for market sizing.** Our numbers represent generally accepted consensus figures of market sizes and growth, as reported by industry analysts and market research firms. The report does not include more detailed financial forecasts. (See Methodology section below for more explanation.)
- **This report series focuses on particular energy technologies.** The terms “clean energy,” “alternative energy,” “renewable energy,” and “New Energy” embrace a wide range of technologies. At the beginning of the *Poised for Profit II* process, the Steering Committee made the decision to restrict the research to the areas of fuel cells (this report), solar, wind, and Smart Energy. By design, neither this report nor the others in the series discuss such areas as superconductivity, electricity storage, tidal power, or biomass.

THE METHODOLOGY

Athena analysts are specialists in the growth of emerging markets. Athena’s *Research + Action Regional Competitiveness Program* aids leaders in growing

an industry in their region. The program combines emerging markets expertise with a systematic research methodology:

- Extensive review of secondary data and industry reports. Over the course of this project, Athena analysts located, obtained, read and reviewed more than 225 energy- and economic development-related research reports
- Multiple interviews, discussions and research roundtables with regional and national players, including energy companies, utilities, investors and policy/program leaders. Over the year-long project, Athena analysts directly interviewed more than 135 experts
- Attendance at key energy, grid and investment conferences. Athena analysts attended (and in many cases participated in) more than 105 individual sessions at three dozen different events
- In-house technical sessions with analysts to map information, generate market scenarios, and establish key findings
- Submission of draft reports to a review committee of advisors and industry experts

Market numbers are included in this report to provide the broadest sense of overall market potential. To size markets at this level, Athena serves as a meta-analyst, using a consensus approach:

- Identify top analysts covering each of the markets and secure their latest estimates
- Review the assumptions, models, and timing of projections through discussions with key analysts
- Explore areas of disagreement and reconciling the estimates against our own understanding of the marketplace to generate consensus figures

When commissioned specifically to provide market sizing or economic modeling for growth impacts on a community, Athena combines those broader perspectives with detailed modeling. In the case of market projections, we identify companies that are currently or will be top market makers; review market reports, SEC filings and other documentation; hold analyst briefings with key managers in those companies; conduct formal surveys with a representative group of additional companies, investors, and others attached to the market of focus; and build financial models. In the case of economic modeling for jobs and other growth impacts, Athena experts utilize modeling techniques standard and defensible in the research field. Those more exhaustive methodologies were not part of the funding or scope of this current project.

The Bibliography

Researchers and others interested in more details may request the bibliography as a separate document by sending email to FuelCells@theathenainstitute.com.

ABOUT CLIMATE SOLUTIONS

Climate Solutions is a public interest group that works to make the Pacific Northwest a global warming solutions leader. Since 1998, the group has targeted development of a clean energy technology industry cluster as a globally significant contribution the Northwest can make to reduce greenhouse emissions into the atmosphere. Climate Solutions generates leading-edge information and knowledge on clean energy technology and economic opportunities it presents. The organization issues reports, organizes conferences and builds cross-cutting alliances to further the goal of rapid energy transition.

ABOUT THE ATHENA INSTITUTE AND THE CENTER FOR SMART ENERGY

The Athena Institute is a research organization that helps executives and organizations find success in emerging markets. Its methodologies and insights have been implemented by many organizations, ranging from Fortune 1000 corporations to public policy agencies.

The Center for Smart Energy (www.centerforsmartenergy.com) is operated and maintained by Athena. It is dedicated to making North America the leader in Smart Energy innovation. Center activities provide information and tools to support investors, businesses, technology owners, and regional policy makers as they work toward commercial success in Smart Energy.

ABOUT THE ANALYSTS

PS Reilly is a noted expert, researcher, and advisor on commercial success in emerging markets. Her insights and predictions are regularly featured in articles, columns, and keynotes. Most recently she was Vice President of Emerging Markets for Ziff Davis Media, where she provided strategic advice to leading technology companies, including IBM, Peoplesoft, and many others. She has designed and led numerous large-scale research projects, from analysis of a single market, to investigating the economic impact of regional policy and infrastructure changes.

Jesse Berst is an internationally known technology and business analyst. He has authored or co-authored more than a dozen books on technology topics, written hundreds of articles for leading publications and keynoted dozens of business events in the U.S. and abroad. He combines two decades of professional experience in emerging markets with a personal interest in environmental and energy issues.

Jeff Canin brings 20 years of experience in the financial services sector. As a stock analyst with Hambrecht & Quist, Montgomery Securities and Salomon Brothers in San Francisco, he provided in-depth high tech research coverage to institutional

investors in North America and Europe. Since 1995, he has worked as a venture capitalist and consultant to emerging growth companies in the information technology and distributed energy fields.

David Amdal has a 25-year career heading international market research firms. He was formerly head of market research for BIS Strategic Decisions for the Asia-Pacific region, a \$30M operation with ten offices in seven countries. (BIS has since become Giga Information Group.) He has conducted 300+ market entry evaluations, identifying the sectors, customers, and communication with the strongest potential for success. Clients have included Apple, IBM, Canon, S.C. Johnson, Foremost, R. J. Reynolds, Heineken, Guinness, Bayer, BIC, Coca-Cola and Gillette, as well as regional development authorities.

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