# FUEL CELLS AT THE CROSSROADS

## ATTITUDES REGARDING THE INVESTMENT CLIMATE FOR THE US FUEL CELL INDUSTRY AND A PROJECTION OF INDUSTRY JOB CREATION POTENTIAL

A Study from the Breakthrough Technologies Institute

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# EXECUTIVE SUMMARY

Fuel Cells at the Crossroads examines financial community and fuel cell industry views on the investment climate for the fuel cell industry. It also explores the investment history of the US fuel cell industry and projects potential future job creation. The scope of the study included the transportation, stationary power generation and portable sectors.

Interviews were conducted with industry and financial experts. The results of the interviews provide a snapshot of industry perspective just prior to President Bush's endorsement of a hydrogen economy in his 2003 State of the Union address.

*-- Crossroads Issues --*

*There is great uncertainty about the future of the US fuel cell industry. Generally, however, respondents were cautiously optimistic.*

*The Japanese and European governments appear to be committed to their fuel cell industries. The US government has a significant opportunity to support the development of the domestic fuel cell industry.*

In April 2003, we conducted a spot check to test whether the State of the Union address had changed opinions. We found little change among the financial and investment communities, but some guarded new optimism among industry leaders.

The general outlook of our sample was cautiously hopeful. There is no question, however, that the current climate is one of great uncertainty, particularly when compared with the enthusiasm that existed just a few years ago. Among other things:

- Respondents generally believed that the energy industry will undergo profound change over the next few decades, resulting in some form of hydrogen economy. They acknowledged, however, that huge technology and cost hurdles must be overcome to achieve a hydrogen economy.

- Respondents were worried about the future of the industry, including timeframes for market development, foreign competition, technical problems, and the current poor investment environment.

- Respondents generally believed that the US federal government must provide strong leadership to ensure American leadership in the fuel cell industry. They believe that governments in Europe and Japan are highly committed to fuel cells, thus providing European and Japanese companies with significant advantages.

- Respondents frequently mentioned several areas of concern, including the situation in Iraq, the increased commitment to fuel cells in Europe, and recent actions by Toyota and Honda.

The following are highlights from the key areas of this study.

*Attitudes of Key Market Players*

- Corporate strategic players will be the major source of fuel cell funding in both the transportation and stationary sectors. Public market funding of the fuel cell industry will be minimal and venture capital support will be limited, probably primarily to the portable sector. In the future, there might be a role for raising capital through venture investment and equity issuance in the public market but only with a much clearer outlook to profitability.

> -- *Crossroads Issues* --
>
> *Attracting future investment will require a clearer path toward profitability. This means*
>
> - *Better performance and reliability*
> - *Higher volume and lower costs*
> - *Proven demand, perhaps beginning with government purchases*

- The economic downturn has had a significant detrimental effect on perceptions of American leadership and on the financial health and stability of smaller fuel cell companies. The result has been closures, consolidations and mergers.
- Corporate cost cutting measures, which tend to gravitate towards R & D and operations less critical to a company's immediate profitability, have affected even larger companies involved in fuel cell development.
- Successful commercialization will depend upon improving performance, demonstrating reliability, increasing volume, reducing costs, and exercising sound business judgment and marketing.
- Lack of consumer demand is a major concern and there is little clarity about who or what will provide the catalyst to develop markets for fuel cell products.
- Although the US is perceived as the leader in the stationary and portable sectors and competing for the lead with the Japanese in the automotive sector, that lead is highly tenuous, and there is great uncertainty about whether it can be maintained.
- The majority believes that strong US government support is needed to successfully commercialize fuel cells, particularly in light of the strong support being provided in Asia (principally Japan) and Europe. Clear policy direction and investment support is imperative if the US fuel cell industry is to maintain a leadership role.
- Potential catalysts for fuel cell industry investment include legislative action, such as that taken by California and New York, the political climate in Iraq and the Middle East, and changing energy prices.
- Speed of market development was most frequently cited as the best proxy for a change in the investment environment.

*Fuel Cell Investment and Employment History*

To assess investment and employment in the fuel cell industry, we conducted a literature search, reviewed various public documents, and gathered information during our interviews. The following are the results of our analysis.

- Private sector investment has consistently surpassed U.S. federal government support since at least 1996. Private sector investment reached a peak in 2000 at $1.1 billion and has declined significantly to less than half that level in 2002. Meanwhile, federal government funding grew steadily from $114 million in 1996 to $159 million in 2002.

*-- Crossroads Issues --*

*Private sector investment has declined significantly. America's future role in the fuel cell industry depends on the government's willingness to support the industry at this critical time.*

- Public equity investment across all three sectors peaked in 2000 at $585 million. Between 1995 and 2002, the stationary sector raised more than twice as much funding as the transportation sector in the public equity markets.

- Between 1997 and 2001, corporate venture funding averaged at least $100 million annually, and most of this funding was directed toward the transportation and stationary sectors. In 2002, corporate venture funding declined significantly and was directed almost exclusively toward the portable sector.

- Venture capitalist or angel funding averaged $17.6 million annually over the last six years (with the exception of 2000), mainly for the stationary and portable sectors. In 2000, $81 million in angel funding was raised by two stationary power companies, and this amount was excluded from the average.

- Internal R&D programs were funded at roughly $300-400 million per year, principally in the transportation and stationary sectors. Exact numbers were difficult to obtain, and little information was available for the portable sector.

- We estimate that total employment in the US fuel cell industry in 2002 was approximately 4,500 to 5,500.

    - Venture or angel-backed independent private companies employed only a few hundred people, primarily in R&D. Nearly three quarters of those were in the stationary sector with the remainder in the portable sector.

    - Other independent private companies, funded primarily by strategic players, were estimated to employ at least 500. These jobs appear to be allocated approximately equally among the transportation, portable, and stationary sectors.

- Public "pure play" fuel cell companies employ nearly 2,000, divided fairly equally between the stationary and transportation sectors.

- Internal employment by major strategic players in the US fuel cell industry is estimated at roughly 1,500 to 2,000 presently, apparently divided fairly equally between the transportation and stationary sectors.

- Fuel cell component manufacturers appear to employ roughly 400-500 people focused in areas such as the development of MEAs and membranes and bi-polar plates.

*Future Outlook*

We examined three scenarios for North American fuel cell market development through 2021: a base case, a high capitalization case, and a low capitalization case.[1] We found that as many as 189,000 jobs may be created by 2021 as a result of the fuel cell industry. Of these, roughly 75,000 would be directly associated with the industry and the remaining 113,000 would be indirectly associated with the industry.[2] The results are presented in the following table.

**Potential Job Creation --2021**

| | High | Base | Low |
|---|---|---|---|
| Transportation | | | |
| Direct | 16,981 | 15,472 | 10,468 |
| Indirect | 25,471 | 23,208 | 15,702 |
| Stationary | | | |
| Direct | 47,095 | 41,333 | 29,269 |
| Indirect | 70,642 | 61,999 | 43,903 |
| Portable | | | |
| Direct | 3,063 | 3,033 | 2,973 |
| Indirect | 4,594 | 4,549 | 4,459 |
| Major Components | | | |
| Direct | 8,321 | 7,438 | 5,235 |
| Indirect | 12,481 | 11,157 | 7,852 |
| Total | | | |
| Direct | 75,460 | 67,276 | 47,945 |
| Indirect | 113,188 | 100,913 | 71,916 |
| Grand | 188,648 | 168,189 | 119,861 |

[1] The base case reflects the status quo or current expectations for market development. The high capitalization case reflects a more optimistic outlook for investment with market development accelerating 2-3 years in the transportation sector, 1-2 years in the stationary sector and 1 year in the portable sector. The low capitalization case reflects a more pessimistic outlook with delays in the market development of 5-7 years in the transportation sector, 2-3 years in the stationary sector, and 1-2 years in the portable sector.

[2] The estimate for indirect job creation is based upon a study conducted by Price Waterhouse in Canada, which found that applying a multiplier of 2.5 to direct fuel cell employment will derive a reasonable estimate of total job creation for the Canadian fuel cell industry.

Among other things, we concluded that:

- Over time, employment in the transportation sector may surpass that in the stationary sector. However, because the market for fuel cells in transportation is expected to take a long time to develop, the job projections in 2021 are relatively low for the transportation sector.

- Although products for stationary applications are being introduced now, significant cost reductions are necessary to penetrate the market. The timeline over which this is expected to occur is much longer than that for portable applications.

- The portable sector is expected to penetrate the market more rapidly than the transportation and stationary sectors, in part because some products for portable applications are near commercial viability. However, the overall premium battery market is much smaller in size than the automotive and stationary markets.

## SECTION I: INTERVIEWS WITH MEMBERS OF THE FINANCIAL COMMUNITY, INDUSTRY LEADERS AND FUEL CELL CONSULTANTS

We conducted over 40 telephone interviews with members of the financial community and with fuel cell industry leaders and consultants. A number of general observations permeated the results:[3]

- **Leadership and investment often are perceived in terms of companies, not countries, making it difficult at times to distinguish among national efforts.** The larger companies often are global, with operations located in multiple countries. Many partnerships involve companies from different countries. There also was frequent discussion regarding intellectual capital located in one country and manufacturing ultimately located in another country.

- **Concerns about reliance on foreign oil may encourage investment in fuel cells**. Some speculated that awareness of US energy dependence on the Middle East will increase as tensions continue in that region, providing political support for alternative energy options. Indeed some felt that, without a highly visible, dramatic threat, development of fuel cell products and the hydrogen economy would be very slow in coming.

- **Europe and Japan are highly committed to fuel cells and this is seen as a threat to the US industry**. The European Union's increased spending on fuel cells was seen as an indication that Europe is strongly committed to fuel cells.[4] Appraisals of American leadership were clearly impacted by this

*-- Crossroads Issues --*

*Key points:*

- *Foreign competition enjoys strong commitment to fuel cells by their governments*
- *The US government has an opportunity to make a similar commitment, and this commitment is urgently needed*
- *Concerns about foreign oil may create significant opportunities*

[3] It should be noted that our interviews were completed before the State of the Union address in which President Bush pledged $1.7 billion in research to develop clean, hydrogen powered automobiles. In order to determine how significant an effect this pledge may have had on the funding outlook for the fuel cell industry, and subsequently the conclusions drawn in this report, we had follow up conversations with over 33% of our original interviewees. In general, we found that opinions regarding the outlook for the industry had not changed much if at all. Several participants noted that if there was an impact from the announcement, it is that increased public awareness of the issue may spurn some additional investment in the longer term assuming that the visibility results in investors becoming more educated about hydrogen and associated fuel cell related uses. Details regarding the subsequent conversations are included in the last portion of this section.

[4] According to the Wall Street Journal, the EU indicated "plans to spend €2.12 billion ($2.09 billion) from 2003 to 2006 on renewable energy development, mostly technologies related to hydrogen. That's up from €127 million spent between 1999 and 2002."

announcement. Respondents often couched their answers in a "before the European announcement" and "after the European announcement" framework.

Toyota and Honda's recent leasing of fuel cell vehicles in the US and Japan had a similar effect on our respondents. Although the outlook and time frame for commercialization of fuel cell vehicles is somewhat unclear, respondents generally felt that both Japanese industry and government have the commitment necessary to become the first in widespread commercialization in the automotive sector.[5]

The following is a discussion of our interviews. We have divided this portion of our report into seven sections:

A. Who, what and how: the target groups, methodology, time frame
B. General outlook
C. Investment climate, current and future
D. American leadership in the fuel cell industry
E. The role of the US government in advancing fuel cell technology and commercialization
F. Views on alternative energy and competing technology
G. Impact of the State of the Union address and subsequent administration statements.

A list of those interviewed and our discussion guide are included in Appendices D and E.

[5] It is worth remembering that responses clearly reflect where the interviewee "sits." Only a small percentage of those we interviewed represent businesses where fuel cells are the main focus. Venture capitalists, even those focused exclusively on energy technology, invest with an eye to making money in a relatively short timeframe. They are looking for **business** deals where products will return revenue and profits in the foreseeable future. Investment analysts are assigned to cover industries and/or companies where there is significant public interest and stock market activity. As is well known, there are few investment houses where the fuel cell industry is tracked by analysts; that number has decreased in the last two years and shows little sign of revitalization.

Many of the industry leaders we contacted work in companies where fuel cells are only a sideline to their employer's main business. These companies, which clearly have the capacity for long term investment, may see fuel cell products as the inevitable replacement to what they currently manufacture or as a means of significantly improving the products they now market. But currently their focus is on what today's market is buying or on modifications of current technology.

Eliminating the aforementioned groups, we are left with fuel cell companies and fuel cell consultants, people whose professional lives are singularly focused on fuel cells. Interviews with people from these categories comprised perhaps one fourth of our sample. It seems to us that this sample composition is appropriate for realistically viewing a world where fuel cells are not on the horizon of the average consumer.

*A. Who, What and How: the Target Groups, Methodology, and Time Frame*

This study targeted the investment community and the fuel cell industry. Within the investment community, we targeted venture capitalists and investment analysts. Within the fuel cell industry, we targeted fuel cell industry leaders and consultants to the fuel cell industry.[6]

The majority of financial interviews were with venture capitalists, in part because few investment analysts still cover the industry or companies within the industry. The fuel cell industry interviews were divided among large, diversified corporations and smaller companies that focus exclusively on fuel cells.[7]

Each interview was designed to be a relaxed discussion to determine the interviewee's:

- general view of the direction of the fuel cell industry given the current investment climate;
- view of how each sector (portable, stationary and vehicular) might develop;
- opinion of where they saw the United States on the leadership continuum with other nations, including Europe and Japan;
- view on the current and desired roles of the federal government in bringing fuel cell products to market.

