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Commercial, environmental and legislative factors that influence the implementation of fuel cells

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Abstract

Fuel cells and other advanced electric-generation technologies have not experienced a record of successful commercialization efforts. To lower costs for these technologies, it requires substantial production volumes with a significant investment in manufacturing facilities, all dependent on developer confidence in the ultimate market. Yet, market acceptance by buyers requires an adequate demonstration of technical performance and an assurance that these lower costs can be reached. In addition to this fundamental commercialization challenge, there are significant external factors that are greatly influencing the market's (utility's) future implementation of new alternative energy-generating technologies. The factor that has possibly the greatest impact today is the public demand for environmentally benign and renewable resource technologies. There is a growing trend of involvement by consumers, regulators and intervenors in the business and utility industry that is shifting the economic playing field by which industries make resource decisions. Concerns over air pollution, global warming, acid precipitation, depletion of the ozone layer and the hazards of electromagnetic fields (EMF) from power lines, have all led to more stringent regulations and environmental mandates. The utility business environment itself is rapidly changing. Higher public expectations from energy providers and increasing competition are leading to major changes in the American utility sector. Competitive requirements to reduce the cost of utility service is leading to business decisions that provide both opportunities and problems for increased use of alternative energy-generating technologies, like fuel cells, and/or renewables, such as wind and solar photovoltaics. Bringing new energy technologies to market is very expensive and this financial burden cannot be shouldered by the market, manufacturers or federal government alone. Further, for the market to assume a key position in early commercialization, the technology must offer a strategic and competitive advantage to early buyers. In order to break this problematic cycle of investments depending on market assurance and of market reluctance until cost goals are met, fresh approaches must be sought to address the unique challenges of each commercialization effort. Market-driven collaborations in which potential buyers, such as electric utilities, work together to define and implement a commercialization program that meets the market's requirements, with one or more suppliers, and with the federal government as a catalyst, provide perhaps the best opportunity for further commercialization of renewable energy and energy-efficient technologies. The key is that the market – not government agencies – determines the objectives and manages the resulting program. Two examples of such collaborations, the Fuel Cell Commercialization Group (FCCG) and the Utility PhotoVoltaic Group (UPVG), have so far proven to be successful in their new technology commercialization attempts.

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Commercialization: the challenge

In a 1987 report 'Our Common Future', the World Commission on Environment and Development states [1]: 'Energy is not so much a single product as a mix of products and services, a mix upon which the welfare of individuals, the sustainable development of nations and the life-supporting capabilities of the global ecosystem depend... A safe, environmentally sound and economically viable future is clearly imperative. It is also possible. But it will require new dimensions of political will and institutional cooperation to achieve it.'

The biggest challenge facing the energy industry today is how to plan for the future. Utilities must find ways of developing new energy capacity with less abundant, more expensive real estate, growing public concern over the depletion of energy resources, the desire for a cleaner environment, growing legislation to appease these public concerns, and increasing competition to reduce the costs of the energy products.

Incorporating new technologies requires addressing, in addition to these business challenges, traditional commercialization challenges. The market must be satisfied with the new technology. This requires adequate demonstration to prove the performance of the product, and assurance that eventually the cost of the product will be competitive with alternative ways of providing the same resource.

On the other hand, the developer of the new technology has its own requirements. Facing uncertain success of technology development efforts, the supplier must prove to itself that the investments necessary to achieve commercial success will not be too risky for its investors. Risk must be manageable. And, of course, the supplier must have measurable confidence that the market exists for its product.

Any commercialization effort must address, not only these traditional economic and technological uncertainties, but also the current external uncertainties that are to do with public perceptions, public interests and the translation of these into legislative, regulatory and other market realities.

The next part of this paper discusses the current set of challenges, but we will call them 'opportunities'. These are the factors that will help create change, and in change there is opportunity for new products and markets.

Commercialization: the opportunities

The green movement has taken hold

One of the major trends that is influencing the business and utility sectors' interest in renewable energy, alternative energy and energy-efficiency technologies, is the growing realization that the 'green movement' is here to stay. Fundamental changes have occurred in American environmental values, beliefs and opinions, and environmental protection has become an important public value. Evironmental protection has become 'environmental self-protection'.

The public feels that they no longer necessarily need to choose between energy development or economic growth and the environment. Surveys show that while the economy of the USA worsened, people remained supportive of environmental protection. Throughout the recent recession period, polls consistently demonstrated stronger and stronger support for this 'green movement' [2].

Consumers are more aware of their energy choices and will continue to look to companies, – especially utilities – to become more environmentally and economically responsible. This trend appears to cut across the conventional demographic, regional and ideological divisions that characterize American society, and will affect the economy and the political arena.

