



South Carolina Next Energy Initiative

South Carolina Hydrogen &
Fuel Cell Economy Strategy

Final Report

September 2005



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Final Report

September 2005

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South Carolina Next Energy
Initiative

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1. The World is Changing: The Emerging Hydrogen and Fuel Cell Economy

1.1. Global Trends in Energy: New Sources Are Essential

The world is facing a challenge in meeting its needs for energy. This is leading to accelerated efforts to find new ways to derive and produce energy. Over the coming 20 years the world economy will be adjusting itself to accommodate a wide range of systems to produce needed energy—to heat homes, power industries and run transportation. These systems will rely less on current fossil fuels and more on a wide range of new sources, including renewable forms of energy such as solar, wind and biomass sources as well as nuclear sources. In these scenarios hydrogen is likely to play a vital role as the energy carrier of choice to bring the energy from sources of production to points of consumption, and fuel cells are likely to be used to convert this hydrogen to electricity.

Hydrogen, while the most basic and ubiquitous element, faces important challenges to cost effective and environmentally sound production, storage and distribution at the scale that markets will require. Yet, if breakthroughs in hydrogen generation, storage and distribution are achieved, many aspects of every day life will change. Optimists believe that the world's restructuring around hydrogen will be on par with the revolution around coal and steam power in the industrial age. Others believe that a diverse array of fuels and power generation will include hydrogen as well as nuclear and other renewable sources—photovoltaics, wind and hydropower. For this reason, hydrogen and fuel cells have gained attention on a scale never before seen—politically, technologically, and economically.

- **Increased Demand for Non-Renewable Sources:** Fossil fuels—coal, oil, and natural gas—are currently the source of 85 percent of worldwide energy use. Their apparently nonrenewable nature has created a crucial challenge for a world that has relied on them to meet energy needs. Increases in GNP of China and India has increased the demand for these fossil fuels and market forces are likely to produce higher costs to consumers and thereby create an opportunity for alternative fuels. Experts have predicted—unanticipated discovery of major new sources notwithstanding—that there is only enough affordably recoverable crude oil left to last the world another 20 to 40 years at most. The possibility of using coal to generate power or produce fuel remains a high possibility, given the scale of reserves, environmental issues notwithstanding.
- **Concerns about Energy Dependency:** Regardless of availability of energy sources, there is pressure to reduce dependency on sources outside of North America. Politics and geophysical events (such as hurricanes) have increased American concerns about reliance on fossil fuels. Today the U.S. derives one-third of its oil from the Middle East. Experts predict oil reserves in other parts of the world will dwindle earlier than in the Middle East, leaving the U.S. reliant on that region for as much as two-thirds of its oil supply in 2030 if nothing is done to change American energy use.
- **Rising Environmental Concerns:** Environmental worries have heightened concerns about finding alternatives to traditional sources of energy. Over the last 150 years, burning fossil fuels has resulted in a more than 25 percent increase in the amount of carbon dioxide in the Earth's atmosphere— contributing to the greenhouse effect and global warming. Many US

states now have policies supporting use of renewable energy resources that generate less carbon dioxide.

- **A Public Mission:** Hydrogen energy is believed to have the potential to at least partially address the challenge of worldwide dwindling reserves of fossil fuels. Hydrogen can be derived from a variety of sources (though not without expense of energy to release it) and produces no carbon dioxide emissions on conversion to energy—the only byproducts of its burning are heat and pure water. However, the extraction and processing of hydrogen can, in some cases, produce harmful emissions (a topic explored in the next section). Hydrogen has the potential to be used more efficiently than fossil fuels, and its applications are seemingly endless.

Fuel cells, as a means for converting energy or generating power, can be fueled by hydrogen, and may eventually be able to productively generate hydrogen internally themselves. Yet in the near-future fuel cells can and will use other available fuels.

Fuel cells are highly efficient electrochemical energy conversion devices that directly convert chemical energy to electricity. A variety of fuel cell technologies are known and under active development. Low temperature fuel cells operate on pure hydrogen while high temperature fuel cell can internally produce hydrogen from other fuels such as natural gas and biogas. In the context of electricity generation, fuel cells will be important as a means for distributed power generation, that can work independent of the existing power grid and help decentralize power resource that have historically been highly centralized (power plants).

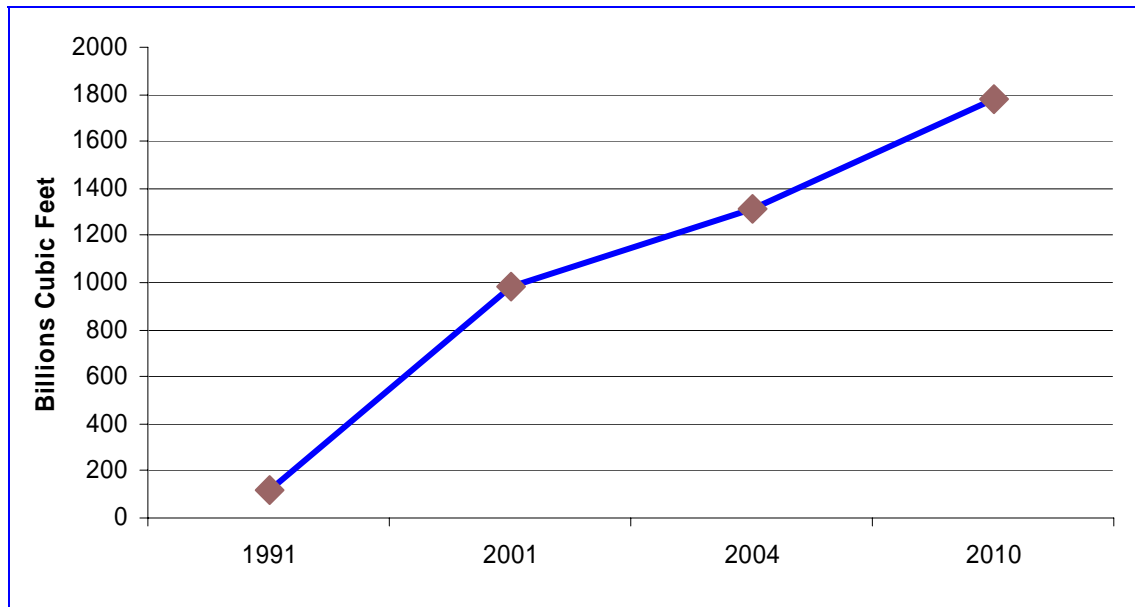
Hydrogen energy and the renewable forms of energy that contribute to its production and use (solar, wind, biomass, and methanol energy) are expected to grow in importance and reshape the world's energy system at an ever accelerating pace in the future. These reshaping will provide opportunities for economic development.

1.2. Technology Directions: Uncertainty and Opportunity

Hydrogen is found everywhere on Earth—in water, biomass, natural gas, and all living things—yet it is rarely found in its free elemental form. Hydrogen must be liberated from the chemical compounds in which it is found using some form of energy. A number of different sources of energy can be used to extract hydrogen, including such nonrenewable sources as natural gas, oil, coal, and nuclear power, as well as renewable sources such as wind and solar power. There are also a variety of chemical processing methods that will yield the hydrogen product from the hydrogen-containing feedstock. Whether or not carbon dioxide is released to the atmosphere in the process depends on the feedstock and the energy source used for hydrogen production. Fossil feedstocks and fossil energy sources almost always result in carbon dioxide release, while the use of renewable energy to extract hydrogen from a water feedstock does not.

There is already substantial production of hydrogen in the world (about 50 million tons annually), for use in fertilizer (ammonia) and methanol manufacture as well as for petroleum refining—and South Carolina possesses some of this industrial activity. This production level represents about 1.5 percent of the world's energy consumption, and is growing at 2.1 percent compound annual growth rate (CAGR). More instructive about the current dynamics in the hydrogen market is the faster growth (5.2 percent CAGR) that is being observed in the segment called the “merchant market” which has experienced sizzling growth as shown below.

Table 1-1. Forecast Worldwide Consumption of Merchant Hydrogen



Source: AirProducts, Inc.

The worldwide consumption of hydrogen, which stood below 200 billion cubic feet in 1991, is expected to reach 1,800 billion cubic feet in 2010. Although a part of this growth represents replacement of old capacity, it also indicates that growth in the energy-related sector of the hydrogen market is over twice the rate of the general market. From 1991 forward, most of this growth has been stimulated by the increased use of hydrogen for production of cleaner grades of petroleum-based fuels.

To date, few realistic projections have been made regarding increases in hydrogen production to support future transportation and stationary fuel cell application marketplace. While the transportation fuel cells will almost exclusively use hydrogen fuel, many large scale stationary fuel cells will likely operate on more conventional fossil fuels and other waste energy sources. Currently, about 80 percent of the hydrogen in the world is produced from natural gas through steam reforming. Steam reforming strips the hydrogen atoms from the natural gas and releases carbon dioxide as a byproduct. So far steam reforming has proven to be the lowest cost method of hydrogen production, but it is “nonrenewable” due to its reliance on natural gas.

Nuclear power may become a major source of energy for hydrogen production in the future—which is important to South Carolina because of its nuclear friendly environment. There is also a great deal of global effort to develop hydrogen production processes that are renewable and emission-free. Development is underway on methods of producing hydrogen through the thermochemical and photoelectrochemical splitting of water—both of which are areas of strength for South Carolina. However, efficiency must be improved and costs reduced before these methods can be competitive with the natural gas steam reforming process.

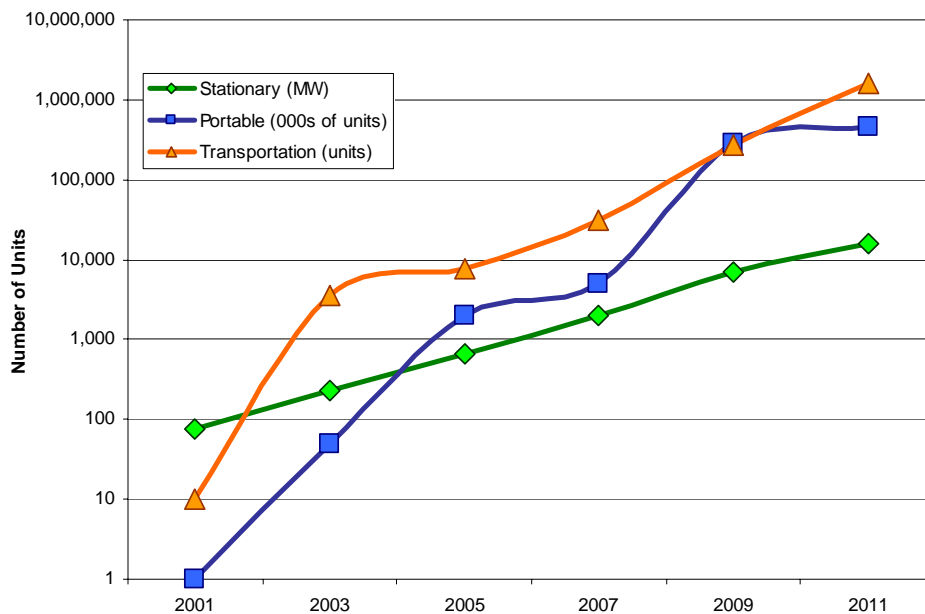
Once hydrogen has been extracted, it is distributed and stored in one of a variety of forms, depending upon its ultimate use. Hydrogen is the smallest and lightest known molecule, so storing it is a challenge. Hydrogen must be stored as a gas at high pressure or must be liquefied by cooling to very low temperatures (-423 °F) to be compact enough for storage in specialized

cryogenic containers. These are not particularly convenient means of storage for widespread use of hydrogen in energy applications, because they require considerable energy expenditure and heavy, bulky, and specialized containers. Leakage and embrittlement are also problems. In the future, hydrogen storage may involve using specifically tailored amorphous solid materials which can adsorb hydrogen for storage and readily release it for use.

Hydrogen can be transformed into energy through any number of energy conversion devices, including fuel cells. Hydrogen is already being used as a clean burning fuel, although it is not yet cost-competitive with existing fuels. Fuel cells represent an important future technology for conversion of hydrogen; they are a major improvement over the energy conversion devices we use today. Fuel cells convert hydrogen and oxygen into water, and in the process produce electricity, with no harmful pollutants. They also have the potential to operate at efficiencies two to three times that of an internal combustion engine.

Applications for fuel cells are far outpacing any new growth in hydrogen production. The demand for hydrogen to support the growth in fuel cell applications as shown below will be very sizable compared to the demand in the merchant hydrogen market segment. For example, to support 10,000 MW of stationary fuel cells with hydrogen fuel in 2011 will require new production capacity of 2.2 trillion SCF per year, which is 120 percent of the projected merchant capacity in that year. By comparison, the transportation demand for hydrogen to support 1 million cars is only about 85 billion SCF per year, or only 5 percent of the merchant production capacity.

Table 1-2. Projected Growth in Fuel Cell End Markets by Number of Units, 2001–2011



Source: PriceWaterhouseCoopers, "Fuel Cells: The Opportunity for Canada," 2002

As with hydrogen production, there are many challenges for the future of the fuel cell. A process must be developed for manufacturing fuel cells in an environmentally-friendly way. Fuel cells need to demonstrate higher efficiency and much higher reliabilities than they are currently achieving and their manufacture needs to achieve significantly lower costs so that they can

compete with, and then replace the combustion turbines, furnaces and boilers, and internal and external combustion engines we have today.

Fuel cells will be used in all the markets we use power in today—the stationary market, the transportation market, and the portable power market. Thus fuel cells are scalable from a postage stamp to a power plant. Besides their ability to promote a transition to renewable energy sources, fuel cells are able to promote energy diversity, because they will run on hydrogen, no matter where the hydrogen comes from—which provides a great degree of energy security as well.

1.3. Economic Potential: A Portfolio of Possibilities

The shift to a hydrogen and fuel cell economy offers wide economic opportunities for those ready and able to participate. Each stage of the hydrogen and fuel cell value chain (production, delivery, storage, conversion, and end-use markets) will require basic and applied research to overcome existing technological barriers. Most of the necessary technologies to overcome these barriers are not yet developed or commercially viable. In addition to focusing on research to solve technological barriers, there is also a need to overcome market barriers through developing a strong regulatory system, investing in a hydrogen infrastructure and pursuing demand-side actions that help build markets for hydrogen and fuel cells. Generating these solutions will result in the emergence of new firms and industries with potential access to a fast-growing global marketplace.

Over the next generation, the hydrogen and fuel cell economy could provide hundreds of billions of dollars in new economic opportunities in the U.S. alone. Many states and regions are positioning themselves to help solve the technological barriers to the growth of functioning industry and are seeking to reap the economic benefits from the ensuing investment and job creation. This wide range of actors across the public and private sectors reflect a growing awareness of the potential enormity of the economic opportunity of hydrogen and fuel cells.

In the area of Merchant Hydrogen production and consumption (storage, allocation and use), a baseline growth of 5.2 percent CAGR in a typical consumer market translates to multiples of 2 to 3 times in 'creation' markets, where supply is actually produced, prepared for the marketplace, and distribution is controlled. These will replicate traditional energy distribution models, when reflecting the adoption of new energy sources.

In the development of the hydrogen infrastructure, some regions are already taking a lead. While the ultimate delivery system for hydrogen is not yet developed, some regions have chosen to build hydrogen fueling stations as an initial step in the creation of a broader infrastructure. Currently, there are slightly more than 100 hydrogen fueling stations worldwide. That number will increase by at least 40 before the end of 2006 with most of the growth occurring in the United States.¹ Although not all regions which build fueling stations will reap economic benefits, the development of such infrastructure provides an opportunity to test appropriate technologies and solve implementation challenges which could provide economic development opportunities to the regions able to solve the challenges and export those solutions to other places.

¹ Source: Fuel Cell Today, May 2005

In the area of fuel cells, there is already a proven opportunity, which increases exponentially when combined with hydrogen as an energy source. According to one estimate, global demand for fuel cells is expected to reach \$2.6 trillion by 2021.² These forecasts do not yet encompass the large secondary economic multipliers that may arise from the emergence of this new industry over time. While any industry projection is necessarily of limited value in such an early stage of its emergence, it is clear that the opportunity for company formation and job creation in fuel cells is significant. Further, the projected growth of fuel cells, using hydrogen or other energy sources, will have an even greater effect on local economics and employment. Those who participate in the design, sourcing, manufacturing, distribution, servicing and repair of fuel cell products will control a burgeoning market, with high demand and initially, for at least 15 years, high margins on services delivered. The quality and productivity of these jobs, combined with their quick expansion during the first generation, will create tremendous local economic growth, and build the skill sets required for future technology development and deployment. Not every state or region will be the location of headquarters or final production assembly in the emerging hydrogen and fuel cell economy, many states and regions, however, will be where first or second tier production of key inputs will take place. There will be a wide range of economic opportunities that will take shape in this changing world.

In any major market shift, when moving from one base technology to another, the highest paying jobs come at the beginning (research and design) and end of the value chain (sales, marketing, and relationship management). The hydrogen and fuel cell market demand for valuable, first wave design and deployment expertise will be without precedence. Further out, as the hydrogen economy slowly evolves into the next energy commodity, those who move first today into positions of initial command over core product and infrastructure design and deployment will control the future of energy, locally, nationally and globally.

South Carolina has a distinct potential to generate and capture important parts of the emerging hydrogen and fuel cell economy. With its position in applied research and development, the state is poised before a large window of research and development opportunity, ready to create many higher paying research jobs, a next generation skills portfolio, and the centers of excellence which form around such activities. Using the methods proposed in this strategy and leveraging existing institutions and companies to collaborate in new ways, South Carolina can secure investment and create jobs on a continuing basis. While leadership in a new industry is never guaranteed, South Carolina today has an opportunity to take part in and benefit from a major economic transformation.

1.4. Framework for this Strategy: Build the Innovation Pipeline for Economic Growth

Around the world nations and states have become increasingly active in leading the charge in building their next generation economies. South Carolina, too, now has recently started its first Council on Competitiveness and recognizes hydrogen and fuel cells as an emerging cluster among those that the state expects to grow and help to achieve competitiveness. States once focused most of their economic development policies around maintaining low cost business environments and emphasizing industry recruitment—smoke stack chasing. They have changed

² Note: These projections are based on a 50 percent compounded growth rate between 2007 and 2021. Source: PricewaterhouseCoopers and Industry Canada.

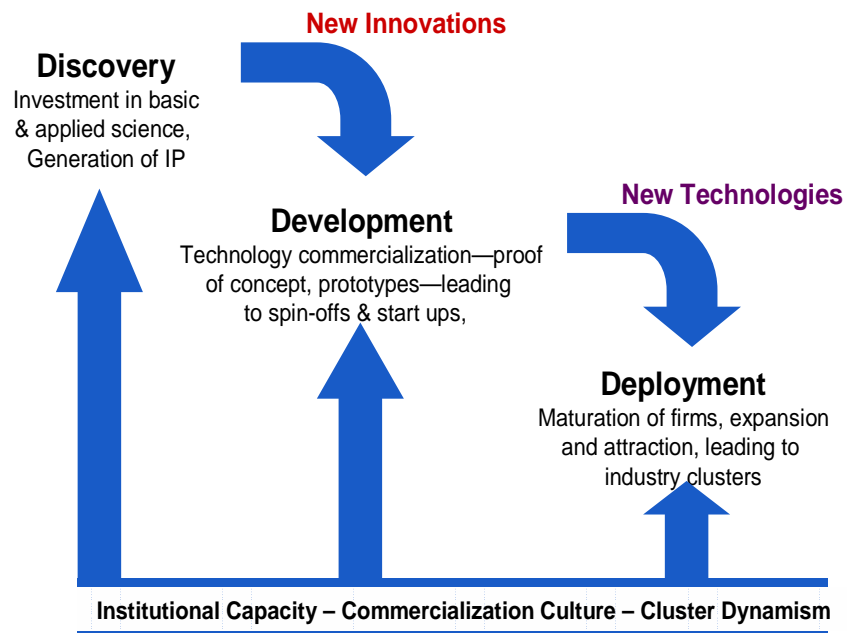
direction, now actively enabling the formation, expansion and attraction of industry by continually improving their sources of economic input advantage for specific industries they hope will grow and eventually “cluster” in their state.