In some cases, we also asked the respondents for their best estimates of market size, cost and timeline. Generally, however, they were reluctant to provide this information.

*B. General Outlook*

The general outlook of our sample was very cautiously hopeful. There is no question that the high expectations and optimism of the 1990's has been significantly reduced.

- **The climate is one of great uncertainty.** This is evident even among the most optimistic respondents. People are uncertain about timeframes, markets, sectors, world leadership – in short, about almost everything.

[6] Our goal was to complete roughly 15 interviews with venture capitalists and investment analysts, 12 interviews with industry leaders apportioned among the portable, automotive and stationary sectors and 4 interviews with consultants. In the end, we exceeded our goals and interviewed close to 40 people.

[7] Industry interviewees included company presidents and investor relations representatives. Venture capital interviews were almost exclusively with high level executives, partly because these firms are generally small and do not have many employees in mid-level management. Investment analysts had either focused upon the fuel cell industry or currently cover particular fuel cell companies as part of their portfolio. The fuel cell consultants were either individual consultants or the heads of their organizations.

- **There is no consensus on a wide range of issues.** For example, respondents did not agree when commercialization will occur, which sector will ultimately be most successful, and what needs to happen before commercialization can occur.[8]

- **There is a consensus that the energy industry will be undergoing a profound change over the next few decades.** A majority believes that the result will ultimately be some form of a hydrogen economy. Exactly what form this will take is unclear. As one interviewee said, "The jury is still out. Until products are selling, you just don't know."

- **The US federal government has a significant opportunity to promote the development of the domestic fuel cell industry.** Among other things, respondents felt that the government should become an early consumer of fuel cell products.

*1. Financial Community*

The financial community believes that the fuel cell industry is not likely to be profitable in the near future. Thus, although there is substantial interest in the energy sector, they are cautious and quite conservative regarding fuel cells.[9]

- Fuel cells are seen as a *replacement* technology, not an *additive* technology. Generally, the financial community sees this as highly significant, because it is much more difficult to substitute one technology for another – particularly when there is not a high level of dissatisfaction with the existing technology. For example:

*-- Crossroads Issues --*

*"The winners will have the best management, not necessarily the best technology."*

*Government can be the "swing factor" in bringing fuel cell products to market. What's needed?*

- *Clear, supportive policy;*
- *Tax incentives and subsidies;*
- *Demand creation through government purchasing.*

[8] For example, a sizable portion of our sample felt that the portable market offered the greatest immediate promise of commercialization. Many felt that the technology, which might eventually replace conventional batteries, would be available and on the market by late 2004. This group felt that users of cell phones (particularly those in countries like China where residential phone service is almost nonexistent) constituted a huge potential market. Many also felt that users of PDAs, laptops and other high tech equipment would appreciate the capabilities fuel cells offer in the portable arena. An equal number of respondents felt that the portable market had been over-hyped and would not materialize at the level some have projected. One consultant noted that only one of ten laptop users reports having used battery power. These people also pointed out that users of cell phones, laptops and PDAs do not feel highly inconvenienced by having to recharge their equipment. They questioned whether there was real need and/or a significant market for the advantages promised by portable fuel cells.

[9] One can say with certainty that every one of the firms we spoke with is doing business differently today than they were two years ago. Most are concentrating on nurturing existing investments and are very cautious when it comes to making new investments.

    - People like the cars they have. To consider fuel cell vehicles, they need to be in the same price range and offer the same service and amenities.
    - Inexpensive electricity is hindering demand for energy alternatives. This was even reflected in the portable sector, where some people were doubtful about the need to replace existing battery technology.

- The internet bubble created and took companies public that should never have existed. They described a climate where capital was available for almost anything, and they noted that now that things have returned to normal, companies and products are being realistically valued. None saw the possibility of the previous climate returning.

- There is great uncertainty regarding the current economic climate. Some felt that the economic downturn had had a "huge" affect on the fuel cell industry. Others felt that the current downturn will have little effect because commercialization is still many years away. Most agreed, however, that one result may be that the fuel cell industry ultimately will be controlled by large existing companies. As one said, "The big guys can afford to wait it out. The small companies were not key to succeeding anyway."

- There is considerable skepticism about how serious the automobile and oil companies are about fuel cells. Some noted that they are "hedging their bets"; most noted that, even though these companies know change is coming, they are not in any hurry to hasten it. All of this makes for a very murky future, one that is interesting, but creates a wait and see attitude among potential investors. "Everything is just too early," said one.

- A number of respondents pointed out that creating fuel cell products is very complicated and difficult to make profitable. Challenges include getting the volume up high enough to bring the costs down, the difficult technical problems still to be solved and figuring out how to create markets for these products.

- According to one respondent, "The winners will have the best management, not necessarily the best technology." They generally see and hear from people with a scientific background; they have trouble envisioning the business case.

- Government investment can influence the outcome. The financial respondents generally agreed that government can be the "swing factor" in bringing fuel cell products to market. Here they were referring not only to the creation of supportive, clear policy, but also to the use of tax incentives, subsidies, and purchasing power.

*2. Industry Leaders and Consultants*

Respondents from industry and the consulting field expressed many of the same views as those interviewed from the financial community. Their knowledge, however, was deeper and broader. And, significantly, they were slightly more optimistic.

*-- Crossroads Issues --*

*Hydrogen may be inevitable, but the "breakthroughs have stopped," largely because private capital has dried up.*

*Government is the key to commercialization and success of the industry.*

- The hydrogen economy is inevitable. Most agreed that solar and wind energy were complementary technologies with limited applications.

- There was a general view that fuel cell cars will eventually become a major part of the mass market. The outlook for the stationary and portable sectors is less clear.

- Many felt that other technologies might emerge to challenge fuel cells, particularly because the timeframe for commercialization is so long. For example, some noted that internal combustion engines could eventually become very low emission. There was little discussion, however, about the energy security implications of continuing to use internal combustion engines and not switching to fuel cells.

- Big companies will ultimately be the winners. Some felt that this was inevitable and acceptable. Others noted that sacrificing the smaller players stifles innovation and entrepreneurship, slows things down, and may result in products of lesser quality. On the whole, respondents felt that the consolidation and downsizing is disappointing, but that the damage is mostly in the short term.

- The US economic downturn has had a significant impact on the fuel cell industry and American leadership has been threatened as a result. According to one, the "breakthroughs have stopped." Companies are seriously affected because capital is much less available. Some companies have folded, other have merged. Most expect this trend to continue. There was also agreement that during the good times, money had been wasted and that companies were now running more efficiently.

- Government involvement is key to commercialization, particularly in the transportation and stationary sectors. Government must go beyond traditional roles like R & D, tax incentives, and subsidies. Many insisted that government needed to be the first major customer for fuel cells thus helping, among other things, to drive prices down to competitive levels. Respondents also saw the government playing the leading role in educating the public about fuel cells, building confidence in the technology, and creating consumer demand.

Respondents often noted that Japanese and European companies were able to rely on their governments, and asserted that US companies were not. Some mentioned that the US government supported a wide range of potential technologies instead of focusing on the most promising. Others noted that the Japanese, for example, were not as severely affected by economic cycles because their government supported them in all climates.

- Some fuel cell products, such as distributed fuel cells with combined heat and power (including residential heating) and cell-phone batteries, will be better suited to countries other than the US. Cheap energy in the US could reduce demand for fuel cells. Moreover, US industry leaders often partner with non-US companies, thus potentially preparing for entry into foreign markets.

- Timeframes for market development are uncertain. Generally, the respondents suggested that portable fuel cell products would reach the market in two to three years; that stationary fuel cell products would be widely commercialized within the next five years; and that fuel cell automobiles would be available to consumers within fifteen to twenty years.

*C. Investment Climate, Current and Future*

The respondents agreed that the changing investment climate has negatively impacted the entire fuel cell industry, and this impact has been greater than in many other industries. Small fuel cell companies have been particularly hard hit. Respondents also agreed that the conditions that existed during the internet bubble are not likely to return.

*1. Financial Community*

Respondents were quick to offer reasons why they would be reluctant to invest in fuel cells. This was true even among venture capital groups whose investment funds focus on energy. Among the reasons offered:

- It is impossible to value fuel cell companies. During the "bubble," everything looked good to investors, but now we are back to conventional ways of valuing companies.

- The fuel cell industry needs good management, not just good scientists.

- The portable sector is the only area where it appears that investment is justified in the near-term. Venture capitalists typically make investments with

■ *Crossroads Issues –*

*Energy security and air quality concerns may create opportunities for fuel cells. To take advantage of these opportunities, the fuel cell industry must recover from the hype of 1999-2001. Government support is a key to repositioning the industry for success.*

a five-year time horizon and it is simply too early for most venture capitalists to invest.

- Overall the economic climate is bad; the investment environment is flat at best.

- The fuel cell industry lacks credibility as a result of over-promising and hype.

- To make fuel cell products competitive with existing technology, costs must come down. It is difficult to envision how this will happen.

- No market currently exists for most fuel cell products – except possibly in the portable sector and in isolated segments of the stationary sector.

- Concerns exist about how and when remaining technology problems will be solved.

Despite the lengthy lists of deterrents, financial respondents suggested that the following events might benefit the fuel cell industry:

- Over the next few decades, substantial changes may occur in the electric utility industry. These changes could be similar to changes that have occurred in the telecommunications industry and may create opportunities for investment.

- States may follow California by adopting stringent emissions controls.

- Developments in the Middle East may cause dramatic price shifts or increased awareness and pressure to lessen dependence on foreign oil.

- US, European, and Japanese activities are creating an undercurrent that something big must be happening.

- Overall, most said that they would recommend investing in energy, but would do so very cautiously.

**The transportation sector.** As one respondent said, this is the "big brass ring." The financial community knows that there is significant money to be made if and when fuel cell cars become commercially competitive.

Respondents noted that the automobile industry is in considerable trouble overall as the result of the economic downturn. They question the commitment of the industry to developing fuel cell technology.

Respondents showed substantial concern about how the infrastructure for hydrogen fuel delivery will be developed and financed. "So many problems have to be

solved for fuel cell cars to become a commercial reality," said one, "and the capital requirements are so great."

Although estimates of when fuel cell cars would be on the road and in what numbers varied widely, significant market penetration generally was not envisioned until 2020. One rather optimistic prediction suggested that by 2030, 50% of new cars sold would be powered by fuel cells.

There was also a divergence of opinion about whether fuel cell cars would ultimately be one option among several or the only option. Many noted that there would be significant competition to fuel cell cars and that no one can accurately predict who will win or what the mix will be.

Respondents agreed that investment in fuel cell automobiles would come from the major auto companies themselves. This field is unlikely to attract much, if any, venture capital. The automotive sector is by far the most technically complex and the funding required, according to some, is disproportionately high.

**The stationary sector.** The future for the stationary sector seemed much more opaque to the financial community. Respondents seemed to know less about this sector than either of the other two.

There was agreement that more investment could hasten commercialization, but most felt that there was too limited a market in the US for significant residential use. They noted that the grid covers almost everyone and that power is cheap. Certain markets do exist for high quality power, but the market is limited. Generally, people agreed that as costs come down, back-up power from stationary fuel cells might become attractive to a larger market. Some respondents pointed out that it would take years of testing to prove that stationary fuel cells were reliable and that, until then, they would not have credibility in the marketplace.

**The portable sector**: Many respondents noted that this is the only sector currently compelling to venture capitalists and outside investors. Indeed this may continue to be the case for the foreseeable future. The reasoning was that the market for portable fuel cell applications currently exists, the technology is relatively simple and the cost of development is lower compared to the other sectors. Respondents said that this sector will get upwards of 80% of any outside investment money. They noted that the trend towards and interest in miniaturization help make this sector attractive.

Respondents noted that funding from within the industry is now flat and that the economic downturn has hurt this sector, though probably less than the other two. Some suggested that prototypes could be available within a year and that commercialization could occur some time in 2004.

It should be noted that enthusiasm for portable fuel cell products varied widely as did views on what kind of product could succeed. "Everyone is still looking for the killer application," said one respondent.

*2. Industry Leaders and Consultants*

Industry leaders and fuel cell consultants echoed many of the sentiments of the financial community. There was general agreement that capital has dried up and that the economic downturn has had a major effect on the industry. Respondents saw investment by major corporations as flat, at best. Outside investment has come nearly to a halt. They also noted that R&D is a "controllable" cost and easy to cut.

*-- Crossroads Issues --*

*Small companies are losing in the current economic environment. Large, diversified companies "can afford to wait it out."*

*Uncertainty over future government commitment is contributing to unwillingness to invest in the industry.*

*"The Japanese can afford to be as aggressive as hell and that's how they're behaving."*

Some small companies have been taken over or closed. In an industry that requires "a large amount of capital and a long time frame," the current environment favors the "big guys." "They can afford to wait it out," said several respondents. One small company executive reported that two years ago, he approached eight venture capital groups for funding and received funding or an offer of funding from six. More recently, he approached 54 different groups and only one is willing to invest.

Despite the downturn, industry leaders frequently mentioned the pent up interest in the energy sector. Some feel disadvantaged compared to the Japanese who they see as having plenty of money and/or financial support of their government. "The Japanese can afford to be as aggressive as hell," one said, "and that's how they're behaving."

Competition for capital was also seen as coming from other technologies. "It looks increasingly possible to produce a combustion engine with very low emissions," said one. "Why wouldn't that be easier to market and cause less disruption?"