This new trend of environmental protection is forcing utilities to re-evaluate their objectives and organization. New business strategies must be developed that incorporate better communication with the public and government watchdog agencies, and that prove a commitment to the environmentally friendly energy technologies. The public concern over the issues of air and water pollution, global warming, acid rain and the suspected hazards of electromagnetic fields (EMF) has produced a growing number of lawsuits that are resulting in difficult and delayed permit and siting processes for new electric-power transmission and substation facilities. Situations such as this will inevitably lead utilities to reconsider their power systems and give them a strong incentive to investigate energy alternatives.

With their minimal environmental impact, competitive costs, and unsurpassed operational benefits and flexibility, fuel cells have the winning combination to become one of these alternatives.

Alternative and renewable energy technologies are good for the economy

There is a growing trend of public attitude that alternative and renewable energy technologies are also good for the economy. It is not always necessary to choose between economic development and environmental protection. Both can be achieved by taking an integrated approach and making intelligent decisions about alternatives for energy development and use. More and more research analysts support the notion that investments in renewable and alternative energy resources, public transit and fuel-efficient vehicles are good for the economy and will create more jobs than continued increased investment in traditional energy sources and new highway construction [3]. Money saved by energy efficiency is money that can be put back into the local economy by consumers and business.

The new global environmental focus can offer global profit-making export opportunities. The focus on energy efficiency and cleaning up air, water and soil has become a US$ 200 billion+ annual business and will continue to be a major source of new jobs throughout the 1990s [4].

In 1989, the New York State Energy Office found that every million dollars invested in efficiency and renewable technologies generated from two to ten times as many jobs in the state as fossil fuel investments did. One reason this refocus of energy planning often creates more jobs is that, in general, alternative/renewable energy projects can be built and installed much faster than traditional technologies. Money invested in traditional technologies can be tied up in financing of construction for years. The California Energy Commission found that solar and wind projects can come on line in six months to three years, while natural gas, coal and nuclear projects usually take three to twelve years [3].

Reports by Greenpeace, Worldwatch, and Laitner and Geller on job growth and economics of energy choices conclude that pursuing a high-efficiency strategy will result in 293 000 more jobs and reduce energy consumption by 3.4 quads by 1995. By 2010, they predict 1087 million more jobs and reduced energy consumption of over 20 quads [3].

Sustainable development is a worldwide goal

There is a growing realization that environmental problems, no matter how local, eventually become global problems. Global problems require global solutions. The traditional framework for world development, both in the industrial and underdeveloped countries, no longer provides the best solutions to today's economic and environmental dilemmas. The new development focus is that of 'sustainable development'. The goal of sustainable development is to obtain economic progress without exhausting the earth's resources. This change in development strategies has led to growing international environmental cooperation. Attendance grows at more frequently held international meetings of public interest groups, private organizations, and government agencies, and there is increasing cooperation among industries, including those associated with energy.

It is difficult for developed countries to comprehend that 50% of the world's population does not have any electric service. Electric power is central to any country's growth and survival, and it will be a rapidly increasing energy, and therefore environmental, issue worldwide. The success of global sustainable development will depend on how countries choose to meet this need for electricity.

Industry is linked to sustain development because such development depends on electricity. The electric power industries in almost all developing countries are very inefficient and polluting. The choices countries make for their energy production has the potential to create global, regional and transboundary environmental problems. It is therefore in the best interest of the industrial countries to assist developing countries with their energy and environment problems. Demands for natural resources created by a more crowded and poorer world will create the need for accelerated technology advances. These technologies will use fuels more efficiently and will produce them with the least possible adverse effects on the environment.

Global market expansion is inevitable and attractive

Technology and energy equipment markets are becoming global markets. If global sustainable development succeeds, the market for electric equipment of all types will grow and there will be a competitive advantage for countries that have developed these products. This globalization of equipment markets means engineers around the world will increasingly use similar practices and will conform to international equipment standards, resulting in more mechanisms for transnational information exchange.

Many developing countries are changing their financial and political structures to encourage foreign investment, private ownership and market-based economies. Developing countries are looking for ways to develop new generating capacity; make improvements in existing capacity; make upgrades to their transmission and distribution systems and find new ways to comply with stricter environmental standards. Large opportunities for investment by the industrial world exist, especially for experienced electric utilities.

Realistically, few of these electric power projects are fully privatized. There are very large capital requirements, but many governments are unwilling to transfer total control of such strategic industries to the private sector. Many governments are instead proposing different kinds of investments to encourage private-sector involvement in state-owned utilities rather than complete control. Options for private industry include site and environmental studies, professional training and management, system planning and operations contracting. These options provide unprecedented business opportunities for utilities.

There are many risks involved with overseas expansion, but the potential for success is good enough to make foreign investment attractive. By 1992, growth in the USA utility industry had slowed to less than 2% a year. There is a growing need for utilities to look elsewhere for business expansion.

