POISED FOR PROFIT II:
PROSPECTS FOR THE FUEL CELL SECTOR

Preliminary Findings
Official Progress Draft
March 13, 2003

THE ATHENA INSTITUTE

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PREFACE TO THE OFFICIAL PROGRESS DRAFT

This document is part of a larger Poised for Profit II research initiative, an effort to discover near-term opportunities for the Pacific Northwest in energy technologies. (See the Appendix for more about the research initiative.) This document is one of four deliverables that make up the first Market Map module:

- Investigation of Investor Attitudes and Perceptions
- Inventory and Analysis of Existing Research
- Survey of Utility Needs and Positions
- Preliminary Analysis of Near-Term Opportunities

Specifically, this document is part of the Preliminary Analysis of Near-Term Opportunities. It reports on the fuel cell segment. Future documents will cover prospects in wind, solar and Smart Energy.

THE ROLE OF THIS REPORT

This report is *not* intended to represent a final decision. It is not for use to promote our region externally. It is an internal tool to help the Steering Committee decide where to focus the next stages of the research. The role of this preliminary analysis is to identify appropriate niches to investigate in more detail. Follow-on research can then examine those niches and select the most promising ones to pursue. (See Figure 1.)

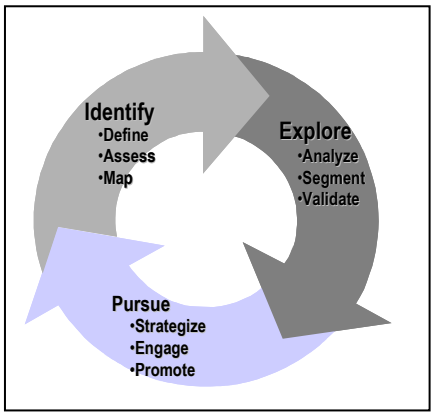


Figure 1
Preliminary reports identify market niches worthy of further effort. The Steering Committee decides which ones to explore in more depth, and which ones to pursue with strategies to engage the stakeholders and promote to the outside world.

THE ROLE OF FOLLOW-ON RESEARCH

Each research phase further narrows the focus. In the Identify phase, we choose which niches to explore. In the Explore phase, we validate the preliminary findings with further analysis and segmentation. In the Pursue phase, we work on the "finalists" and research the best ways to promote their success.

The Explore phase will include an Athena Regional Economic Potential (REP) appraisal of each niche. The REP methodology provides a numerical assessment and analysis of growth potential across a wide range of factors. It assesses a region's ability to support a particular industry through its stages of growth. Although REP scoring provides useful insights, 1) it requires more information than we have available at this point and 2) it would waste money to perform the detailed appraisal on a niche the Steering Committee does not wish to pursue.

THE ROLE OF THE STEERING COMMITTEE

The decision whether or not to move one or more fuel cell niches to the Explore phase rests with the Steering Committee. Current indications are that the Committee prefers to de-emphasize fuel cells, solar and wind in favor of Smart Energy. We will verify this decision before proceeding to the next phase, and modify our targets as requested.

INTRODUCTION AND EXECUTIVE SUMMARY

Can the fuel cell sector provide near-term jobs and growth for the Pacific Northwest? This document presents preliminary findings. As the project progresses, we may secure additional information that causes us to revise our current perspective.

We divided this document into four areas:

- **Market Overview** in which we assess the global growth potential, including economic development impacts and consensus sales projections. (Consensus estimates use an informed analysis of many different projections to arrive at a best-guess number.)
- **Regional Overview** in which we review the Northwest's assets and challenges in relation to the fuel cell sector
- **Regional Potential** in which we suggest where the Northwest could find near-term opportunities
- **Analysis and Conclusions** in which we present our preliminary opinions and recommendations

For those unfamiliar with fuel cells, we include an appendix with a Technology Overview as well as more detail on the Poised for Profit research initiative.

What exactly is a "near-term opportunity?" As used in this report, it refers to a market niche that can generate thousands of high-quality local jobs 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 so-called "latent entrepreneurs" to leave their current jobs and start up related businesses.

EXECUTIVE SUMMARY

The following seven paragraphs give a quick scan of our overall conclusions. We cover the details and the basis for these conclusions in the main body of the report.

The fuel cell opportunity is enormous measured on a global scale. Fuel cells will drive significant economic growth. The Pacific Northwest is one of a dozen regions around the world that could, in theory, become a global center of excellence.

The Northwest has great potential in at least three key market niches. Our research has uncovered three market niches that have potential for near-term growth and a good match with our regional strengths. They are 1) balance of

plant, 2) auxiliary power for transportation and 3) portable and backup power. We also found four opportunities with modest potential.

The Northwest has many strengths, including fuel cell research facilities, proximity to Vancouver, B.C. (arguably the most active fuel cell cluster in the world) and access to early markets such as heavy truck manufacturers, shipbuilders and forward-thinking utilities.

The Northwest faces many challenges, including assets that are scattered widely instead of clustered in one locale. The most daunting challenge is a lack of interest on the part of investors, entrepreneurs and elected officials. As a region, we do not have any of the necessary catalysts -- a major fuel cell company, a major fuel cell research center, a high-profile advocate -- to allow us to catch up with fuel cell front runners such as California, Connecticut, Michigan and Japan.

Barring an immediate upsurge in interest and commitment, the Northwest is unlikely to reach its potential in fuel cells. In theory, fuel cells could bring thousands of new jobs to the Northwest in the next five to seven years. In practice, we expect to see hundreds instead. We predict Vancouver, B.C. will enlarge its role as a global fuel cell center. We do not expect Vancouver's growth to have a major impact south of the border. We also believe that several regional companies will succeed individually. However, those islands of success will not provide the critical mass to fuel an engine of growth. The body of the reports explains the basis for these conclusions.

Only a major wild card will change the outcome. A wild card -- such as a major plant relocation or a major governmental program in support of fuel cells -- could provide the impetus to make our region a front runner. Prospects are slim for such an event.

The Northwest should focus its energy efforts in other areas. The Northwest should do everything possible to encourage entrepreneurial activities, including fuel cell companies. When it comes to special efforts to accelerate the fuel cell sector, the Northwest may be wise to focus on other energy sectors more compatible with historical strengths and current interests. We acknowledge, however, that this decision is a "close call" and we can provide further research into the most promising fuel cell segments should the Steering Committee so desire.

MARKET OVERVIEW

Powerful political and market forces will bring rapid growth to the fuel cell sector, with the major upswing beginning in 2004 for certain segments. This section explains the key market drivers, reveals the five major fuel cell markets and comments on the worldwide economic development potential. For a discussion of the regional implications, please see the two sections that follow. For an overview of fuel cell technologies and a breakout of the technology advantages for each type, please see Appendix A.

FUEL CELLS WILL SEE RAPID GROWTH, BEGINNING IN 2004

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.

President Bush has called fuel cells "the wave of the future," proposing funding of $1.7B over five years via a variety of programs. Other countries are aggressively pursuing fuel cells as an engine of growth. For instance, Japan far outstrips the U.S. in fuel cell research when private and public funding is combined. The European Commission provides as much as $70M per year on top of funding from individual countries. Canada -- with little more than a tenth of the population -- is expected to spend 50% as much for R&D as the U.S. In addition, Korea, Australia and Singapore are significantly increasing their investments.