Respondents also noted other barriers to investment. These center on the inability to answer tough questions and to see clearly into the future of the industry. They need a clearer picture of how the markets will develop and whether fuel cell products will dominate the market or simply be an option. Questions about the role of government and how volume will be increased and costs reduced are also widespread.

Finally, industry leaders understand that "you have to prove you can do it" to attract investors. This is viewed as necessary for both developing the technology and marketing fuel cell products.

Industry leaders noted that large companies, seeking higher returns, may avoid additional investments in fuel cells, at least in the near term. They may revisit the issue when the time frame for fuel cell investment is shorter and the prospects are more certain. They know they have to get the volume up and the costs down in order to attract more money. New projects are heavily scrutinized.

Some noted that, with additional funding, the time frame for commercialization would be moved up by several years. One very pessimistic respondent suggested that the whole industry could disappear if money continues to be scarce. Another noted, "you could buy the whole thing for about $2 billion anyway as it is." "It was too easy to get money during the 'bubble'; now it's too hard." Several noted that until the economic climate improves, ideas and entrepreneurs are not likely to get much attention.

**The transportation sector.** Respondents agreed that the automotive sector is "where the money is." Yet many, including a representative from one automobile manufacturer, feel that the general slump in the automobile industry is causing automobile companies to scale back on fuel cells, despite public statements to the contrary. Others note that the level of investment by the auto companies would be higher in a better economy. There is increased interest in hybrids because "you can make money off them right now." There is agreement that venture capitalists are unlikely to be players in this sector.

Estimates of when commercialization will occur and what eventual market share fuel cell powered cars will have ranged widely, but all were fairly long range. One respondent sees fuel cell cars having 50% of the new car market in 2030. Some respondents see 2020 as the date by which fuel cell vehicles will be commercially available; others see them available to consumers by 2010 or 2015. Some see fuel cell powered automobiles as eventually dominating the market; others see them eventually as being one of several viable options for consumers.

**The stationary sector.** Respondents agreed that this sector has been hard hit, but noted that the costs involved in developing stationary fuel cell products are not nearly as high as those that will be incurred by the automotive sector. Some respondents also note that cost targets in this sector can be more easily achieved. Several observed that utilities, which have been key to development to date, are no longer investing heavily. Respondents saw venture capital as playing only a limited role in future development.

Respondents see the stationary sector developing to be commercially viable over the next five years. Improvement in the investment climate could move the time line ahead by two or three years. Major concerns exist over reliability and cost. Most consider the major potential for growth in the market to be replacement of back up units in institutions such as hospitals.

**The portable sector.** Industry leaders noted that this sector requires the least investment and faces the fewest technological challenges. Although industry leaders expected to see venture capital invested in the portable sector when the economy begins

to improve, most see the bulk of investment funds coming from within the industry itself. Industry leaders expect to see some commercialization, or at least prototype fuel cell products, in the next year.

Yet even in this promising field, some note that funding is flat and small companies are in trouble due to the economic downturn. Moreover, there was disagreement over the future potential of this sector. Some believe that fuel cell technology will revolutionize the way portable products are used. The need, they say, is "compelling." Others offered comments like, "Batteries do a great job."

*D. US Leadership in the Fuel Cell Industry*

All respondents were asked who they considered the world leader in the fuel cell industry. Although answers varied widely even within sectors, it is evident that the US has not firmly established itself as the clear world leader in the fuel cell industry – even in the stationary and portable sectors where the US is most often mentioned as being the leader.[10]

*-- Crossroads Issues --*

*The US is not a clear world leader in the fuel cell industry. Whether it becomes a clear world leader depends to a great extent upon whether the US supports its domestic fuel cell industry.*

Many noted that this is not a race among countries, but among companies, and companies often had partners from a country other than their own. Some wanted to talk about North America rather than the US due to the huge, looming presence of Ballard. There was some agreement on the fact that big companies – throughout the world – will be winners in the competition for leadership. Many respondents mentioned the recent actions by the Japanese and the EU.

Respondents considered a number of factors important in determining leadership. Among criteria mentioned were:

- amount of investment;
- proximity to production;
- infrastructure in place;
- level of government support and commitment;
- financial muscle;
- clear understanding of how commercialization would be achieved;
- cost; and
- reliability.

Most respondents felt that the economic downturn had a significant detrimental effect on the perception of US leadership. Some noted that the downturn hit the

[10] Respondents noted that identifying leadership in the stationary and portable sectors is easier because companies are farther down the road toward commercialization than in the vehicular sector. To some extent, leadership in that sector is judged based on performance of prototype vehicles.

component manufacturers and smaller companies particularly hard. A few respondents felt that the downturn had not affected US leadership at all.

Respondents noted that bankruptcies and consolidations create a perception of weakness, which is exacerbated by the over-promising and hype of the last few years. Respondents saw the US as being in a "shakeout" period. They worry that the US will not continue to be at the forefront of the industry.

Respondents also see the economic downturn as an opportunity for the Japanese or Europeans to overtake the US. They see the Japanese industry as being "sheltered" from the economic climate.

*1. Financial Community*[11]

The financial community generally viewed the US as leading the stationary and portable sectors but not the automotive sector. It was clear, though, that significant threats were perceived to the US leadership position.

*-- Crossroads Issues --*

*"The Japanese will be the ones who will engineer a breakthrough."*

*"No one in the US is willing to take the risk."*

*"The winners will have the best management."*

For example, Ballard and the Japanese were frequently mentioned in the interviews. One respondent argued that the US is hurt "because we don't have a Ballard." Japanese success in automobiles and portable electronics was seen as foreshadowing their performance in fuel cells. "The Japanese will be the ones who will engineer a breakthrough," said one respondent. The Japanese government is viewed as more focused and supportive of Japanese industry than the US government is supportive of US industry.

Similarly, Europe is seen by some as providing the incentives and subsidies needed to expeditiously advance the fuel cell industry. "No one in the US is willing to take the risk," said one. Some mentioned that the climate in the US is just not the same as elsewhere when it comes to caring about the environment and noted the US refusal to sign the Kyoto Protocols. "We are spoiled," said one. Another noted that Europe and Asia are ahead because of their openness to supporting demonstrations.

The financial community uniformly noted that commercialization potential is a key ingredient of global leadership. The "winners will have the best management," said one. Phrases like "the ability to bring product to market", "based on the business path," "ability to see beyond R & D", were often repeated.

[11] As in other areas, the financial community tended to have more generalized views on US leadership in the fuel cell industry. One should keep in mind that most of the venture capitalists interviewed have not invested in fuel cells and are looking at this question from some distance.

A majority viewed the economic downturn as negatively impacting the perception of US leadership. More, however, noted that the downturn has fostered a perception of weakness in US leadership. People know that venture capital money is typically critical to helping early stage companies move toward commercialization; they also know that that this money is not available presently to most US fuel cell companies. Several respondents noted that views on American leadership have been affected by promises not kept; they feel that this is connected with the collapse of the internet "bubble" that, in some ways, folded all technology development into its wake.

Some said that the downturn has had no effect on fuel cell development in the US. One noted that this industry has a different, longer term horizon than most and is not affected by the traditional financial cycles.

**The automotive sector.** The Japanese (Toyota and Honda) and the Ballard/Daimler Chrysler/Ford partnership most often were mentioned as leaders in this sector. A significant minority mentioned that the US may be tied with one or another of these players. It is important to note the US is not considered out of the running.

**The stationary sector.** The US (specifically United Technologies Corporation) is most often mentioned as the leader here, but almost always with qualifications. Some feel that other parts of the world are better suited as markets for stationary products and that, as a consequence, Europe or Japan may catch up.

**The portable sector.** The US is most often mentioned as the leader here, but people feel that the Japanese are poised to catch up. Two respondents felt that the US will develop the technology in this sector, but that manufacturing will take place in Asia.

*2. Industry Leaders and Consultants*

Overall, respondents felt that leadership was shared by the US[12] and Japan. They frequently note that the situation in all three sectors was in flux and that things probably would change. As one industry leader said, "What matters is who leads when there is an actual market. The leaders who best apply the technologies will win."

*-- Crossroads Issues --*

*"What matters is who leads when there is an actual market."*

*Although the US may have better technology at the moment, Japan and Europe appear to have a strong commitment, focus, and desire to commercialize fuel cells.*

The consensus was that the US was ahead in developing technology but that Japan and possibly Europe appear to have great commitment and desire to commercialize fuel cells. Respondents frequently cited Japan's strong commitment as making them less susceptible to distraction caused by other technologies or economic trends.

[12] In citing the US, respondents often referred more broadly to North America because of Ballard. Thus, many saw leadership split between North America and Japan, not the US and Japan.

**The automotive sector.** The Japanese were frequently mentioned as the leaders in the automotive sector. Some respondents felt that the US/North America and Japan were tied for leadership. General Motors often was mentioned in connection with US leadership, but respondents were uncertain about GM's long term commitment, in part because of the weakness of the entire US automotive market. "Detroit is having trouble selling cars and making profits period," said one. "That's got to be the prime concern." The whole industry is "struggling. They're pulling back," said another.

On a positive note, some felt that recent announcements from the Japanese and EU governments will put competitive pressure on the US industry. For example, the Japanese announcement helped push Honda and Toyota to begin delivering cars which, in turn, puts pressure Detroit to speed up its efforts. Respondents felt that this pressure was healthy and would push everyone toward commercialization more quickly.

**The stationary sector.** The US, specifically United Technologies Corporation, was generally named as the leader in the stationary sector. Respondents noted, however, that there is no guarantee that the US will remain the permanent leader. Some noted that Asia was hard to gauge. One respondent named Japan and Canada as the leaders. Others noted that Europe and Asia offer better possibilities for development of fuel cells for the residential markets.

**The portable sector**. The US tentatively emerged as the leader here, but Canada, Japan and South Korea were seen as nipping at its heels. There was less knowledge about the status of development in Asia than there was in the vehicular sector. Frequently people mentioned the popularity of cell phones in Europe and Asia and the lack of residential phone service in some Asian countries.

*E. Role of the US Government in Advancing Fuel Cell Technology and Commercialization*

We asked respondents whether the US government has done enough to promote the development of the fuel cell industry.[13] The following are general observations taking into account comments from the entire survey sample:

- US policy on fuel cells is still forming and there are great opportunities for strong leadership. Respondents felt that government policy has a significant role to play in accelerating the commercialization of fuel cells. These policies include research support, purchasing fuel cell products, and even regulatory activity, such as controlling emissions from existing technologies.

[13] Specifically, we asked: "What about the role of the US government is playing in fuel cell development….can it be improved? Or is the government doing all that can realistically be expected?" We emphasized "realistic" expectations in hopes that these fairly sophisticated people would provide thoughtful responses to our question rather than wishful thinking. It is important to stress that these interviews were completed before the President's 2003 State of the Union Address. Nevertheless, it is interesting to note that the financial community was less aware of US government activities to promote the development of fuel cell industry. Industry leaders offered the most specific and detailed answers. Consultants' responses tended to be fairly brief and generalized.

- The US government has significant opportunities to support the fuel cell industry.[14] The current economic climate likely influenced this view. In other portions of the interview, there was a good deal of discussion of small companies going out of business, of the move towards consolidation, etc. To some extent, when private capital dries up, there is no other place to turn but the government. However, respondents did not focus exclusively on money.

- The US government is seen by many as key to commercialization—at least in the stationary and vehicular sectors. Government actions and policy are seen as dramatically affecting the timetable for commercialization. There is a feeling among many that the portable sector can develop with private support.

- The US government should transition from being the R & D provider to becoming an early adopter. The government gets credit for having done excellent R & D work over the years.

*-- Crossroads Issues --*

*Strong, supportive government policies and actions are the key to success for the US fuel cell industry.*

*There are significant opportunities for government, including becoming a purchaser of fuel cell products.*

*"We need to fund this effort big – to solve environmental problems and oil dependence."*

*"We need to take a stand on this."*

- However, respondents frequently referenced the enormous buying power of the US government as a way to address the "chicken and egg" problem (i.e., the need to build higher volumes to lower costs).

- Government policy can address the need for national (or "homeland") security, for energy independence, and for a cleaner environment. Some mentioned that the rest of the world takes environmental concerns more seriously than we do in the US.

- There is an awareness of and agreement with the recently released "Fuel Cells and Hydrogen: the Path Forward" among many respondents.

*1. Financial Community*

A high percentage of the financial community mentioned the need for policy clarification. A high percentage also mentioned the government's R & D work, mostly in a positive way.

[14] A small minority felt that the government should do nothing different or do nothing at all. The latter response comes from those in the venture capital community who believe everything should be left to the private sector.

Views differed as to specific actions the government should take. A few respondents suggested that government could break the "logjam" associated with the need for lower costs and higher volume. Some also felt that the government ought to "take care of its own" as they see the Japanese government doing. It was noted that this is particularly important in the current economy. According to one respondent, the "private market is a long ways off—subsidies are needed now."

Finally, some raised the international climate and the importance of becoming energy independent. "We need to fund this effort big – to solve environmental problems and oil dependence," said one. "We need to take a stand on this," said another.

*2. Industry Leaders and Consultants*

The general consensus was that the government's current activities are good. Respondents also noted that there remain significant new opportunities for leadership. Many believed that the federal government should make a transition from being primarily an R&D supplier to becoming an early consumer of fuel cell technology. Some suggested that the US should undertake an effort similar to the massive highway building project adopted under Eisenhower. Most were more conservative, suggesting tax breaks, grants and subsidies.