New legislation will shape future utility action

The importance of energy security is imporatant to any country. The recent war between the USA and Iraq placed energy issues at the top of America's policy agenda and subsequent Iraqi agression hastened the introduction of several items of energy legislation by members of the US Congress. The public is concerned with America's obvious dependence on Middle Eastern petroleum products. The push for increased energy independence, as well as the flourishing environmental movement and the growing focus on global sustainable development, global markets and technology transfer, have led to a surge in US environmental legislation during the past decade. Federal polices saw a lot of action in 1990 – by the end of that year, over 100 environmental laws affecting electric utilities were enacted by Congress, each reflected society's concern for higher environmental quality. From 1980 to 1990, there were over 37 environmental laws, amendments and re-authorizations. These laws are continuously being rewritten and amended as new data are collected and new environmental problems recognized.

Since 1970 Clean Air Act and the 1990 Clean Air Act amendments, the most important piece of energy legislation has been the 1992 National Energy Policy Act (NEPA) [5]. NEPA was the largest rewrite of energy lay in over a decade and it changed the basic structure of the Investor-Owned Utility industry. Now that NEPA has been implemented federal agencies, especially the Department of Energy (DOE), the Federal Energy Regulatory Commission (FERC), the Securities and Exchange Commission (SEC), and the Nuclear Regulatory Commission (NRC) must craft hundreds of rules to implement the new law.

In general, programs in NEPA make incremental improvements to the existing energy laws and only begin to address US energy problems. The legislation affects areas of transmission, environment and conservation. Overall, it tries to enhance energy efficiency in residential, commercial and industrial sectors by using more stringent standards for buildings, and by establishing performance standards for energy-intensive products.

Under NEPA, state commissions must consider new Public Utility Regulatory Policies Act (PURPA) standards that encourage the use of conservation, demand-site management programs and integrated resource planning. NEPA declares that utilities must consider rate incentives to make these programs at least as profitable as new energy supply options. It also requires commissions to consider providing rate incentives for utilities to make energy efficiency improvements in power generation and supply. Important to the fate of commercialization of new energy technologies, it calls for expansion of the joint-venture programs between the federal government and the private sector to develop commercially viable renewable technologies and applications. An important concept recognized in NEPA is the importance of a deeper role played by federal agencies and state regulatory commissions in energy development.

There were also several industry sponsored provisions in NEPA: 100% tax exclusion for utility conservation rebates to residential customers, and phased-in exclusions (40% in 1995, 50% in 1996, and 65% in 1997 and beyond) for commercial and industrial rebates. The utility industry spends more than US$ 2 billion annually on energy efficiency investments (including these rebates). This provision will ensure that these measures can continue smoothly. Other incentives will make electrical vehicles (EVs) cost-competitive with other alternative fueled vehicles. To encourage the development of renewable resources, the law grants permanent 10% business tax credits for solar and geothermal energy and a production tax credit for wind and biomass energy.

The arrival of a new administration brought changes that will continue to influence the legislative environment for alternative and renewable energy generating technologies.

Most notable is widespread reorganization of the Department of Energy, as well as the government's National Laboratories. The new administration is moving away from defense R&D and nuclear energy and focusing more on the commercializing of renewable energy projects and the increased use of natural gas.

Nuclear capacity is decreasing

Between 1990 and 1991, the total installed nuclear generating capacity declined for the first time since commercial nuclear power began in the 1950s. There have been several premature nuclear plant shutdowns. Some utilities closed down plants because of the great difficulties in renewing licences. While NEPA has made these licensing procedures somewhat easier, there are still complications and many utilities are finding it cost effective to close plants and find other energy alternatives including gas-fired powerplants, gas turbines, cogeneration, renewable energy projects and energy-efficiency measures. The potential for nuclear plant closings becomes significant when you realize that 44 plants are up for relicensing between 2002 and 2014.

Growing public concern with nuclear accidents, such as Chernobyl and Three Mile Island, and nuclear waste disposal indicate that the nuclear industry will have an extremely difficult time making a comeback. Because it is a renewable resource and an established technology, nuclear power will not be erased from the current energy mix; however, its benefits do not seem to be enough to truly revive the industry.

Natural gas use is increasing

For the eighth consecutive year, world natural gas production reached a new high in 1991 at 77 trillion cubic feet [6]. Its use is growing faster than oil or coal and could surpass oil as the dominating energy source after 2000. Public polices over the last several years have encouraged greater use of natural gas and it has become the 'fuel of choice'. Compared with other fossil fuels it has the best emissions rating of CO_2, SO_2 and NO_x. It is fairly plentiful and domestically produced, thus it is a more secure energy source.

The USA is the number two producer of natural gas in the world and is estimated to have at least 60 years of the resource at today's extraction rate. Of the natural gas used by the USA, 90% is domestically produced. Other bonuses are that it has favorable captial costs, construction of gas-fired generating plants is easy, there is price deregulation and its uses open access transportation.

Supporters of hydrogen as a future energy carrier to link renewable resources with energy applications note that the infrastructure for natural gas transportation and use is very similar to what would be required for a future hydrogen economy.