As virtually all industries today are innovation-driven, states are recognizing how important it is for them to provide the distinctive inputs that an early stage industry requires. Today, virtually every state has a biotechnology, nanotechnology or other next generation technology-focused strategy in place to guide public as well as private policy. Hydrogen and fuel cell technology is one of the major themes to which states are now waking up. There are at least 15 states that are very actively pursuing new energy technologies, among their other industry development objectives.

Technology industries do not materialize over night— they take time to grow. Yet, what is often missing in state policy and private action is a framework to guide this growth process. Without a sustaining framework, most states will produce a patchwork of good intentions comprising of committees, various funds of money, and magic bullet projects. The history of high performing economies has shown that a state must pursue a longer-term developmental process if it is to successfully plant the seed of a major new technology, see it grow to maturity, and retain the growth and its secondary benefits within the state.

The South Carolina Hydrogen and Fuel Cell Strategy has been developed using a framework that is based on the practices of high performing economies. This framework sets in place a way of understanding both needs and actions that are essential to enabling technology-based economic growth. This framework is called the Innovation Pipeline.

Figure 1-1. Innovation Pipeline



Discovery: Research Feeds Innovation

Every state has a “Discovery System.” This system comprises institutions performing basic and applied research. The discovery system exists to provide new knowledge that feeds innovation. States with strong universities and national laboratories are fortunate to have a good foundation for innovation. A strong discovery system can be detected by its inputs and outputs. The inputs include solid budgets for the university operations, a winning record, a strong share of federal R&D, and leading faculty in key fields. The outputs are leadership in science (highly cited publications), effectiveness in converting knowledge into intellectual property (patents), and high involvement of industry in co-sponsoring university projects. States with strong discovery capacity are able to feed their development system with innovations that can be used to grow the economy. Many strong discovery systems fail to “capture” innovation in their own backyards and are, essentially, subsidizing the innovation processes taking place around the world—including competing states. Therefore, the first question to answer in developing the South Carolina Hydrogen and Fuel Cell strategy is: How well does South Carolina’s discovery system work—in the field of hydrogen and fuel cells? South Carolina needs to have a knowledge generator that feeds the marketplace with distinctive ideas for commercialization in this field.

Development: Innovation Enables Commercialization

Most states have a “Development System” that is invisible to the outsider. While industry laboratories are where most development has historically taken place, today, the entrepreneurial world is a major greenhouse for new innovations that become commercialized. Development requires a process in which an idea is conceived and then is proven and then for which prototypes are prepared and tested, and finally, with necessary support, moves to commercial production and distribution. Interlacing this process is the fundamental need for entrepreneurship. Without this, ideas will be exported from the state to other users. A high performing economy therefore has an infrastructure for supporting development that begins at the earliest stages—even before a company may be formed. States that reward innovators—whether faculty, staff or entrepreneurs from other businesses—and provide small amounts of funding to prove ideas and help them get transformed into the basis for companies, are able to grow a higher volume of start-ups. States that also have abundant talent for managing new enterprise *and* sources of early stage capital to help companies at their riskier stages are able to get start-ups across the chasm of their earliest stages so that they may then progress to commercial scale-up. High performing states have business and government support that adds up a natural or virtual incubator. The second question to answer in crafting the South Carolina Hydrogen and Fuel Cell Strategy is: How well does South Carolina’s development system work—in the field of hydrogen and fuel cells? South Carolina needs to have a technology commercialization infrastructure that captures innovation and puts it to work in the state economy—in this target field.

Deployment: Commercialization Yields Clusters

The economies that states envy are those that have achieved a size, depth, and dynamism that seem to replenish itself, creating new industries and new jobs on an ongoing basis. In the old economic development model states felt that by attracting companies with incentives that they would achieve a stronger economy. Yet it is difficult to recruit ones way to a high quality economy. Today, we know that economies are footloose and move often as the global marketplace shifts. In high performing economies states are able to understand their customers, much as do suppliers, and they learn to focus on creating sets of input advantages that speak to the needs of specific

industries. The “Deployment System”—however formal or informal—is how states and local partners put in place policies and programs for a responsive business climate. Where once that meant cheap land and labor, today this means building a package of adaptable education and training resources, accessible sources of technology innovation, adequate financial incentives, advanced physical infrastructure, and acceptable customer-centered regulatory and administrative policies. Moreover, to achieve better integration of these factors states are using planned “next generation communities,” such as technology parks and innovation zones that help create a concentration of business activity. These new planned micro-economies are more than real estate projects, they are environments where businesses can achieve advantages in operation through services and inter-firm synergies. So, the third question to answer in shaping the South Carolina Hydrogen and Fuel Cell Strategy is: How well does South Carolina deployment system work? South Carolina needs to create business settings where companies can form, expand or move in and, overtime, achieve the agglomerative effects that are what industry clusters are all about—a closely knit concentration of producers, suppliers and their key institutions—focused on this emerging industry.

The Strategy Process

This framework was used to guide the research and strategy development process that has been undertaken to ensure that this strategy has a solid underpinning and well defined stakeholders to support future actions. The strategy was developed through completing a four step process:

- **Mobilize—Prepare and Engage Stakeholders:** Leaders across South Carolina were contacted and briefed on the goals of this strategy initiative and invited to participate and a “stewardship group” was form representing major centers of hydrogen and fuel cell activity in South Carolina. Stewards included statewide leaders as well as regional and institutional representatives.
- **Analyze—Analyze and Benchmark South Carolina’s Position:** The consulting team conducted a national comparison of South Carolina at each level of the innovation pipeline, within the limits of available data, which included benchmarking of hydrogen and fuel cell research, commercialization and industry supply chain as well as comparison of the range of state policies and programs for hydrogen and fuel cell economy development.
- **Catalyze—Develop Collaborative, Bottom-Up Market-Driven Actions:** The consulting team worked with three regional centers of hydrogen and fuel cell activity and completed three rounds of collaborative strategy with each center. The first round focused on presenting South Carolina’s current competitive position in hydrogen and fuel cell innovation and defined shared competitive challenges. The second round brought examples of policies and programs from other states and defined priority actions to overcome South Carolina’s challenges in hydrogen and fuel cells. The third round of collaborative activity focused on articulating brief business plans for regionally-specific actions that might also become the basis for statewide efforts.
- **Realize—Build an Integrated State Strategy:** After each step in this process the consulting team reviewed the achievements with Stewardship group, seeking common needs for a statewide strategy. Working from the shared challenges and actions the consulting team has defined two levels of strategic directions for consideration at the state level. These are Flagship initiatives that are crosscutting in nature and are the focus for statewide public and private actions. Separately, there are also early stage regional strategies. These represent

interests and intentions of the three centers of hydrogen and fuel cell activity in South Carolina to establish nodes or hubs for ongoing growth. This strategy document integrates all these elements, also providing a set of recommendations for future organizational structures that may be initiated to achieve the Flagships and other statewide initiatives, and concluding with a practical vision of how South Carolina might change in the near, medium and longer-term, if the state pursues the course set out here and stays the course over time.

2. South Carolina's Position: Undervalued Assets in a Competitive Marketplace

2.1. A Lens for Exploring Choices

The purpose of this portion of the South Carolina Hydrogen and Fuel Cell Strategy is to make the case for the set of needs on which the strategy should focus. The Innovation Pipeline provides a simple lens with which to examine how South Carolina is performing in building a hydrogen and fuel cell economy relative to competitors and internal needs. The objective of the following section is to:

- **Summarize Building Blocks:** Briefly examine the assets from which South Carolina can grow its hydrogen and fuel cell economy.
- **Review South Carolina's Position:** Review the state's competitive position at each level of the innovation pipeline, as best as comparative data permits.
- **Show Competitor Strategies:** Examine the competitive ranking and policy directions of a selection of leading states in the hydrogen and fuel cell economy to illustrate South Carolina's range of choices.
- **Present State Challenges:** Introduce the *shared* challenges that regional stakeholders from across South Carolina have agreed set the stage for this strategy.

Figure 2-1. South Carolina



Source: www.myscgov.com

2.2. Discovery: South Carolina's Distinctive Assets

South Carolina's potential to become a leader in the hydrogen and fuel cell economy emerges primarily from its existing research assets, almost all of which are concentrated in the Discovery stage of the state's Innovation Pipeline. Hydrogen and fuel cell technologies lead the programs at the state's universities and labs, with strengths in several areas of research, particularly related to hydrogen production, hydrogen storage, and the development of proton exchange membrane (PEM) fuel cells.

Hydrogen Production, Storage, and Delivery

Savannah River National Laboratory

One of South Carolina's greatest assets in the hydrogen and fuel cell economy is the Savannah River Site (SRS), a Department of Energy (DOE) R&D center. SRS, with 310 square miles and 14,000 employees in Aiken, has been involved in hydrogen-related research since 1951, longer than any other federally-funded research organization. It was built for national defense purposes to produce materials for the fabrication of nuclear weapons, primarily tritium, an isotope of hydrogen.

Savannah River National Laboratory (SRNL), located on SRS, became the newest DOE national laboratory in 2004. It has a \$139 million annual budget from the federal government and a concentration of hydrogen researchers (ninety) that may be the largest in the U.S. and even the world.

Ninety percent of all hydrogen-related R&D money in the state is at SRS³, and though the majority of the research is defense-related, SRS is engaged in important industry research as well:

- **Thermochemical hydrogen production:** Developing a process for hydrogen production by thermochemically splitting water from nuclear, renewable sources. This will have a high strategic impact in the future of the hydrogen and fuel cell economy, but there is a need for greater efficiency and lower costs in this process.
- **Hydrogen storage:** Developing and patenting hydrogen storage devices using hydride beds. This will also have a very high strategic impact in the future, when the cost of producing the hydrides is lowered.
- **Hydrogen delivery:** Partnering with Concurrent Technologies Corporation (CTC) on a DOE-funded research project on the use of advanced materials to build pipelines for hydrogen delivery, and for co-transporting hydrogen with natural gas.

Center for Hydrogen Research

The Center for Hydrogen Research is a brand-new facility in Aiken specially designed for collaborative hydrogen research. It is schedule to be completed in October 2005, was constructed with \$10 million from Aiken County, and will be managed by the region's Economic Development Partnership. The 60,000 square foot facility will house about 80 hydrogen researchers, half of whom will be from SRNL and the other half of whom will be from academic

³ Concurrent Technologies Corporation. The South Carolina Hydrogen Economy: Capitalizing on the State's R&D Assets.

institutions and industry. SRNL is in the process of establishing representation in the facility from major automobile companies.

Figure 2-2. Center for Hydrogen Research



Source: www.srs.gov

The University of South Carolina

The University of South Carolina (USC), located in Columbia, is one of the nation's leading academic institutions in research for the hydrogen and fuel cell economy, mainly by virtue of the fact that it is home to the only fuel cell center funded by the National Science Foundation (NSF) in the U.S.—the National Science Foundation Industry/University Cooperative Research Center for Fuel Cells. The NSF selected USC in 2003, with the center's mission being to help lead the nation's fuel cell initiatives by performing research with industry aimed at developing and commercializing the use of fuel cells.

Besides its focal research in fuel cell design and modeling (which will be expounded upon in the next section), USC performs major research in hydrogen production and storage:

- **Hydrogen production:** Developing the science and processes for producing hydrogen by various methods: electrochemical devices, sulfur-dioxide depolarized electrolyzers for thermochemical processes, and liquid fuel reformer methods. This includes leveraging a strong catalysis research group as well as Intellectual Property for electrolyzers.
- **Hydrogen storage:** Developing solid-state hydrogen storage materials.

USC has fifteen industry partners, including General Motors, Dupont, John Deere, BASF, Plug Power, Dana Corporation, Eastman and LG Electronics.

In the past three years, USC has attracted \$10 million from the federal government and \$6 million from the State of South Carolina for its fuel cell and hydrogen-related research. USC also announced in May 2005 that it has secured \$32 million from a group of state, federal, and private sources for the new Horizon Center, a place of collaboration with industry in four areas of research, one of which is next generation energy technologies.

Figure 2-3. The Horizon Center



Source: http://president.sc.edu/Research_Campus/Horizon_Center.html

Clemson University

The hydrogen-related initiatives at Clemson University primarily relate to research in advanced materials, one of the top three research priorities at the university, located in Clemson, South Carolina. The university has a specialty in manipulating carbon fibers for hydrogen storage.

Clemson is also involved with SRNL in the research on a sulfur-based process for thermochemically splitting hydrogen and oxygen, and a photobiological process for producing hydrogen.

Fuel Cells

The University of South Carolina

USC's research in fuel cells was bolstered by its national recognition as home to the National Science Foundation (NSF) Industry/University Cooperative Research Center for Fuel Cells. USC has a particular specialization in designing proton exchange membrane (PEM) fuel cell systems and modeling their performance.

What characterizes the USC fuel cell center from other similar centers is its emphasis on the complete value chain for the fuel cell/hydrogen device. Research spans the reformer, the storage, fuel cell and its components, and the power conditioning systems.⁴ The analogies to the automobile industry are the refinery, the gas tank, the engine, and the computer that controls the engine. The center's research involves interaction between the fuel, solid-state hydrogen storage materials, fuel cell-related devices, and the interface between the device and the fuel cell. It is important to note that a fuel cell has many components and the supply chain will have tier 1 through tier 4 industries. USC's center has strength in methods to understand failure and durability issues with fuel cell materials.

⁴ Concurrent Technologies Corporation. *The South Carolina Hydrogen Economy: Capitalizing on the State's R&D Assets*.

In the area of power distribution and USC researchers have also developed a virtual test bed (VTB), which has been used to evaluate the use of fuel cells in the propulsion systems of U.S. Navy vessels.

Clemson University

Clemson has attracted federal and industrial sponsors for its research related to the use of electrolytes to improve fuel cell membranes, and the development of electrodes and nanosponges to improve fuel cell performance.

End-User Applications and Transportation

International Center for Automotive Research

The International Center for Automotive Research (ClemsonICAR) has a vision of being the premier automotive and motorsports research and educational facility in the world. Its location in South Carolina, with 200 automotive-related businesses and another 114 industry suppliers, is key to local and regional economic activities. ClemsonICAR, located in Greenville, is also situated along a corridor between Charlotte, North Carolina and Atlanta, Georgia, that is home to two-thirds of the nation's motorsports racing teams.

Figure 2-4. ClemsonICAR



Source: www.clemson.edu

ClemsonICAR was launched in 2004 by Clemson University with \$115 million in public and private monies. Besides being a collaborative automobile research center, ClemsonICAR has explicit provisions for developing and commercializing energy-related innovations.

ClemsonICAR will house cooperative research programs involving Clemson, BMW, IBM, and Microsoft. Other partners include Michelin and TIMKEN.

South Carolina State University

South Carolina State University (SCSU), in Orangeburg, is home to the Clyburn Transportation Center. The center conducts research with an emphasis on linking the various modes of transportation using advanced technologies and concepts to address future critical transportation needs.⁵ The Clyburn Transportation Center has teamed with SRNL to test hydrogen containers and demonstrate hydrogen-powered busses.

2.3. Development: Resources for Commercialization

Institutions, policies and legislation must exist that encourage the creation of new companies that will develop and commercialize basic research. South Carolina has a significant number of strong assets in the discovery of new innovations in hydrogen and fuel cells, however the state has yet to fully realize the potential of those assets because it has very few structures or institutions actively involved in the development and deployment of its applied research in the marketplace.

Supporting R&D and Commercialization: South Carolina Research Authority

The South Carolina Research Authority (SCRA), headquartered in Columbia, is an applied R&D organization. SCRA takes applicable technologies and innovative strategies and adapts them to the needs of clients, who include government agencies, universities, and private corporations.

The South Carolina Research Authority's (SCRA) core competence is in creating and managing consortia focused on specific applied research, technology transfer, and economic development outcomes. They provide program management, contract management, and financial management support to hundreds of initiatives, across thousands of contracts, which are very similar in nature to the Next Energy Initiative. SCRA has over 180 corporate and industry partners, and have within their ranks experienced Program Managers who are either veterans of the Nuclear Navy, nuclear qualified engineers, or are familiar with alternative energy technologies, such as fuel cells.

The CEO of SCRA serves on the Board of the National Energy Marketers Association (NEMA), which was instrumental in supporting passage of the recent US Energy Bill. Through NEMA, SCRA has access to key US Representatives and DOE members to advocate for South Carolina's energy mission. NEMA's technology provider membership also is a potential source for SC Innovation Center clients with interests in developing alternative energy related businesses. These contacts could be helpful in recruiting R&D partners as well as producers and suppliers who might undertake operations in South Carolina.

SCRA also manages a system of research parks that attracts technology companies. They are now home to 40 technology-oriented firms employing nearly 6,000 people.

SCRA is currently not engaged in hydrogen or fuel cell projects, but it has the potential to do so in the future. SCRA has proven large-scale project management capabilities that can be applied to the organization and operation of pre-competitive R&D consortia that can be harnessed to support South Carolina's university, national laboratory and industry collaboration. SCRA is available and ready to support the initiatives arising from the South Carolina Hydrogen and Fuel Cell Strategy.

⁵ James E. Clyburn University Transportation Center. <http://www.utc.scsu.edu/index.htm>

State-Funded Venture Capital

In 2004, the State of South Carolina passed legislation authorizing \$100 million to be spent on the creation of two venture funds within the Department of Commerce:

- **South Carolina Venture Capital Fund:** A \$50 million fund with allowance to give up to \$5 million, or 15 percent of the committed capital of the investor, whichever is less, in the form of equity, near-equity, and seed capital.
- **South Carolina Technology Innovation Fund:** An annual fund for the creation and continuation of Technology Innovation Centers at each of three state research universities to support the commercialization of university research.

Concurrent Technologies Corporation

CTC is an applied R&D organization—it is a national nonprofit with 35 locations in the US, including four in South Carolina. CTC is frequently engaged in technology transfer, technology commercialization, and technology road mapping projects for government and private-sector clients, some of which focus on alternative energy technologies. CTC is actively encouraging development of pre-competitive initiative as well as technology commercialization efforts in hydrogen and fuel cells in South Carolina.

FuelCellSouth

FuelCellSouth is a nonprofit organization based in Columbia, South Carolina that serves as a forum to bring together researchers, entrepreneurs, and existing businesses who are engaged in fuel cells and hydrogen-related work. FuelCellSouth's intention is to create the marketplace for fuel cell industry growth in the southeast.

Industrial Development Activities

With only one exception (Kemira Oyj⁶—see next section for discussion), there are currently no private-sector commercial operations in South Carolina that are involved in development or production of hydrogen or fuel cell-related products. This lack of regional industrial activity and market creation, leveraging South Carolina's core research, reflects the loss of a significant commercial opportunity.

2.4. Deployment: Achieving Survival, Expansion and Attraction

The growth of a strong hydrogen and fuel cell economy relies on institutions in the state to enable enterprise formation, expansion, and globalization. This means that corporations need to grow not only in the hydrogen and fuel cell industries, but also in the “seedbed industries” that can contribute to the hydrogen and fuel cell supply chain.

⁶ Concurrent Technologies Corporation. *The South Carolina Hydrogen Economy: Capitalizing on the State's R&D Assets*.

It has been noted that South Carolina only has one existing hydrogen-related corporation, but the state is strong in many seedbed industries, including:

- Chemicals industry, with potential in hydrogen production.
- Seals ceramics and electronics industries, with potential in fuel cell manufacturing.
- Transportation and transportation equipment manufacturing industries, with potential for end use.

Some of the highlights of South Carolina's potential seedbed industries include:

- **Kemira Oyj**

Kemira Oyj is the only existing hydrogen-related commercial operation in South Carolina. It is the leading producer of sodium chlorate in the southeastern United States, and has a production facility in Eastover that produces hydrogen gas as a by-product. More than 1 million pounds of hydrogen could be made available by the company to conduct validation, testing, and demonstration activities related to fuel cell technologies.

- **GE Energy**

GE Energy is one of the world's most innovative companies in hydrogen-related technology, and its R&D department stands as a major opportunity area for the commercialization of homegrown South Carolina research in hydrogen. The company is headquartered in Atlanta, Georgia, but GE Energy's Gas Turbine Center of Excellence for Engineering and Manufacturing is in Greenville, South Carolina. The Greenville campus is involved in systems and gas turbine development of fuel cell hybrid systems, but all hydrogen-related R&D for GE is occurring out of state. Future South Carolina hydrogen-related production operations are possible.