After decades of ramping up, the fuel cell industry is poised for takeoff. Key products have moved from prototype to commercial shipment, with more coming online throughout 2003. Government support is growing. Public attention is increasing. When the economy recovers in 2004, at least three segments -- balance of plant, portable power and mobile power -- will begin their ascent. Other segments will follow shortly thereafter.

FUEL CELLS WILL DRIVE SIGNIFICANT ECONOMIC DEVELOPMENT

According to the Breakthrough Technologies Institute, worldwide fuel cell employment has already reached 13,000. The U.S. Department of Energy estimates fuel cells could add 750,000 jobs to the U.S. economy by 2030. If Washington and Oregon were each to receive 1/50 of that total, the region would gain 30,000 new jobs.

The government of British Columbia currently attributes more than 1,200 jobs directly to fuel cells. Observers expect that number to grow at least 20% per year over the next five years, based on fuel cells' growing commercial success and Vancouver's role as a global center. Those projections would bring the total to nearly 3,000. Spin-off jobs would conservatively number an additional 6,000 - 9,000.

By rough estimate, Washington and Oregon have some 300 fuel-cell-related jobs today. If the region were to aggressively pursue the fuel cell opportunity (something we do *not* expect to happen), that number could easily be 1,500 in five years, plus 3,000 - 6,000 spin-off jobs. Instead, we believe the five-year total will be closer to 600, with 1,200 - 1,800 spin-off jobs.

FUEL CELLS WILL GENERATE SIGNIFICANT 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 here.

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 1 -- 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 1000TM 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 of 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

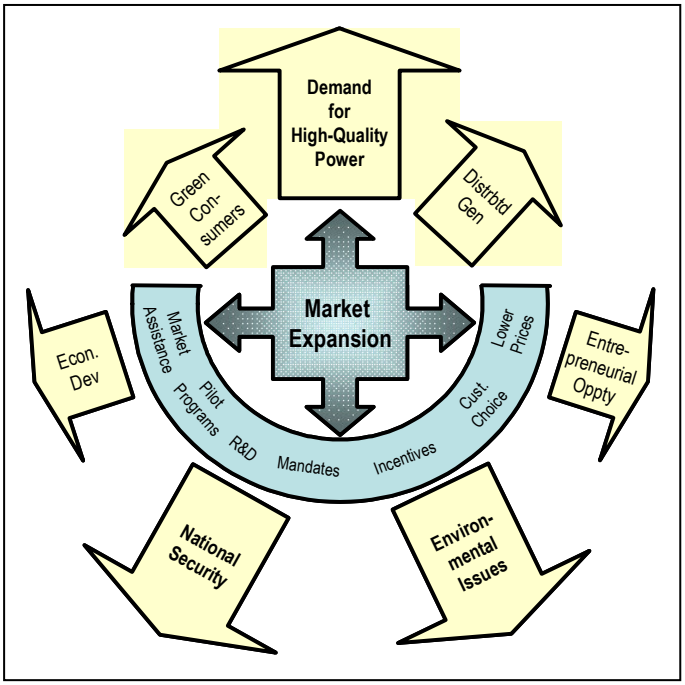
Tokyo Boeki. Spokane's Avista Labs has a distribution agreement in Italy and is actively seeking partners in other countries. And Vancouver B.C.'s Ballard Power Systems, the worldwide leader in PEM fuel cells, has long-standing agreements with automakers in the U.S., Europe and Asia.

The Northwest's strong port operations and status as a gateway to Asia could also be assets to regional companies wishing to export fuel cell-related products.

POWERFUL MARKET DRIVERS ARE INFLUENCING GROWTH

Powerful forces are converging to stimulate growth in the fuel cell sector, including at least three direct and four indirect drivers. A "direct" driver stimulates customer demand. An "indirect" driver stimulates government incentives or market forces, which then serve to motivate customers. (See Figure 2.)

Figure 2
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.



It is important to distinguish market drivers from technology advantages. As discussed in the Appendix, different fuel cells have different advantages. An advantage -- low emissions, let's say, or fuel flexibility -- may or may not translate into a benefit that drives market choices.

DIRECT DRIVERS OF DEMAND

These forces act directly to influence customer decisions. In approximate order of importance, they are:

A rising demand for 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

Growing interest in distributed generation. More and more utilities are considering distributed generation -- placing small power plants near the customer. DG minimizes construction time and construction costs, since plants can be up in months, not years. It also reduces the need for new transmission lines. Fuel cells are one of several technologies suitable for distributed generation.

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 forces work through various agencies to influence the market. In approximate order of importance, they are:

National security concerns spark massive government investment. 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. Together, these three national security concerns are leading to billions of dollars in research, development, pilot programs and market incentives.

Environmental regulations and incentives bring modest benefits. Fuel cells have not benefited from environmental concerns to the same extent as wind and solar. Nonetheless, the promise of emissions-free electricity has generated a growing number of incentives and tax credits.

Entrepreneurial opportunity brings choice and lower prices. 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.

Economic development efforts accelerate funding and startups. At least half a dozen regions have chosen fuel cells as an engine for economic growth. They are investing tens of millions in research facilities, incubators, investment programs and other mechanisms to accelerate commercial success.

Sidebar 2 -- Connecticut Opens Major Fuel Cell Research Facility

February 2003. The first fuel cell test stations have been installed at the new Connecticut Global Fuel Cell Center based at the University of Connecticut. The newly-created center of excellence is dedicated to developing advanced fuel cell technologies and educating industry-specific employees

MISSING MARKET DRIVERS

Consumers buy products that are cheaper, faster or better than the alternatives. They switch from old favorites only when something comes along that is far superior -- something that is so much cheaper, faster or better that it justifies the risk of abandoning a proven solution.

To date, fuel cells have made modest inroads into the realm of "better," but even then only for a few selected applications. Fuel cells still have a long way to go before they will appeal to mainstream buyers. The first personal computers were curiosities for pioneers and visionaries. Gradually they were picked up by early adopters. It was several years before they crossed the chasm and found success with mainstream buyers. They did so by creating tangible benefits and business advantages for customers. Fuel cells must still pass through these phases.

SIGNIFICANT MARKET BARRIERS REMAIN

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

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 from prototype to mass production. *Scaling up to mass production may prove 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 costs down 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. 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. (See Figure 3.)

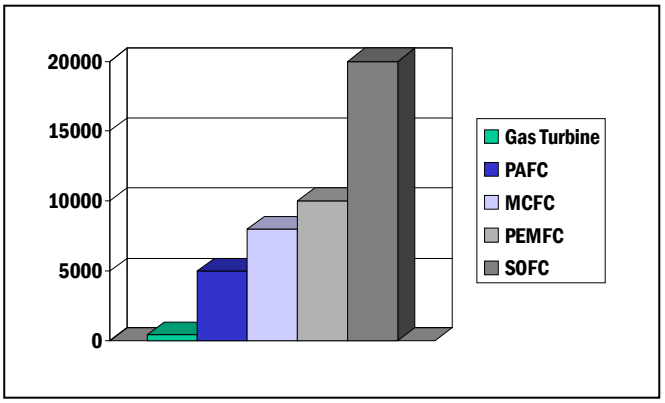


Figure 3
Initial Cost. Natural gas turbines (far left) are far less expensive than fuel cells. Capital costs must drop dramatically before fuel cells become competitive. The cost disparity is even worse for transportation applications. Source: Reed Global Advisors, September 2002

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 believes fuel cells could be come 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."