The utility industry is changing

Utilities face three driving forces of change today: cost reduction, customer service and competition. In fact, competition is the root cause of increased interest in cost reduction and improved customer service. The increased attention to these three factors in the US utility industry is unprecedented and is affecting all aspects of the business. Competition and the need to improve business base is inevitably leading utilities to focus on energy efficiency, improved environmental performance and alternative energy options. Utilities must be flexible with their energy mix and adaptable to rapid change.

To meet these challenges, utilities are 'down-sizing' and reorganizing; integrating small renewable and alternative energy projects into their systems; diversifying energy production technologies; merging with other entities, and expanding overseas. Competition is leading to reductions in utility staffs, reorganization that separates the competitive elements of the business (e.g., generation) from less competitive departments (e.g., distribution), and reductions in non-revenue-producing departments (such as research).

These competitive pressures will be both an opportunity and a threat to new technologies like fuel cells. Research budgets will be drastically reduced in some utilities, while others will see the necessity of commercializing clean, high efficiency technologies like fuel cells as soon as possible.

Fuel cells provide a unique combination of strategic and financial benefits to utilities and customers. Due to short lead times, investments are incurred only when the capacity is needed. Because of high efficiency and reliability, including a part-load operation, operating costs are expected to be competitive. Siting and operation flexibilities and benefits unique to fuel cells can lead to site-specific benefits that swing overall competitive evaluations towards fuel cells.

Other changes in the utility industry will have less effect of still significant impact on the introduction of new technologies. Demand-side management (DSM), least cost planning and integrated resource planning (IRP) strategies are increasingly being incorporated into businesses. The concept of DSM is to postpone the need for new generating capacity by reducing the amount of electricity that is required to accomplish a given task in home and industry [9]. Most utilities use DSM programs that focus on a single technology such as lighting, heating/cooling and motors. The environmental benefits of DSM are that energy efficiency is improved and fewer stations and transmission lines need to be built thus less fossil fuel is burned. According to the Edison Electric Institute, DSM programs and industrial self-generation will account for almost one-third of the 164 GW of electric resources currently under construction or planned for the 1990s [7]. To improve efficiency, NEPA legislation requires electric utilities and federal power marketing agencies to adopt IRP programs as a means of providing energy service to their customers. IRP provisions establish new rate-making standards that encourage states to use rate-making practices that encourage utilities to use DSM and efficiency measures to meet customers' needs.

Finally, the electricity title of the NEPA legislation restructures the electric utility industry. It amends the 1935 Public Utility Holding Company Act (PUHCA) and, thereby, makes it easier for entities to compete to supply the nation's incremental electricity demand. The Act also overhauls the federal law that governs the provision of transmission services. This amendment of PUHCA will allow independent power producers, A&E firms, fuel suppliers and others to compete to supply incremental electricity demand in the USA, free from the regulatory structure of the Holding Company Act. This provision is expected to expand the number of wholesale power generators and creates a new category of power suppliers — exempt wholesale generators (EWGs) — that are exempt from the Holding Company Act. Increased competition is expected to lead to reduced rates for consumers and to benefit the economy as a whole. The NEPA legislation also made revisions to the PUHCA that ease, or eliminate, many of the restrictions on US utility operations abroad. The impact that these changes will have on fuel cells is unknown.

The roles of US federal agencies are changing

A recent event that will greatly assist the commercialization of fuel cell technology in the USA is the approval of two provisions by the US House Armed Services Committee. In its consideration of the Department of Defense's (DOD) budget for fiscal year 1994, the Committee advises the DOD to direct US $100 million to programs that deal with electric vehicle and fuel cell technology research and development.

Funding would be eligible for all four fuel cell technologies. If this funding is approved by Congress, DOD could become the government leader in assisting fuel cell and EV markets. DOE's fiscal year 1994 budget request was US$ 2 million below the fiscal 1993 level of US$ 51 million. This bill requests US$ 50 million for fuel cell technology, i.e., more than DOE's entire request for 1994. The other US$ 50 million would be for electric and hybrid EV research and infrastructure development. The committee wishes to accelerate the development of infrastructure to establish 'market pull' for these technologies [8]. This interest in, and potential support of, new energy technologies reflects interest in using DOD technologies, contractor personnel and budgets to support civilian, peace-time interests.

The DOE is also changing the view of its role in new technology development. In recent years, it has viewed its job as ending prior to final demonstration activities that precede commercial application. Today, the tide is changing. Earlier this year, DOE's Morgantown Energy Technology Center (which manages DOE stationary fuel cell development) released a US$ 150 million request for proposals for product definition and demonstration of commercial designs for carbonate fuel cell developers. This move into commercialization activities is a welcome change and positions the market to play an important role as DOE, we expect, leaves the management of these sensitive activities principally to the forces of the competitive marketplace.