Many believed that the government could break the "chicken and egg cycle" so often mentioned in this series of interviews. The government is a "huge consumer with direct buying power," according to several interviewees. "The government can create demand." This demand is necessary to bring costs down to the level where fuel cell products become commercially viable. "Otherwise, this chicken and egg cycle thing could go on forever," said one respondent.

Respondents often mentioned activities of the Japanese and Europeans. "It's a race to reduce costs to make these businesses viable," according to one executive. Several noted that the US government offers little support compared to governments in Europe and Asia. "Our government takes a very traditional approach," said one "and that's not enough."

Strong sentiment among many was that the US government should "take a stand." People wanted the government to choose a clear direction, "pick a fuel," choose among technologies, and stop "playing all horses." According to some, current policies are leading to confusion and, given the current climate, confusion is adding to an already slowed pace of development.

It should be noted that two industry leaders felt that what the government was doing had little effect on the development the fuel cell industry. They felt the industry was developing totally due to efforts of the private sector and that government should not do anything.

*F. Views on Alternative Energy and Competing Technology*

Respondents generally believed that the energy industry is in a fundamental transition that will take decades. They found fuel cells relevant and very interesting. However, as one respondent put it, it's like "being a blind man in a fog". There is great uncertainty about how everything will sort out, who will be the winners, and who the losers. On balance, more respondents lean toward the view that ultimately hydrogen will be a winner and fuel cell powered products will have a place in our energy future, though not necessarily an exclusive one.

*-- Crossroads Issues --*

*The energy industry is "going through fundamental change that will have a profound impact."*

*Fuel cells likely will emerge as a key component of America's energy future.*

*Fuel cells are competing against entrenched and relatively inexpensive technologies.*

*1. Financial Community*

Interest in the energy sector in general, and in alternative energy solutions in particular, is high. According to one venture capitalist, "This is a huge industry going through fundamental change that will have a profound impact."

This does not mean, however, that enthusiasm for investing in energy is equally high. Indeed these people are very cautious and see the situation as lacking clarity and producing confusion in the short term. They also see little short term return on investment, particularly when it comes to fuel cell technology. They have assumed a "wait and see" stance. At least one respondent compared activity in this sector to changes that occurred in the telecommunications industry.

One pessimistic thread ran through several interviews. People pointed out that fuel cells, and similar technologies, are competing against technologies that are cheap and entrenched. The demand for change, they say, will be hard to develop and, according to one analyst, change will come only if there is a national energy crisis. People are generally happy with their cars and gas stations, and electricity for residential and business use is relatively inexpensive in most parts of the US.

Several respondents noted that wind and solar power already are commercialized and both offer better prospects for investment. For example, wind turbines are in use all over Europe. According to one venture capitalist, wind and solar energy are growing at a compound rate of 25% a year. Another noted that solar is growing at an annual rate of 30% in Europe. Several respondents also noted, however, that applications of wind and solar energy may ultimately be limited.

The financial community showed significant interest in the "next generation of entrepreneurs" and what they may produce. "Competition will be very tough for the fuel cell industry," said one investment analyst, "because there's a whole new crop of people thinking about all this."

One venture capital firm that we interviewed focuses on "power management" as a whole. They are looking at any power applications that require less energy. They noted that fuel cell products currently in development have high risk profiles and there is no clear roadmap.

*2. Industry Leaders and Consultants*

Industry leaders and consultants generally were more knowledgeable about competing technologies and echoed the high level of interest in the energy sector as a whole. "Everyone is in the same place," said one industry leader, "No one has a clear picture of how all this will develop." A majority of these respondents feel that hydrogen will emerge as the fuel of choice and that fuel cell powered products will become a key portion of the transportation, stationary and portable markets.

Many industry leaders felt that fuel cells ultimately will dominate in the automotive sector. According to one auto manufacturer, the cost of diesel hybrids is just too high. Another argued that hybrids will be a bridge technology leading to fuel cell powered automobiles.[15] Yet another interviewee felt that tighter regulatory restrictions would eventually put diesel out of the running. From an investment standpoint, however, hybrids are being well received by some because "you can make money on them now."

Many respondents saw wind and solar energy as complementary to fuel cells in the stationary sector, rather than competitive. The feeling was that each of these types of power would have a place in the total market.

There was a strong minority sentiment that new developments may considerably alter the current picture and provide formidable competition to fuel cells. For example, one respondent spoke at some length about advanced internal combustion engines that produce almost no emissions and operate at 45% efficiency. "Don't count the internal combustion engine out," he said.

*G. Impact of the 2003 State of the Union Address*

We revisited roughly one third of our respondents after the 2003 State of the Union Address. The perception was that the public markets and venture capital will remain unlikely options for financing the transportation and stationary sectors, at least until there is increased clarity regarding the timeline to profitability. A few felt that there might be an increase in corporate venture and corporate R&D funding in the automotive sector, but that opinion was not pervasive. The announcement was seen as having little effect on the portable sector.

*-- Crossroads Issues --*

*Industry leaders generally were optimistic about the President's announcement, although they still view the industry as a long-term venture with substantial risk.*

[15] This respondent offered the historical analogy of ships using both coal and sails simultaneously for a period of time; ultimately coal won out.

It was noted by some that the most likely impact would be increased federal government support, as the announcement has raised the profile of hydrogen related technology within Congress. However it was noted that local public institutions, with their shorter budgeting time horizons, are likely to direct their funding support towards hybrids or other technologies expected to materialize in the nearer term.

*1. Financial Community*

The general consensus was that the President's recently announced program has not improved prospects for venture or equity market funding of the fuel cell industry. Any increased interest in the sector as a result of the address was viewed as fleeting, with one venture capitalist noting "most of the 'tourists' will go home once they realize this is a tough area in which to invest; a sector which requires significant domain expertise."

Some viewed the announcement as a concession that would be expected from any administration to the environmental lobbies. Others attributed motivation for the announcement to energy security concerns. Both venture and public equity investors remain very skeptical of the industry generally, with the exception of portable applications, and are very focused on near term profitability and return on investment.

The portable sector continues to receive some attention from the venture, corporate venture, and corporate R&D communities. The President's recently announced program was not viewed as having any effect on the level of interest. It was noted by one interviewee that the President's announcements may have generated increased interest in the component area, particularly from larger companies.

*2. Industry Leaders and Consultants*

Respondents here seemed slightly more optimistic about President Bush's proposed program, particularly regarding heightened awareness in Congress and the potential for additional funding from the federal government.

Nevertheless, respondents still viewed the industry as a long-term play with substantial risk. A few interviewees thought that companies were "struggling as much or more than before the Bush address."

Some were disappointed that the level of funding proposed by President Bush was lower than the level of EU and Japanese funding. They noted that much of the funding was already in the budget.

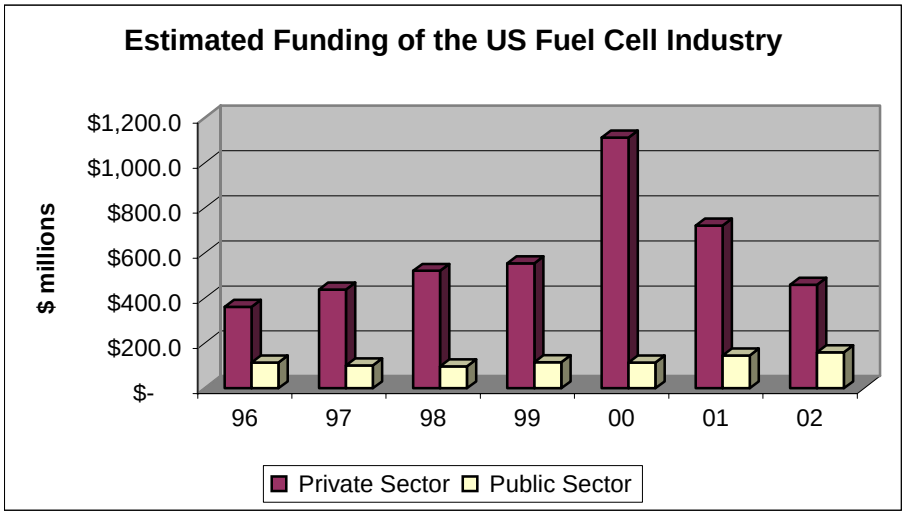
Others noted that funding for 2003 is late and that, in some recent cases, agencies actually have received less than anticipated. There was also disappointment that the President's remarks did not include stationary applications, because some stationary applications are commercially available. "As an industry, we need to focus on applications that can be financially successful now rather than waiting for the mass markets."

## SECTION II: FUNDING HISTORY & EMPLOYMENT

This section reviews the history of funding in the fuel cell industry and examines job creation, both past and future. Funding by U.S. government, particularly the Department of Energy (DOE), and the private sector[16] is reviewed. Also included is a summary of employment in the industry to date and job creation projections in three scenarios.

Private sector investment has consistently surpassed federal government investment since at least 1997. However, private sector investment reached a peak in 2000 at $1.1 billion and has since declined to less than half that level in 2002.

Meanwhile, federal government investment grew from $114 million in 1996 to $159 million in 2002. The totals are based on reports of Appropriations Committees of the Congress. Overall federal support for fuel cells is significantly higher, because many agencies, such as the Department of Defense, support fuel cell research and development as part of larger programs. These "embedded" programs are extremely difficult to quantify and thus were not included in the analysis.




| FUNDING ($millions) | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | TOTAL |
|---|---|---|---|---|---|---|---|---|
| Federal | $114 | 101 | 98 | 115 | 115 | 145 | 159 | $847 |
| Private Sector | $361 | 438 | 521 | 554 | 1,112 | 722 | 459 | $4,169 |

Sources: US DOE Statistical Tables, SEC filings, websites, news articles, Venture One, Nth Power.

[16] For DOE, we have provided funding information from 1996-2002. For the private sector, although an attempt was made to find information as far back as 1990, very little information on investments made in the US fuel cell industry prior to 1995 was found. Information sources reviewed included public sources such as SEC filings of public companies, websites and news articles. Other sources included private venture capital databases, industry reports and interviews with industry stakeholders.

Government cost-shared contracts have played a key role in the industry. This appears to be particularly true in areas where there is little advantage to being the first to offer a tangible product, such as transportation and fuel infrastructure.

In the past, government funding has focused on R&D programs. As the private sector increased R&D efforts, the federal government shifted some of its focus to other issues, such as consumption.[17]

*A. Public Sector Fuel Cell Industry Funding*

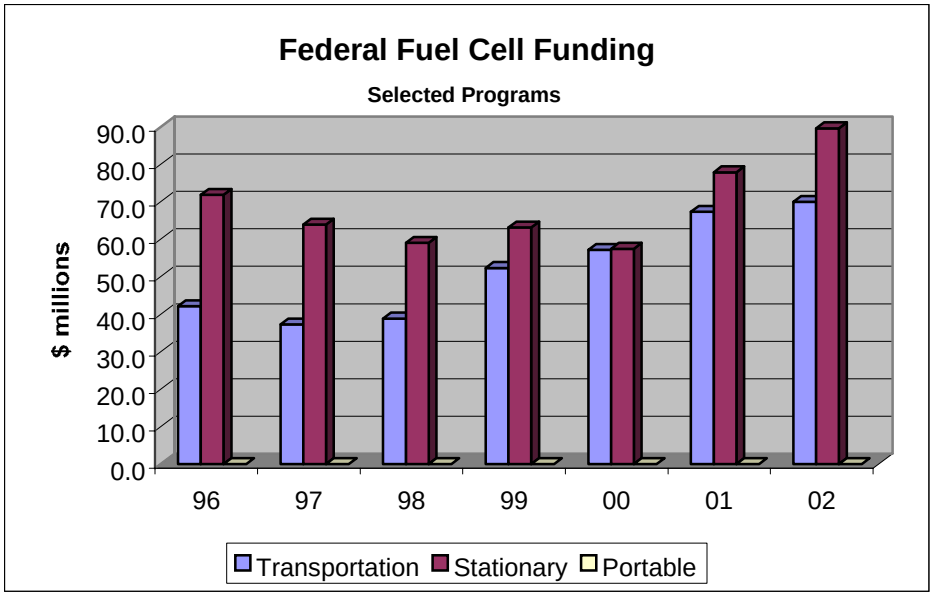
Public sector investment in fuel cells has been through three main federal programs: the space program, dating back to at least the 1960s; civilian applications principally through DOE; and defense programs, mainly through the Department of Defense (DOD). Several other agencies, notably the Departments of Commerce and Transportation and the Environmental Protection Agency, have also supported fuel cell research and demonstration, often through funding directed by Congress and not included in presidential budget proposals.

Based solely on spending identified in Congressional reports, the total federal investment in fuel cells was $847 million for the period FY 1996 through 2002.[18] It is our belief that the true level of federal spending on fuel cells is significantly higher, although almost certainly not as high as private sector investment. The chart below estimates the level of funding for federal fuel cell programs by sector. [19]

[17] This shift is evident in DOE's Fuel Cell Report to Congress**.** Although there is significant R&D in core areas, like cells, stacks and components, additional emphasis is being placed upon areas that have extremely high cost barriers, such as fuel infrastructure. Recently, the Bush Administration proposed significant new monetary resources allocated to the funding of hydrogen RD&D, through newly formed and ongoing hydrogen initiatives.