The disparity is made worse by the fact that nuclear and fossil fuel generating plants are a) fully amortized, b) subsidized and c) not required to build in the cost of their external effects -- pollutants, damage to health, global warming, disposal and mothballing at the end of their useful life, and so on.

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

mobile power. For instance, today's small batteries and photovoltaic strips come in at $4,000-10,000 per kW. (See Figure 4.)

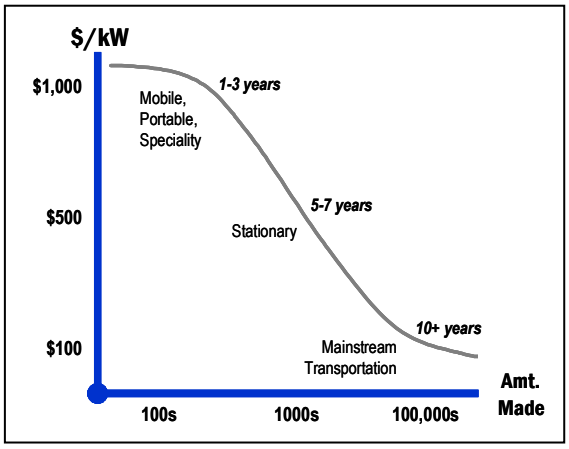


Figure 4
Cost vs. Volume.
Mobile and other specialty applications can justify a high cost per kW. Other applications are more price sensitive. They will not switch to fuel cells until manufacturing volumes climb, thereby lowering costs. Source: Center for Automotive Research at ERIM, Inc., 2001

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.

Sidebar 3 -- Vancouver, WA Company Pioneers New Approach to Hydrogen Production

Hydro Environmental Resources Inc. (HERI) of Vancouver, WA, believes it can bring low-cost hydrogen production to the ordinary consumer.

Current hydrogen production methods are costly, or require complex equipment, or cause pollution or all of the above. HERI believes it has found a new method that can produce enough hydrogen to power a fuel cell car in a facility not much larger than a backyard barbeque.

HERI's hydrogen "reactor" uses a proprietary blend of chemicals, metals and a catalyst to create a safe, electrochemical reaction that produces commercial grade hydrogen, water, heat and an inert waste.

The company's founder discovered the method accidentally while working to clean up toxic run-off from mines. He inadvertently produced hydrogen. Working backwards, he devised a reproducible formula.

They were wrong, and today fuel looms as the biggest unsolved issue on the way to the hydrogen economy. First comes the problem of obtaining hydrogen. There are large obstacles in obtaining hydrogen from fossil fuels. And even larger obstacles in producing it from water. Then comes the problem of transporting, storing and

dispensing it. In fact, the Department of Energy believes the U.S. public won't be able to obtain pure hydrogen through a mass infrastructure until 2030.

Institutional Barriers

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

Financial Barriers

Many of the barriers discussed above can be overcome with sufficient investment. 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. Newcomers have had little access to new capital. As a result, we have seen a slowdown in the formation of new companies and consolidation amongst old. This consolidation is likely to continue, even as the market strengthens for start-ups.

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 5.)

- **Backup and portable power** -- for standby electricity or off-grid use
- **Mobile power (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

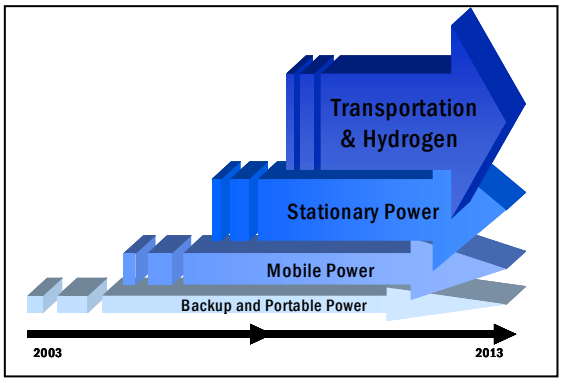


Figure 5
Fuel Cell Roadmap. Backup and mobile uses will lead the fuel cell sector. Transportation will catch on more slowly, but will eventually be much larger. The hydrogen infrastructure will develop in parallel with transportation. Source: Athena consensus estimate

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.

BACKUP AND PORTABLE POWER COULD REACH $3B IN A DECADE

This segment is made up of two related niches served by similar products. Fuel cell products in this segment typically replace battery banks or small generators.

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.

Figure 6
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

Portable power applications provide temporary standalone power to a location not connected to the electric grid. 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 and remote navigational aids and more.

The backup and portable power market is relatively price-insensitive. Current battery solutions only supply power for short durations 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. We believe shipments will ramp up more quickly, with initial quantities in 2004 and a significant upswing in 2005. We estimate this market could hit $3B by 2013. (See Figure 7.)

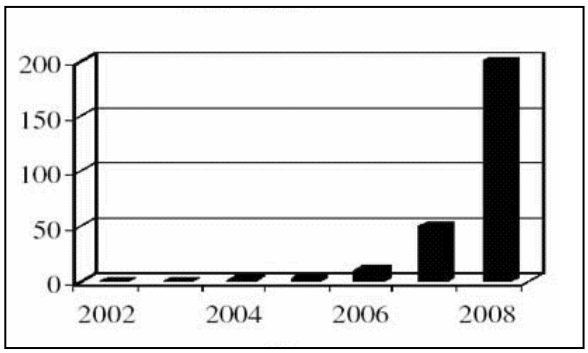


Figure 7
Global Portable Fuel Cell Unit Shipments 2002-2008. Athena believes growth will occur more quickly than these projections, growing significantly in 2005. Source: Allied Business Intelligence

MOBILE POWER COULD HIT $4B BY 2013

Often called *micro fuel cells*, 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 8.)

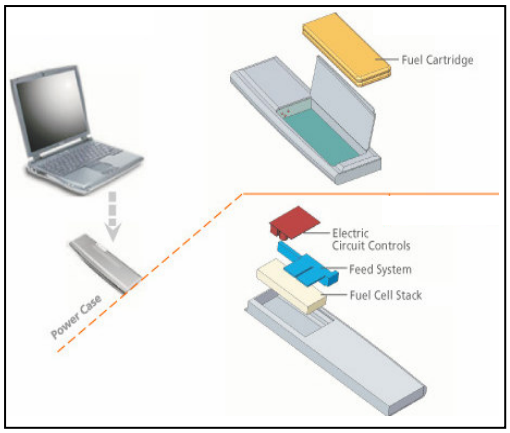


Figure 8
Mobile fuel cells could soon replace batteries in laptops, cell phones and other electronic devices, providing longer duration and quick "recharging" via a sealed fuel cartridge. Courtesy Neah Power.