Commercialization: new approaches

New commercialization approaches are needed

The primary commercial barrier for alternative and renewable energy technologies is the gap between the cost of the energy technology system and the value which the market buyer can afford to pay for the function it performs. Since many advanced technologies like fuel cells will be factory fabricated, the fundamental commercialization challenge for these technologies is that sufficient volumes of the product must be produced for the manufacturers to be able to offer lower unit costs; yet the market is unwilling to pay the higher-than-competitive prices for the earlier units that are necessary to develop the market and supplier confidence that leads to these larger manufacturing volumes.

For example, as a mass-produced technology, photovoltaic technology exhibits declining unit costs as a function of volumes produced. Until production economies are realized, unit prices will remain too high to achieve significant market penetration. Compounding this problem is that planning tools and the perspective within the utility industry often do not recognize the opportunities that currently exist for the commercial application of these technologies.

Power generation technologies have often benefitted from large financial resources provided by government to initiate utilization of the technology and to cover large R&D costs associated with development. Unfortunately, very limited funding has been available for fuel cell technology and other alternatives. Traditionally, resources have been devoted to nuclear technology and military spending on gas turbine technology (foundation of the aeroderivative gas turbines now used by the utility industry). With limited development budgets, industry, government and markets must find creative solutions to overcome commercialization barriers.

Solutions must create a real market, not an artificial one created by one-time tax credits or other limited incentives. Legislation such as NEPA has encouraged the use of alternative and renewable technologies by offering various financial incentives.

Although the use of incentives to address market failure or decrease large gaps between current and commercial prices will help bring alternative energy technologies to the market, they cannot necessarily keep them in the market. Without focusing on the real market potential, and with no strategic plan for reaching commercialization, incentives can create false markets that can disappear with changing administrations and new public policy.

False commercialization starts are counterproductive

History is littered with false commercialization starts. In California, wind and solar projects in the 1980s received both federal and state incentives which disappeared with different political agendas. Investors seeking the tax shelters turned to other opportunities and the economics of these renewable energy projects changed significantly. New technologies need long-term commercialization plans for them to be fully integrated into today's mix of energy options. Real markets must be developed.

Interest in photovoltaics (PVs) suffered a similar fate in the 1980s as federal R&D budgets took a dramatic downturn with changing political support and more cautious evaluation of the risk/reward setting for PV investments. PV companies were sold and investments consolidated to address smaller market goals. In this case, utilities suffered unrealistic cost projections and later lost interest without ever experiencing the market education and involvement that was possible even then.

Fuel cells saw several attempts in the early 1980s to develop commercial markets in ranges of tens of kW and several MW. While major corporations and significant R&D institutions were behind such initiatives, market interest was never developed. Realistic commercialization plans that contained the appropriate sharing of risks and rewards failed to emerge. Expectations that utilities are 'deep pockets' capable of subsidizing high-cost, new technology projects were ill-conceived then and are absolutely inaccurate today.

Yet, the electric utility market is viewed by DOE and technology developers and manufacturers as essential to the next phase of market expansion for technologies such as fuel cells and PV. Only electric utilities offer the number and diversity of larger-scale applications to achieve the needed market leverage. Electric utilities have experience in the supply of bulk power and are the only potential purchasers well-positioned to exploit many larger applications. The diversity among the nation's 3200 electric utilities makes broader market acceptance easier.

In the utility industry, reliability is very highly valued and there are few rewards for taking cost risks and many penalities if the risk is unsuccessful. Clearly prices must be driven down to competitive levels or these technologies will remain only in niche applications. When evaluating competing technologies, however, utilities consider many factors. These include: capital costs; performance; reliability; construction and siting complexity and time, and operation and maintenance costs for the total system.

Suppliers of new renewable energy and energy efficiency technologies often approach these broader system perspectives naively. While technology proponents from outside the industry often criticize utilities as too conservative, most utilities would argue that their conservatism is necessary to minimize risks and maintain high standards of reliability and service for their customers. Improved sharing of cost, risk, system evaluation and other information between the developer and the market, in both directions, are necessary to accelerate utility commercialization success.

New collaborative approaches

Effectively managed, market-driven commercialization programs that provide the framework for supplier, buyer and government collaboration offer the appropriate structure for achieving commercial success. Demonstrations, government funding, supplier investments each by themselves will not yield the desired results. Commercialization plans must integrate the perspectives and interests of each of the related organizations and balance the ability to absorb risk, the need for information, and the benefits of success among them.

The solution to commercialization problems of renewable energy and energy efficiency technologies are market-driven collaborative programs. Potential buyers, such as electric utilities, working collectively among themselves to define product/system needs and to promote among themselves the market opportunity, together with the supplier industry (and others as appropriate), and with the federal government as a catalyst, provide perhaps the best approach to commercialization of renewable energy and energy efficiency technologies. Market education and development, familiarization of the supplier with the market's needs and its requirements, and joint efforts in product definition, technology configurations and support systems are all part of such programs to encourage early market adoption.

Examples of utility market-led collaborations included fuel cells (Fuel Cell Commercialization Group), photovoltaics (Utility PhotoVoltaic Group), refrigerators (Golden Carrot Program), wind generators, electric vehicles, coal gasification (DOE Clean Coal program), and heat pumps. Three of these that seem to have the key elements of a complete commercialization program are discussed in sections that follow.