[18] FY 2003 appropriations of $151.7 million bring the total to nearly $1 billion. We looked at the DOE and DOD programs for transportation, stationary and portable applications. We also took a brief look at investment in the hydrogen program. The Department of Energy through EERE has a robust and growing hydrogen RD&D program which has been integrated into EERE's fuel cell transportation and distributed power programs. Hydrogen funding since 1996 is included in the overall spending totals

[19] We have accounted for Department of Defense, Environmental Protection Agency and Department of Transportation programs directed by Congress beginning in 1996. Funding for DOD purchase subsidy programs are also included, but research dollars embedded in larger programs and not reported by Congress are excluded. We allocated DOD spending based on our review of the record and the National Defense Authorization Act for fiscal year 2003. Hydrogen program spending was allocated equally to stationary and transportation sectors since advances in the field likely will benefit both sectors.




Sources: US DOE Statistical Tables, DOE internal documents, websites, Breakthrough Technologies Institute estimates.

Research funding has accelerated recently, taking place primarily through the DOE's Office of Energy Efficiency and Renewable Energy (EERE) and Office of Fossil Energy (FE). The amount of funding for stationary program R&D has stayed relatively steady. Transportation and hydrogen programs have seen their combined funding allocations grow by nearly two-thirds from $42 million in 1996 to more than $70 million in 2002.[20] The portable sector has received limited direct funding from the federal government and that which it has received was not identified by specific dollar amounts in our review of publicly available information sources.

*1. Transportation*

DOE's involvement in this sector primarily has been R&D on low temperature fuel cells. DOT's involvement primarily has been through the Fuel Cell Transit Bus Program, managed by Georgetown University, which builds upon the joint Federal Transit Administration (FTA) and U.S. Department of Energy test bed fuel cell bus program. Finally, DOD has made transportation investments through its Army and Navy RDT&E programs, which have both directed funding to the transportation and stationary sectors. Between 1996 and 2002, direct "line item" funding at DOD totaled $364.8 million.

| FUNDING | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | TOTAL |
|---|---|---|---|---|---|---|---|---|
| ($ millions) | $42.1 | 37.3 | 38.8 | 52.3 | 57.1 | 67.3 | 69.9 | $364.8 |

[20] A further increase to $90 million was approved for FY 2003.

*2. Stationary Power Generation*

The bulk of stationary R&D funding has come from the DOE's Office of Fossil Energy (FE). DOE's Office of Energy Efficiency and Renewable Energy (EERE) has operated a small program for fuel cells in buildings for several years. FE's fuel cell RD&D emphasis has been on large stationary applications and distributed generation (grid). For most of the 1970s and early 1980s, the FE program included development of the phosphoric acid fuel cell (PAFC) system, considered one of the "first generation" of modern-day fuel cell technologies. In the late 1980s, the FE shifted its emphasis to higher temperature fuel cell technologies, specifically the molten carbonate and solid oxide fuel cell systems.

The Defense Department purchased and installed 30 PAFC units in the early 1990s. Between 1996 and 2002, Congress appropriated $39.5 million to subsidize the installation of PAFC units; a smaller program for PEM units was initiated in 2001. A substantial percentage of these dollars was reprogrammed by the Department for other uses. The Fuel Cell Buy-Down program received an additional $7 million in FY 2003.

In 1999, the DOE (FE) launched a major initiative, the Solid State Energy Conversion Alliance (SECA) to bring about dramatic reductions in solid oxide fuel cell costs by 2010, which would make fuel cells competitive for virtually every type of power application. DOD has also made investment in this sector through the Army and Navy RDT&E programs mentioned above. These programs have included phosphoric acid fuel cell demonstration programs, proton exchange membrane RD&D, and the sponsoring of a fuel cell test and evaluation center which may also have overlapping benefits in other sectors. Spending in the sector by the Department of Energy and the actual spending in the DOD purchase subsidy programs are reported below, along with a portion of DOD "line item" spending identified in Congressional Reports.

| FUNDING | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | TOTAL |
|---|---|---|---|---|---|---|---|---|
| ($ millions) | $71.8 | 63.9 | 59.0 | 63.1 | 57.4 | 77.8 | 89.6 | $482.6 |

*3. Portable*

Although not reflected in the chart above, as specific dollar figures were not available, there has been some public sector involvement in the portable sector, primarily through the DOD. DOD's involvement in portable fuel cells through Army, Navy and Defense Advanced Research Projects Agency (DARPA) has included funding of demonstrations of fuel cell applications that provide power in remote locations as an alternative to battery generators. The DOE also hosted a portable fuel cell application workshop recently. The Department of Commerce, through its Advanced Technology Program, also supports some micro-fuel cell research. It recently granted $4.6 million to MTI MicroFuel Cells. Federally supported research into direct methanol fuel cells and innovative "micro-reformers" has contributed significantly to hopes of early commercial entry for micro-fuel cells.

*4. Hydrogen*

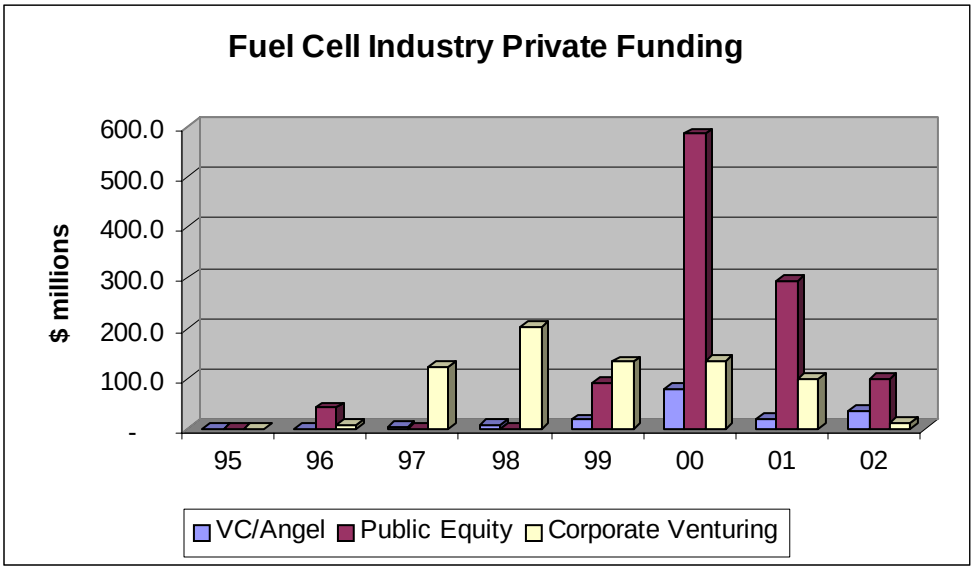
EERE has funded hydrogen programs at least since the 1980's. Since 1996, DOE funding for hydrogen has doubled from $14.5 million in 1996 to $31 million in 2002. Proposals made in 2003 by President Bush and Members of Congress seek to increase funding for the development of a hydrogen infrastructure to support fuel cells. These totals are included in the sector allocations above and included here for convenience.

| FUNDING | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | TOTAL |
|---|---|---|---|---|---|---|---|---|
| ($ millions) | $14.5 | 14.8 | 19.0 | 24.0 | 28.0 | 32.0 | 31.0 | $163.3 |

*B. Private Sector Fuel Cell Industry Funding*

Private sector funding is relatively new to the fuel cell industry. As the commercial potential for fuel cells has become apparent, private sector funding has grown significantly. We looked at four sources of private funding; venture/angel investment; corporate venturing; public equity markets; and internal R&D programs.[21]

The chart below illustrates funding of independent fuel cell companies by the venture/angel investor communities, corporate strategic players, and the public markets. It excludes investment in internal R&D programs of corporate strategic players such as General Motors or Motorola, which are discussed separately at the end of this section. Funding included in the chart was for independent fuel cell companies, those either based in the US or with significant manufacturing promise for the US such as Ballard Power.

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Source: SEC filings, Venture Economics, Nth Power, news articles.

[21] For those unfamiliar with the venture capital industry and other players who typically provide capital to companies in emerging industries, we have provided a summary of the various players from the National Venture Capital Association in Appendix A.

The bulk of public equity funding was secured during a relatively short time period generally associated with the internet "bubble". The vast majority took place during a 20-month period that stretched from November 1999, when Plug Power's initial public offering (IPO) raised net proceeds of $93 million, through June 2001, when Fuel Cell Energy raised $241 million in a follow-on offering.[22] Public equity funding peaked in 2000 at $585 million.

With the exception of 2002, corporate venture has been a relatively consistent source of funding for the fuel cell industry, providing at least $100 million annually since 1997. Many respondents felt that the corporate players involved in this area had deep enough pockets that they would continue to invest despite the poor economic environment of 2002. However, the level of corporate venturing in independent fuel cell companies was much lower in 2002 than the level of any of the previous five years; only $12 million in new non-venture capital lead investment was identified.

Finally, venture funding has been limited relative to equity and corporate funding.

*1. Public Equity Offerings*

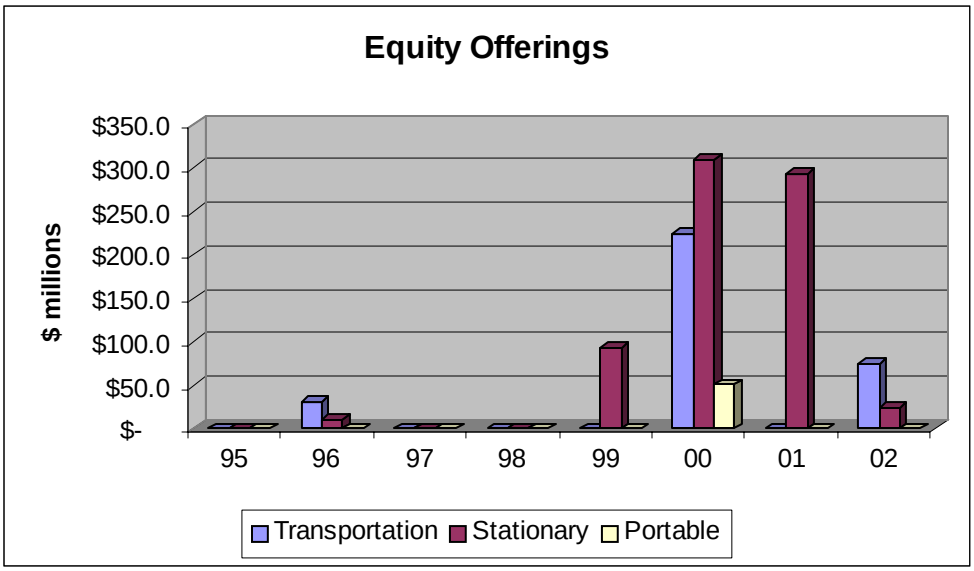
In the past seven years, several companies have made initial public offerings or raised follow-on rounds of equity funding from the public markets. It appears unlikely that this source of capital will be available again soon, except to the most established fuel cell companies. Some respondents noted that the industry should have waited to access public equity markets, because now public equity investors likely will not fund the industry until there is a clear path toward profitability.

Public equity fundraising by the fuel cell industry peaked in 2000 at $585 million. Even after the burst of the internet bubble, Fuel Cell Energy was able to raise $241 million in a follow-on equity offering in 2001. Also in 2001, Plug Power raised $51.6 million in follow-on offerings, bringing the industry total to over $292 million for the year.

The chart below shows past public market funding events by sector, including the $100 million Ballard Power deal placed in December of 2002. It does not include events for companies that have been de-listed prior to 2003 or that appear to have effectively ceased operations.[23] Since 1995, the stationary sector has raised $731 million, or more than twice the $332 million in funding that the transportation sector raised from the public equity markets.

[22] In December of 2002, Ballard Power announced a "bought deal" which is an offering of public equity placed with a select group of investors and not generally marketed to the public at large.

[23] If a public company articulated strategies dependent on two or all three sectors an attempt was made to reflect an approximate level of funding for each area. For instance, three quarters of the funds raised by Ballard were allocated to the transportation sector and one quarter to the stationary sector.




Source: SEC filings, news articles.

Several fuel cell companies, faced with the lack of access to the public markets as a source for funding their efforts since mid-2001, have been forced to consolidate. Some of these players had ramped operations to such a significant extent that they have already undergone significant operational restructurings and employee headcount reductions. Others have ceased operations or are expected to close their doors in the relatively near future. However, a few companies were able to secure sufficient funding through the public markets to cover their cash needs for the next several years, and by that time they may fit the more traditional risk-profile accepted by the public markets.

*2. Corporate Investment*

Corporate venturing, or strategic investment by corporate players in independent companies, has been a major source of funding for the fuel cell industry. Strategic players have provided at least $700 million since 1995 in external funding to independent fuel cell focused companies. Some of these companies have remained private while others have since gone public.