Mobile power is likely to be the second fuel cell category to reach commercialization. Indeed, Toshiba announced in October 2002 that it intended to market a fuel cell-powered laptop computer by 2004. 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. Fuel cells also have an environmental advantage over batteries, which often require special disposal.

Although several companies are now shipping prototypes, much remains to be done to get traction. 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.

If progress occurs quickly, the mobile category could outpace portable and backup power. More realistically, it will trail by a year or two. Once it gets off the ground, it could become a large segment. The global market for batteries was $6B in 2000. Reed Global Advisors predicts that micro fuel cells could be a $1B market by 2005 or 2006. We project $4B by 2013.

STATIONARY POWER MAY REACH $12B IN 10 YEARS

Products in this category produce power for industrial, commercial and residential buildings. The stationary power segment will be led by four areas: 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 companies 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 9.)

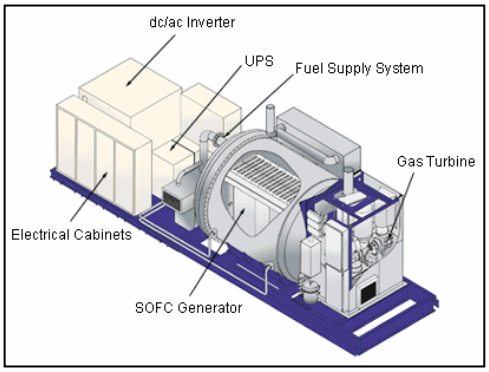


Figure 9
Combined Heat and Power Fuel Cell. High-temperature fuel cells can use waste heat to heat water or power a turbine, raising total efficiency as high as 85%. Source: Siemens Westinghouse

Remote power includes buildings that are 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 more quiet, clean and 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 typically provides all or most of the power for a factory, building, office park or military base. Today it is typically supplied by gas turbines or diesel generators.

Sidebar 4 -- Long Island Power Authority Buys 45 More Fuel Cells for Distributed Generation

February 27, 2003. 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.

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.

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 place fuel cells at various commercial locations.

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.

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 10.)

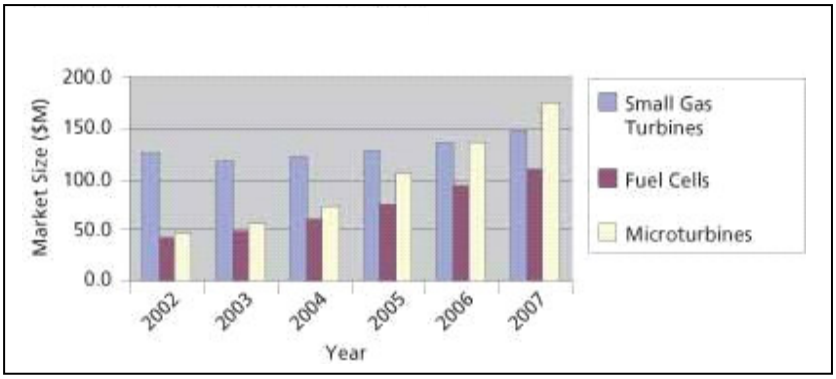


Figure 10
As distributed generation gradually becomes a reality in North America, fuel cells and microturbines will increase their market share versus traditional gas turbines. Source: Venture Development Corporation

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

- *Fuel Cell Today* predicted in late 2002 that the market for stationary units more than 10 kW would grow by 12% per year (from a very small base)
- Wintergreen Research says the stationary fuel cell markets was $45.2M in 2001 and will reach $11.4B by 2007
- Allied Business Intelligence believes the stationary market was at $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

We believe the biggest obstacles to the stationary power market lie not with the technology, but 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 $12B by 2013.

TRANSPORTATION COULD GENERATE $10B 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.

Figure 11
The advent of sexy fuel cell concept cars, such as the GM Autonomy, has led some to mistakenly believe that commercial models are just around the corner. Courtesy General Motors

The overemphasis on passenger cars has led most observers to ignore the tremendous 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
- Auxiliary power

- Industrial and campus applications (forklifts, utility vehicles, campus vehicles, airport tugs and ground support, golf carts and small-scale people movers)
- Scooters, Segways and fuel cell bicycles
- Small delivery trucks for urban areas
- Passenger vehicles and light trucks
- Heavy trucks and RVs

In particular, we expect strong mid-term growth for military vehicles, fleet operations and auxiliary power.

The military vehicles segment will 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 5 -- 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 pessimistic, 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 $10B by 2013.

Sidebar 6 -- California Fuel Cell Partnership

The California Fuel Cell Partnership is a public/private consortium of auto makers, 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.

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.

Put bluntly, nobody yet knows how, whether or when the hydrogen infrastructure will arise. In light of this extreme uncertainty, we we've made no attempt to project the growth of the hydrogen infrastructure or to consider it as 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. First is the existence of General Hydrogen across the border in Vancouver. 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. We question how much benefit BC 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. IdaTech of Bend, OR, has made fuel processing a core competency with an onboard processor that can operate on a variety of fuels. 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. (See Sidebar 3, earlier in this document.)

We also note that the Northwest has been mentioned as a possible site for experimenting with using renewable power to generate hydrogen. Hydroelectric dams often generate "throw-away" power late at night, when demand is low. Theoretically, that power might 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 also be tapped to create hydrogen. (See Figure 12.)

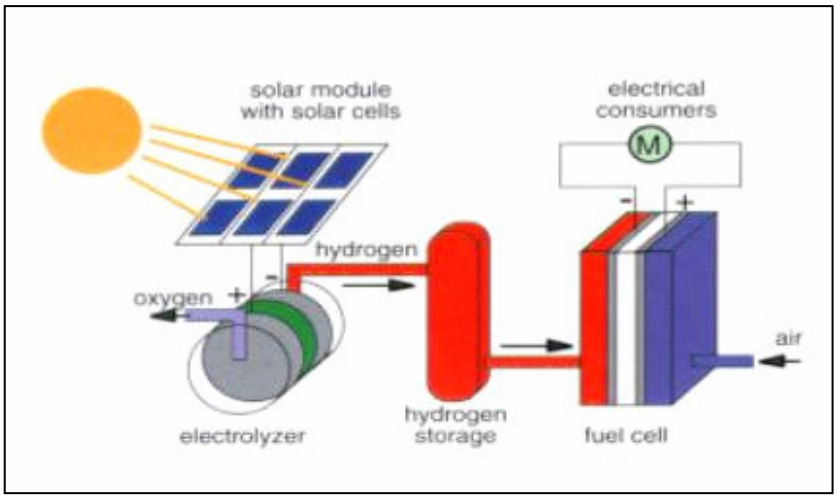


Figure 12
Some experts believe we can tap wind, solar and hydroelectric power to generate hydrogen and have suggested the Northwest as a place to experiment. As yet there is no evidence that such an approach would be economically viable.

THE OVERALL MARKET SHOULD REACH $29B 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 current 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 more than triple through 2005 to US$8.5 billion, and exceed US$23 billion by 2010,

We believe the fuel cell industry will grow to $29B by 2013, from less than $1B annually today. (See Figure 13.) Equally important, that growth will create many new companies and new jobs. By contrast, the wind industry will be larger by revenue, but will have fewer economic benefits. The wind industry has already consolidated to a few major players, almost all of them outside the United States.