The 'Golden Carrot' Super-Efficient Refrigerator Program (SERP) has 24 utilities pooling US$ 30 million as a prize to the manufacturer that can build the best and cheapest super-energy efficient non-CFC refrigerator. This project received early support from the US Environmental Protection Agency. Another project is the 'Solar Hot Water' program organized by the American Public Power Association, Edison Electric Institute and 20 member utilities. These organizations formed this commercialization group to further the development of cost-effective solar hot water systems. The DOE's Solar Buildings Program is providing support for this new group. Although these projects may be examples of utility collaboration to achieve commercialization, it is not clear that they contain all of the successful elements of a complete strategic commercialization plan with incentives that are well developed for all participants.

Wind power generation [9, 10]

The example discussed below is not a single program but a collection of individual efforts that appear to be addressing the remaining challenges for this technology — market-directed, cost-driven technology development and federal incentives for market action. These activities will be contrasted with the highly structured fuel cell and PV programs.

Wind represents less than 1% of the world's electricity, but it is one of the fastest growing sources of energy. Wind is the one alternative energy that could provide successful competition with today's conventional generating technologies. Because of design and engineering breakthroughs, wind is ready to jump ahead in the commercialization struggle of alternative and renewable generating technologies.

California is home to almost all of the US wind and solar electric generation facilities of any practical size. In the early 1980s, small-scale wind turbines in northern California received generous tax credits and other subsidies that helped move the technology into the commercial arena. Unfortunately, many of these federal and state tax subsidies ended up as tax shelters that never performed very well. Development slowed in the late 1980s, due to slower growth in power demand and the elimination of many of the tax credits. Since 1986, wind power has survived without tax credits, but it is still more expensive than adding natural gas or coal-fired capacity. Nevertheless, with growing environmental concerns, wind power has received a boost in popularity. According to the American Wind Energy Association, California avoided about 1.35 million tons of CO_2 emissions in 1991 by using wind to generate electricity.

NEPA legislation provides for a federal production incentive of 1.5 cents per kWh for wind-generated electricity, but the cost of wind is gradually decreasing, even without such incentives. Wind power has gone from 25 cents/kWh in the early 1980s to 7–9 cents/kWh today (this figure represents the best California locations and is most likely the best expected under best conditions). Wind power generating capacity increased 17% in 1991, to a new high of 2215 MW. Wind produced 3.7 billion kWh of electricity in 1991, enough for half a million US homes. Today, more than 15 000 turbines in California (mainly in three areas: Altamont Pass, San Gorgonio Pass, Tehachapi Mountains) produce 1600 MW. Besides California, other areas of the USA are showing increasing interest in wind power. Interest is growing in the Midwest, particularly in Minnesota and Iowa. A recent DOE study has shown that there are 37 states where there are good prospects for wind generation.

One of the current wind projects that will help make wind power more commercially competitive with other power sources has PG&E, Niagra Mohawk, US Windpower and Electric Power Research Institute (EPRI) developing a variable-speed turbine that is designed to produce electricity at 5 cents/kWh. That makes wind competitive with conventional generating technologies. This new windmill is the result of a US$ 40 million R&D program that began in 1989. This year, Niagra Mohawk will be the first to use the new wind turbines in a commercial-scale test. This new 33M-VS technology also has the interest of other utilities. Idaho Power, Portland General Electric Co., PacifiCorp and Puget Sound Power & Light have formed a consortium and are planning a 50-MW wind farm at Rattlesnake Hill in Washington state. With this goal of 5 cents/kWh in 13-mph wind, EPRI and DOE have joined forces to run large-scale wind power demonstration projects at up to four host utilities – a US$ 40 million R&D effort.

These projects and incentives may be successful in achieving competitive costs for wind generation, and they address many of the fundamental requirements of market-driven collaborative programs. They are not, however, designed collectively as strategically complete commercialization programs. The next two are.

Utility photovoltaic group

Solar photovoltaic (PV) electricity is the direct conversion of sunlight to electricity using thin slices of silicon called solar cells. These cells are manufactured into modules that provide small but useful amounts of electricity. When mounted in larger arrays, PV modules can perform functions that are considered by many to be cost-effective today. Nevertheless, PVs cannot yet compete with even highly valued energy supply alternatives in site-specific applications like DSM or reinforcement of the local transmission and distribution system.

The industry, with the assistance of EPRI, has been researching the technology for approximately 20 years. One of the world's faster growing high-tech industries, it has expanded from 2 MW in 1975 to 6.5 MW in 1980 and 23 MW in 1985 to 55 MW in 1991. This represents an annual growth rate of more than 15%. Primary applications have been for remote sites and niche applications. To move PVs into central station generation will require lower costs. Efficiency improvements and the development of lower cost manufacturing processes have helped to reduce the cost of solar electricity by a factor of 4 during the 1980s. Although solar power has become more economical, at about 30 cents/kWh, costs have to be cut a lot more to compete for grid electricity. The challenge in expanding PV use over the next several years is to reduce current costs of US$ 8 to US$ 10 per peak watt to below US$ 4/W for high-value, site-specific applications, to US$ 2/W to compete with conventional resources [10]. Many believe the US$ 4/W target can be reached by the end of this decade.