- **BMW**

BMW is one of the leading automakers in the quest and adoption of hydrogen-related technologies. BMW is already developing hydrogen-powered vehicles in Europe. Currently, BMW's hydrogen research is taking place in Munich, Germany.

The company's primary North American production facility is near Greenville, representing another major opportunity for the commercialization of South Carolina innovation. As BMW is building stronger research relationships with Clemson University and ClemsonICAR, expanded opportunities in hydrogen R&D in South Carolina are possible.

- **Electric and Gas Utilities**

South Carolina is a nuclear-friendly state, which is a potential asset when DOE and private-sector firms look for a location for nuclear-based hydrogen production facilities. Nuclear facilities generate 56 percent of South Carolina's electric power, compared with 20 percent nationally.

All three of South Carolina's investor-owned utilities operate nuclear reactors, and all are considering building new reactors in the state, as is Santee Cooper, a state-owned utility. They are, however, involved in very few renewable energy projects.

- **Chemical and Carbon Materials Companies**

A number of chemical and carbon materials companies that have locations in South Carolina (and headquarters elsewhere) are manufacturing materials for fuel cell membranes or fuel cell components out of state.

2.5. Position of South Carolina's Hydrogen and Fuel Cell Economy

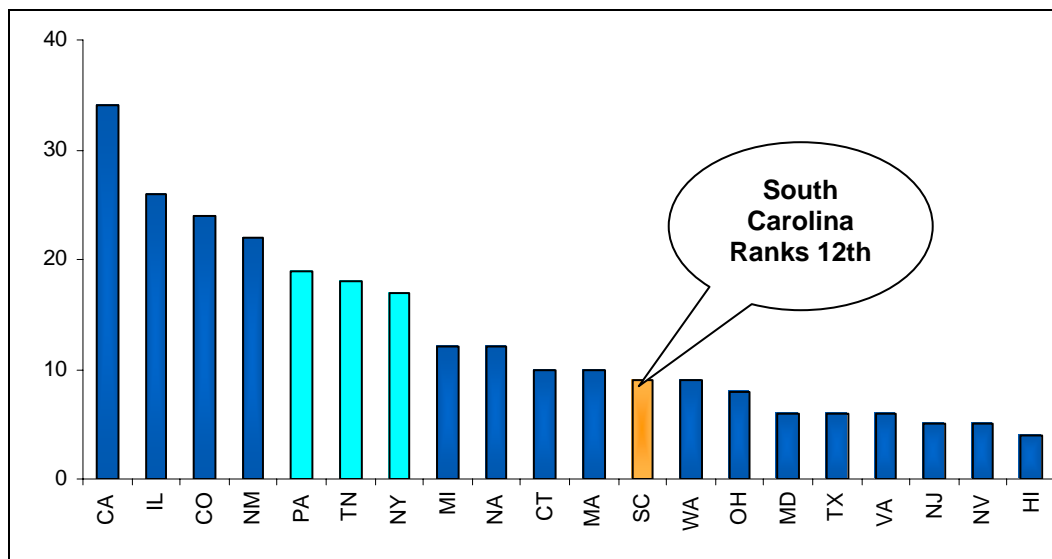
South Carolina's position and success relative to other states in the transition to a hydrogen and fuel cell economy can be evaluated by applying the three stages of the innovation pipeline: Discovery, Development, and Deployment.

Discovery: Punching Above Your Weight

South Carolina ranks well among the fifty states in measures of the level of its research in hydrogen and fuel cell technology. DOE's Hydrogen, Fuel Cells, and Infrastructure Technologies program funds hundreds of research projects each year, and South Carolina does well in capturing them. Among the fifty states, South Carolina ranks:

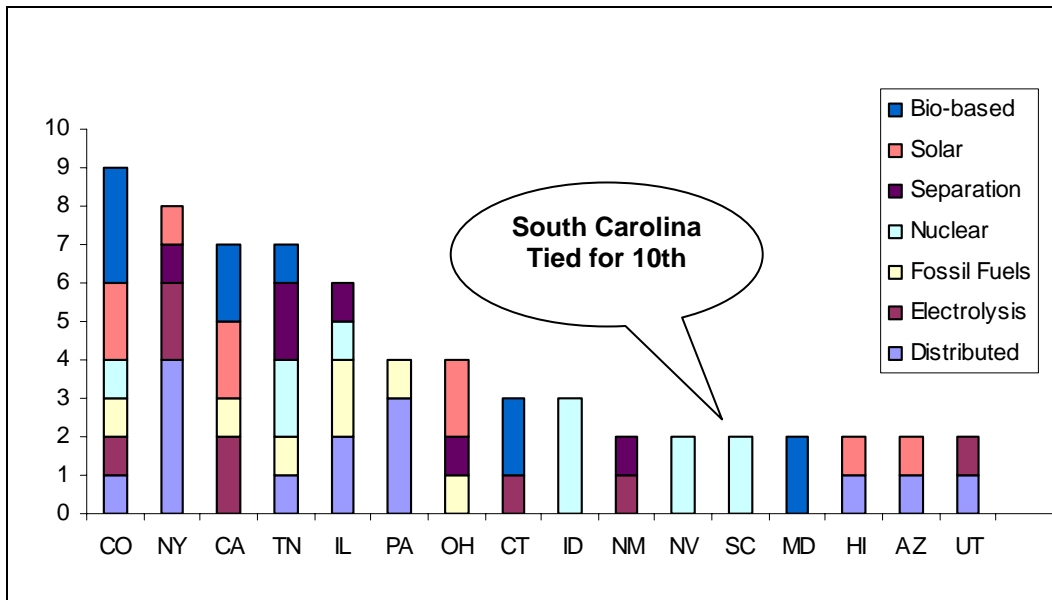
- 12th in total number of DOE hydrogen projects.
- 7th in number of DOE hydrogen projects at federal and academic organizations.
- Tied for 10th in number of DOE hydrogen production projects.
- Tied for 4th in number of DOE hydrogen storage projects.
- Tied for 3rd in number of DOE hydrogen delivery projects.
- Tied for 13th in total number of DOE fuel cell projects.
- Outside the top 20 in number of DOE hydrogen end-market projects.

Figure 2-5. Total Number of DOE Hydrogen Projects by State, 2005



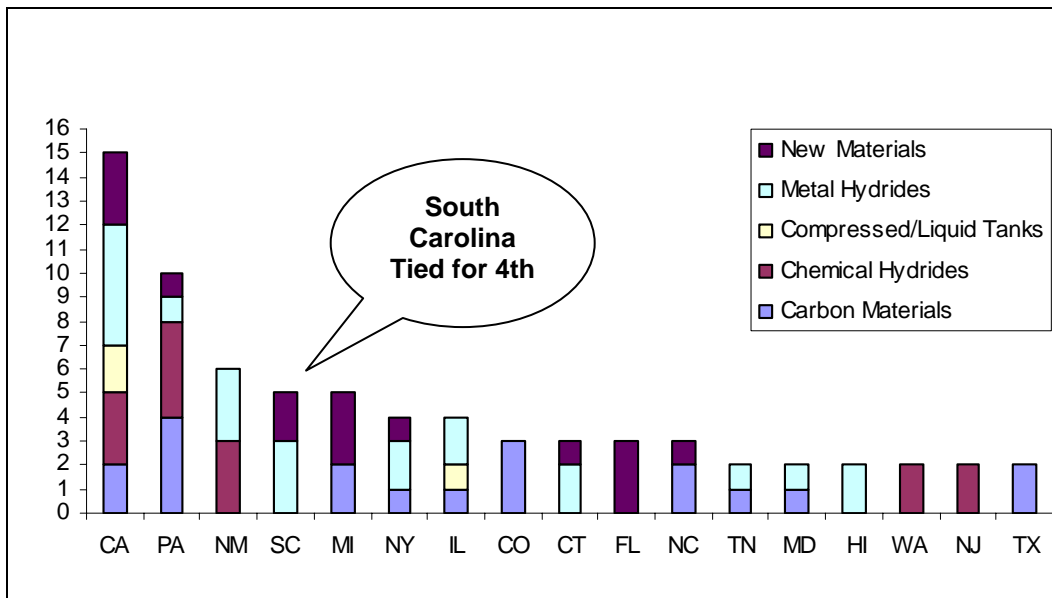
Source: 2005 Hydrogen Program Review

Figure 2-6. DOE Hydrogen Production Projects by Segment and State, 2005



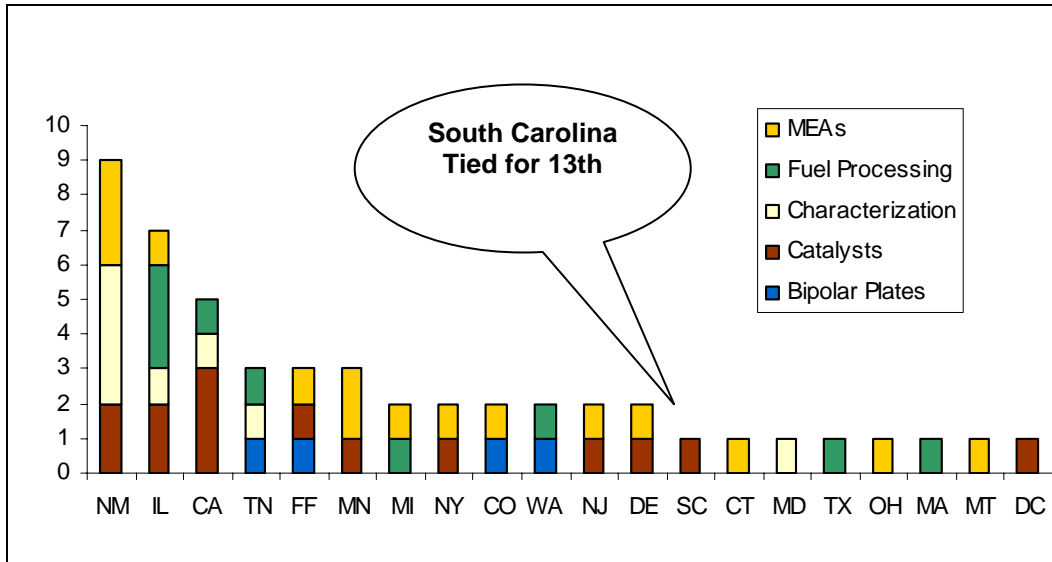
Source: 2005 DOE Hydrogen Program Review

Figure 2-7. DOE Hydrogen Storage Projects by Segment and State, 2005



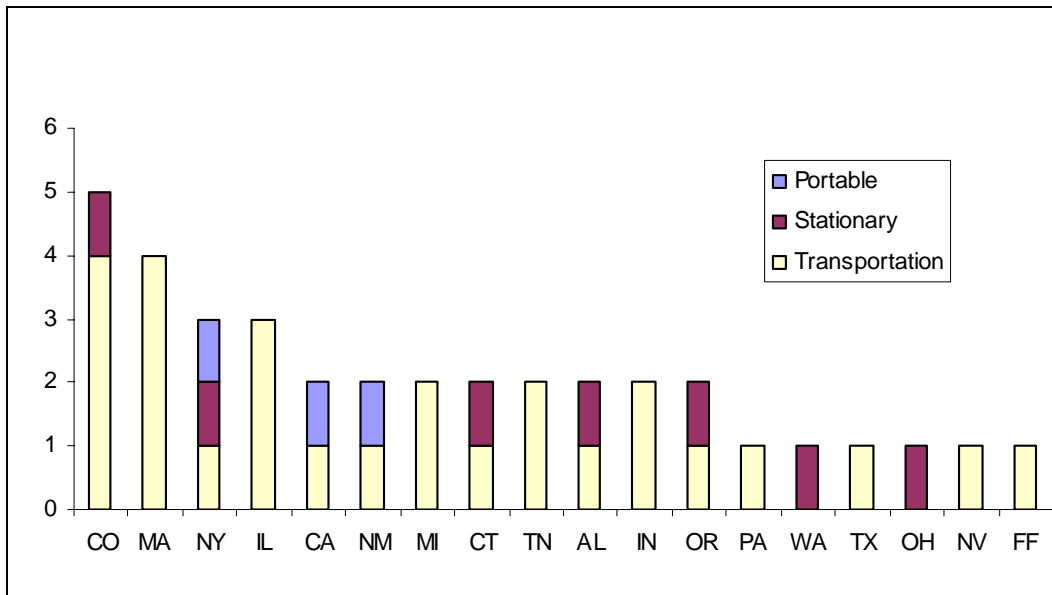
Source: 2005 DOE Hydrogen Program Review

Figure 2-8. DOE Fuel Cell Projects by Segment and State, 2005



Source: 2005 DOE Hydrogen Program Review

Figure 2-9. DOE Hydrogen End-Market Projects by Segment and State, 2005



Source: 2005 DOE Hydrogen Program Review

While South Carolina ranks well in Discovery, the majority of the funds for the research have come from the federal government. The State has done little, in comparison to other states, in funding research in hydrogen and fuel cell technologies.

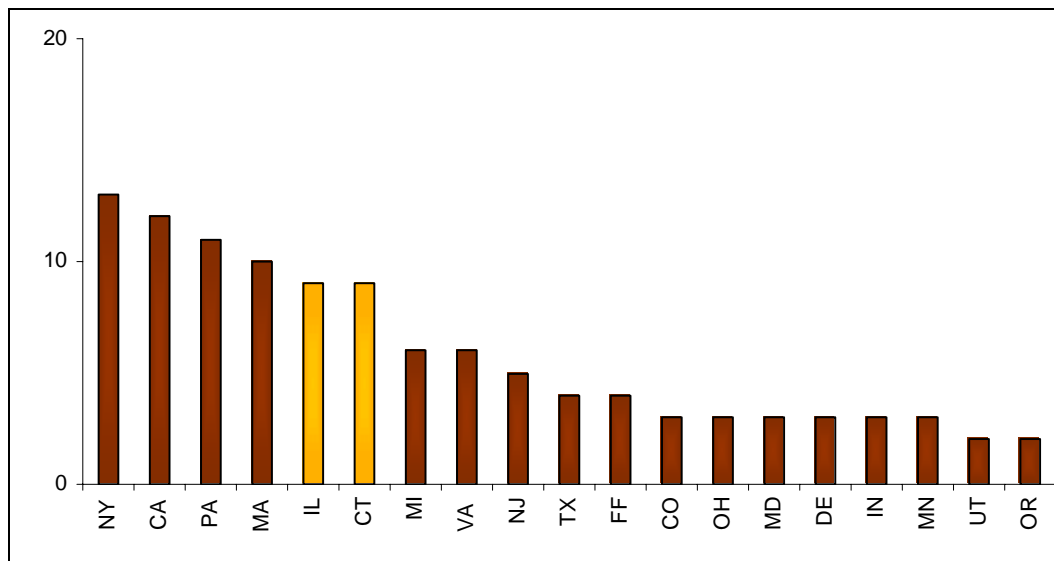
Development: Batting Below Average

Considering the high-potential research generated in South Carolina, there are very few institutions and policies, and limited infrastructure that support accelerating discoveries through development and into product deployment. As such, South Carolina has not experienced nearly the amount of entrepreneurship and commercialization that is beginning to be seen in other states. One example is the lack of venture capital sources, which has had the effect of limiting start-ups, patent generation, and product development and manufacturing within South Carolina.

As a result, among the fifty states, South Carolina ranks:

- Outside the top 20 in total number of DOE hydrogen projects at private organizations.
- 39th in overall level of entrepreneurial activities and risk capital.
- 43rd in proportional share of science and technology workers.
- 29th in total number of patents.
- 37th in total number of university spin-offs.
- 37th in Small Business Innovation Research (SBIR) grants.
- 37th in total venture capital investments.

Figure 2-10. DOE Hydrogen Projects at Private Organizations by State



Source: 2005 Hydrogen Program Review

Deployment: Does Not Pass Muster

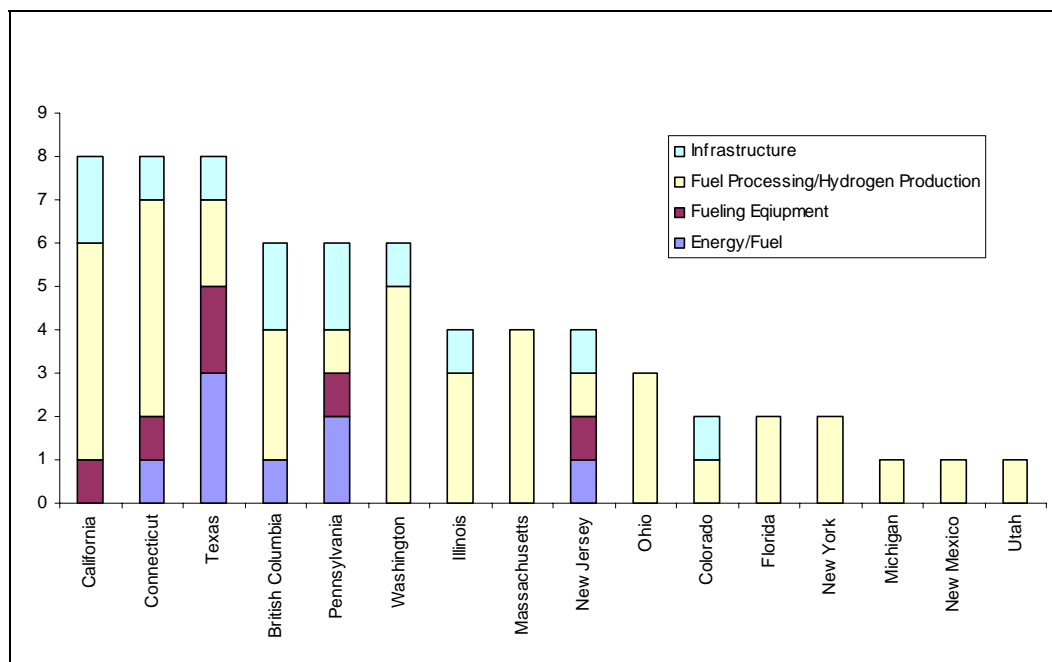
In addition to having an environment that has not been able to generate or support start-ups, South Carolina has done little, in relation to other states, to attract or expand companies involved in alternative energy. South Carolina has produced few policies or initiatives that show aggressive leadership in the creation of a commercial base involved in the hydrogen and fuel cell economy.

The State of South Carolina has only one corporate incentive for producing renewable energy, while it has no incentives for purchasing renewable energy. On average, other states have an average 4.7 economic incentives, and South Carolina's main competitors have up to ten.

As a result, among the fifty states, South Carolina ranks:

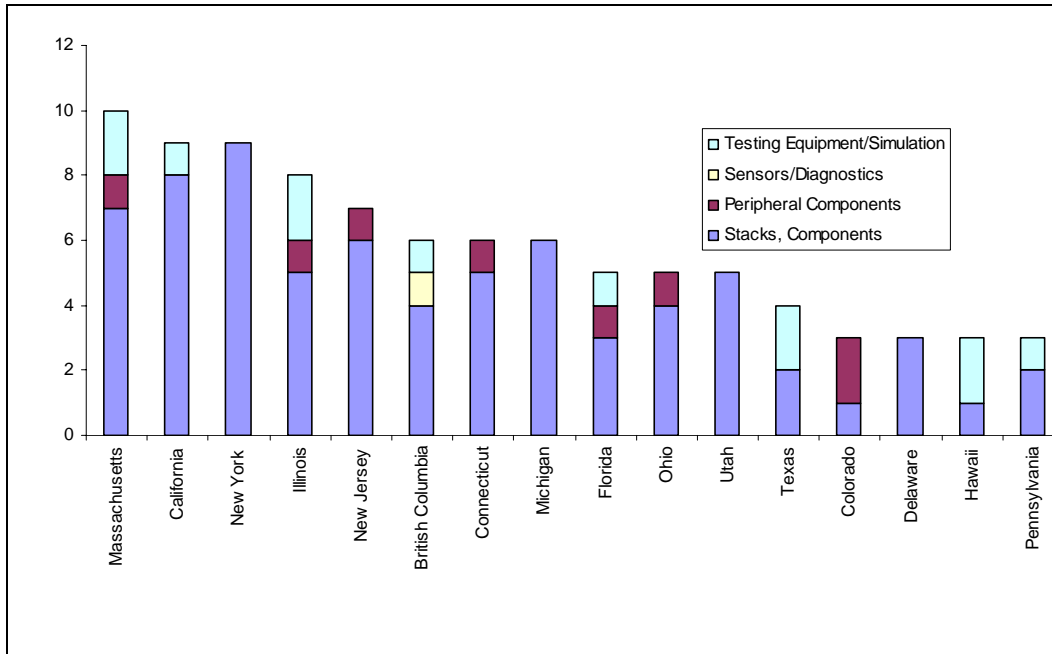
- Outside the top 20 in number of companies with capacity in fuels/production/infrastructure/delivery space.
- Outside the top 20 in number of companies with capacity in fuel cell/component space.
- Outside the top 20 in number of companies with capacity in systems/end-use applications.