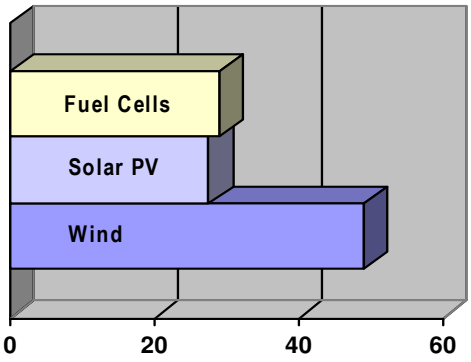


Figure 13
2013 Growth Projections. We project Fuels Cells to reach sales of $29B in 2013. For comparison purposes, we show the estimates from Clean Edge for Solar PV, at $27.5B, and Wind Energy at $49B.

FIVE CUSTOMER SEGMENTS ARE KEY TO THE MARKET

Five customer segments are key 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 (see below) summarizes key customer segments with regard to 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-power 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.	Currently, most research in this area is outside the region.
Government	Buildings	The federal government has already embarked on a program to make its 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 or state government, 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. 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 OVERVIEW

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.

THE NORTHWEST HAS SEVERAL FUEL CELL ASSETS

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

PROXIMITY TO THE VANCOUVER FUEL CELL CLUSTER

In theory, our close proximity to the thriving Vancouver fuel cell cluster should provide many synergies and opportunities not available to other regions. In practice, this may not be the case, as we will discuss.

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 Fuel Cells Canada

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

In addition to the many research centers across the border in British Columbia, the Northwest has several other research institutions with programs relevant to fuel cells.

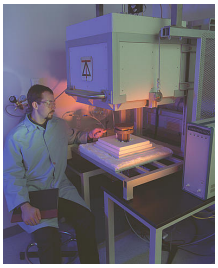
Pacific Northwest National Laboratory is one of the country's top fuel cell research centers. PNNL has a major facility in Richland, WA plus offices in Seattle, WA, Tacoma, WA and Portland, OR. PNNL has established a High-Temperature Electrochemistry Center with Montana State University to perfect the clean use of fossil fuels in fuel cells. Along with the Bonneville Power Administration, PNNL is also a leader in research on interconnection issues, many of which apply to use of fuel cells for stationary power.

The University of Washington and Oregon State University include fuel cell topics in their engineering and chemistry curricula.

The Washington Technology Center, located on the University of Washington campus, has a 15,000 sq. ft. microfabrication facility open to industry and academic users.

The Oregon Institute of Technology, which houses the Oregon Renewable Energy Center.

Sidebar 7 -- PNNL Establishes Role as National Center for Fuel Cell Research



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.

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.

PNNL continues to plan expansions to its facilities, including a sophisticated fuel cell observatory.

ENTREPRENEURIAL EXPERIENCE AND INFRASTRUCTURE

Washington State ranks very high in most measures of entrepreneur energy and infrastructure. Oregon typically ranks in the top third. The region 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 and Portland, 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.

EXPORT EXPERIENCE AND INFRASTRUCTURE

Washington often ranks at the top of all states in exports per capita. Oregon has made progress in recent years with the advent of semiconductor manufacture and other high-tech businesses. The region has outstanding port facilities and wide expertise in export issues.

The Northwest's location makes it a natural gateway to Japan and Asia. In the case of fuel cells, however, our gateway status could be misleading. However, many smaller Asian countries have only a modest interest in fuel cells. Other markets are quite large and quite interested-- China, Japan, Indonesia -- but relatively inaccessible.

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. The Pacific Northwest, however, does not have any geographical, historical or cultural ties to give it an inherent competitive advantage in Europe.

SYNERGISTIC INDUSTRIES

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

Aeropace. 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.

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. In the mid-90s, Washington State firms commanded three-fourths of the global market for power inverters, a necessary component for most solar, wind and fuel cell installations. In the late 90s, British Columbia firms purchased the top companies. They have since moved management to Canada, outsourced much of the manufacturing overseas and greatly reduced their presence in Washington. Nonetheless, we retain several small spin-off firms.

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, PGE and Avista
- Bonneville Power Administration, a national leader in power planning
- Northwest Energy Efficiency Alliance, which boasts one of the country's best track records 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 world's largest truck manufacturers, Paccar and Freightliner, and to the Northwest Alliance for Transportation Technologies. It also has programs in advanced transportation technologies at the University of Washington and the University of Idaho.

THE NORTHWEST IS A LOGICAL VENUE FOR MANY FUEL CELL ACTIVITIES

In terms of fuel cell chemicals and basic materials, the Northwest is unlikely to gain a significant role. Our region is, however, well-positioned for most other aspects of the fuel cell value chain. Virtually all of these activities a) coincide nicely with Northwest strengths and b) 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 SEVERAL DIFFICULT CHALLENGES

The Pacific Northwest has no systemic issues that prevent it from rapid success in fuel cells. Even so, the region faces several challenges that, taken together, are likely to retard its progress.

LACK OF AWARENESS

On one hand, the Northwest has Vancouver B.C. in its backyard, one of the world's largest fuel cell clusters. On the other, it has a President who champions fuel cells with big research dollars.

Nonetheless, the region remains largely unaware of fuel cells as a growth industry and a source of economic development. This gap is particularly acute with Northwest investors. Regional venture capitalists traditionally focus on software. They have largely ignored other regional strengths (such as aerospace, semiconductor manufacturing), other regional opportunities (such as Boeing spinouts) and other sectors (such as energy technologies).

We don't see this as a mistake. Venture capitalists must stick with their expertise. With a few exceptions, our region's VCs have little experience beyond software and related categories. It's not surprising that they pay little attention to opportunities from the energy space. However, our "software blinders" do mean we're likely to miss opportunities in other sectors.

GEOGRAPHICAL DISTANCE AND REGIONAL RIVALRY

Economic clusters occur when businesses exist in close proximity. Although the Northwest collectively has enough assets to become a force, those assets are widely scattered. Although videoconferencing ads suggest otherwise, it is difficult if not impossible to maintain tight interconnections without frequent face-to-face meetings.

Like all locales, we also have 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 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.

RESEARCH CHALLENGES

Although the Northwest has fuel cell research underway, it is scattered amongst several institutions. Even taken together, the total budget for fuel cell research in the Northwest is a small fraction of what's being spent in other regions. California

has four different universities with major, multi-million dollar fuel cell research operations. Connecticut and Michigan are centralizing much of their research at new facilities created and designed to assist fuel cell commercialization.

Much of the Northwest's fuel cell research is located at Pacific Northwest National Laboratories. Although PNNL is a tremendous asset, it is a federally funded facility with little impact on regional entrepreneurs and investors. By contrast, research universities such as Stanford and MIT are famous for their entrepreneurial clout. As one interviewee said of Stanford, "you can practically start a company in the halls between classes." PNNL lacks the national recognition of those public research universities, a reputation that draws entrepreneurs.