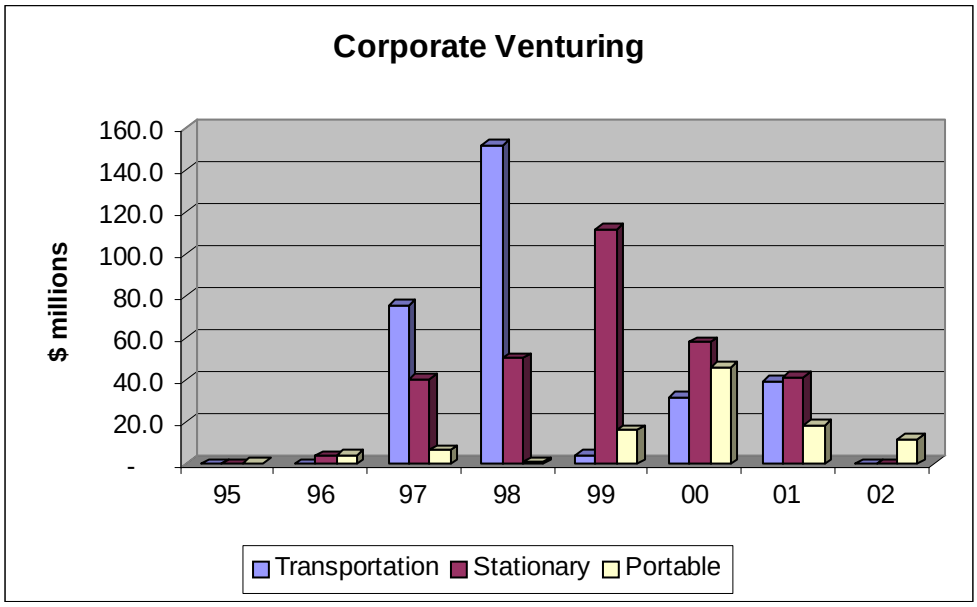
As the chart below shows, 1997 and 1998 were significant years for corporate venturing in the transportation sector at $76 million and $152 million respectively.[24] During these years, sizable investments were made by Ford and DaimlerChrysler in Ballard Power.

In 1999, of the $133 million raised, the stationary sector received the vast majority. The primary recipient was Plug Power, which prior to its IPO at the end of that

[24] Many of these investments made by strategic players were in companies that are dividing efforts among two and sometimes all three of the sectors covered in this study. If a company indicated that it was involved in multiple sectors, an attempt was made to reflect the approximate amount allocated to each sector in the chart below.

year raised over $95 million through multiple rounds of investments provided by several strategic parties.

The years 2000 and 2001 saw corporate venturing relatively evenly dispersed between all three sectors, but it appears that only the portable sector was able to secure any significant level of strategic investment last year at a modest $12 million. Conversations with industry participants indicated that the portable fuel cell field is one in which independent companies are playing a significant role and one of the few areas receiving venture capital or corporate venture funding presently.




Sources: Interviews with industry executives, news articles, Breakthrough Technology Institute estimates.[25]

Industry leader respondents were hesitant to give specific figures on the level of internal corporate investment on internal R&D. The amount appears to range between $400 million and $600 million annually. Our review of other sources indicated that the combined corporate spending in the transportation and stationary sectors was at least $300 million to $400 million annually over the past several years, split roughly equally between the two sectors. Very little specific information was available about the portable sector. It is also estimated that $100-$200 million is being spent annually on internal R&D in components for fuel cells by players such as DuPont, 3M, Gore and Air Products, which presumably will benefit all three sectors.

[25] Of note is an announcement made in late 2002 by Ford and Daimler Chrysler. According to this announcement, the two auto manufacturers have agreed to provide a total of $97 million in new funding to Ballard over the five years, to begin at the end of 2003. Because this is an agreement for future funding which has not yet taken place, it is not included in this chart.

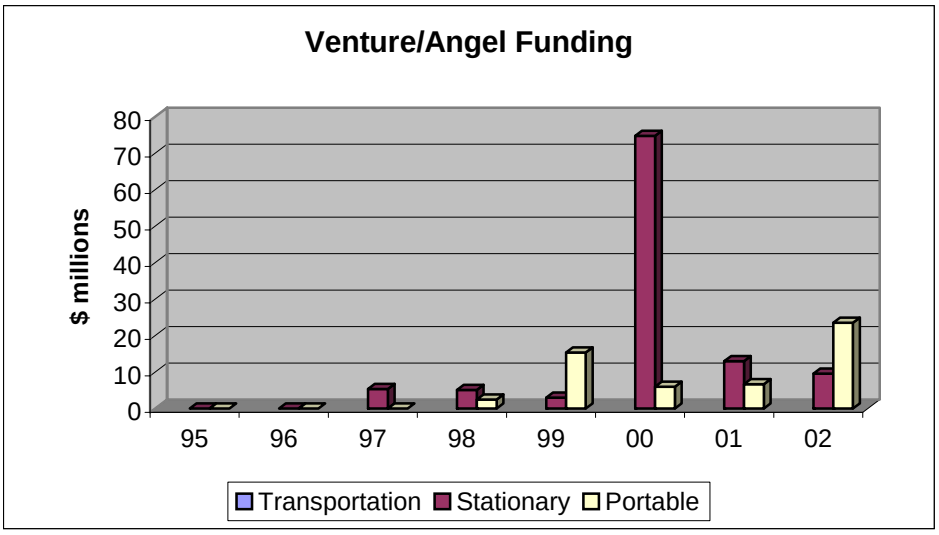
*3. Venture Capital/Angel Funding*

Venture/angel funding has played a relatively modest role in funding the fuel cell industry. For example, in 2000, the peak year for venture/angel funding of fuel cells, these entities invested $80.7 million out of $100 billion invested across all industries.

A number of reasons have been offered for the low levels of venture/angel funding of fuel cells, including:

- Venture investment generally takes place in the earlier stages of a company's life, when operations require less capital. Many fuel cell companies are beyond this point.
- The time horizon for most venture investments does not exceed five years. As noted by several interviewees, however, there are significant hurdles before a realistic commercialization timeline can be ascertained that is compatible with venture participation. This appeared to be particularly true of the transportation sector.

The chart below shows that, excluding the year 2000, venture/angel funding since 1995 has been split relatively evenly between the stationary and portable sectors. During 2000, two stationary companies raised $75 of the total $81 million of venture fuel cell financing. The funding rounds, at $24.6 and $50.1 million, were both much larger than individual funding rounds raised during any other year reviewed. Presumably this reflects the positive attention drawn to the stationary sector by Plug Power's initial public offering, which took place during a time when it was perceived by many in the investment community that the stationary sector would be the first to achieve material commercial status.




Source: SEC filings, Venture Economics, Nth Power, news articles.

Although energy specific venture funds remain interested in stationary applications, portable companies received more than two-thirds of the $37 million in

venture funding invested in the fuel cell industry last year. The rationale appears to be that this market is nearer to significant market penetration, with initial commercial application introduction anticipated within a three to five year horizon. Venture capital funding in the transportation sector to date has been relatively limited due to the large amounts of capital required and the length of time anticipated before a sizable market will develop.

### *C. Employment to Date*

We estimate that total direct employment in the US fuel cell industry in 2002 was approximately 4,500 to 5,500. [26]

- Venture or angel-backed independent private companies focused on fuel cell development were estimated to employ perhaps only a few hundred people, primarily in R&D. Nearly three quarters of those appear to be employed in the stationary sector with the remainder in the portable sector.
- Other independent private companies, funded primarily by strategic players, were estimated to employ at least 500. These jobs appear to be allocated approximately equally among the three sectors.
- Despite the limited role, the public markets are expected to play in funding the industry over the next several years, public pure play fuel cell companies employ nearly 2,000, with approximately half of those employed by Ballard Power. The number of employees appears to be divided roughly equally between the stationary and transportation sectors.
- We believe that total internal employment by major strategic players in the US fuel cell industry is roughly 1,500 to 2,000.[27] Company executives were hesitant to give specific figures regarding the number of employees focused in each sector; however, it was implied that employment is divided roughly equally between the transportation and stationary sectors. Although there has been quite a bit of funding in the portable sector recently, most of it and consequently most employment appears to have been associated with independent companies.
- Estimated employment by component manufacturers is at least 400-500 people focused in R&D areas such as the development of MEAs, membranes and bi-polar plates which presumably benefit each of the three fuel cell sectors.

### *D. Job Creation Scenarios*

In this section, we estimate how many jobs might be created in the US fuel cell industry by 2021 under different investment scenarios. To develop the investment scenarios, we reviewed several studies on the outlook for the fuel cell industry in addition

[26] Estimates of job creation to date are based on our review of SEC filings of publicly traded fuel cell companies, venture capital databases, and other industry reports. This number is constantly changing, as evidenced by Ballard Power's recent announcement of a significant restructuring and associated layoffs.

[27] Less public information was available regarding strategic players' internal efforts. In news articles GM's program alone has been cited as employing 600 people. Information from our interviews also was included in our estimates.

to interviewing industry executives regarding their expectations. Below is detail regarding our methodology and expectations regarding future employment in the fuel cell industry.

*1. Scenario Development*

We developed three scenarios: a base case, a high capitalization case, and a low capitalization case. The base case reflects the status quo or current expectations for market development, and by association the current investment outlook. It is important to note that the base case scenario is by no means guaranteed, but rather reflects what at the time were considered to be reasonably conservative projections for the development of the markets in each sector. The high capitalization case reflects a more optimistic outlook for investment. The low capitalization case reflects a more pessimistic outlook. Each scenario takes place over a 20-year time horizon through 2021 and reflects different speeds of North American market development, which was the measure cited by our interviewees as the best proxy for a change in investment environment.[28]

In each scenario, we established estimated market sizes, then conducted the following steps to arrive at US job creation estimates:[29]

- Corresponding costs per unit were derived from the base case demand curve.
- The market size unit number was multiplied by the assumed cost/unit, in order to arrive at a market size in US dollars. For components, an assumption was made regarding the percentage that each category represented by sector of total unit cost in order to arrive at market size in US dollars.
- After making assumptions regarding achieved profit margin in 2021 for each sector and each component, we subtracted profit from the total projected dollar market size in order to arrive at total dollar cost of production.
- An assumed percentage that labor represented of total cost was then applied to calculate an estimated dollar cost of labor.

[28] In order to develop scenarios regarding how different investment climates might affect job creation, we reviewed several sources and used what we considered to be conservative projections of market size in units and cost/unit for our base case scenario. We then interviewed industry participants in order to verify the reasonableness of these projections, to understand how they believed different investment environments might affect the relative leadership position of the US in the fuel cell industry, and to understand how they would expect the market to develop in each investment environment.

The low capitalization case assumes that for any number of reasons there is a restriction of the private sector's ability to maintain current investment levels while government funding continues to be stable, resulting in slower market development. Based on our interviews, it was indicated that in such a case, it might be reasonable to expect delays in the market development of 5-7 years in the transportation sector, 2-3 years in the stationary sector, and 1-2 years in the portable sector. Corresponding costs per unit were then derived from the base case demand curve in order to arrive at estimated market size.

The high capitalization case assumes that increased government and private sector spending leads to more rapid market development but the acceleration does not mirror the delay associated with the low capitalization case. For the purposes of this study, in the high capitalization case it was assumed that a reasonable acceleration in the market development from an increase in funding would be 2-3 years in the transportation sector, 1-2 years in the stationary sector and 1 year in the portable sector.

[29] Because the fuel cell industry is in its infancy, and there are many technical, regulatory and other hurdles to be overcome before fuel cell technologies can be made widely available to the public, industry projections will likely change significantly over the next few years.

- This estimated dollar cost of labor was divided by an assumed average salary for each sector and for components in order to derive an estimated number of jobs created in North America.
- Finally, an assumption was made about the percentage of these jobs captured by the US and applied to calculate US fuel cell jobs created.

Specifics regarding the market size, growth rates, salaries and other assumptions are explained in Appendix B - Details Regarding Scenario Development.

*2. Results*

As suggested by several respondents, increasing the level of investment should lead to job creation. More importantly, however, decreasing the level of investment would reduce job creation, and this reduction would be of a greater magnitude.

As interviewees indicated, it is unlikely that an increase in funding would result in an acceleration in market development that mirrors the delay associated with the low capitalization case. Factors assumed to have mitigating effects include practical limits on the speed of scientific innovation, lack of fuel infrastructure, the need for development of some common standards of production, and the lack of clarity regarding the government's preferred alternative energy technologies in each sector.

Although the job creation figures may appear relatively modest, they reflect an industry that will still be in relative infancy at the end of our projection time horizon. The following are the resulting job creation outcomes for the base, high capitalization and low capitalization cases:

| ***JOB CREATION SUMMARY- 2021*** | | | |
|---|---|---|---|
| | **HIGH** | **BASE** | **LOW** |
| TRANSPORTATION | 16,981 | 15,472 | 10,468 |
| STATIONARY | 47,095 | 41,333 | 29,269 |
| PORTABLE | 3,063 | 3,033 | 2,973 |
| MAJOR COMPONENTS | 8,321 | 7,438 | 5,235 |
| Total | 75,460 | 67,276 | 47,945 |

These projections reflect job creation directly associated with the manufacturing of fuel cells for transportation, stationary and portable applications. In addition, there also should be indirect job creation and other economic benefits.

For example, PricewaterhouseCoopers, in its study "Fuel Cells: The Opportunity for Canada", estimated that applying an employment multiplier of 2.5 to direct fuel cell industry employment figures will derive a reasonable estimate of the total number of direct, indirect and induced jobs created by the fuel cell industry in Canada. Using the same multiplier, the total number of jobs we project could be as high as roughly 190,000.

Similarly, according to the study "Contribution of the Automotive Industry to the US Economy in 1998: The Nation and its Fifty States", there are 2.9 indirect jobs and 3.7

expenditure induced jobs created for every direct job created as a result of automotive manufacturing activities, indicating an employment multiplier of 6.6.

Although employment in the transportation sector eventually may surpass that in the stationary sector, the current low expectations are reflected in the significantly lower job creation expectations by 2021. Our base scenario projections indicate the number of fuel cell vehicles sold will reach 3 million in 2021. This allows for quite a bit of additional production market share and subsequent job creation, considering that 13,000,000 light vehicles were produced in the US in 1999. (This was a record high at the time.)