Figure 2-11. Companies with Capacity in the Fuels/Production/Infrastructure/Delivery Space, by State and Segment



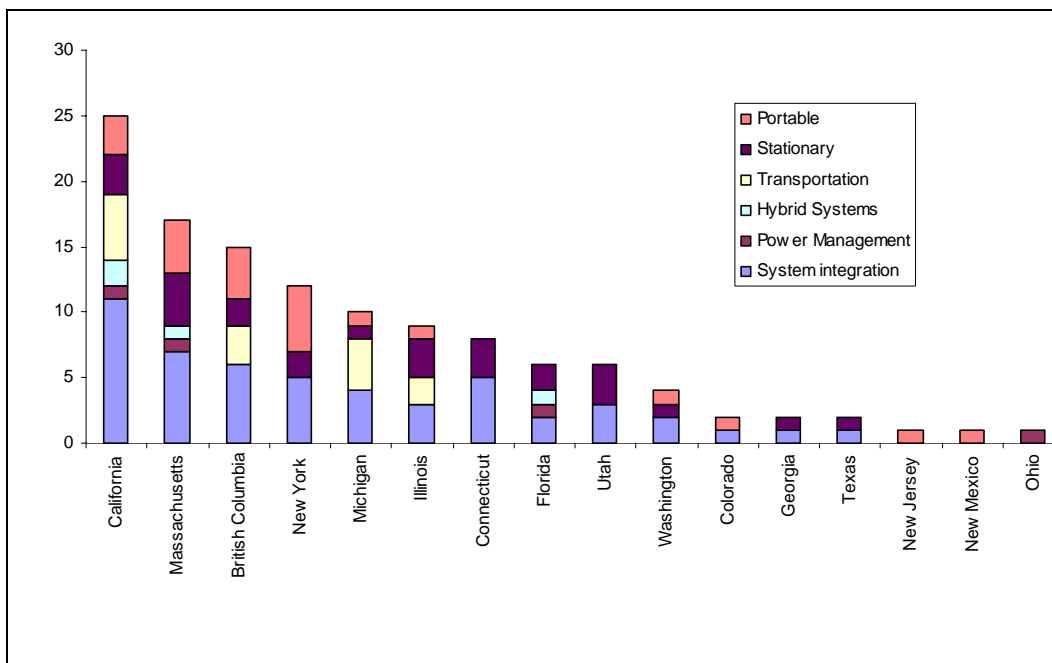
Source: FuelCellToday/SRI

Figure 2-12. Companies with Capacity in the Fuel Cell/Components Space, by State and Segment



Source: FuelCellToday/SRI

Figure 2-13. Companies with Capacity in Systems/End-Use Applications, by State and Segment



Source: FuelCellToday/SRI

South Carolina: Assets Create Potential for State to Surpass Competition in the Future

Competitive Position on Overall Innovation Pipeline

South Carolina's potential to be a leader in the hydrogen and fuel cell economy is due mostly to its long history in hydrogen research at SRNL, and the state has expanded its other assets in research considerably. However, South Carolina loses significant commercial opportunity, especially in comparison to other states, because it lacks a system to encourage regional industry activity and market creation for hydrogen and fuel cell technologies. South Carolina is competing in the developing hydrogen economy against states that, in many cases, have larger and more comprehensive hydrogen and alternative energy initiatives across the stages of discovery, development, and deployment. None the less, South Carolina has sufficient assets to surpass many of the leaders, if the state can create the strengths required in the Innovation Pipeline, especially in the areas of development and deployment.

- **Discovery System Benchmarks**

South Carolina ranks:

- 29th in university R&D intensity
- 39th nationally in federal R&D intensity.
- 28th in industry R&D intensity.
- 37th in terms of science and engineering articles per \$1 million of academic R&D.
- 37th nationally in patents awarded per 1 million people.
- 29th nationally in total research expenditures at universities per patent issued.

- **Development System Benchmarks**

- 10th in active licenses per start-up company.
- 24th nationally in business formation rates.
- 40th and 35th in of SBIR Phase I and II awards, and 31st on STTR award toward the middle.
- 30th in business “churn” rate (starts & stops as a share of total firms) which is a measure of enterprise dynamism.

- **Deployment System Benchmarks**

- 28th in venture capital investment per worker.
- 30th lowest on the cost of living index.
- 8th lowest in terms of total taxes per capita.
- 18th highest in taxes per \$1000 of income.
- 11th in reliance on general sales and use taxes as a percent of total taxes collected.
- 27th in reliance on individual income tax as a percent of total tax collections.
- 37th in state and local highway spending as a share of general spending and ranks.
- 18th in percent of interstate miles in unacceptable condition.
- 35th in number of high speed lines per 1 million people.
- 16th lowest in total energy costs per 1 million BTUs for industry.

South Carolina Hydrogen and Fuel Cell Approach

South Carolina does not as yet have a hydrogen and fuel cell strategy—and there are at least 15 states that already do, at least in some measure. South Carolina, however, has good building blocks for developing an effective strategy, despite weaknesses along the Innovation Pipeline—including having only one incentive for renewable energy. The state can leverage its core assets to create a significant position in commercialization and market deployment, leading to regional—and consequently statewide—economic growth, if a strategy is in place that creates new and continually improving sources of advantage. The cornerstone of the state’s strategy both technically and regionally include, as introduced and described earlier and as will be discussed in depth later:

- **Strengths in Hydrogen Production, Storage and Distribution Research:** The Savannah River National Laboratory is a national asset in hydrogen production, storage, and delivery. The new Center for Hydrogen Research will make Aiken an even stronger regional center in the future. USC and Clemson, too, are both strong in related materials science research areas and house complimentary aspects of thermochemical hydrogen production suitable for work with SRNL. Moreover, the state is “nuclear friendly” and has a good array of chemical industry stakeholders that are likely to play a role in exploring new energy solutions. Leveraging these competencies is part of the overall strategic direction that will differentiate South Carolina. USC and SCSU have degree programs in nuclear engineering.
- **Strengths in Fuel Cell Research:** The University of South Carolina has strong fuel cell research capabilities, with a distinct focus on PEM fuel cells. USC has the only NSF-funded fuel cell center in the nation. USC also has strong research groups in chemical and electrochemical catalysis, hydrogen storage, and materials science and these talents link to hydrogen technology development. The newly established Horizon Center at USC is planned as a site for collaboration with industry in next generation energy technologies. Moving fuel cell innovation from research to the marketplace here is a clear opportunity that needs to be fostered.
- **Strengths in End-User/Transportation Applications:** Founded in 2004, ClemsonICAR has strong materials, chemical engineering, and systems science and a vision of being the premier automotive research facility in the world with provisions for developing and commercializing energy-related innovations with its industry partners—including major automotive producer, BMW—at its ClemsonICAR-research park. Harnessing end-user demand to draw innovation into the marketplace to capture production activities at the earliest stages is a clear possibility here—for hybrid energy systems and the evolving power systems of the future.

But while these assets are important, they cannot be examined in isolation. South Carolina needs to view its future in terms of how its current position and capabilities stand up to competitors across North America—if not globally.

2.6. What Are South Carolina’s Competitors Doing?

South Carolina’s rival states and regions have moved to design hydrogen economy initiatives that focus on each aspect of the innovation pipeline: discovery through development and on to deployment and local economic growth. Most efforts by competing states have been launched within the past five years. These initiatives, in combination with their broader statewide efforts to strengthen the overall innovation pipeline are helping these competing states to improve and differentiate their competitive position in hydrogen and fuel cells and in other emerging technological drivers of the economy as well—from nanotechnology to biotechnology and beyond.

The following briefly outlines how some of the leading states in the emerging hydrogen economy are performing and why. Each state's foundation measures have also been used to benchmark and reveal other aspects of their economies' health and performance. Where appropriate, some of their policies and commitments have been considered in crafting the South Carolina Hydrogen and Fuel Cell Strategy, and are outlined in Section 4, focusing on Strategy Drivers: Proposed Flagship Initiatives.

California: Scale and History in Hydrogen and Fuel Cells

Competitive Position

California is an excellent example of how well funded, statewide initiatives and institutions can drive the growth of a major new economic sector. This is an example most regions are hard pressed to replicate. California has arguably become the leading state in the country in the hydrogen and fuel cell economy. The state ranks first in total DOE hydrogen projects, and it ranks in the top three in: number of companies with capacities in production, storage and delivery; number of companies with capacity in fuel cells and components; and number of companies in fuel cell systems and end-use applications. There are many institutional formation and project deployment lessons that can be learned from California.

- **Discovery System Benchmarks**

- California ranks 22nd nationally in university R&D intensity.
- 13th nationally in federal R&D intensity.
- 7th in industry R&D intensity.
- California ranks 34th in science and engineering articles per \$1m of academic R&D.
- 5th in patents awarded per 1 million population.
- 3rd nationally in total research expenditures at universities per patent issued.

- **Development System Benchmarks**

- California ranks 28th in active licenses per start-up company—middle of the pack.
- California ranks 35th nationally in business formation rates, relatively low.
- California ranks 7th on both SBIR Phase 1 and 2 awards and 16th nationally on STTC awards.
- California ranks 28th in business churn rate.

- **Deployment System Benchmarks**

- California ranks 2nd in venture capital investment per worker.
- The state's cost of living index is 2nd highest nationally.
- California ranks 9th in total taxes per capita.
- Ranks 15th highest in taxes per \$1000 of income.
- California ranks 31st in terms of its reliance on sales and use taxes as percent of total tax collections.
- Ranks 9th highest in terms of individual income tax as a percent of total tax collections.
- California ranks 2nd to last on highway spending as a share of generally spending
- 8th worst in percent of highway in unacceptable condition.
- Total energy costs per 1 million BTUs to industry are 9th highest nationally.
- California ranks 6th in high-speed lines per 1 million people.

California Hydrogen and Fuel Cell Approach

The state's already strong university system and its commitment to alternative energy are supported by clear and focused public policies. These include:

- **Overall High Degree of Direction and Leadership by the State:** The State of California has made hydrogen and fuel cell technologies part of its larger clean energy initiative. The State has a goal of capturing between five and 25 percent of future global fuel cell sales.
- **Major State Funding Available for Research:** The California Energy Commission founded the Public Interest Energy Research (PIER) program in 1997 as a multi-year energy R&D and demonstration program for innovative energy technologies. The PIER program is one of the flagship institutions that funds hydrogen and fuel cell research in the state. PIER has a minimum of \$62.5 million per year to spend supporting R&D in new firms, existing firms, or consortia programs. PIER is funded by a public goods surcharge and administered by the California State University system, in collaboration with other state universities.
- **Consortia that Link the Right Players Together:** California has a significant number of organizations devoted to collaboration in the hydrogen and fuel cell economy. The major consortium is the California Fuel Cell Partnership, a public/private partnership of automakers, energy companies, fuel cell technology companies, and government agencies. The consortia demonstrate fuel cell technologies, promote fuel cell commercialization, and provide leadership of the fuel cell industry at the state level.
- **Promotion of Commercialization of Fuel Cells:** Specific goals of the California Fuel Cell Partnership include facilitating members' placement of up to 300 fuel cell cars and buses into fleets and promoting fuel stations to support the vehicle fleets.
- **State Renewable Energy Standards:** The State has adopted a standard that 20 percent of retail electricity must be generated from renewable sources by the end of 2017, with increases of one percentage point per year beginning in 2003.
- **Tax Incentives for Use of Renewable Energy:** The State has instituted several incentives to encourage the purchase of renewable energy. Incentives include rebates and reductions in state personal, corporate, and property taxes.

Michigan: Leveraging Industry Know-How to Attract New Growth to Next Energy Zones

Competitive Position: Leaders in the state of Michigan believe that hydrogen and fuel cells will pose both challenges and opportunities for their industries and economy. For this reason, they have mounted an aggressive approach to accelerating formation and attraction of hydrogen and fuel cell technology and industry—building from their strong universities and large scale industrial R&D base. Michigan ranks 8th in total number of DOE hydrogen projects, and ranks in the top ten in DOE hydrogen projects in private companies; number of companies with capacity in fuel cells and components; and number of companies with capacity in fuel cell systems and end-use applications. Michigan provides many examples of state-sponsored programs to attract the growing group of companies dedicated to the hydrogen and fuel cell economy.

Basic comparative indicators suggest that while Michigan's industry leaders are active in innovation, the state needs to break out of its current middle of the pack economic competitive position:

- **Discovery System Benchmarks**

- Michigan ranks 24th nationally in university R&D intensity.
- 35th nationally in federal R&D intensity.
- Number 1 in industry R&D intensity (distinctive).
- Michigan ranks 22nd nationally in terms of science and engineering articles per \$1m of academic R&D.
- Michigan ranks 12th nationally in patents awarded per 1m population.
- 23rd in terms of total research expenditures at universities per patent issued.

- **Development Systems Benchmarks**

- Michigan ranked 25th in active licenses per start-up company.
- 38th in business formation rates nationally, fairly low.
- Michigan ranked 26th and 39th in SBIR Phase I and II awards and 25th on STTR awards.
- 42nd in business churn rate (low/stable).

- **Deployment Systems Benchmarks**

- Michigan ranks 30th in venture capital investment per worker.
- The state has the 27th highest from the top cost of living index (middle).
- 11th highest in per capita taxes per capita.
- Ranks 9th in taxes per \$1000 of income.
- Michigan ranks 18th in terms of dependence on sales and use tax as a percent of total tax collections.
- Ranks 35th in terms of individual income tax as a percent of total tax collections.
- Michigan state and local highway spending as a share of general spending is 6th lowest nationally, ranking 15th in percent of interstate miles in unacceptable condition.
- Michigan ranks 32nd lowest in total energy costs per 1 million BTUs in the industrial sector.
- Michigan has the 23rd highest number of high-speed lines per 1 million people.

Michigan Hydrogen and Fuel Cell Approach: With respect to hydrogen and fuel cells the state has chosen to accelerate its activity through one particular approach:

- **Corporate Attraction through Tax Incentives/Next Energy Zone:** The State of Michigan has created and funded the NextEnergy Center, a 700-acre, state-owned site in Detroit that offers a 20-year state and local tax exemption for companies that locate and perform alternative energy technology research, development, manufacturing, and demonstration. The facility includes a hydrogen fueling system and an on-site hydrogen generation test bed. The mission of the NextEnergy Center is to create a vibrant environment that will attract alternative energy companies. The Michigan NextEnergy Authority manages the Center.

In addition, Michigan offers companies locating or expanding alternative energy operations in the state to receive business and personal property tax exemptions.

Ohio: Linking Energy Technology and the Manufacturing Supply Chain

Competitive Position: Like Michigan, Ohio is a state that anticipates hydrogen and fuel cells impacting the structure and performance of its industries and creating the possibility of new economic opportunity. Ohio is able to combine its solid research capabilities with a high concentration of related industries that have interest in, and commitments to hydrogen and fuel cell technology. The vision of transforming the Ohio economy is backed by a strong state-level financial commitment. Ohio ranks 7th among the states in number of DOE hydrogen production projects. Even though Ohio ranks outside the top twenty in DOE hydrogen storage projects and in DOE fuel cell projects, the state ranks in the top ten in number of companies with capacity in production, storage, and delivery, and in number of companies with capacity in fuel cells and components. Ohio has addressed a number of more fundamental and long-term industry foundation issues thorough its programs, including training and education, and a primary focus on technology commercialization and production.

- **Discovery System Benchmarks**

- Ohio ranks 36th in university R&D intensity.
- 12th nationally in federal R&D intensity.
- 17th in industry R&D intensity.
- Ohio ranks 9th in terms of science and engineering articles per \$1m of academic R&D.
- 16th nationally in patents awarded per 1m population.
- 28th nationally in total research expenditures at universities per patent issued.

- **Development System Benchmarks**

- 15th in active licenses per start-up company Ohio (fairly high productivity of licenses).
- Ohio ranked 45th nationally in business formation rates, toward the bottom.
- Ohio ranked 19th and 15th in of SBIR Phase I and II awards, and 27th on STTR award toward the middle.
- On business churn rate Ohio ranked 47th, very low/stable.

- **Deployment Systems Benchmarks**

- Ohio ranks 33rd in venture capital investment per worker.
- The state has the 30th lowest cost of living index.
- Ranks 25 (middle) in terms of total taxes per capita.
- Ohio ranks 27th highest in taxes per \$1000 of income.
- 27th in reliance on general sales and use taxes as a percent of total taxes collected.
- 10th highest in terms of reliance on individual income tax as a percent of total tax collections.
- 10th in state and local highway spending as a share of general spending and ranks 35th in percent of interstate miles in unacceptable condition.
- Ohio ranks 25th in number of high speed lines per 1 million people.
- Ranks 17th from the top in total energy costs per 1 million BTUs for industry.

Ohio Hydrogen and Fuel Cell Approach: Ohio has made this progress in hydrogen and fuel cells through a strong public policy agenda that includes:

- **High Level of State Commitment:** The State of Ohio has committed \$103 million to the Ohio Fuel Cell Initiative, a major part of the ten-year, \$1.1 billion Third Frontier Project. The Third Frontier Project is the state's largest-ever commitment to expanding Ohio's high-tech research capabilities and promoting innovation and company formation, with the purpose of creating high-paying jobs for generations to come. The Third Frontier Project's three core areas of spending are on: 1) building world-class research; 2) supporting early-stage capital formation and the development of new products, and 3) financing manufacturing technologies to help existing industries become more productive.
- **State-Funded Skills Development:** Part of the State's \$103 million Ohio Fuel Cell Initiative is \$3 million set aside for fuel cell skills training, with a 50-50 cost share for companies that utilize it.
- **Creation of an Initial Cluster:** Ohio's strategy is to be the national leader in manufacturing of fuel cell systems, components, and balance-of-plant equipment. In such, it has promoted growth of the fuel cell cluster through investment in R&D, support of current Ohio fuel cell-related companies, building the fuel cell supply chain through outreach to potential participants, and attracting new companies.

Two additional points about Ohio are important:

- **Initiatives Have Been Recent:** One of the main lessons from Ohio's experience is that initiatives in its fuel cell economy have been recent. The Ohio Fuel Cell Roadmap, which outlines the state's strategy, was only completed in 2004. The state's leader in the fuel cell economy, the Ohio Fuel Cell Coalition, was only established in 2003. The point for South Carolina is that Ohio, like many of these states, only entered the fray in the past five years. This leaves plenty of opportunity for states that are only launching a comprehensive hydrogen and fuel cell strategy now.
- **Importance of Development and Deployment:** Ohio is an example of a state that houses far less research than South Carolina does, but still has far more companies with capacities in fuel cells and hydrogen production, storage, and delivery than South Carolina does. The point for South Carolina is, if the state creates and implements strong strategies for development and deployment in order to fully utilize its current high level of research, it could become a leader in the hydrogen and fuel cell economy.

Connecticut: Industry Leadership in Forming a Fuel Cell Seed Cluster

Competitive Position: Connecticut is an interesting case in which industry has led the way in market creation and adoption. There is a long history in the development of hydrogen and fuel cell technologies, beginning with Praxair (hydrogen production) and United Technologies Corporation (fuel cells) in the 1950s. Connecticut's vision is to be a national leader in clean energy technology and to be an international leader in clean energy commercialization, entrepreneurship, and company formation. The state has been able to leverage a high concentration of related industries that have interests in, and commitments to hydrogen and fuel cell technology to build an active marketplace of regional and national buyers. Connecticut ranks 8th among the states in number of DOE hydrogen production projects, 12th in fuel cell projects, 7th in fuel cell systems and end-user applications, and is tied for 1st in fuels production, storage and delivery. Although Connecticut ranks lower than South Carolina in DOE hydrogen storage projects, the state tied for 1st in number of companies with capacity in production, storage, and delivery, and 5th in number of companies with capacity in fuel cells and components. Moreover, the state is just getting ready to launch a statewide effort to grow its fuel cells and power technology cluster and will engage many public institutions and power companies as partners in this effort—supported by collaboration between their Clean Energy Fund and their state Department of Community and Economic Development.