LACK OF ADVOCACY

Most regions that are experiencing early success in fuel cells have had a high-profile individual or organization leading the way. In Vancouver, fuel cell pioneers such as Geoffrey Ballard brought about what is now a global center of excellence. In Michigan, Governor John Engler has led the charge to make fuel cells part of the state's economic future. In California, the California Fuel Cell Partnership has been able to generate tremendous press coverage, not to mention financial support from automakers and fuel cell makers around the world.

Sidebar 8 -- 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, develop 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.

Washington and Oregon have made excellent progress in building and maintaining high-tech economies. Both states have excellent trade associations and economic development entities. Both states have governors with strong commitments to economic growth and high-tech jobs.

However, neither state includes fuel cells in their focus. As we've said earlier, that decision may well be a wise one. But even those who think we're wrong to ignore fuel cells need to recognize that a) fuel cells cannot reach their potential here without a strong advocate and b) our region has no such group or individual.

LACK OF INTEREST

For many reasons, including those discussed above, the Northwest does not exhibit the drive to pursue fuel cells with the necessary vigor to challenge the leaders. Indeed, it has already fallen behind other regions. (See Figure 14.)

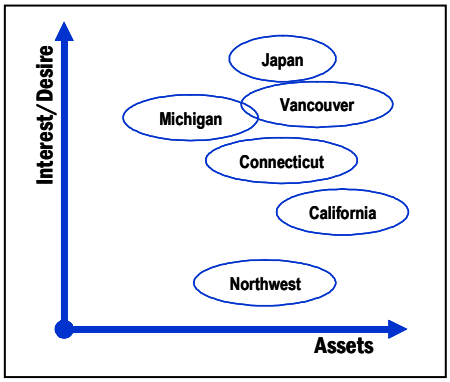


Figure 14
Fuel Cell Regional Positions. Although the Northwest has significant fuel cell assets, it has not shown the desire to be a player on the global scene. Meanwhile, other regions -- including areas with fewer assets -- are aggressively pursuing the opportunity with growing success.

This lack of interest manifests in several ways. We do not compete vigorously (or at all) to capture government grants and research awards. We do not have an incubator facility. We are not promoting ourselves to the fuel cell industry. Other regions have demonstrated a stronger understanding of the fuel cell opportunity and a greater funding commitment. Michigan has earmarked more than $40M for a state-of-the-art NextEnergy facility, much of it devoted to fuel cell research. Connecticut has broken ground on a new fuel cell research facility at the University of Connecticut and has earmarked millions for investment in regional fuel cell companies. In March, 2003, Connecticut hosted a high-level fuel cell investment summit. California, Texas, Pennsylvania, Japan and Colorado are some of the other regions in active pursuit.

LACK OF A CENTRAL CATALYST

A study of the literature on the growth of clusters reveals that successful clusters started with at least one central catalyst. In many cases, it is a large company that becomes a training ground for entrepreneurs. That is the role played for fuel cells by UTC in Connecticut and nearby states. UTC has been in the fuel cell business since the first space applications. Its early leadership has led to many spin-outs.

In other cases, it is a major research facility that acts as the catalyst. We are seeing several universities play this role for the California fuel cell industry, as Stanford once did for the Silicon Valley.

The Northwest has many fine companies and research facilities, but none that are in a position to play the catalyst role for fuel cells.

REGIONAL POTENTIAL

So far we've examined the global scene and our regional issues. 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 THREE IMPORTANT NICHES

At this early stage of the game, the Pacific Northwest could still gain a leading stake in the fuel cell sector. Our research uncovered three 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. Should the Steering Committee wish to go further, we can perform an in-depth evaluation of these or any other niches.

TABLE 3 -- STRONG OPPORTUNITIES FOR NORTHWEST FUEL CELL GROWTH

Opportunity	Assets	Challenges	Organizations
Balance of Plant	▪ 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	▪ Trace purchased by Xantrex, moving mgmt to Canada, mfg. overseas ▪ Applied Power purchased by Schott, moving many operations to CA ▪ Software blinders by investors	▪ Xantrex ▪ Outback ▪ Schott Applied Power ▪ Boeing ▪ Aerojet ▪ Aerospace Operations
Backup and Portable Power	▪ Spokane's Avista Labs shipping now ▪ B.C.'s Ballard Power Systems shipping now	▪ Few synergies between U.S. and Canada despite proximity	▪ Avista Labs ▪ Ballard Power Systems (B.C.)
Auxiliary Power	▪ Home to two of world's largest truck manufacturers ▪ PNNL leads related SECA initiative ▪ Strong aerospace expertise ▪ Legacy shipbuilding	▪ Theory only. No regional company attempting to commercialize ▪ Still not recognized as an important opportunity by fuel cell startups	▪ PNNL SOFC research ▪ SECA initiative ▪ Paccar ▪ Freightliner ▪ Northwest Alliance for Transportation Technology

BALANCE OF PLANT

A complete fuel cell system includes several components in addition to the fuel cell stack itself. These components are known collectively as *balance of plant*. (See Figure 15.) They may include a fuel processor or fuel reformer, fuel storage, power conditioning components (such as inverters and voltage controls), motors, compressors, blowers and fans, valves and piping, even conventional batteries complementary to the fuel cell stack.

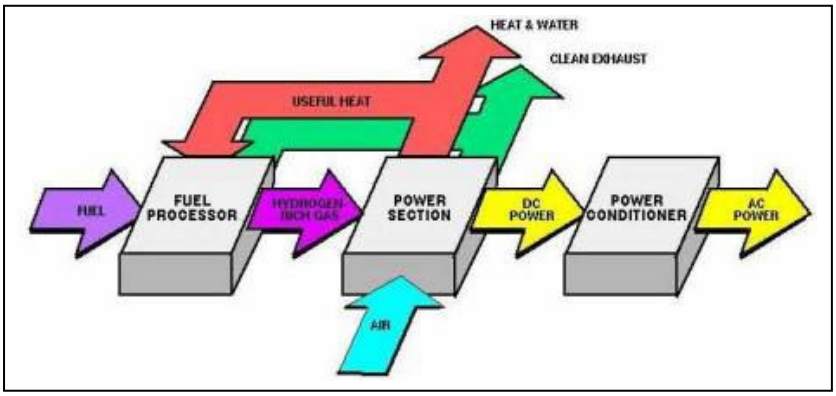


Figure 15
A typical fuel cell system includes a fuel processor, a fuel cell stack (labeled power section in this drawing), and balance of plant components including power conditioning, thermal management and water handling. Source: National Fuel Cell Research Center.

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.

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, and recreation, as well as business uses that need a transportable solution.

In this space, the Northwest's opportunities lie in its vendors. Avista Labs in is commercial production on transportable power units for the premium power niche. On paper, at least, Avista products seem to offer unique advantages, including a patented modular design. 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 -- further validation that this category has potential.

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.

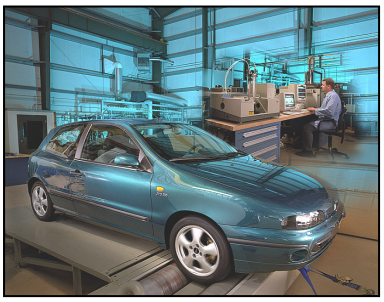


Figure 16
PNNL has partnered with truck makers, auto makers and Northwest aluminum producers to study advanced vehicle materials and emissions technologies. Source: PNNL.