The transportation employment projections seem plausible when compared to statistics for auto manufacturing employment in the state of Michigan, where the 10 engine plants and 5 transmission plants employed approximately 27,000 in 2000, representing 34% of engine manufacturing and 39% of North American automotive transmission manufacturing. (These statistics do not include the thousands employed by suppliers who manufacture parts and components for these powertrains.)

Results for the stationary sector show significantly higher job creation than the other sectors. There are a number of reasons for this, including:

- the stationary market is already in its beginning commercial stages and the market will sustain a much higher price per kilowatt than will be accepted in the automobile sector;
- we assumed a slightly larger proportion of production costs are attributed to labor in the stationary sector than in either the transportation or portable sector based on our interviews with industry executives and consultants; and
- we assumed by 2021 a large market of 20,000MW, representing nearly all of the Energy Information Administration's (EIA) projected new capacity additions for that year. We based this assumption on a review of EIA data using, as a proxy, the market share capture of new capacity additions by natural gas combined cycle turbine generators from 1990, the first year natural gas information was available, through 2001. (EIA data is cited as preliminary for 1990 through 2000, and estimated for 2001.)[30]

Although the portable sector is expected to penetrate the incumbent market the most rapidly of the three sectors, the overall premium battery market is much smaller in size than the automotive and stationary sectors. There is not much variation between the final job creation numbers in large part because interviewees indicated that the technology was well on its way to being commercially ready. Consequently, a change in capital availability would change the development timeline in the portable sector to a more limited extent than in the other two sectors. In addition, costs decline at a more rapid rate after 2008 than in the other two sectors.

[30] We have made the assumption that combined cycle turbine generators are the dominant natural gas technology included in the natural gas category of EIA's historical capacity figures.

Nevertheless, it is not a foregone conclusion that fuel cells will replace the incumbent technology in this sector. According to a study by the Darnell Group[31], fuel cells for portable applications still have several hurdles to overcome, including the need to improve energy density over the incumbent technology, the need to achieve price declines, and the need to establish a worldwide distribution network for refill cartridges.

In addition, there is the possibility that a new competing technology will emerge that is superior to fuel cell technology for portable applications. While the projections used reflect what industry executives believe is the realistic outlook for market penetration presently, if some or all of the above hurdles are not overcome, the Darnell study recognized that fuel cell technology may be relegated to niche status in the portable sector and job creation numbers may not reach the levels forecast even in the low capitalization case.

Finally, in the component sector, job creation numbers are relatively low because, among other things, component manufacturers indicated that most component production is expected to be highly automated. Moreover, the market size for components is reflected in the model as a function of a percentage of the cost of the unit itself, and reductions in the cost of components are expected to continue.[32]

*3. Sensitivity Analysis*

In the sensitivity analysis, several key assumptions were tested to see how the job creation forecasts in the base scenario would change if one of the assumptions was increased or decreased in the model. For instance, in the transportation sector, if the original assumption that 19% of the fuel cell cost is represented by labor were altered by increasing the percentage by an increment of 5% to 24%, the resulting job creation would be 19,544 jobs. Alternatively, if the assumption were decreased by an increment of 5% to 14%, the resulting job creation would be 11,400 jobs. In addition to the key assumptions tested, there are many other assumptions in the model that, if changed, would also have an effect on job creation outcomes.

[31] "Fuel Cells for Portable Power: Markets, Manufacture and Costs – Revised Final Report for Breakthrough Technologies Institute & U.S. Fuel Cell Council", Darnell Group, December 20, 2002.

[32] Estimates were made as to the proportion of the overall unit price components would represent were based on Arthur D. Little's study of 2000 cost components for transportation fuel cells and DOE draft technical targets from *Fuel Cells for Transportation: FY 2001 Progress Report*. However, there remains a reasonable amount of uncertainty in this area.

Below are the results of the sensitivity tests:

| **Transportation** | | Base job creation | 15,472 | |
|---|---|---|---|---|
| | **Original Assumption** | **+/- increment** | **Job creation range** | |
| % Labor = of fc costs | 19% | 5% | 19,544 | 11,400 |
| Unit growth 2016-2021 | 10% | 5% | 19,323 | 12,261 |
| Unit growth 2011-2016 | 25% | 5% | 18,824 | 12,615 |
| Annual compensation | $65,000 | $15,000 | 20,114 | 12,571 |

| **Stationary** | | Base job creation | 41,333 | |
|---|---|---|---|---|
| | **Original Assumption** | **+/- increment** | **Job creation range** | |
| % Labor = of fc costs | 25% | 5% | 49,599 | 33,066 |
| Unit growth 2016-2021 | 15% | 5% | 51,089 | 33,127 |
| Unit growth 2011-2016 | 27% | 5% | 50,125 | 33,820 |
| Annual compensation | $65,000 | $15,000 | 53,733 | 33,583 |

| **Portable** | | Base job creation | 3,033 | |
|---|---|---|---|---|
| | **Original Assumption** | **+/- increment** | **Job creation range** | |
| % Labor = of fc costs | 15% | 5% | 4,044 | 2,022 |
| Unit growth 2016-2021 | 10% | 5% | 3,788 | 2,403 |
| Unit growth 2011-2016 | 15% | 5% | 3,752 | 2,428 |
| Annual compensation | $51,000 | $10,000 | 3,773 | 2,536 |

# APPENDIX A

The information below is quoted from the National Venture Capital Association website:

> Venture capital is money invested alongside management's investment in young, rapidly growing companies…Venture capital and private equity firms are pools of capital, typically organized as a limited partnership, that invest in companies that represent the opportunity for a high rate of return within five to seven years…Individuals may be venture capitalists. In the early days of venture capital investment, in the 1950s and 1960s, individual investors were the archetypal venture investors. While this type of individual investment did not totally disappear, the modern venture firm emerged as the dominant venture investment vehicle. However, in the last few years, individuals have again become a potent and increasingly larger part of the early stage start-up venture life cycle. These "angel investors" will mentor a company and provide needed capital and expertise to help develop companies.
>
> Venture capital firms will often co-invest with other professional venture capital firms and may manage multiple funds simultaneously. Venture firms may invest before there is a real product or company organized (so called "seed investing") or may provide capital to start up a company in its first or second stage of development known as "early stage investing." Also, the venture capitalist may provide needed financing to help a company grow beyond a critical mass to become more successful ("expansion stage financing").
>
> One type of investing that was popular in the 1980s and is again very popular is corporate venturing. This is usually called "direct investing" in portfolio companies by venture capital programs of non-financial corporations…. The typical distinction between corporate venturing and other types of venture investment vehicles is that corporate venturing is usually performed with corporate strategic objectives in mind while other venture investment vehicles typically have investment return or financial objectives as their primary goal. The other distinction of corporate venture programs is that they usually invest their parent's capital while other venture investment vehicles invest outside investors' capital.
>
> The venture firm will provide capital and management expertise and will usually also take a seat on the board of the company to ensure that the investment has the best chance of being successful. A portfolio company may receive one round, or in many cases, several rounds of financing in its life as needed…. Depending on the investment focus and strategy of the firm, it will seek to exit the investment in the portfolio company within three to five years of the initial investment…. While the initial public offering may be the most glamorous and heralded type of exit for the venture capitalist and owners of the company, most successful exits of venture investments occur through a merger or acquisition of the company by either the original founders or another company.

# APPENDIX B

## Details Regarding Scenario Development

Although the job creation analysis in this study was not complex, we worked with an economist to review our projections and insure that our methodology in creating forecasts of market size and estimating resulting job creation was sound. The economist we worked with, Victor Valdivia, has a PhD in Economics from Northwestern University as well as a Masters in Electrical Engineering from Stanford University. Mr. Valdivia is currently an Adjunct Associate Professor of Economics at New York University and head of a research firm, Hudson River Analytics. He has made specific comments regarding our methodology in Appendix C below.

The projections through 2011 for the North American market size in units for the transportation sector are drawn from the Price Waterhouse Study "Fuel Cells: The Opportunity for Canada". This study was also used as a guide for cost per unit and the percentage of costs represented by labor for the stationary sector; however, the market size projections were derived from Energy Information Administration projections for new capacity additions and historical data regarding natural gas combined cycle turbine generators' market share of new capacity additions.[33] The projections for the portable sector through 2011 are drawn from the projections labeled as conservative (vs. aggressive) in "Fuel Cells For Portable Power: Markets, Manufacture and Cost, *Revised Final Report"* by the Darnell Group. By sector, additional unit growth rate assumptions are made from the end date of the base projections to arrive at an estimated market size in units in 20 years. The specific assumptions are detailed by sector below. Projected cost per unit assumptions were derived from a variety of sources, including the two reports referenced as well as documents from the US Department of Energy.

In each scenario the following assumptions are made:

**Annual salary and annual salary growth rate.** For the transportation and stationary sectors, we have assumed a base compensation (salary and benefits) in 20 years of $65,100, which was the average compensation in 1998 for SIC code 371, the motor vehicle and motor vehicle equipment industry, according to the US Department of Labor Bureau's Labor Statistics. For the portable sector and components we have assumed the average compensation is $50,900, which is the average compensation in the same year for all of durable goods manufacturing. We use a constant salary between 1998 and 2020 because the projections for cost per unit and market sizes were based in constant 2001 dollars for the transportation and stationary sectors and apparently constant 2002 dollars for the portable sector (the report was written in 2002 but did not specify on which year dollar value the cost per unit projections were based.) 1998 was the most recent year for which SIC code segmented salary information was available. In the sensitivity section, we show the effect that an increase or decrease in average compensation, of $15,000 in

[33] We have made the assumption that combined cycle turbine generators are the dominant natural gas technology included in the natural gas category of EIA's historical capacity figures.

the transportation and stationary sectors and $10,000 in the portable sector, would have on base case job creation projections.

**Percentage of costs represented by labor.** The assumptions regarding the percentages that labor represents of total costs, or projected revenues less profit (see profit margins assumptions below), in 2021 for transportation and stationary sectors were 19% and 25% respectively, based on projections from the Price Waterhouse Study. We assumed labor represented 15% of costs for the portable sector and 5% for components based on conversations with industry executives and review of financial results of public companies.

**Percentage components represent of unit price.** In 2021, MEAs are assumed to represent 22% of the fuel cell unit price in each sector, and membranes subsequently 50% of the MEA price by sector. Bi-polar plates are assumed to represent 11% of the fuel cell unit price in each sector. These assumptions were based on Arthur D. Little's study of 2000 cost components for transportation fuel cells and DOE draft technical targets from *Fuel Cells for Transportation: FY 2001 Progress Report*. The proportions were assumed to be the same in stationary and portable sector.

**Continued price declines.** The base prices in the transportation and stationary sectors decline from $300/kW to $50/kW and from $3525/kW to $750/kW over the period 2001-2008 in line with the PWC projections. We have assumed that the price of the fuel cell unit in the transportation sector declines 5% per year after 2008 and in the stationary sector 1% per year after 2008. In the portable sector, the base weighted average price per unit is $29.61 per unit in 2006 declining to $17.31 in 2011 in line with the Darnell projections. We assume the price of a portable unit declines 7% per year after 2011. These price declines are subsequently reflected in component prices which, as mentioned above, are assumed to represent a certain percentage of the transportation, stationary and portable unit sales price (vs. cost). As the price of the unit goes down, the decline is reflected in the component price as well.

**Percentage of jobs captured by other regions.** We have assumed that the United States captures 90% of the job creation associated with North American sales of fuel cell products projected in each of the three sectors and components. This is based on the percentage that Canada's population represented, 10%, of the combined population of the US and Canada in the year 2000. GDP was also considered but represented a lower percentage, as Canada's GDP was 6.6% of total US and Canadian GDP in the year 2000.

The following additional assumptions are made by sector:

**TRANSPORTATION**

**Base case unit growth rate and profit margin assumptions.** The unit compound annual growth rate (CAGR) based on Price Waterhouse projections from 2007-2011 is 134% from a base market of 20,183 units in 2007. We have assumed that the number of units grows at a CAGR of 25% from 2011-2016 and of 10% from 2016 to 2021. Doing so arrives at total unit number of 3 million in 2021. While we expect this market to transition into profitability later than the other sectors, we have assumed that by 2021

enough cars are being produced for fuel cell for vehicle producers to achieve a 10% profit margin.

**High capitalization case unit growth rate and profit margin assumptions.** In order to achieve an acceleration of two to three years in production volumes, we have assumed from a base of 150,000 units in 2007 a CAGR of 65% through 2011, followed by a CAGR from 2011-16 of 15% and of 10% from 2016-2021. As a result, the total number of units produced is increased to 3.75 million in 2021. At this higher unit production volume, we assume vehicle producers are able to achieve a 10% profit margin.

**Low capitalization case unit growth rate and profit margin assumptions.** In order to achieve a delay of five to seven years in production volumes, we have assumed from a base of 4,200 units in 2007, a CAGR in 2007-11 of 76%, followed by a 50% CAGR from 2011-16 and of 35% CAGR from 2016-2021. As a result, the total number of units produced is reduced to 1.35 million in 2021. Given this lower unit volume, we have assumed vehicle producers are able to achieve a profit margin, but at a lower 5% level.

**STATIONARY**

**Base case unit growth rate and profit margin assumptions.** The base case forecasts for the stationary sector were derived using EIA's projected new capacity additions and applying comparable market share capture of new capacity additions percentages to those achieved by natural gas combined cycle turbine generators historically.[34] Based on the precedent of this technology, which grew from 16% when first tracked by EIA to 94% in 2001, we have assumed that fuel cells are able to capture 16% market share by 2011 growing to 94% by 2021. The derived compound annual growth rate (CAGR) from 2007-2011 is 37% from a base of 836 Megawatts in 2007. The number of units grows at a CAGR of 27% from 2011-2016 and at a CAGR of 15% from 2016 to 2021 to a total market size of 20,159 Megawatts. We have assumed that by 2021 producers of fuel cells for stationary purposes are able to achieve a 10% profit margin.