- **Discovery System Benchmarks**

- Connecticut ranks 30th in university R&D intensity.
- 41st in federal R&D intensity.
- 3rd in industry R&D intensity.
- Connecticut ranks 4th nationally in terms of science and engineering articles per \$1m of academic R&D.
- 7th nationally in patents awarded per 1m population.
- Connecticut ranked 4th nationally in total research expenditures at universities per patent issued.

- **Development System Benchmarks**

- Connecticut ranked 22nd in active licenses per start-up up (reasonably productive).
- Connecticut ranked 47th nationally in business formation rates.
- The state ranked 9th and 14th on SBIR Phase I and II awards and 15th on STTR awards.
- Connecticut ranked 44th nationally on business churn rate.

- **Deployment Systems Benchmarks**

- Connecticut ranks 6th in venture capital investment per worker.
- The state ranks 5th highest in cost of living.
- Ranks 3rd in total taxes per capita.
- Connecticut ranks 29th in taxes per \$1000 of income.
- Ranks 23rd in terms of reliance on general sales and use tax as a percent of total tax collections.
- 15th in reliance on personal income tax as a percent of total tax collections.
- Connecticut ranks 3rd in state and local spending as a share of general spending.
- Ranks 35th lowest in percent of interstate miles in unacceptable condition.
- Ohio ranks 3rd in number of high speed lines per 1 million people.
- Connecticut ranks 6th highest in total energy costs per 1 million BTUs for industry.

The Connecticut Hydrogen and Fuel Cell Approach: Connecticut has made this progress in hydrogen and fuel cells through a strong public/private agenda that includes:

- **Strong Private Industry Involvement:** Connecticut enjoys a strong presence of fuel cell developers and manufacturers, including: FuelCell Energy, United Technologies Corporation (UTC Fuel Cells), Proton Energy Systems and close to 40 related companies with over 3,000 employees. This growing cluster matched the nation's strong 15 percent growth in this industry over the 1998-2002 period. To foster growth, Connecticut allows the growth of non-renewable fuel cells, as a bridge toward expected growth in renewable fuel cells in the future.
- **Investing in Connecticut's Future:** Connecticut established the CT Clean Energy Fund (CEF) in 2000, a 5-year, \$100M program that invests in enterprises and initiatives that promote and develop renewable and sustainable energy markets. It is funded by a public goods surcharge, with \$52.8M completed/committed as of September 2004. Administered by Connecticut Innovations, the fund actively promotes fuel cell commercialization through demonstration projects and the development and installation of fuel cell systems that power commercial and institutional buildings throughout the state. Funding examples include the development and installation of a fuel cell system, produced by FuelCell Energy, Inc., for a new building located at the University of Connecticut's Mansfield campus, and the installation of a fuel cell, produced by UTC Fuel Cells, at South Windsor High School to enable the school to be used as an emergency shelter in the town's disaster-relief plan. Three major fuel cell manufacturers partner with CEF (UTC Fuel Cells, FuelCell Energy and Proton Energy Systems), which funds and oversees private sector innovation and uses one fifth of its budget for fuel cell technology development.
- **A Focused Road Map and Message:** A three-prong strategy to achieve its mission during the period of 2004-2007:
 - Ensure a diverse supply of clean energy resources to ratepayers who fund the Clean Energy Fund.
 - Support early development of clean energy industry.
 - Enhance consumer knowledge of clean energy to stimulate demand.
- **Increasing patent activity:** Overall patent activity within this field has been increasing steadily since 1997, with 66 of these patents held by UTC Fuel Cells.

Pennsylvania: Beyond Coal to Hydrogen Technologies

Competitive Position: Pennsylvania is another state that has a long history of university commitment to hydrogen and fuel cells as well as a strong bottom-up drive to explore how to capture the value of these emerging technologies in their economy. The state ranks 5th in total DOE hydrogen projects, 3rd in number of DOE hydrogen projects in private organizations, and 5th in number of companies with capacity in production, storage, and delivery. Pennsylvania offers excellent examples in funding economic growth using an innovation pipeline approach to support the creation and growth of new companies.

- **Discovery System Benchmarks**
 - Pennsylvania ranks 10th in university R&D intensity.
 - 27th in federal R&D intensity.
 - 16th in industry R&D intensity.

- Pennsylvania ranks 15th nationally in terms of science and engineering articles per \$1m of academic R&D.
- 22nd nationally in patents awarded per 1m population.
- Pennsylvania ranked 22nd nationally in total research expenditures at universities per patent issued.
- **Development System Benchmarks**
 - Pennsylvania ranked 14th in active licenses per start-up up (reasonably productive).
 - Pennsylvania ranked 27th nationally in business formation rates.
 - The state ranked 20th and 19th on SBIR Phase I and II awards and 19th on STTR awards.
 - Pennsylvania ranked 29th nationally on business churn rate, toward the middle of the pack.
- **Deployment Systems Benchmarks**
 - Pennsylvania ranks 13th in venture capital investment per worker.
 - The state ranks 21st highest in cost of living.
 - Pennsylvania ranks 30th in taxes per \$1000 of income.
 - Ranks 20th in total taxes per capita.
 - Ranks 24th in terms of reliance on general sales and use tax as a percent of total tax collections.
 - 32nd in reliance on personal income tax as a percent of total tax collections.
 - Pennsylvania ranks 30th in state and local spending as a share of general spending.
 - Ranks 22nd lowest in percent of interstate miles in unacceptable condition.
 - Ranks 25th in number of high speed lines per 1 million people.
 - Pennsylvania ranks 21st highest in total energy costs per 1 million BTUs for industry.

Hydrogen and Fuel Cell Approach: The state has had a multi-decade commitment to fostering technology discovery, development and deployment. Through their state economic development program and its regionally-based technology innovation programs, the state helps build a supporting environment and stronger innovation pipeline for many industries. One of the core resources that anchors statewide efforts is:

- **State-Funded Venture Capital:** Pennsylvania created the Ben Franklin Technology Partners (BFTP) in 1982 to promote technological innovation in the state through a network of regional offices that offer: seed capital, business assistance, support for university centers of excellence, skills development, and development of business parks and incubators. Statewide, the program has invested in 1,850 companies/institutions, and a 2002 economic impact study estimated that every public dollar invested by BFTP yielded nearly \$23 billion of additional state income.

Evaluating Foundation Indicators

When analyzed across all six states, the area of Discovery reveals a bright point for South Carolina. Although statewide industry measures of Discovery systems rank generally lower compared to other states, R&D in hydrogen and fuel cells reveals a strong growth and concentration, equal to or exceeding those of competing regions. This foundation presents many opportunities for increases in not only federal and university funding, but in industry funded R&D as well. Areas where this strength can be leveraged further include increased

numbers of SBIR awards and the support of the formation of new businesses as hydrogen and fuel cell research moves towards commercialization and market deployment.

Globally, there are many countries and regions that are aggressively attempting to stake out a piece of the hydrogen economy. Each has its own preference and place in the supply chain, and economic strategies range from hap-hazard to well-formed. In addition to the examples presented above, many states in the U.S. have a broad range of programs, policies and initiatives for economic development, but few have a useful set of measurable results. Florida has a focused plan of action and an existing manufacturing base, while Illinois is sponsoring their hydrogen initiative through an existing science and technology coalition. New Mexico is leveraging their national laboratories, while New York is seeking proposals to develop a New York State Hydrogen Roadmap.

South Carolina can learn much from the few success stories which are just beginning to surface, but they can gain more from adopting a hybrid of methods and programs which best work to conquer their own set of immediate challenges. This tactic will generate the first steps of an overall strategy, and move South Carolina towards their sustainable piece of the hydrogen economy.

2.7. Defining Challenges facing South Carolina's Hydrogen and Fuel Cell Economy

Building Common Ground for South Carolina's Strategy

A fundamental objective of this strategy process has been to carry out a bottom-up, user-driven, market-focused process of defining crosscutting themes that will ensure the validity and utility of the South Carolina Hydrogen and Fuel Cell Economy Strategy. To accomplish this objective a systematically structured set of facilitated work sessions were carried out with over one hundred regional stakeholders in August 2005. The working groups were organized around three regions of South Carolina and their distinctive areas of interest and activity in the hydrogen and fuel cell economy. The working groups were based in:

- **Aiken Region:** Hydrogen Production and Storage, held at the Savannah River National Laboratory in Aiken;
- **Midlands Region:** Fuel Cells; and
- **Upstate Region:** End User Applications and Transportation.

Invitees were recruited from along the existing and emerging continuum of research, development and commercial activity currently or potentially likely to be concerned with hydrogen or fuel cells. Participants included university and lab researchers and scientists, members of state and local governments and agencies, economic development representatives, and spokespersons from private industry, such as General Motors, John Deere, and BMW.

As described in the introductory framework, the consulting team worked from the bottom up through three rounds of working sessions with each group, to define competitive challenges facing South Carolina and each region as they go about building a hydrogen and fuel cell economy. The crosscutting challenges that emerged from these work sessions confirm the shared issues that must be addressed and form the case for the core elements of the overall strategy.

Cross-Cutting Challenges: Roots of Flagships

Cross-regional challenges were identified during the first meetings and these are the drivers of the overall strategy. Each regional group later defined specific actions they would like to take. Those challenges that are cross-cutting in nature are part of the Flagship Initiatives which are intended to support all of South Carolina's needs. Those actions that can or should be specific to a regionally-based package of initiatives are described in detail in Section 4. Regional Drivers: Foundations for Growth. The strategic set of challenges facing South Carolina is summarized below by stage of the Innovation Pipeline:

Discovery Challenges: Building Knowledge and Capturing Innovation

- **Research Funding:** Need for new sources of funding for applied science research, flexible and able to support promising segments of hydrogen research—able to support the state's research universities as well as the Savannah River National Laboratory.
- **Growing Faculty & Staff:** Need to recruit and retain leading faculty and laboratory staff in hydrogen and fuel cell-related science and engineering in order to build federally sponsored research and attract industry research partners.
- **Energizing Innovation:** Need to more effectively motivate faculty and laboratory staff to generate intellectual property (patents) and need to increase efforts to identify and file for patents in the field of hydrogen and fuel cells.
- **Coordinating Research:** Need for new mechanisms to enable and coordinate growth of cross university, laboratory and company research and national pre-competitive R&D consortia to generate revenues from new sources and build state visibility.
- **Increasing Visibility:** Need to define and become a more nationally visible “Center of Excellence” in hydrogen and fuel cell technologies, so as to attract research talent, research partners, and research funding to South Carolina.
- **Retaining Talent:** Need to stem the loss of new graduates to markets outside of SC.
- **Focusing Statewide Resources:** Need to counteract institutional and geographic “turf” barriers across universities and institutions that limit collaboration and spread resources and funding too thin.
- **Expanding Pre-Competitive Efforts:** Need to build more applied research and pre-competitive relationships with and for industrial sectors.

Development: Transitioning from Innovation to Commercialization

- **Define Commercialization Road Map:** Need to build a technology road map of the market path that fuel cell development (and related hydrogen infrastructure) may take to help guide university and technology development capabilities—better focus and preparation means higher visibility of South Carolina to corporate partners.
- **Showcase Innovation:** Need to conduct large scale demonstrations in strategic fields of hydrogen and fuel cell research to position and showcase South Carolina innovations, attract industry and institutional partners to the state and set the stage for downstream supply chain and production.

- **Grow Entrepreneurs:** Need to build and recruit a generation of entrepreneurs and managers that will carry innovation forward into South Carolina's markets given the low level of entrepreneurship in the state—this applies to faculty and national laboratory staff as well as individuals in industry, and includes the need to retain foreign born nationals who leave after graduation, and the need to recruit alumni and experienced business managers into the state.
- **Find Early Stage Risk Capital:** Need for pre-seed and seed capital (early stage, high risk) to induce greater efforts at innovation in hydrogen and fuel cells (even before SBIRs) to enable proof of concept, prototypes, and pilot scale production.
- **Provide Management Support:** Need for management assistance to early stage entrepreneurs to help them form business plans, company teams.
- **Enhance Access to Expertise:** Need to ensure well managed access to university expertise and facilities for start-ups and independent researchers.
- **Recruit Industry R&D Partners:** Need to scale up efforts to recruit world class corporate R&D partners to South Carolina and, where needed, match them to early stage companies here.
- **Prepare Skills for New Markets:** Need to line up workforce skills—several years ahead of need—to fill future job opportunities in hydrogen and fuel cell technical and engineering occupations.
- **Get Demand Intelligence to Firms:** Need to provide better market demand information to emerging companies to enhance their business focus and to find future customers and suppliers.
- **Promote SC as a State for Commercial Development:** Need to promote South Carolina as a state where hydrogen and fuel cell research, development and commercial growth will and are taking shape to position the state for ongoing federal and industry sponsored initiatives.

Deployment: Moving from Commercialization to Economic Agglomeration

- **Establish Incentives:** Need to set in place financial or other incentive mechanisms that will provide revenue to hydrogen and fuel start-ups as they scale-up production and prove their products in the marketplace—they need a financial bridge during their early days—whether from direct procurements, demonstration projects or incentives to others to use their products.
- **Grow Centers of Activity:** Need to establish geographic centers, science and technology parks or zones at which hydrogen and fuel cell activities can locate, leveraging competencies across related industry companies. The sites would provide cost and access efficiencies through sharing common energy production and use, operations technologies, skills, management support and other physical infrastructure.
- **Jump Ahead in Fuel Cell Automation:** Need to aggressively explore how to move South Carolina towards automated production of the next generation of technologies, particularly fuel cells, to enable the state to capture jobs and supply chain revenues.
- **Recruit Producers to South Carolina:** Need to induce out of state companies that are active in the hydrogen and fuel cell marketplace to establish production operations in South Carolina. Inducements should support partnerships between South Carolina companies and out of state businesses that wish to locate here—particularly those working in energy systems for key markets, such as automotives.

- **Focus on Building the Hydrogen Supply Chain:** Need to build increments of the future hydrogen and fuel cell supply chain across the state now to capture attention of major producers.

2.8. Conclusion: Focus on a Portfolio Approach with Continuous Improvement of State Advantages

Take a Portfolio Approach: Focus on Existing Strengths, Not One “Magic Bullet”

South Carolina must leverage its research efforts in the marketplace through building and sustaining scale of activity across fields of activity. This will also require more aggressive public and private funding and business support programs to induce entrepreneurs, start-ups and existing companies working in hydrogen and fuel cell technologies to establish operations within the state. South Carolina needs to match if not surpass its competitors in multiple fields. Spreading support *across* the different segments of hydrogen and fuel cells will provide stronger opportunities for future growth and avoid the danger of the state “choosing winners and losers.”

Build a Path to the Economic Future: Create Advantages at Each Point in the Innovation Pipeline

Beginning with its strengths in research, South Carolina must further extend abilities at each stage of the Innovation Pipeline across the state and its regions. Investment in each level of the innovation pipeline should create distinctive advantages for specific segments of hydrogen and fuel cells, focusing on forming and growing the hydrogen and fuel cell value chain. Only if each level of the pipeline is well linked to the other and provides opportunities not available elsewhere will South Carolina be able to feed ideas to the mechanism that enables commercial growth. Shortcomings in any one area—discovery, development or deployment—will block economic opportunity for taking shape.

Concentrate on Getting on the Road Map to the Hydrogen and Fuel Cell Value-Chain

South Carolina is very different than its competitors in that the majority of them have a highly developed constituency of industries already in place—many of them facing significant challenges in remaining competitive in the global economy. In contrast, South Carolina has a more open playing field in which to grow its future. To do this successfully, South Carolina needs to ensure that its thinking focuses on the goal of building an economic value-chain that creates a wide range of opportunities for enterprise (and workforce). A good example of how thinking might focus is to consider how major vehicle subsystems are changing. They are shifting from a mechanically-centered model to an increasingly electronic and electrical basis. Many of the more mature industry centers across North America will not be adequately prepared for this transition—legacy suppliers may not be able to adapt to changing requirements of this new environment. By learning the emerging industry “road map” (stages of expected industry technology changes) South Carolina can not only be position to form valuable new start-ups but also (and very importantly) be able to attract next generation manufacturing to the state. There are already ongoing discussions and “battles” over by whom and how the needed enabling technologies for future vehicles will be won. The technological hurdles that need to be overcome for vehicles, for purposes of illustration, may progress in this sequence:

1. Electric drive motors
2. Power electronic packages for vehicles
3. Integrated electric drive systems
4. Integrated electro-mechanical transmissions
5. Energy storage systems (for electrical energy)
6. Hydrogen storage systems.

South Carolina should focus on participating in addressing and “winning” a position in these incremental steps, each of which must evolve and become commercially viable before fuel cells and hydrogen can become viable. Because large transportation equipment companies (OEMs) are now seeking solutions worldwide, South Carolina has the possibility—with its diversity of competencies—to serve as a developer of at least some if not all of these component systems. Moreover, efforts to effectively demonstrate South Carolina capabilities and position the state may pay off sooner than expected. This can happen if, for example, South Carolina makes a concerted effort to align its capabilities with recruitment and start-up efforts focusing on OEMs who will be able to produce this high value-content for future vehicles—starting with electrical propulsion and ultimately progressing to hydrogen storage, fuel cell components and supporting equipment and systems. South Carolina could successful form firms but also succeed in attracting leading producers, such as Toyota, who will soon be seeking sites for production of electric drive systems, for example. By concentrating on identifying and penetrating and positioning itself on the production road map for new energy technologies South Carolina can incrementally grow the value-added it produces and become a center for suppliers and producers—achieving a thoroughbred cluster that combines new energy technology and end-user markets, such as transportation. This same logic can be applied to other value-chains in industry, such as stationary power, as well.

Collaborate Statewide: Reinforce and Link Assets Together

South Carolina must better coordinate and position its assets, initially in research, to more effectively compete for federal funds and private investment. Providing a unified front, by more efficiently using research resources and eliminating in-state competition, reinforces a statewide hydrogen and fuel cell economy strategy to the national and global marketplace. If the state degenerates into regional feuds, the entire objective of state strategy will be unattainable and the state will become simply end up having subsidized the export of South Carolina knowledge to other states.

Timing: Start Now and Stay the Course

Regional themes and initiatives can begin today to build the foundations for a healthy hydrogen and fuel cell economy in South Carolina. Couched within a larger series of statewide energy and economic development programs, regional projects can deliver short and middle term results, exhibiting solid market growth and stability to the larger national marketplace. As the hydrogen and fuel cell economy expands, this acts as a significant attractor to those companies and institutions searching for a key partner in South Carolina.