Some of those synergies relate to ongoing work at Pacific Northwest National Laboratories. PNNL is a founding member of the Northwest Alliance for Transportation Technology, which is conducting research on lighter vehicles and on fuel cells. It is also a co-leader of the Solid State Energy Conversion Alliance. This national organization has an ambitious and well-funded program to dramatically 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 that the engine is 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. Observers believe 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 9 -- Oregon Fuel Cell Maker Gets Contract for Demonstration Military Vehicles

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).

The 2 kW systems will provide on-board power for "silent watch" field exercises in which quiet operation is essential.

The Army's Communications - Electronics Command (CECOM) is also field-testing IdaTech's FCS 1200, a self-contained fuel cell system

IdaTech is a Bend, OR, developer of fuel processors and PEM fuel cells. Its core capability is its patented fuel processing technology.

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. They 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.

THE NORTHWEST HAS AT LEAST FOUR MODERATE OPPORTUNITIES

Our early research has uncovered at least four 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
Mobile Power	▪ Region's "gateway to Asia" status could give access to Asian manufacturers ▪ Regional wireless, telecomm and gaming software companies have relationships with device makers ▪ Early stage startup Neah Power has hallmarks of a winner	▪ Most major distributors, partners and customers are located elsewhere	▪ Neah Power ▪ Frazier Technology Ventures ▪ WTC Microfabrication Lab ▪ PNNL research
Stationary Power	▪ Many 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	▪ 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)	▪ PNNL ▪ Idatech ▪ BPA ▪ Avista Utilities ▪ PGE ▪ PSE
Marine Transportation	▪ Seattle remains a major port and marine-industry hub with legacy boat-building operations ▪ Everett, Bremerton and Bangor Naval facilities ▪ PNNL researching SOFCs, a prime candidate	▪ Sector unlikely to see strong growth for several years, excepting pilot projects for the military	▪ Numerous small shipyards ▪ Naval bases and facilities ▪ PNNL
Truck Transportation	▪ Home to two of world's largest truck manufacturers ▪ Vancouver BC Hypercar Effort ▪ Aerospace expertise in materials fabrication, control electronics	▪ Auxiliary power will be an early market. Primary power will be much longer to develop for trucks, perhaps more than a decade away.	▪ Paccar ▪ Freightliner

ANALYSIS AND CONCLUSIONS

THE NORTHWEST IS UNLIKELY TO REALIZE ITS FUEL CELL POTENTIAL

To understand the Northwest situation, it is important to distinguish between *could* and *will.*

Each year, hundreds of economic development reports study the feasibility of a given industry for a given region. We have yet to see a "this one is not for us" recommendation. Inevitably, the report concludes the region *could* become a leader. Typically it recites the economic benefits, catalogs the region's strengths and concludes with a dire warning that the region will lose out unless it acts quickly.

We respectfully submit that what a region *will* do is more important than what it *could* do.

Our preliminary findings reveal the Pacific Northwest *could* become a leader in key sectors of the larger fuel cell industry. However, we believe the region is unlikely to seize the opportunity and may be wiser to focus its efforts on sectors that have more political, public, financial and business support.

As this report has shown, the issue is not with opportunities or assets. The region has more than enough of both. The problem lies in the lack of a central catalyst and the lack of a high-profile advocate. These gaps have led to a lack of awareness, interest and desire. To modify the old adage: "Where there's *no* will, there's *no* way."

ISLANDS OF SUCCESS ARE THE MOST LIKELY SCENARIO

We are skeptical of the Northwest's prospects to become a global leader in fuel cells. That doesn't mean we predict failure for regional fuel cell companies. Indeed, we think firms such as Avista Labs, IdaTech and Neah Power have strong prospects. But these firms are likely to succeed in an isolated fashion, without becoming the magnet for an economic cluster.

For instance, Spokane's Avista Labs may well become a leader in the portable and backup power market. That doesn't mean the Spokane region will automatically see the arrival of significant economic growth. Yes, Avista Labs itself would be a source of employment. But it might choose to source its materials and components outside the region. It might contract for manufacturing and sales in other states or countries. And it might become an acquisition target for an out-of-region company that would eventually move operations elsewhere.

THE IMPORTANCE OF FOCUS

The Northwest's lack of awareness and interest in fuel cells is not necessarily a bad thing. Focus is essential for success in economic development. It is often wiser to build on a region's preferences than to force feed a sector that has failed to capture the imagination of investors and entrepreneurs.

A WILD CARD COULD IMPROVE REGIONAL PROSPECTS

It's always possible a wild card will change the game. Some of the possibilities include:

- Relocation of a major fuel cell facility to the Northwest. For instance, if Siemens Westinghouse had opened its SOFC manufacturing plant in the Northwest instead of Pennsylvania
- A decision by a large Northwest company to spearhead the market. For instance, if Boeing were to spin out a fuel cell business in this region
- A government pronouncement locating a major trial in the Northwest. For instance, a large military rollout or a "fuel cell corridor" program
- Emergence of an influential advocate. For instance, a local fuel cell investment by Paul Allen or a major program by an elected official

We do not see any wild cards imminent on the horizon.

FOLLOW-ON RESEARCH

Given the shortage of funds, we believe it may be most appropriate not to go any further into fuel cells. In particular, we think the Smart Energy sector holds significant promise and will benefit from additional effort. However, we recognize that the Steering Committee may prefer to take one or more of the fuel cells sectors from the Identify stage to the Explore stage.

Research in the Explore phase focuses primarily in the following two areas:

1. MARKET & COMMERCIALIZATION INFORMATION

- Market potential overall
- Current market structure—existing businesses in and out of region
- Customer segmentation
- Customer feature/benefit drivers
- Pricing and cost analysis

- Production scaling assessment
- Distribution and sales channel assessment

2. Economic Development Information

- Workforce/competency issues
- Regional ability to support
- Economic development impact
- Clustering effects/multiple calculation
- Infrastructure issues
- Program/Policy recommendations

Next Steps

We will review this material with the Steering Committee at the next meeting, discuss the issues and ramifications, and move forward as instructed.

APPENDIX A - TECHNOLOGY OVERVIEW

TECHNOLOGY DEFINITION

Fuels cells combine a fuel (usually hydrogen) with oxygen to produce electricity. They do so without combustion through an electrochemical process that has 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 17.)

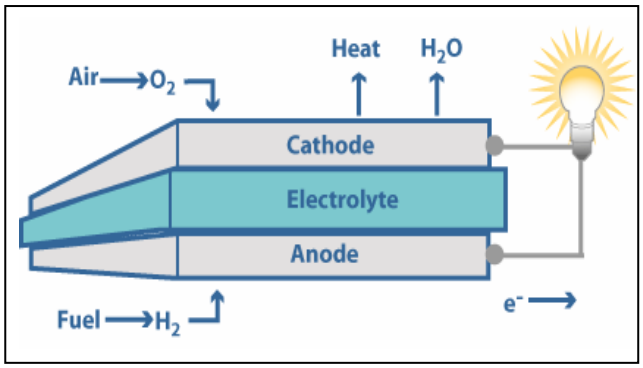


Figure 17
Fuel Cell Schematic. Fuel enters at bottom where a catalyst strips off the electrons. The resulting ion migrates through the electrolyte. The electrons flow through a wire to the other side, creating a current. Source: National Fuel Cell Research Center

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. (In some cases, it's the oxygen ion that migrates.) 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 you put in fresh hydrogen.