The establishement of US$ 2 to 3 billion in combined private sector and governmental expenditures has also helped bring systems into the initial stages of widespread, cost-effective, commercial availability. Many agree that increased purchases of larger-scale (typically 100 kW or greater) PV systems for niche applications will be one of several precursors to competitive PV costs and sustainable markets.

The history of solar energy in California is similar to wind. State and federal tax credits were available for the development of renewable energy. Non-hydro elements got a great deal of assistance from the Public Utilities Regulatory Policies Act of 1978 (PURPA). This legislation forced electric utilities to purchase electric power from developers of power projects. When this legislation went into effect, fossil fuels were more expensive, so 'avoided costs', used as a measure of what utilities should pay, were relatively high. Today, however, fossil fuels are considerably lower in cost, so that, when all cost factors are considered, the renewable energy that California utilities purchase is among the most expensive resource on the utility system.

To commercialize successfully any new utility technology, the hardware initiatives must avoid the lure of one-shot 'buys' and, instead, address sustainable markets. Initiatives should deal with a range of applications, potential system sizes and technologies, and technology advancement (from emerging to proven), in order to provide the best opportunities for all promising suppliers and packages of systems.

The Utility PhotoVoltaic Group (UPVG) is the newest and most visible example of collaboration between the US DOE, buyers and suppliers to bring a new technology to the competitive marketplace. The UPVG is an organization of 67 electric utilities with a mission to accelerate the use of current cost-effective, high-value applications of PV, and to push for market-driven ways to lower costs and boost expanded uses of the technology in the near future for the benefit of electric utilities and their customers.

With the difficulty of defining the strategic, competitive advantage PV holds for utilities, the initial phase one program, has a multifaceted schedule that addresses promotional opportunities for near-term, small-scale applications, while it evaluates all aspects of successful commercialization to define strategies for large-scale applications to come. In March 1993, the UPVG received US$ 800 000 from DOE in cost-sharing funding to support the aggressive phase one list of market education and strategy development tasks.

Even before this phase of the program is complete, the UPVG is developing its next phase, a US$ 513 million, 50-MW hardware initiative involving public and private funding. A major hardware initiative called TEAM-UP (Technology Experience to Accelerate Markets in Utility PV) is to be started in 1994. This aggressive hardware demonstration initiative will result in earlier indications of market interest and will develop the experience base across a broad number and spectrum of utilities and applications. The combination of UPVG's market-acceleration strategies, hardware demonstration and definition of packaged systems that meet utility standard of acceptance should go far in providing this assurance.

The Department of Energy is an essential partner in PV commercialization. Besides the UPVG, DOE is involved with Solar 2000, PVUSA, PVMaT, and PV:BONUS.

DOE's Solar 2000 program has an objective to install 900 MW of US manufactured PV systems by the year 2000. 50 MW are already earmarked for utility applications over the next few years. In addition, DOE is supporting the establishment of state working groups to facilitate communications and planning by utilities, state utility regulators, state energy offices and other interested organizations.

Fuel Cell Commercialization Group

The Fuel Cell Commercialization Group (FCCG), with Energy Research Corporation (ERC), has achieved an innovative market/supplier collaborative effort to commercialize carbonate fuel cell power systems. The FCCG was formed in 1990 as an outgrowth of an American Public Power Association initiative that invited fuel cell developers worldwide to propose a collaborative market and technology development program with interested utility buyers to help break the impasse in bringing fuel cells to market maturity.

The FCCG is a consortium of potential utility and industrial buyers of fuel cell power plants. The FCCG's mission, in partnership with ERC of Danbury, Connecticut and its subsidiary, the Fuel Cell Engineering Corporation (FCE), is to commercialize ERC's multimegawatt carbonate Direct Fuel Cell power plant, by the end of the decade. The twin objectives of this buyers organization are to promote ERC/FCE's technology and commercialization opportunity to potential buyers throughout North America (having obtained incentives and guarantees for these early buyers), and to coordinate the development of buyer information in support of the program.

To encourage participation by the market, FCCG members receive royalties and other incentives and risk management considerations from the supplier in exchange for funding of the demonstration and commitment to purchase EPUs. The FCCG is preparing to break ground in the building of the first 2-MW carbonate fuel cell power plant, with contract negotiations for nearly 100 MW in early commercial orders now underway to implement initial commitments.