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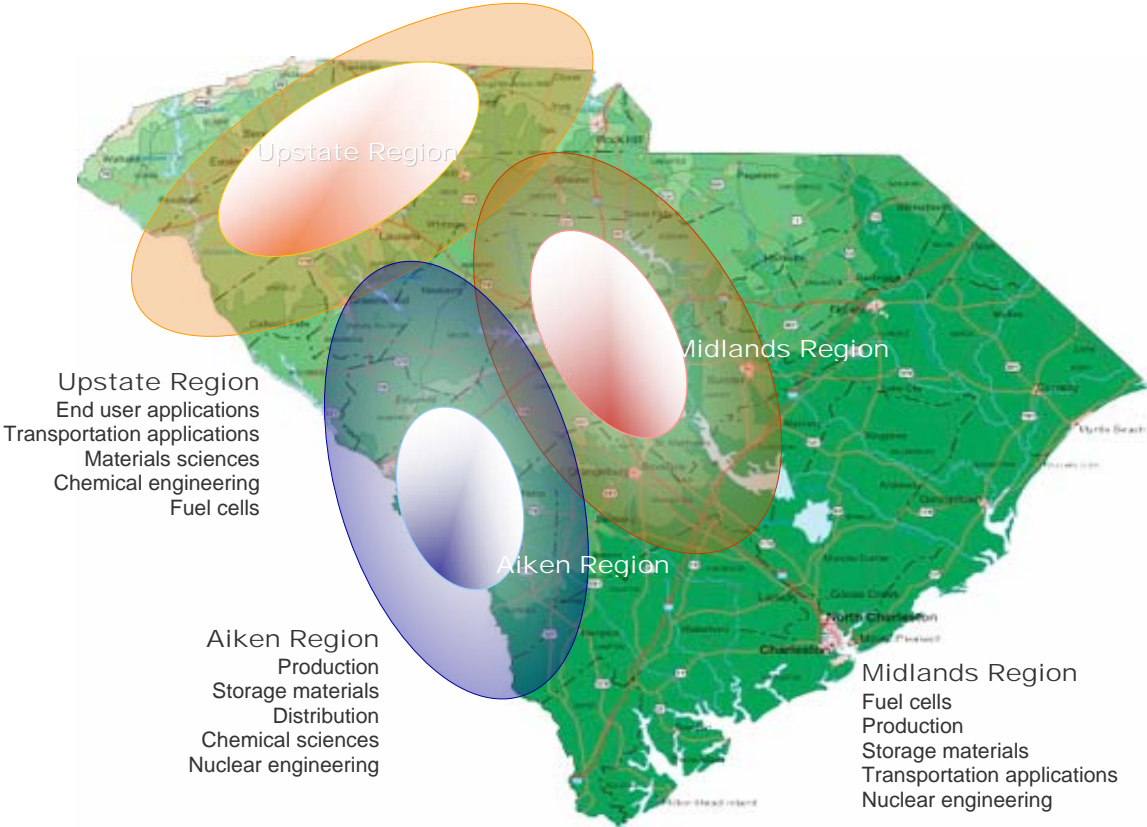
3. Regional Drivers: Foundations for Growth

3.1. Building Regionally to Compete Globally

South Carolina is distinct among states vying for leadership in the emerging hydrogen and fuel cell economy. It currently has three regional centers of competency that collectively help build a *portfolio* of capabilities that should enable South Carolina to compete effectively in one or more technologically-driven market-segments of hydrogen and fuel cells—thus creating new jobs and wealth. These regions and the hydrogen and fuel cell themes on which they are focusing are:

- **Aiken Region:** Hydrogen production, storage and distribution.
- **Midlands Region:** Fuel cell and related support technologies.
- **Upstate Region:** Hydrogen and fuel cell end-user applications, such as transportation.

Figure 3-1. Regional Themes in South Carolina



These three regions do not represent the entirety of South Carolina assets, but they are the most active in hydrogen and fuel cell-related science and technology. The competencies in these regions—at universities and laboratories—may enable them to serve as the anchor for future concentrations of research, commercialization and industrial growth.

In order to ensure that the South Carolina Hydrogen and Fuel Cell strategy is bottom-up, market-driven and collaborative, three working groups of stakeholders were organized to craft strategic directions on which they would work regionally. Many of the challenges facing these regions and the actions they proposed to work on have much in common. The cross-cutting nature of these challenges and actions is evident in the proposed Flagships which form the core of the statewide strategy.

However, the stakeholders in each of these three regions have worked on their own to define the elements of their regional strategies. They have done this in the hope and expectation that their own commitments *in combination with* future statewide support will enable them to build distinctive regional “innovation pipelines” that will discover, develop and deploy hydrogen and fuel cell-related technology-based jobs into the state economy.

While each region is naturally interdependent with other regions, they have their own identities which should be encouraged and reinforced to strengthen the diversity and range of South Carolina’s future prospects in the hydrogen and fuel cell economy.

Each South Carolina region is expected to actively pursue the formalization and advancement of its own regional hydrogen and fuel cell economy strategy. This is a very positive feature of the state and differentiates South Carolina from many other competitors. However, the crucial next step in South Carolina is for the state to encourage and support each region as they build their organizational capacity to advance their strategic directions. Then, once the state has helped energize and reinforce the regional efforts, it needs to determine how best to provide cross-cutting support that will help all the regions enhance their respective innovation pipelines. At all costs, the state should avoid devolving into a feudal mode of policy-making that is driven by politics or position. The goal should always be to create a rising tide that raises all boats in the South Carolina economic portfolio. Regions are the foundations for South Carolina’s growth and this should not be forgotten in strategy development.

The proposed strategic directions and building blocks of each region are summarized here, but are supported by detailed action business plans prepared by stakeholders in the course of this strategy process (available on request). What is important for decision-makers is to recognize that a powerful portfolio of capabilities exists in South Carolina and to consider how to respect their regional foundations while fostering collaboration on statewide development over time.

Table 3-1. The Three Regions

Region	Aiken	Midlands	Upstate
Regional Theme	Hydrogen production, storage, and distribution	Fuel cell and related support technologies	Hydrogen and fuel cell end-user applications, such as transportation
Actions	<ul style="list-style-type: none"> • Introduce Thermochemical Hydrogen Production Processes through a Pilot Plant Initiative • Create a Pre-Competitive Industrial Hydrogen Storage Partnership • Establish a Fully Functional Hydrogen Distribution Test Facility • Create a Pre-Competitive Hydrogen Technology Alliance 	<ul style="list-style-type: none"> • Expand the Hydrogen and Fuel Cell Industry Center of Excellence • Establish a Uniform System for Technology Validation Initiatives and Demonstrations • Organize a Fuel Cell Production-Automation Partnership • Establish a Set of Energy Parks/Zones 	<ul style="list-style-type: none"> • Establish New Energy End-User Application (NEUA) Assessment Center • Stimulate Entrepreneurship through ClemsonICAR • Organize Hydrogen Transportation Demonstration Projects Matched with the Development Needs of the Upstate • Explore Partnership with SRNL

3.2. Aiken: Hydrogen Production, Storage and Distribution

Regional Assets

The Aiken region of South Carolina is distinctive as the home of the Savannah River National Laboratories (SRNL). This laboratory is recognized for its leadership in scientific and technological innovations in hydrogen and is committed to collaborating with partners in building on its competencies to support national goals as well as regional economic development. The Aiken County Economic Development Program (EDP) has been active as the catalyst of regional efforts to harness and leverage the technological capabilities of SRNL to generate industrial growth in hydrogen production, storage and distribution. Aiken County and its EDP have funded the construction of the National Center for Hydrogen Research (NCHR) which will serve as an important bridge between research in the national laboratory and the marketplace. The center (managed by the County) will offer 60,000 square feet of laboratory facilities, co-location of SRNL researchers along with industrial and academic partners. The center management will facilitate technology transfer and joint research that focuses on hydrogen production, storage and distribution infrastructure. The NCHR is located near sites that have been proposed as locations for a potential “energy park” that will attract commercial next generation power production and foster synergistic activities across the region. Aiken’s focus on hydrogen production, storage and distribution will naturally link with USC competencies in each of these areas. USC faculty is present in the region, as are Clemson faculty, working on hydrogen-related research programs.

Table 3-2. Policy Options. Aiken

Action	Introduce Thermochemical Hydrogen Production Processes through a Pilot Plant Initiative	Create a Pre-Competitive Industrial Hydrogen Storage Partnership	Establish a Fully Functional Hydrogen Distribution Test Facility	Create a Pre-Competitive Hydrogen Technology Alliance
Policy Options	<ul style="list-style-type: none"> Establish a Center of Excellence in production based on strengths in chemical and hydrogen expertise Leverage strengths in Nuclear Engineering from USC, SCSU and Clemson Create partnership between government, academia, and industry to develop centralized hydrogen production technology Leverage IP from SRNL, USC and Clemson 	<ul style="list-style-type: none"> Create pre-competitive industrial partnership to develop safe, efficient, cost-effective hydrogen storage Focus on development, testing, and demonstration Make cooperative research and development agreements (CRADAs) with regional universities and corporate participants Encourage shared corporate/government participation in R&D, and intellectual property results 	<ul style="list-style-type: none"> Design, construct, and operate a hydrogen production and distribution pipeline and test loop Integrate the three main hydrogen sectors—production, transport, and utilization Locate at SRNL 	<ul style="list-style-type: none"> Enable the development of validation and demonstration initiatives in hydrogen production, storage, and distribution

Proposed Aiken Region Collaborative Actions

The participants in the collaborative working group—which includes representatives from SRNL (and the Washington Group), Aiken County, USC, Clemson and a range of industries active in hydrogen research specified three major demonstration and technology validation initiatives that they believe they could undertake to advance their hydrogen-based economy and one overarching action to provide a mechanism to enable their development. These actions are as follows:

- Action 1. Thermochemical Hydrogen Production Process Development Pilot Plant Initiative:** This initiative would create a government, academic and industrial partnership to advance the development of centralized hydrogen production technology. SRNL already has extensive and broad-based expertise in conducting the R&D associated with the high temperature thermochemical process for producing hydrogen. Both USC and Clemson are also engaged in related research and SCSU has related training programs. The goal is to harness this unparalleled level of expertise in the state, working with the DOE to ensure that SRNL so that the state is designated as the leader in the research, process development, and testing of the thermochemical process. This development should enable attracting energy producers as well as downstream hydrogen users to the region. This initiative was initially described in the South Carolina Hydrogen Economy report: “Capitalizing on the State’s R&D Assets” (CTC, July 2005).

- **Action 2. Industrial Hydrogen Storage Partnership Initiative:** This initiative would create a pre-competitive partnership to support the SC-based development of safe, efficient and cost-effective hydrogen storage for stationary and portable power applications. The focus of the work will be the development, testing and demonstration of hydrogen storage units and systems to move the technology from the lab bench to eventual commercialization (including compressor technology). The pre-competitive entity (a non-profit) would have cooperative research and development agreements (CRADAs) with SRNL and contracts with universities, funded by consortia members. The multi-sponsor, pre-competitive consortia would seek participants such as Deere and BMW as members, with the research being carried out from engineering scale to pre-commercial (heat transfer, safety, vessel design, onboard, large scale cycling, modeling). Companies could perform portions part of the pre-competitive R&D as part of the consortia. Intellectual property results would be shared. Companies would have first right of refusal. Work could start at the Center for Hydrogen Research, linked with university partners.
- **Action 3. Hydrogen Distribution Test Facility Initiative:** Establish a fully functional test bed in SC to be used to evaluate pipeline materials and components as well as other aspects of hydrogen distribution. This initiative would design, construct and operate a hydrogen pipeline and test loop. The test loop will circulate hydrogen in various different sections of pipe with various different components like valves, compressors, and sensors that can be tested and evaluated in actual hydrogen service. The facility will require a source of hydrogen which can also lead to the testing of various hydrogen production technologies (electrolyzers or steam reformers etc.). The facility could also be used to provide hydrogen to small fleet of hydrogen vehicles or a stationary power application. This integration of the three main hydrogen sectors—production, transport and utilization—will make for an effective demonstration and evaluation of hydrogen applications. The overall facility will be planned as a user facility in which various commercial and pre-commercial components and subsystems can be tested and evaluated. The proposed location of the test loop is the Savannah River Research Campus which is in the vicinity of the SRNL and next to the new Center for Hydrogen Research. Testing and evaluation of components and subsystems both during hydrogen service and after service will be carried out with the assistance of university students and participants from USC, Clemson and SCSU.
- **Action 4. Hydrogen Technology Alliance for Pre-Competitive Initiatives.** A new organization is needed enable the development and management of hydrogen production, storage and distribution demonstration and technology validation initiatives. The Aiken region—working regionally or at the state level expects that its National Hydrogen Research Center can play a role regionally. However, a formal dedicated capacity is required to effectively prepare, market and manage such initiatives. The proposed organization could be a working group of universities, laboratories, public sector, industries and organizations with expertise across the fields of hydrogen research and development that would develop and execute pre-competitive R&D consortia across hydrogen technology themes in South Carolina—but created to enable the initiatives described above. The requirements of this organization is that it build on experience (recognizing differences across participants—universities, the lab, industry), that it aggressively markets its members shared ideas, promote pre-competitive research and successful builds and sells multi-sponsor initiatives. This organization would need to coordinate or administer operations of these pre-competitive initiatives, whether serving as the prime or seeking a lead institution who subcontracts to other participants. This entity would need to understand state-wide competencies and facilitate communication from concept to research to end user, and facilitate communication

and delivering results. The entity should minimize administrative complexity and burden to university, laboratory and industry members of each pre-competitive consortium

Aiken Region Hydrogen Vision

Stakeholders in the Aiken regional working group believe that if their region successfully implements the collaborative actions they have defined, over the next three to five years their regional economy will see these changes:

- Global companies will have an established R&D presence in this region at Aiken facilities, perhaps five companies and 100 employees.
- There will be one or more start-ups in portable/stationary hydrogen storage systems.
- The Center for Hydrogen Research adds 40 additional full time scientists (with USC and Clemson participation) and 90 people total.
- There is now at least one endowed chair in each of the three fields centered in this region at the state's universities, with each chair attracting 10 graduate students and \$500k in research.
- Demonstration and validation project related job growth exceeding 300 new staff (and their economic multipliers) for all the facilities, including the thermochemical facility.
- High quality and higher paying jobs increase as the region adds research, engineering and technical support positions.

3.3. Midlands: Fuel Cells

Midlands Regional Assets

The Midlands region is home to the University of South Carolina and its strong fuel cell and hydrogen-related research programs. In addition to its National Foundation Industry/University Cooperative Research Center for Fuel Cells for pre-competitive research USC and the Center for Electrochemical Engineering, and its nuclear engineering program, USC has funding (\$9 million) from the state appropriations and lottery-based endowed professorships program to establish a Center of Excellence for the Fuel Cell Economy. These professorships will be in the areas of hydrogen storage, electrochemical sensors, and catalysts for hydrogen from renewable resources and they have a mission of strengthening hydrogen and fuel cell research activities.

This set of core competencies will be extended through the new \$32 million center Horizon Center which will serve as a hub for collaboration with industry in next generation energy technologies. The Horizon Center, with its facilities for hosting research, collaborative projects with industry and technology commercialization will link to surrounding research park facilities helping to create a geographic concentration of discovery, development and deployment in fuel cell and hydrogen technology over time. In the Midlands region, USC is the anchor institution for building the innovation pipeline in fuel cells and hydrogen. However, as the state capital, this region has key partners in industry associations, the City of Columbia, Chambers, technical colleges, financial institutions and industry that will play important roles in realizing the growth of the hydrogen and fuel cell economy, including representatives from the Aiken and the Upstate regions.

Table 3-3. Policy Options. Midlands

Action	Expand the Hydrogen and Fuel Cell Industry Center of Excellence	Establish a System for Technology Validation Initiatives and Demonstrations	Organize a Fuel Cell Production-Automation Partnership	Establish a Set of Energy Parks/Zones
Policy Options	<ul style="list-style-type: none"> • Designate the mission to be achievement and sustenance of global leadership in basic and applied fuel cell research • Establish a non-profit research and development corporation • Establish an incubation facility • Establish a joint venture facility 	<ul style="list-style-type: none"> • Use demonstrations for testing, transition to commercialization, and production scale-up. • Fund with co-sponsorships with public institutions, procurements for a minimum number of units, and tax incentives for use by early adopters • Work with the power companies to do a fuel cell distributed generation demonstration • Work with a municipal wastewater facility in a hydrogen generation demonstration • Work with state or regional transit authority or public/private sector partners to build a fleet of hydrogen powered vehicles 	<ul style="list-style-type: none"> • Create a group of public and private stakeholders to explore the requirements, standards, and process technologies for fuel cell production • Organize a consortium of manufacturers capable of pilot testing and automated production of fuel cells • Over time, develop and recruit companies capable of providing integrated production • Run the initiative through SCRA in the beginning • Leverage IP from SRNL, USC and Clemson 	<ul style="list-style-type: none"> • Designate certain geographic areas as Energy Parks • Offer economic advantages to hydrogen and fuel cell-related businesses that locate in the parks • Carry out initiative through partnership between USC, SCRA, City of Columbia, and regional chambers—working closely with existing and emerging businesses

Proposed Midlands Region Collaborative Actions

The participants in the Midlands region working group included a strong contingent from USC, including the vice president for research, offices of technology transfer and faculty from across the key USC departments that are leading research in fuel cells and hydrogen. Participants also included representatives of associations, such as Fuel Cells South, the South Carolina Research Authority, City of Columbia, Chamber of Commerce, economic development organizations from the Midlands region

and corporations working with USC, including national firms active in fuel cell research and interested in future developments here. The stakeholders defined a set of actions that they believed will support and sustain the growth of a critical mass of ongoing fuel cell and hydrogen research—leveraging existing strengths—as well building a stronger entrepreneurial base and technology commercialization output. All this requires enhancing the visibility of the region (and state’s) key capabilities among state decision-makers and in national markets:

- **Action 1. Expand the Hydrogen and Fuel Cell Industry Center of Excellence:** The mission of the “Center” would be to achieve and sustain global leadership in applied fuel cell research, intellectual property creation and technology licensing. The structure of the Center would be to build on the existing success of the NSF I/UCR pre-competitive research model by creating and sustaining a complementary organization that focuses on industry and local economic impact through intellectual property development, technology / company incubation and joint venture operations. The Center would consist of three parts:
 1. **A non-profit research and development corporation:** Establish “Palmetto Fuel Cell Research Corporation” whose mission is to create intellectual property related to core fuel cell technology, balance of plant components, manufacturing processes and systems management capabilities for license and use by public and private entities.
 2. **An incubation facility:** Establish “Palmetto Fuel Cell Technology Incubator” for fuel cell technology start-up companies, who will have specific state / regional incentives to base their operations in South Carolina, including becoming a South Carolina Innovation Center company, having facilities and support infrastructure within the Horizon Center and working cooperatively and contractually with Palmetto Fuel Cell Research Corporation to create and market fuel cell components, products and services.
 3. **A joint venture facility:** Create “Palmetto Fuel Cell Ventures” for established businesses and promising start up companies to co-locate engineering and product development teams in the Horizon Center, providing specific state / regional incentives and collaboration opportunities with the NSF I/UCRC, Palmetto Fuel Cell Research Corporation and the Palmetto Fuel Cell Technology incubation companies.

The Center would initially leverage existing funding tied to the Horizon Center as seed capital for the business development and marketing efforts. These efforts would be focused on adding public and private research funding sources, and would include marketing the Centenary Research Faculty Program in direct support of the needs and wants of targeted industrial and start-up companies. Upon securing anchor sponsors and participants, the Research Corporation would focus on contract/partner -specific funding to sustain its operations. In addition, promising start-up and joint venture companies would have access to grants, loans, seed capital, venture capital and supporting business and technical service companies with knowledge and expertise in fuel cell technology and markets.

This Center would also focus on using pre-competitive R&D initiatives with federal and industry sponsors to accelerate development in strategic theme areas of national and/or industry importance in the field of fuel cells. The initiative would have a strong advisory board of businesses that would also be provided possible matching funds for grants they may award to the Center of Excellence research activities—whether strictly faculty research or pre-competitive R&D consortia. The initiative would establish research operations at the Horizon Center in facilities dedicated to corporate needs.

The intellectual property policies for the Center of Excellence would be designed to ensure that patents are carefully identified and managed so that licenses are granted to firms or partners whose commitments to work in South Carolina are best developed.

In direct support of the Center for Excellence for Fuel Cell Technology, USC and the Regional Stewards would provide funding and resources to support the marketing and business development programs, including conferences and tradeshow, recruiting missions, public education and demonstration programs.

- **Action 2. Technology Demonstrations and Validation Initiatives:** The mission of this initiative is to test technologies that are near market readiness but need to receive refinement as well as visibility (and revenue) to transition to readiness for full commercialization, including production scale-up. This initiative or series of initiatives would start with existing companies and their technologies seeking market awareness and validation. Preference shall be given to companies that demonstrate a commitment to South Carolina in terms of research funding and/or participation in one or more Fuel Cell Center of Excellence programs. Over time and more specifically as innovations generated by South Carolina universities, laboratories and, in particular, South Carolina fuel cell-related businesses become available, a continuing series of technology demonstrations and validations will be organized and managed through this program.

The structure of these demonstration and validation initiatives would be designed to both help the producers finalize their products as well as provide early-stage revenues to the start-ups or established producers entering or active in the fuel cell marketplace. This would be achieved through securing sponsors and partners as the test beds for new fuel cell technologies, such as public users (universities, public buildings and transit districts, for example). This could include state and local or institutional agreements not only to co-sponsor but also use procurements for a minimum numbers of units (stationary, mobile and portable), and possibly coordination of tax incentives for use by early adopters of fuel cell technologies (such as equipment sales and property tax exemptions).