A single fuel cell generates very little power. However, like batteries, individual fuel cells can be combined into stacks with an effectively 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.

TECHNOLOGY APPROACHES

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

Low-temperature fuel cells produce anywhere from a few watts to a few thousand watts. They are best suited for mobile, portable, backup and premium power. High-temperature fuel cells make sense for large-scale stationary power. For power plants meant to be left on, high-temperature fuel cells provide the option of *combined heat and power*.

Some types are in commercial production already. Others are still in the laboratory. Table 5 shows the six 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	Effi-ciency	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 company press releases

PHOSPHORIC ACID

Capable of producing 200-1000 kW, PAFCs are the only commercially available fuel cells to ship in any volume. However, the technology is limited in its uses and, more importantly, in its potential for cost reduction. Suppliers are switching away from this technology.

ALKALINE

Used extensively in space applications, AFCs are efficient, compact and reliable. They are so expensive that most people consider them impractical for the 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, MOFCs 30-50,000 hours and SOFCs 50-100,000 hours

This type of fuel cell also benefits from the DOE's Solid State Energy Conversion Alliance (SECA). Under this program Siemens Westinghouse and several other industry teams have been selected to develop small low cost SOFC systems that are intended for remote, residential and transportation application. The long range

goals of the program include developing 5-10 kW systems that have a cost in high volume manufacture of as low as $400/kW.

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

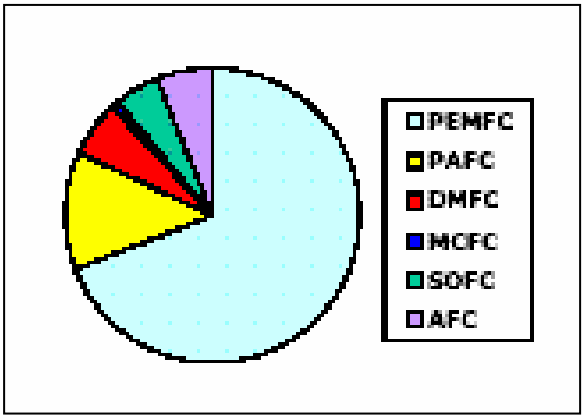
PROTON EXCHANGE MEMBRANE

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. More sensitive to contaminants and must use pure hydrogen.

PEMFCs currently gets 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 18.)

Figure 18
Worldwide fuel cell installed base by technology.
Source: Fuel Cell Today, November 2002



DIRECT METHANOL

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

POROUS SILICON

A form of DMFC that substitutes silicon in place of a polymer membrane. The inventors, Neah Power of Bothell, WA, argue that silicon enables higher power density and more efficient operation. They also believe it can be manufactured at

low cost by taking advantage of the decades of research into silicon and semiconductor manufacture.

TECHNOLOGY ADVANTAGES

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** -- provide 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

On their own, fuel cells typically achieve 40-60% efficiency. When the excess heat is captured, the total efficiency can exceed 80%. Traditional power sources typically range from 20-40%. A typical internal combustion engine operates at 20% efficiency. (See Figure 19.)

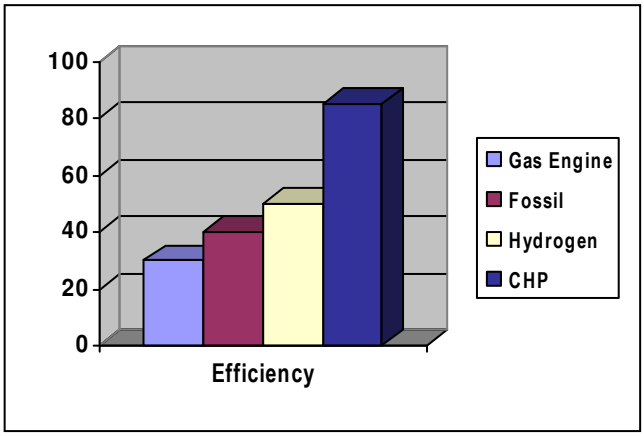


Figure 19
Efficiency Comparison. Fuel cells are inherently efficient. When powered by fossil fuels they achieve 40% efficiency. Use of hydrogen raises the figure to 50% or higher. When their excess heat is captured for combined heat and power, total efficiency can exceed 85%.Source: Breakthrough Technologies 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 power plant creates less than one ounce of pollution per 1,000 kilowatt-hours. Internal combustion systems generate 400 ounces (25 lbs).

However, 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 some pollutants and greenhouse gases. Even in that case, however, fuel cells represent an improvement over internal combustion engines.

MODULARITY AND FLEXIBILITY

Because fuel cells stacks can be mixed and matched to suit customer power needs, they offer unmatched 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 20.)

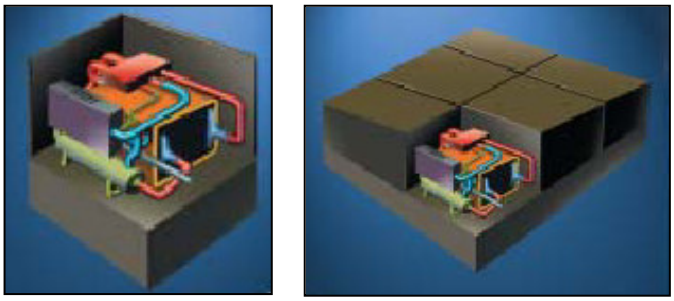


Figure 20
Fuel cells are inherently modular. They can be built as small, standard units, then combined to suit the customer's current needs.
Source: Solid State Energy Conversion Alliance

Fuel cells also offer a faster 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 and 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.

APPENDIX B - PROJECT OVERVIEW

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 was released by Washington Governor Gary Locke and prominent economic development and technology leaders in November 2001.

A new partnership of co-funding organizations has come together to launch *Poised for Profit II* -- follow-on research that will support the next steps toward a world-class clean energy industry in the Pacific Northwest. This large research initiative, launched in November 2002, will produce a series of reports containing critical information necessary to help investors, entrepreneurs, policymakers and others build a thriving clean energy industry cluster. It will also produce tools for promoting the Pacific Northwest as a leading region to locate and develop clean energy businesses.

ABOUT THE ATHENA INSTITUTE

The Athena Institute is a research organization that helps executives and organizations unleash strategic leadership in emerging and growth markets. Athena's comprehensive programs are based on ongoing studies of the factors that drive business success. Its Market Power program helps governments, regions and corporations find victory in emerging markets. Its Partner Assets program assists regions and corporations looking to partnerships as a source of competitive advantage. Athena's methodologies and insights have been implemented successfully by leaders across many types of companies and organizations, ranging from Fortune 1000 corporations to public policy agencies.

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.

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.

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.

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.