**High capitalization case unit growth rate and profit margin assumptions.** In order to achieve an acceleration of one to two years in production volumes, we assume a market size of 1,999 Megawatts in 2007. From this base we assume a CAGR of 28% through 2011, a CAGR of 19% from 2011-2016 and a CAGR of 13% from 2016-2021. Doing so arrives at total market size of 23,257 Megawatts. We have assumed that these volumes are also sufficiently large that producers of fuel cells for stationary purposes are able to achieve a 10% profit margin.

**Low capitalization case unit growth rate and profit margin assumptions.** In order to achieve a delay of two to three years in production volumes, from a base market of 250 Megawatts in 2007, we have assumed a CAGR in 2007-11 of 57%, followed by a 29% CAGR from 2011-16 and 21% from 2016-2021. Doing so arrives at total market size of 13,919 Megawatts. We have assumed that these volumes are also sufficiently large that producers of fuel cells for stationary purposes are able to achieve a 10% profit margin.

[34] We have made the assumption that combined cycle turbine generators are the dominant natural gas technology included in the natural gas category of EIA's historical capacity figures.

**PORTABLE**

**Base case unit growth rate and profit margin assumptions.** In the projections it labels conservative, Darnell group assumes a market entry year of 2006. At the end of this first year of availability, it is assumed that 7.6 million portable fuel cell units (for mobile phones, laptops, PDAs, digital cameras, and camcorders) are sold, representing a penetration of about 4.5% of the projected premium battery market in 2006. The unit compound annual growth rate (CAGR) assumed in Darnell Group's projections from 2006-2011 is 44%. From this point, we have projected that the number of units grows at a CAGR of 15% from 2011-2016 and a CAGR of 10% from 2016 to 2021, which results in a market size of 151.9 million units in 2021. We have assumed that this production level is sufficient for producers of fuel cells for portable applications to achieve a 10% profit margin.

**High capitalization case unit growth rate and profit margin assumptions.** In order to arrive at a one-year acceleration in the market in 2021, off a higher base of 12,500,000 units sold in 2006 (which represents a penetration of the premium battery market of 7.3% during the first year of introduction), we assumed the number of units grows by a CAGR of 33% from 2006-11. This is followed by a CAGR of 13% from 2011-16 and a CAGR of 11% from 2016-2021. As a result, the total number of units produced in 2021 is 167 million units. We have assumed that this production level is sufficient for producers of fuel cells for portable applications to achieve a 10% profit margin.

**Low capitalization case unit growth rate and profit margin assumptions.** In order to arrive at a one to two year delay in the market unit size as of 2021, we assumed a delay of one year in the introduction of the market, and a base of 5 million units sold in 2007 which represents an estimated 2.6% of the projected premium battery market. This is followed by CAGRs of 65% from 2007-11, 17% from 2011-16 and 10% from 2016-2021. As a result, the total number of units produced is reduced to 130 million. This volume is still assumed to be sufficient for producers to achieve a 10% profit margin.

# APPENDIX C

The following are comments from Victor Valdivia, who worked with us to create the market size forecasts and corresponding job creation estimates for this study. Dr. Valdivia has a Ph.D. in Economics and is currently an Adjunct Associate Professor of Economics at New York University.

General Comments on the Methodology
Victor Valdivia, Ph.D., 12-12-02, Hudson River Analytics, Inc.

The basic projections rely on a static (time-invariant) demand function for the transportation, stationary and portable segments. The different data points in each projection are obtained by changes in quantity demanded (i.e. movements along a fixed demand curve), rather than by changes in the demand curve itself. Therefore, an implicit assumption being made is that there is no significant shift in the demand curve over time or in the factors that would shift the demand curve.

The stability of the results has been checked with fairly thorough sensitivity analysis on the key model parameters. This sensitivity analysis suggest that the number of jobs created in 2021 is likely to be of the same order of magnitude as the number reported here, subject to the main assumptions of the study.

Main assumptions underpinning the approach:

1. *Time-invariant demand curve assumed in each market.* The study assumes a time-invariant demand curve for each market, with projections obtained assuming that each market moves along this curve over time as price declines. This means that the study assumes that there is no significant shift in demand over time, or changes in the factors that could shift demand, such as potential future changes in consumer preferences (e.g. a change in attitude towards vehicles running on imported oil), successful future advertising campaigns, the impact of standard of living improvements, etc. Obviously, any of these effects could have a substantial impact on the final estimates. This assumption is usually made in economic studies such as this one because it greatly simplifies the analysis.

2. *Technological change will allow for future price declines.* The study assumes that firms will be able to supply fuel cells at lower prices, year after year. For this to occur, firms will have to lower their costs steadily in the future. Technological changes would be a key driver of such price declines. Although this is a reasonable assumption, as it agrees with historical evidence, there is no guarantee that this will be in fact achieved in the case of fuel cells.

3. *No substantial job-saving technology is introduced in the production of fuel cells in the future.* The study assumes that labor earns a fixed proportion of industry revenues in 2021. The proportion is obtained by looking at data from other industries. Sensitivity analysis suggests that the study's final results are somewhat robust to reasonable changes in the proportion of revenues earned by labor. In addition, there is substantial empirical evidence that the share earned by labor stays fairly constant over the long-term. Nevertheless, a significant labor-saving technological innovation could cause a large drop in the number of jobs in the industry.

4. *No substantial job loss overseas or job creation from overseas markets.* Although an assumption was made that 10% of jobs in North America would be captured by Canada, there is an assumption of minimal job loss overseas. Clearly, changing this assumption would impact the final results. There is also no attempt to estimate jobs created from the development of overseas markets, as it is assumed those regions would also experience minimal overseas job losses.

# APPENDIX D

## INTERVIEWS

| | |
|---|---|
| Adams, Harkness, Hill | Eric Prouty |
| Air Products & Chemicals | Ed Kiezek |
| Arete Micro-gen | Dr. Robert Shaw |
| Avista Labs | Peter Christensen |
| Ballard Power | Stephen Kukucha and Paul Lancaster |
| California Air Resources Board | Alan Lloyd |
| Chevron Texaco Technology Ventures | Don Riley |
| Chrysalix Energy | Michael J. Brown |
| Credit Suisse First Boston | Cameron Jeffries |
| Draper Fisher Jurvetson | Tim Draper |
| DuPont | David Peet |
| EnerTech Capital | Wayne Gardner |
| Ford Motor Company | John Wallace |
| Franklin Fuel Cells | David Kelly |
| General Motors | Greg Ruselowski |
| H2Gen | Sandy Thomas |
| Hydrogen Ventures LLC | Elias Azrak |
| HydrogenSource (UTC Fuel Cells & Shell Oil) | Mark Mauss, Larry Holland, Fran Kocum |
| Intel Capital | Mike Rocke |
| Jefferies & Co. | Masroor Siddiqui |
| Mayfield | David Ladd |
| Mechanical Technologies/MTI Micro Fuel Cells | Bill Acker |
| Microcell | Ray Eshraghi |
| Millenium Cell | Rex Luzader |
| Motorola Labs | Jerry Hallmark |
| Neah Power | Leroy Ohlsen |
| Nth Power | Tim Woodward, Maurice Gunderson, Nancy Floyd |
| Plug Power | Al Bucknam |
| PolyFuel | Jim Balcom |
| Prospect Street Ventures | John Barry |
| RockPort Capital Partners | David Prend |
| Technology Partners | Jason Yotopoulis |
| UTC | William Miller |
| Ventures West Capital | David Berkowitz |
| World Fuel Cell Council | Stephen Glaser |
| Consultant | Andrew Beebe |
| Consultant | Al Meyer |
| Consultant | Peter Teagan |
| Consultant | Robert Wichert |

# APPENDIX E

INDUSTRY LEADERS QUESTIONNAIRE

General information

l. Describe your company's involvement in the fuel cell industry?

2. From your vantage point, how do you expect the fuel cell industry to develop over the next 10 years?

3. How do you expect the fuel cell industry to develop over the next 20 years?

4. What inroads do you expect fuel cells to make during this timeframe relative to existing technologies? (take __% of market, surpass, small impact, = to incumbent)

5. By comparison, how do you see other alternative technologies competing relative to fuel cells?

Leadership

6. Do you see the US as the current leader in fuel cell development? Why or why not?

7. What do you base your assessment of US leadership on? (patents, production, visibility?)

8. When we get closer to actually producing and selling fuel cell products, how will "leadership" be determined?

9. What effect, if any, has the current economic downturn had on the US fuel cell industry's perceived leadership?

10. What other factors are affecting the US leadership position in the fuel cell industry worldwide?

11. Which companies do you see as leaders in the portion of the industry you're engaged in?

12. What about the role the US government is playing in fuel cell development…can it be improved? Or is the government doing all that can be realistically expected?

History of Investment

13. I've asked about the effect of the economic downturn on US leadership. Now I'd like to know what you think the impact of the downturn has had on private investment overall? In terms of your company's investment in its own fuel cell operations? In terms of your company making investments in other fuel cell related companies?

14. What other factors are affecting the pace of investment by the private sector? By your company?
15. How much has your company invested internally in fuel cell development over the past decade? Can you break that amount down by year….or could you provide me a breakdown by year by e-mail later?

16. What outside companies has your company invested in? FOR EACH COMPANY: What sector do they operate in? How much have you invested? What is your ownership position? Can you break your investment down by year and amount - if not now, then later in writing?

17. As of today, do you see your company's investment in fuel cell development increasing, remaining steady at current levels or decreasing over the next decade? Can you give us an estimate of what you have budgeted for that period for fuel cells?

18. What could cause your company to change its plans?

19. How would you compare the investment climate for fuel cells with the investment climate for alternative energy as a whole?

Scenario Development

20. In the current low capitalization environment, what aggregate level of investment, (total investment dollars) do you see being invested in the _____sector of the US fuel cell industry over the next 10 years? What about the next 20 years?

21. Describe the environment that would lead to this level of investment. Eg. what level economic growth; national security concerns, energy prices, etc.

22. Under these circumstances, how much money would you expect to come from venture capital? From the industry itself? From public markets?

23. If the_____ industry were funded at this level, how would you expect US leadership to be affected? For example, would other countries move ahead of the US in some areas or not?

24. In this scenario, what would you expect the US market size for fuel cell products to be 20 years from now in the _____ sector:
    a) in term of power units sold for transportation
    b) in terms of units sold for portable, and
    c) in Megawatts for stationary.

25. What would you expect the price to be 20 years from now in the _____ sector:
    a) per power unit in transportation? (By this we mean, combined fuel cell system including fuel cell, fuel processor and controller & sensor systems. We are not including fuel tank or electric drive train.)
    b) per fuel cell unit in portable applications and

c) per kilowatt for stationary fuel cell units.

26. In 20 years, (ask question for the appropriate sector):
    a) in the portable sector, what % age of the price of a fuel cell power unit will labor represent?
    b) in the stationary sector, what % age of the price of a fuel cell power unit will labor represent?
    c) in the transportation sector, what %ages of the price of a power unit will labor, represent? How does this compare to the % age that labor represents of the price of an ICE today?
    d) if a fuel cell manufacturer, what %age will labor represent of the price of the fuel cell? (by sector)
    e) if component manufacturer, what %age of the price of your component will labor represent? What portion will major commodities represent? (i.e. platinum)

27. What would you estimate is the average salary for an employee in your industry today?

Now let's assume a more positive, but not exuberant, environment.

28. In an improved environment, what aggregate level of investment, government and private, (total investment dollars) do you see being invested in the ____ sector of the US fuel cell industry over the next 10 years? What about the next 20 years?

29. Describe the environment that would lead to this improved level of investment? E.g. what level of economic growth; national security concerns, energy prices, etc.

30. Under these circumstances, how much money would you expect to come from venture capital? From the industry itself? From public markets?

31. If the _____sector of the industry were funded at this level, how would you expect US leadership to be affected? For example, would other countries move ahead of the US in the _____ sector?

32. In this scenario, what would you expect the US market size for fuel cell products to be 20 years from now in the _____ sector:
    a) in term of power units sold for transportation
    b) in terms of units sold for portable, and
    c) in Megawatts for stationary.

33. What would you expect the price to be 20 years from now in the _____ sector:
    a) per power unit in transportation? (By this we mean, combined fuel cell system including fuel cell, fuel processor and controller & sensor systems. We are not including fuel tank or electric drive train.)
    b) per fuel cell unit in portable applications and
    c) per kilowatt for stationary fuel cell units.

34. In 20 years, (ask question for the appropriate sector)
    a) in the portable sector, what % age of the price of a fuel cell power unit will labor represent?
    b) in the stationary sector, what % age of the price of a fuel cell power unit will labor represent?
    c) in the transportation sector, what %ages of the price of a power unit will labor, represent? How does this compare to the % age that labor represents of the price of an ICE today?
    d) if a fuel cell manufacturer, what %age will labor represent of the price of the fuel cell? (by sector)
    e) if component manufacturer, what %age of the price of your component will labor represent? What portion will major commodities represent? (i.e. platinum)

Additional Questions

35. Who in the fuel cell industry or in the financial world do you suggest we talk with to gain perspective?

36. We've looked at studies that project the future of the fuel cell industry, but we'd like your suggestions on what studies you believe might be most helpful and relevant to our study.

# APPENDIX F

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