In support of these demonstrations, a marketing effort would be undertaken to increase South Carolina citizenry awareness and to stimulate demand for products and services. Examples of near-term opportunities are as follows:

- **A distributed generation demonstration program:** Working with local power companies and one or more existing fuel cell companies, a group of fuel cells would be installed at local schools, multi-family units and/or healthcare facilities, providing emergency back up power and the capability for off-grid power. The DG program would be designed to develop and validate distributed systems management capabilities, collect usage data and provide public awareness.
- **A hydrogen generation and power generation program from wastewater:** Working in conjunction with a municipal wastewater facility, demonstrate the on-site creation of hydrogen in support of fuel cell power generation and hydrogen refueling capabilities. The program would validate on-going research reforming technologies and provide a source for both local power and hydrogen refueling.
- **Build a fleet of hydrogen powered public / private vehicles:** Working with the regional transit authority, state government fleet managers and public/private sector partners design and test a H2 fueling program in conjunction with the validation of current H2 powered vehicles provided by industry partners. These demonstrations will coordinate with SCSU Transportation Center.

- **Action 3. Fuel Cell Manufacturing Automation Initiative:** The mission of this initiative will be to get an early start on positioning the Midlands Region and South Carolina as location for mass production of future fuel cell and balance of plant components, fuel cell products and fuel cell manufacturing support services. The structure of this initiative would focus on organization of a fuel cell production-automation partnership, leveraging intellectual property from USC, Clemson and SRNL. This partnership would encompass national, regional and local stakeholders with manufacturing technology competencies first, to win defense department bids to explore the manufacturing automation requirements for their fuel cell requirements, such as standards, process technologies and supply chain requirements and then, begin to organize either a spin-off or consortium of SC-based producers capable of establishing pilot testing and scalable flexible production facilities for automated production of fuel cells. This developmental process would, over time, seek to develop or recruit companies capable of providing an integrated production capacity that can serve early and maturing fuel cell customers, whether defense or civilian, and in doing so generate jobs and foster growth of a critical mass of business cluster activity. This initiative could be initially driven by SCRA with the direct support of specific national programs currently undertaken by ATI. USC and Midlands Technical College could support the development of manufacturing standards, processes and best practices, including prototyping and validating a manufacturing line for fuel cell components and/or integrated systems.
- **Action 4. Energy Park or Energy Zone Initiative:** The mission of this initiative will be to create a business environment within which fuel cell and related hydrogen and energy technology-based economic development can take shape. The structure of the Energy Park or Zone would be to designate a geographic area, perhaps starting within the existing university research park campus (Innovista) that will serve as a location for a continuum of fuel cell-related research, development and commercial production over time. This zone would provide a systematic package of economic input advantages for fuel cell and hydrogen-related businesses. These would include access to specific university research consortia on emerging technologies, access to contract research services (from ‘business-like’ providers, whether in the university or external to them, such as through a new institute), access to research facilities, pilot scale production and test bed infrastructure, as well as a shared energy system that permits application and utilization of fuel cell and related energy innovations. This initiative would be carried out through a partnership between USC, SCRA the City of Columbia and surrounding regional chambers, working closely with existing and emerging fuel cell related enterprises over time.

Midlands Region Fuel Cell & Hydrogen Vision

As the proposed initiatives go into effect over the coming five years our region will experience these economic changes:

- Fuel cells will become a visible aspect of every day life and citizens will “touch” fuel cell and hydrogen technology, recognizing its importance to the South Carolina economy and future (for example, with fuel cell shuttles between the airport and Horizon Center).
- South Carolina will be positioned with full support to and readiness to capitalize on the national fuel cell agenda, focusing on promotion of realistic expectations.
- The Horizon Center will become fully occupied by ongoing research programs, with many national and international corporations with onsite presence creating a major center of fuel cell and hydrogen activity in Columbia.

- The first generation of new fuel cell and hydrogen-related spin-offs from companies and new start-ups will emerge from within the Horizon Center with technologies at the early-stage of commercial development.
- One or more divisions of larger companies that have had a research presence in Columbia and have been anchor tenants in the Horizon Center may move divisions to South Carolina to continue development and scale-up production.
- South Carolina will be able to win a larger share of recruitment bids with companies from out of state because the state has established an effective package of incentives and resources to create a competitive advantage for fuel cell and hydrogen industry development here.
- State and local utilities and power generators have recognized the long-term importance of fuel cells and hydrogen and are scaling up support for research, technology as well as including these technologies as part of their energy portfolios, stimulating demand for fuel cell and hydrogen innovation in Columbia and the state.

3.4. Upstate: End User Applications

Upstate Regional Assets

The Upstate region has a distinct identity with strong connection to the broader Northern Tier area. The key assets of this region include the growing research capabilities of Clemson University in the field of advanced materials, automotive engineering, and design—with the new ClemsonICAR campus just taking shape now—as well as the burgeoning automotive cluster taking shape, anchored by BMW and its advanced supplier network. Although these assets are broadly distributed geographically, they offer a platform for the end-user applications of hydrogen and fuel cells in automotive and transportation markets. The region is just at the “tipping” point in its development of its critical mass of research and development around automotive industry needs. For this reason engaging and sustaining the region’s stakeholders in their potential roles in South Carolina’s hydrogen and fuel cell economy will need to take place a step at a time. The Greater Greenville Chamber of Commerce, in collaboration with their allies within the recently formed Upstate Chamber Coalition, are ready to act as an intermediary in pulling together the region’s full inventory of hydrogen and fuel cell assets and talent by sustaining the ongoing dialogue on collaborative action and supporting development of priority actions, including fostering hydrogen and fuel cell demonstrations and validation initiatives, building the entrepreneurial capacity required to take innovation forward into the marketplace and assisting formation and recruitment of companies in the supply chain related to hydrogen and fuel cell applications in regional industry.

Table 3-4. Policy Options. Upstate

Action	Establish New Energy End-User Application (NEUA) Assessment Center	Stimulate Entrepreneurship through ClemsonICAR	Organize Hydrogen Transportation Demonstration Projects Matched with the Development Needs of the Upstate	Explore Partnership with SRNL
Policy Options	<ul style="list-style-type: none"> • Create center that examines end-user applications of hydrogen and fuel cell innovations to stationary, portable, and mobile/transportation energy needs • Locate or affiliate center with ClemsonICAR • Bring together disciplines across Clemson (systems engineering and analysis, energy economics) and collaborate with USC • Initiate multi-company sponsorships or consortium projects—including suppliers and end-users 	<ul style="list-style-type: none"> • Create an Innovation Laboratory where entrepreneurial teams can develop and launch new ventures • Create a hub of information for entrepreneurs on the auto industry • Offer courses on innovation in the auto industry to students, affiliated companies, and entrepreneurs 	<ul style="list-style-type: none"> • Under a demonstration anchored by Clemson University, Clemson Area Transit System (CAT) or other lead applicant, demonstrate hydrogen-powered buses • In the future, use the high-speed rail corridor around the Upstate region to anchor a public/private partnership in support of accelerating the application of hydrogen to high speed rail systems 	<ul style="list-style-type: none"> • Seek out and link Clemson research and development capabilities to the flow of initiatives that will take place in Aiken and SRNL.

Proposed Upstate Regional Collaborative Actions

Among the proposed Upstate hydrogen and fuel cell initiatives on which regional stakeholders are prepared to work on are these three actions:

- **Action 1. New Energy End-User Application (NEUA) Assessment Center:** In partnership with industry and institutional co-sponsors, Clemson University will establish a multidisciplinary applied research center chartered to examine end-user applications of hydrogen and fuel cell-related innovations to stationary, portable and mobile/transportation energy needs. The center would be located within or affiliated with ClemsonICAR. The center would identify and systematically evaluate applications for users. The center would achieve this by bringing together disciplines from across Clemson’s systems engineering and analysis as well as energy economics to assess the feasibility and applicability of hydrogen and fuel cell-related technologies. Some of these activities would naturally be carried out collaboratively with USC, leveraging their competencies for testing hardware in the loop (in software), for example. These end-user application analysis activities would focus on setting the stage for continuous adoption of new energy solutions in specific end-user markets. These end-user application analysis and assessment activities could be undertaken by the center through using multi-company sponsorship or consortium projects where the results. Sponsors could include both suppliers of diverse and possibly competing hydrogen and fuel cell technology inputs as well as groups of end-users. There center activities could be structured around testing and evaluation of solutions in target markets, such as

transportation (given ClemsonICAR's mission), but also stationary markets (with major institutional energy consumers, such as hospitals, government, schools and other end users), and portable market segments (such as appliance, computer and communications companies). The solutions, once evaluated could be used to help support the business-case for innovators who produce in South Carolina (assuming a natural connection with the activities across the state). The results would naturally also be available to increase South Carolina energy efficiency—as well as that of global end user markets. The analytic end-user projects could feed into regional or statewide demonstration initiatives, including those described as part of the Upstate regional strategic direction.

- **Action 2. Innovation Center @ ClemsonICAR:** Stimulate the formation of an entrepreneurial and commercialization culture in the upstate region, leveraging the current ClemsonICAR initiative to incorporate hydrogen and fuel cells into the broader automotive and transportation research and engineering programs. This initiative would encompass four elements, including:
 - **An Innovation Laboratory:** A location where entrepreneurial teams from affiliate companies or operating independently can develop and launch new ventures. This would offer facilities for collaborative research and development (smart offices, incubation space, and "collaboratories") as well as "virtual" elements to support projects by teams created by ClemsonICAR sponsors or at the initiative of ClemsonICAR focusing on research outcomes. This would also include development of entrepreneurial teams, teams from automakers, Tier 1, 2 and 3 auto suppliers, in residence for pre-competitive or proprietary R&D. For example, a team could come to work in the laboratory and then return to their companies, with a continuing linkage to a given project.
 - **Entrepreneurship Center and Support:** A program with resources to draw in entrepreneurial teams, including faculty resident at ClemsonICAR, providing internet enabled learning tools for innovation and information markets, such as an index of the changing auto-economy—how it is evolving, where investment is going, research demands and trends. This would have a general public Internet portal, accessible to entrepreneurs as well as industry, helping the private sector tap into university resources through a central location. The activity of the proposed center would be coordinated with ongoing regional entrepreneurship development activities being carried out through a group led by the Greenville Chamber with the City of Greenville, Greenville Technical College and the Spiro Center for Entrepreneurial Leadership at Clemson University. This effort provides an information hub for technology entrepreneurs with an entrepreneur "conciierge," advocacy and supporting infrastructure that can offer a basic network to enhance the environment for entrepreneurship in the Upstate region.
 - **Auto Technology Research and Education Programs:** Courses that complement research carried out by ClemsonICAR, focused on innovation happening in the auto supply chain—where mobile fuel cell and related hydrogen solutions may be applied. Supports research on the auto system supply chain, including energy systems (such as fuel cells, hydrogen fuels, etc.). The goal would be to convey the research and understanding of innovation to students, to affiliated companies, and to entrepreneurs in the Upstate region.
- **Action 3. Hydrogen Transportation Demonstration Projects:** Organize demonstrations of hydrogen or hydrogen related technologies applications to transportation systems (buses and trains), presenting viable uses for multiple entities. The Upstate region has institutions, such as Clemson University, able to anchor demonstrations and technology validations and

potential partners in transit authorities, such as the Clemson Area Transit (CAT), that are prepared to develop new initiatives with power companies (nuclear and coal gasification plants), industry producers (OEM equipment manufacturers), suppliers of energy technologies, design and engineering companies, as well as political leaders and chambers. Projects can focus on combining end-users aspects of portions of the hydrogen economy including production, storage and distribution, and conversion (stationary and mobile systems). Examples could include:

- **Transportation Demonstrations:** Under a demonstration anchored by Clemson University or other lead applicant for federal and state funding, stakeholders, such as Clemson Area Transit System (CAT) as well as cities and chambers, such as Greenville, are ready to collaborate in possible projects in which alternative energy systems technologies are tested. For example, hydrogen powered buses could link the main Clemson campus in Pickens County, the Clemson Research Park in Anderson County, the ClemsonICAR campus in Greenville County, downtown Greenville, and the BMW facility in Spartanburg County. Any or all of these destinations can be linked into demonstration efforts to test and showcase technologies in which the capabilities of Clemson and ClemsonICAR have been focused, along with other South Carolina universities and SRNL. The goal would be to examine the systems requirements and cost-benefits and utility of different energy systems and showcase South Carolina’s leadership in systematically thinking the technology and economics of emerging innovations, while also fostering development of the supply chain providing and supporting inputs to South Carolina’s next generation public transit. These demonstrations will coordinate with SCSU Transportation Center.
- **High Speed Rail-Hydrogen Demonstrations:** The Clemson-Greenville region is situated along one of eight federally designated high speed rail corridors in the United States. This corridor extends from Washington, D.C. to Charlotte and through the Clemson-Greenville area to Atlanta, Georgia and possibly on beyond. For this reason and because of the vehicle technology capabilities at Clemson University as well as the potential for cross border collaboration with North Carolina and Georgia, this region could serve as the anchor for a public private partnership focusing on accelerating the application of hydrogen and alternative fuel systems to high speed rail systems. This initiative, while discussed, does not have a critical mass of support among Upstate leaders or other South Carolina stakeholders as of yet.

- **Action 4. Explore Partnership with SRNL**

Clemson University and its range of industry partners have strong research and development capabilities that can be important resources for planned initiatives in hydrogen and fuel cells across the state. In particular, the university would like to ensure that it collaborates with the initiatives that Savannah River National Laboratory will be undertaking. To enable this, active outreach, coordination and management of initiatives will be established as regional and statewide initiatives move forward.

Upstate Region Fuel Cell & Hydrogen Vision

The stakeholders from the Upstate region believe that if they make progress on improving the innovation pipeline for end-user applications of hydrogen and fuel cell technology that the following economic changes will take shape over the coming five years:

- Clemson University will become the primary source of innovations relevant to hydrogen and interim/alternative fuels production, and the hydrogen transition, related to materials and energy efficiency.
- New energy technologies will not as yet have impacted the Upstate regional economy, but there will be some demonstrations underway which will attract new relationships between Upstate region and producers, generating new jobs.
- The growth of an innovation center focusing on end user application innovation based on hydrogen and fuel cell-related technologies (or new energy technologies) will enable new synergies between faculty, industry staff and surrounding communities at multiple levels. These in turn will both lead to some expansion of existing industry technology operations in the region and the very first flow of start-ups.
- As these initiatives move forward the Upstate region will become a location to which auto and energy industry are increasingly attracted, not only for automotive systems but also for smaller applications for hydrogen related applications and supply chain products—this region is now on a “short list” for industry locations.
- More companies are attracted to the region that want to be associated with the South Carolina innovation-focused culture in transportation and energy.
- The enhancement of entrepreneurship produces and attracts more innovators as intellectual resources, which in turn leads to an update in start-ups and deal flow.
- The region wins a new federal contracts and multi-client projects that relate to automotives and transportation energy systems engineering, testing and production that attracts more investment and talent.
- The next generation of faculty are successfully attracted and retained due to enhanced research and supporting infrastructure resource availability which also (in turn) attracts more research funding to Clemson and the region.

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4. Strategy Drivers: Proposed Flagship Initiatives

4.1. Principles: Energize and Sustain Statewide Action

This initiative has worked collaboratively from the bottom-up in a market-focused manner to define how South Carolina can build a hydrogen and fuel cell economy. The comparative analysis of South Carolina's strengths and weaknesses in discovery, development and deployment of hydrogen and fuel cell set the stage for defining what South Carolina needs to do.

These analytic findings were confirmed and given specificity through work sessions with business, government and scientific leaders in each of three regions of our state. Working together these leaders defined what they believed to be their region *and* the state's challenges in building a hydrogen and fuel cell economy. Then, with insights provided about what other leading states have been doing, these stakeholders defined the types of actions that they believed the state should take. These actions, described in the previous section, also show the commonalties that regions share in their needs to advance their strategies—from support for research to technology validation and commercialization to accelerating enterprise growth and attraction.

The commonalties that South Carolina's regions share provide a basis for proposing statewide directions for achieving a hydrogen and fuel cell economy. These building blocks—actions that will respond to needs across our state—are the heart of this strategy. These strategic directions are called “Flagship Initiatives” and are the priorities on which decision-makers in South Carolina should focus their attention to capture the economic potential of the hydrogen and fuel cell technologies of the future.

The *South Carolina Hydrogen & Fuel Cell Economy Strategy* has three principal Flagship Initiatives. Each of these initiatives has specific objectives with corresponding action components. The actions supporting each Flagship will require new legislation or changes to existing state policy, commitments by leading state institutions and new public-private collaborations.

State government leadership in developing and supporting new legislation, programs and practices across state agencies and the state marketplace is vital to the success of this overall initiative. There are two reasons for this. First, given the long-time frame of the future of hydrogen and fuel cells the federal government is likely to be the major source of financial support at the early stages of development. States can significantly help their academic and research institutions and businesses obtain a strong share of national expenditures, by strengthening their R&D capabilities and showing commitment to leveraging federal dollars. Second, given this long developmental time frame the private sector will not be able to sufficiently fund it's the early stage activities—nor ensure that the impacts of their developments will be captured in South Carolina. For these reasons, many states and some local governments are becoming active in providing funding, incentives and enabling regulations to stimulate hydrogen and fuel cell research, commercialization and deployment. Government leadership and action is therefore essential to ensure that South Carolina is among the leading states in the emergence of this new technology area.

Understanding Policy Tools

The state of South Carolina has the opportunity to take direct and indirect action to enable the building of a hydrogen and fuel cell economy. Different policy options require different levels of government intervention depending on their goals and their requirements. Interventions can be light to heavy in their action—they can inform, enable, induce, or sustain activities in hydrogen and fuel cells. The following summarizes the range of four types of policy actions that decisions makers in South Carolina will need to consider in building the hydrogen and fuel cell economy strategy. Each level requires more intervention than the next. Interventions in any form should be expected to improve the innovation pipeline across South Carolina's regions. South Carolina has a history as a pro-business state—a state that emphasizes incentives as the tool for achieving action over regulation or taxation. None-the-less, South Carolina needs to recognize that the states with whom it is competing are actively making use of the entire range of policy options described here:

Inform: Change Market Action through Awareness

- **Foster Market Linkages:** Help link together researchers across the state, or link companies with university experts, or connect producers of energy or energy products with suppliers offering alternative energy technologies to facilitate hydrogen and fuel cell development.
- **Share Roadmaps:** Bring together key stakeholders such as researchers, producers and suppliers to share or examine their views of development timing and requirements to achieve paths to commercial markets.
- **Overcome Uncertainty:** Provide information on the added benefits and cost savings of alternative energy technologies such as fuel cells and hydrogen which reduce uncertainties and help accelerate market purchases of new technology.
- **Guide Choices:** Establish power generation disclosure rules about energy mix of utilities and line extension analysis (for rural customers off the grid) to ensure customers have maximum choice in their purchases.

Enable: Reduce Barriers to Research and Investment

- **Encourage Innovation:** Strengthen and expand intellectual property rules and policies at state universities so that personnel policies and career rewards practices foster the development of new ideas and enhance technology transfer to new enterprises.
- **Bridge Science to the Marketplace:** Facilitate development of consortia between universities and industry to enable pre-commercial research and demonstration projects that harnesses state science to produce state technology.
- **Concentrate Development Activity:** Designate special areas as energy zones and facilitate the formation of demonstration projects and potential hydrogen highways using special development policies to achieve a critical mass of activity and shared energy infrastructure.
- **Assist Market Entry:** Reduce the regulatory barriers or lack of operating rules which affects everything from insurance coverage to incompatibility with local building codes by fostering the development of consistent state and federal codes and standards for new energy technologies. The state that shows leadership in these areas will be more attractive to companies seeking a faster track to market.

Induce: Stimulate Growth in Supply and Demand

- **Reduce Marginal Cost of Product Development:** Encourage increased innovation in hydrogen and fuel cell technology through tax incentives (credits) for research, investment and production.
- **Stimulate Demand for Innovation:** Foster growth in the demand for hydrogen and fuel cell technology through tax incentives (corporate, property, sales, and income), low interest loans and rebate programs, renewable energy portfolio standards (RPS), and net metering rules that require utilities to purchase power generated using new energy technologies.