A set of detailed principles negotiated between ERC and the FCCG is guiding the introduction of the fuel cell technology. The 'Principles and Framework for Commercializing Direct Fuel Cell Power Plants' (P&F) is an agreement that defines the buyer responsibilities for promotion and coordination of information development, as well as the supplier responsibilities for meeting certain milestones and for sharing the results of success through a royalty agreement. The P&F contain specific sections on ERC's commercialization plan, ERC and buyer obligations, technical and financial risk protection, financial incentives and benefits for early participation, and the conditions necessary for proceeding to each subsequent step of the program. The P&F are also the basis for negotiating formal purchase contracts between individual buyers and ERC.

The overall US$ 250 million commercialization program includes several demonstration plants, followed by 100 MW in 2-MW pre-commercial units. This will result in commercial power plant production by the end of this decade. One of the FCCG's primary goals has been to secure funding for one of these demonstrations and for 35 buyers of the early 2-MW power plants (63 MW total). This represents a total FCCG member commitment of about US$ 125 million.

The Group currently has 40 members from all sectors of the utility industry, including independent power. Seven of these members have also formed the first demonstration carbonate fuel cell project in the program, the Santa Clara Demonstration Group (SCDG). The City of Santa Clara in California will host this initial 2-MW power plant. Funding and technical support are also being provided by the EPRI and DOE. The latter has allocated US$ 12 million in the fiscal year 93 funds to the FCCG and MC-Power (another organization aimed at commercializing carbonate fuel cells) to support their first demonstration plants.

With its success in achieving more than enough members to meet the program's requirements for buyers, the FCCG is focusing on the remaining contractual and engineering efforts that will lead to firm orders. They are also evaluating what can be done to further develop buyer interest in fuel cells to build an even stronger, longer-term commercial market.

Conclusions

Many lessons can be learned from each attempt to develop the commercial market for new energy technologies. The key lessons learned from FCCG and UPVG experiences include the following.

Commercialization can best be accelerated when driven by buyer needs

The future purchasers and users of a technology are in the best position to judge performance and cost requirements, not government researchers. This collaboration is needed to ensure that the right products are developed for the right reasons. A good test of buyer interest is willingness to provide funding for a project and to assume risks. Buyer needs must be taken into consideration through credible assessments of realistic market potential. Early applications and cost and performance objectives are critical to sustain the confidence and commitment of buyers and sellers to the commercialization process.

Risks need to be managed and benefits need to be exploited

The utility culture can be successfully challenged to embrace new technologies, so long as the factors of risk, competitive costs and reliability can be understood and addressed. The benefits of early buyer involvement need to be well-articulated and the risks need to be understood with effective plans formulated to manage them. The FCCG's Principles and Framework is an example. Participants must realize that the flexibility that is needed in a commercialization schedule because it requires a great deal of patience and a long-haul effort to develop market comfort. Programs in which market and supplier interests each have incentives in the promotion and successful outcome of the program are more likely to be aggressively pursued by the market than those in which the fruits of success go solely to the supplier. Buyers with incentives to expand the market and/or the program become buyers 'marketing' for the suppliers.

Government support is critical

The government needs to take a lead in energy policy that would turn energy services into a true market. No single player can assume the costs and risks involved with successful commercialization alone. Suppliers, buyers, and government must work together. Even if there is a market/supplier collaboration, the market generally feels more comfortable if government support is there, plus financially the market cannot realistically take on the types of financial burden produced from such efforts.

Federal funding must be consistent. Program initiation must be matched with assured funding throughout in order to obtain the commitments desired from private industry and other partners. Limited government support is most effectively earmarked to those critical areas that exceed the risk thresholds of the markets and suppliers. Government participation can take the form of cost-sharing hardware demonstrations or facilitating the start-up of a market-led collaboration or demonstration. Such support lowers cost hurdles and, thereby, stimulates sustainable markets that will eventually allow government support to decrease.

The government's involvement in these projects needs to be multifaceted, e.g., it must incorporate technology development and R&D, improvements in manufacturing processes and the acceleration of the development of commercial markets. Finally, technical partners, such as the Federal Government's research laboratories, are essential because they provide critical research and an analytical base to demonstrate efforts.

Market-led organizations offer an effective means for implementing major commercialization strategies

The market, as the eventual buyers, is best able to convey its technical, financial, performance and business requirements for new technologies to be successful. Close relationships with suppliers lead to a better understanding of the technology and its costs and capabilities. With the market as an important partner in helping to finance early commercialization, suitable incentives and risk and benefit-sharing need to be developed with the suppliers. Potentially, the market contributes product definition and credibility that can accelerate and promote success for the suppliers' early commercialization efforts.

Government completes the triangle necessary for successful commercialization because, often, only government can support the early risks and it is also the best catalyst for commercialization with its linkage to government policy setting. Government, in this catalyst role, can help seed the formation of market-led organizations and once understandings are reached between the market and suppliers, the resulting buyer-led organizations can provide the market voice in fulfilling the commercialization strategy. Leadership by trade associations or other utility-wide organizations is very important because they provide visibility and credibility and access to objective technical support, and thus will increase confidence in the commercialization program.

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