Sustain: Invest and Make Long-Term Commitment

- **Build Critical Mass:** Make significant investments in long-term needs for the hydrogen and fuel cell economy, such as increasing and differentiating state sponsored research that will distinguish the state.
- **Invest in Catalytic Initiatives:** Provide matching funds to help enable pre-commercial demonstration and technology validation projects that will distinguish the state and help tip the market recognition of the state by corporations as the right place for hydrogen and fuel cell economy investment and operations.
- **Reduce Market Risk:** In the absence of adequate private capital provide grants for seed capital funds, incubators and technology parks, and also make financial commitments to purchase new energy technologies or sources of power.
- **Ensure Basics:** Provide steady public sector leadership and investment in the cornerstones of an effective state education system and infrastructure to enable current and future growth.

South Carolina's Three Cross-Cutting Flagship Initiatives

Three proposed cross-cutting Flagship initiatives have emerged from the strategy process that has taken place. These Flagships focus on strengthening South Carolina's innovation pipeline. Each Flagship has an overall mission and key objectives. Each of these objectives is then presented in the form of proposed Flagship components or building blocks, ranked in importance. Each component is described in terms of its own goal and objectives in supporting its main Flagship. Each component includes a menu of policy options that have been drawn from across states and matched to South Carolina. Each Flagship component is also summarized in a table that also shows the "type" of policies, programs or practices that the proposed policy options include—whether they inform, enable, induce or sustain action.

The three candidate Flagships and their building blocks are the core of the proposed state strategy. Their in-depth descriptions follow:

- **Flagship 1 Discovery:** Achieve a critical mass of hydrogen and fuel cell basic and applied research in South Carolina.
- **Flagship 2 Development:** Capture hydrogen and fuel cell technology innovation in the South Carolina economy.
- **Flagship 3 Deployment:** Growth hydrogen and fuel cell industry-based activities in the South Carolina economy.

Table 4-1. The Three Flagships

Flagship	Discovery— Hydrogen & Fuel Cell Research	Development— Hydrogen & Fuel Cell Technology Commercialization	Deployment— Hydrogen and Fuel Cell Enterprise Survival, Expansion, and Attraction
Goal	Achieve a Critical Mass in South Carolina’s Basic and Applied Scientific Research	Capture Hydrogen and Fuel Cell Technology Innovation in the South Carolina Economy	Grow the Hydrogen and Fuel Cell Technology-Based Industry Activities in South Carolina
Components	<ul style="list-style-type: none"> • Establish a South Carolina Hydrogen & Fuel Cell Economy Research Fund • Organize a Pre-Competitive R&D Alliance for Hydrogen and Fuel Cells Science and Technology • Form South Carolina Endowed Chairs 	<ul style="list-style-type: none"> • Launch an Entrepreneurship Accelerator Package • Establish Pre-Seed & Seed Capital Fund for Hydrogen and Fuel Cell Innovation • Start a South Carolina Hydrogen & Fuel Cell Deal Generator • Induce Global Corporations to Conduct R&D with South Carolina universities and Start-ups • Establish Demonstrations and Technology Validation Initiatives • Organize Industry Roadmap Technology Programs • Create Geographic Center of Hydrogen and Fuel Cell Commercialization • Create Risk Management Function to Support the Growth of the Hydrogen Economy 	<ul style="list-style-type: none"> • Enterprise Maturation Package • Business Expansion Support • Industry Attraction Incentives • Geographic Concentration—Hydrogen and Fuel Cell Innovation Zones

4.2. Flagship 1: Discovery—Hydrogen & Fuel Cell Research

Summary: Achieve a Critical mass in South Carolina's Basic and Applied Scientific Research

Mission: Increase the level of basic and applied research in key areas of hydrogen and fuel cells carried out in South Carolina universities and national laboratories to produce a wide range of new scientific advances, intellectual property (patents), and outstanding university graduates and thereby attract industry partners and research sponsors.

Objectives: Build and feed the innovation pipeline. Enable South Carolina to generate the “feedstock” for innovation that can be “captured” in the state economy through increased technology licensing and commercialization within the state. Achieve this through the pursuing the following objectives:

- **Increase Hydrogen and Fuel Cell Research Funding:** Achieve a “critical mass” of funding for research in hydrogen production, storage, distribution, conversion and utilization at South Carolina universities and national laboratories, using new state resources to better leverage federal and industry funding.
- **Grow Hydrogen and Fuel Cell Intellectual Property:** Increase the number and value of innovations arising from a growing portfolio of basic and applied research in hydrogen and fuel cells through aggressive patent development efforts across statewide institutions. This will enable better definition and management of the feedstock for commercialization.
- **Enhance R&D Promotion and Coordination:** Expand the capacity of South Carolina universities and laboratories to organize and manage collaborative research initiatives in order to leverage competencies to prepare, promote and win more national research program awards and (in particular) pre-competitive R&D consortia with industry and government partners that will distinguish South Carolina globally in strategic fields of activity.
- **Attract and Retain Hydrogen and Fuel Cell Scientific and Engineering Talent:** Dramatically increase the recruitment and retention of leading researchers and graduate students in the field of hydrogen and fuel cell research through increased funding for research, laboratory facilities, and equipment.

Table 4-2. Policy Options, Flagship 1: Discovery—Hydrogen & Fuel Cell Research

Achieve a Critical Mass in South Carolina’s Basic and Applied Scientific Research

Degrees of Government Intervention				
	Inform	Enable	Induce	Sustain
Flagship Components	Establish a South Carolina Hydrogen & Fuel Cell Economy Research Fund		<ul style="list-style-type: none"> • Create options on state tax forms for voluntary contributions to research • Offer tax exempt financing for corporations that invest in a research fund • Create tax credits for corporations or universities involved in hydrogen or fuel cell R&D 	<ul style="list-style-type: none"> • Appropriate money from General Fund for to support hydrogen and fuel cell research
	Organize a Pre-Competitive R&D Alliance for Hydrogen and Fuel Cells Science and Technology		<ul style="list-style-type: none"> • Expand existing university collaboration into a pre-competitive alliance • Create a statewide nonprofit institute that manages all pre-competitive collaborative research in the state • Create a statewide nonprofit institute that focuses on pre-competitive R&D in hydrogen & fuel cells • Recruit major industry-sponsored R&D consortia • Establish and co-fund an independent public-private research consortium 	
	Form South Carolina Endowed Chairs			<ul style="list-style-type: none"> • Launch private sector campaign to pay for endowed chairs • Encourage utility and power companies to endow chairs • Use state economic development program to match funds for endowed chairs

Flagship 1 Discovery Components

There are three key elements required to achieve the objectives of Flagship 1: Discovery, ranked in order of importance. These are:

Discovery Component 1:

Establish a South Carolina Hydrogen & Fuel Cell Economy Research Fund

Goal: Enable South Carolina to rapidly increase its total research expenditures in this field by providing seed or matching funding for key hydrogen and fuel cell research programs that along with leveraged industry research investment will increase its ability to win major federal research and development program bids. In so doing, the pipeline will be primed to provide more innovation to support commercialization in the state. Leading states are now spending from \$5 million to \$75 million annually on hydrogen and fuel cell research to build and leverage their assets.

Structure: The proposed research fund, once established, should have a minimum annual budget commitment for a clear period of operation (5 years to start). This fund should be administered by a statewide Hydrogen and Fuel Cell leadership entity with a board comprising research institutions as well as industry (supply and demand stakeholders). Awards should be made competitively, using criteria that emphasize leveraging South Carolina assets and building critical mass of expenditures, competencies and retained results (patents, talent, public or private research partners and future commercialization).

Policy Options: South Carolina should craft a research fund using financial methods that best match the state's budgetary and business culture. While there are many ways to finance this fund, it may be most appropriate for South Carolina to use a combination of tax exempt financing, alternative funding source (i.e. use of interest payments) and voluntary contributions. The following are options that can be considered:

- **Tax exempt financing:** Tax exempt financing allows companies to invest money directly into a fund and then receive a tax credit equal to the amount invested. The company could offset state taxes such as payroll, corporate income, property and sales. For each dollar invested in the research fund, the business would receive a tax deduction of one dollar (up to a maximum amount such as \$1,000,000 per year). This offset would produce a pool of money to be used to fund research in the area targeted by the state (such as hydrogen and fuel cells). A model for this is Ohio where tax-exempt financing covers \$60 million of a \$103 million three-year program.
- **General fund appropriation for the hydrogen and fuel cell economy research:** Some leading states have designated hydrogen and fuel cell research and development as an economic development focus (Ohio, Georgia) funded by state general revenue bonds.
- **Tax credits for research and development investments:** A few states have established tax credits for industries that sponsor university or private R&D on hydrogen and fuel cells, driven by green and renewable energy objectives
- **Voluntary Tax Contributions:** States can establish a voluntary contribution on state tax forms where taxpayers can pay a specified amount (such as \$5) to go into a research fund to be spent on R&D in hydrogen and fuel cells in South Carolina. These voluntary contributions are similar to many other voluntary contributions which already exist on the forms. Their main drawback is the difficulty in predicting how much they will produce.

Discovery Component 2:

Organize a Pre-Competitive R&D Alliance for Hydrogen and Fuel Cells Science and Technology

Goal: Enable South Carolina universities and national laboratories to expand capacity to identify, bid on, win and manage awards from growing federal hydrogen and fuel cell research programs and to establish highly differentiated and globally distinguished pre-competitive research initiatives with industry and government partners.

Structure: Establish a coordinative process or a new statewide entity, such as an institute or collaborative organization, which will maximize the number and success of cross-institutional bids for research programs and proactively seek support for pre-competitive consortia initiatives. This entity should have a board representing USC, Clemson, state colleges and SRNL. The key functions should be to promote and sell national or international pre-competitive R&D consortia initiatives that leverage South Carolina research competencies. These initiatives are typically sponsored by a large group of interested corporations, leveraging federal support. The consortia can administer the prime contract or assign this responsibility to an anchor institution to manage (such as a lead university or lab).

Policy Options: South Carolina should consider models used by other states to strengthen their ability to form and win bids and manage cross institutional collaboration. Considerations should include drawing from the following:

- **University Coordination Organizations:** Most universities have a formed foundations or coordinative mechanisms to permit undertaking collaborative research projects with other state and non-state institutions. South Carolina has experience with one university anchoring a project or program and coordinating with other universities and laboratories. This could be enhanced or expanded to focus on aggressive development of hydrogen and fuel cell related pre-competitive research consortia.
- **Statewide Multifunction Institute:** Universities have sometimes formed non-profit institutes to manage pre-competitive collaborative research (GTRI, IITRI, and SRI, among others).
- **Dedicated Mission Institute:** States have sometimes formed institutes that focus on one specific pre-competitive research mission. California, for example, has four new institutes, supported with state bond funding, dedicated to specific pre-competitive fields of research (such as Nanotechnology or Biotechnology) that are associated with an anchor university but have their own independent facilities and strong industry participation and leadership.
- **Independent Public-Private Research Consortia:** States frequently sanction the formation of new public-private consortia to carry out a mission specific program of research which they may co-fund with industry partners (California Fuel Cell Partnership or CalStart) with universities participating, but not anchoring operations.
- **National Industry Consortia:** Corporations in specific industries will jointly form a national pre-competitive consortium to address specific challenges they face (SEMATECH, USCAR, for example). These consortia are independent, free-standing centers, sponsored by many companies, sometimes with their own dedicated research facilities, sometimes only awarding grants to those responding to annual award programs. Some universities are able to secure for themselves a central role in supporting a specific consortium. Defining and recruiting a major industry-sponsored R&D consortium to South Carolina would be very helpful in building the state's position nationally.

Discovery Component 3: Form South Carolina Endowed Chairs

Goal: Build and retain world class position in research and training in hydrogen and fuel cells at South Carolina universities in order to more effectively bid on and win federal research programs and attract industry sponsorship and collaboration.

Structure: Establish a statewide leadership effort to define targets for a minimum number of new chairs in hydrogen and fuel cell science and technology and then manage an ongoing campaign to annually raise private match for lottery funded chairs. The minimum number of chairs should be based on an appraisal of the number of science and engineering faculty positions which universities in leading hydrogen and fuel cell states have or are targeting themselves. This should also include considering the “economic” return from having leading faculty. The definition of return should include not simply the financial benefit to the university but particularly the ability to retain graduates, win research grants, attract industry research partners, and generate intellectual property. Then a target to meet or exceed competitors in key areas would be formalized. For example, competing universities may be adding an average of one or two chairs annually, but already have a strong faculty in key departments of materials science, chemical or nuclear engineering. For this reason, the campaign to secure match for and establish endowed chairs in hydrogen and fuel cells requires specific information to guide targets, whether one or five chairs. A possible target for South Carolina’s universities could be five chairs annually, requiring \$15 million in funding, one half of which would require private match. Endowed chairs in hydrogen and fuel cells should be joint appointments and emphasize building and linking cross-state competencies.

Policy Options: South Carolina will reap economic utility from having world class faculty lead its hydrogen and fuel cell-related research. For this reason this Flagship can be pursued through more than one path:

- **State economic development program matching funds:** Business leaders have stated that their companies are often attracted to locate R&D centers in regions where there is clear leadership in science. A key measure of this attractiveness is having leading faculty. States can fund endowed chairs when their economic development role is clearly defined.
- **Private sector campaigns:** Raising matching funds for a targeted number of endowed chairs has been the focus of specific campaigns where there is a strategic goal. The chancellor of the University of Texas, Austin, for example, worked with industry leaders to secure a large number of endowed chairs related to computer science and electrical engineering as part of an effort to recruit pre-competitive R&D consortia. These campaigns reach out nationally to companies and alumni who see the value of growing leadership at state universities.
- **Utility-endowed chairs:** As shifts in the importance of new energy sources grows the motivation for utilities and power companies to voluntarily support endowed chairs in research fields that might contribute to addressing energy solutions becomes more attractive.

Expected Outcomes of Flagship 1: Discovery

- **Leadership in Hydrogen and Fuel Cell Research Funding:** At least doubling the total level of research expenditures in hydrogen and fuel cell-related research, from federal and private sources, at South Carolina universities over the next five years.

- **Greater Number of Patents:** Increase the number of relevant patents disclosed and applied for by the university faculty and national laboratory so that South Carolina's output is equal to or greater than that of the top 15 state leaders in hydrogen and fuel cell research.
- **Wins in New Pre-Competitive Consortia:** South Carolina universities will have sustained its existing collaborative research programs with federal agencies, and, working with industry and government partners have successfully planned, promoted and secured a national pre-competitive consortium in South Carolina that will distinguish the state as a center of innovation.
- **Increase of Endowed Faculty:** Grow the total number of endowed faculty by 5 annually, to at least 25 over the coming five years. Along with this increase the retention and attraction of top graduate students in key fields of hydrogen and fuel cell related science.

Flagship 1: Discovery—Delivery and Accountability

The collaborative “stewardship” group that has led the development of the South Carolina Hydrogen & Fuel Cell Economy Strategy proposes that the key research institutions in South Carolina serve as the primary delivery vehicles for executing and implementing this Flagship. These are: The University of South Carolina, Clemson University, Savannah River National Laboratory and South Carolina State University.

The University of South Carolina's Vice Chancellor for Research has been suggested as the anchor for advancing this Flagship. This will include serving as “champion” for efforts to form of a statewide fund for hydrogen and fuel cell research, develop and manage a pre-competitive consortia organization, and to create a matching fund for endowed chairs in this field.

4.3. Flagship 2: Development—Hydrogen & Fuel Cell Technology Commercialization

Summary: Capture Hydrogen and Fuel Cell Technology Innovation in the South Carolina Economy

Mission: Dramatically increase the translation of hydrogen and fuel cell-related scientific discovery generated by South Carolina universities and laboratories *into* new technology and enable their commercial development by South Carolina entrepreneurs and their partners thus retaining economic value of these activities within the state.

Objectives: Ensure that the specific mechanisms and critical resources needed for hydrogen and fuel cell technology development and commercialization are effectively in place in South Carolina, overcoming past disadvantages in entrepreneurship, and creating new advantages that support technology commercialization and associated enterprise creation. Specifically:

- **Grow Entrepreneurial Talent:** Increase South Carolina entrepreneurship for hydrogen and fuel cell enterprise as well as attract out-of-state entrepreneurs to the state to accelerate new enterprise development.
- **Develop Intellectual Property:** Actively identify and package hydrogen and fuel cell innovation, focusing on combining in-state ideas and fostering in-state deals and co-

development efforts. The intellectual property created in the discovery system must flow down into development.

- **Enable Commercialization:** Enable more technology enterprise formation by having more capital available for early stage development, pilot testing and enterprise start-up.
- **Increase Hydrogen and Fuel Cell Deals:** Improve the quality and number of hydrogen and fuel cell start-ups and spin-offs so that they can more successfully attract capital investment.
- **Foster Technology Co-Development:** Expand hydrogen and fuel cell innovation in South Carolina by inducing global companies to conduct R&D in the state using South Carolina universities, expertise and facilities.
- **Establish Demonstrations & Technology Validation Initiatives:** Promote the organization and management of hydrogen and fuel cell demonstrations and technology validation initiatives across South Carolina to strengthen state visibility, attract and leverage national and industry funding and secondary economic multipliers.
- **Get on the Technology “Roadmap” for Industry Enabling Technologies:** Actively learn about the enabling technology “hurdles” that must be overcome in the transportation (and other industries) before hydrogen and fuel cell adoption and undertake technology commercialization, start-up development and partner recruitment and attraction that will bring engineering and production to South Carolina and build the economic value chain.
- **Create Geographic Centers of Commercialization:** Attract and direct university and laboratory R&D centers, corporate R&D partners, demonstrations and validation initiatives, federal program offices, commercialization centers, and start-ups to designated centers in regions across South Carolina to achieve concentration of technology development, collaboration, synergies and downstream economic development.

**Table 4-3. Policy Options, Flagship 2: Development—
Hydrogen & Fuel Cell Technology Commercialization**

Capture Hydrogen and Fuel Cell Technology Innovation in the South Carolina Economy

Degrees of Government Intervention				
	Inform	Enable	Induce	Sustain
Flagship Components	Launch an Entrepreneurship Accelerator Package	<ul style="list-style-type: none"> • Provide support for university faculty in preparing business plans • Offer university resources and incentives to recruit alumni to be entrepreneurs in SC 	<ul style="list-style-type: none"> • Offer rewards and promotions to university faculty who identify existing intellectual property • Provide equity from university to successful faculty start-ups • Offer equity participation and seed capital to recruit alumni to be entrepreneurs in SC 	
	Establish Pre-Seed & Seed Capital Fund for Hydrogen and Fuel Cell Innovation	<ul style="list-style-type: none"> • Encourage pensions within the state to contribute to private funds that invest in 		<ul style="list-style-type: none"> • Reserve a portion of research fund for seed capital

Degrees of Government Intervention				
	SC start-ups			<ul style="list-style-type: none"> • Create a separate early-stage fund, either under a state entity or private management • Invest state employee pension funds in private funds that invest in SC start-ups
	Start a South Carolina Hydrogen & Fuel Cell Deal Generator	<ul style="list-style-type: none"> • Establish a panel within SCRA to screen and prepare start-ups for angel networks and venture capital firms • Add deal preparation services to state or city small business and economic development departments. 		
Flagship Components	Induce Global Corporations to Conduct R&D with South Carolina universities and Start-ups	<ul style="list-style-type: none"> • Create a publication that encourages companies with R&D to relocate to SC 	<ul style="list-style-type: none"> • Prepare locations that can be used by corporations relocating to SC • Provide state-funded workforce training services 	<ul style="list-style-type: none"> • Offer R&D tax credit to companies for expenditures made at SC universities or firms • Follow the R&D tax credit with a manufacturing/production tax credit • Create a spin-off tax credit
	Establish Demonstrations and Technology Validation Initiatives	<ul style="list-style-type: none"> • Set clear and consistent statewide regulations for demonstrations 	<ul style="list-style-type: none"> • Establish statewide network to coordinate all demonstrations, through SCRA or other organization 	<ul style="list-style-type: none"> • Use research fund money to make grants to companies for demonstrations • Establish corporate income tax credit for development of "green buildings"
	Organize Industry Roadmap Technology Programs	<ul style="list-style-type: none"> • Aggressively market the idea that SC understands the development road map for the future of key industries, so as to attract future corporations 	<ul style="list-style-type: none"> • Create pre-competitive development consortium from university and industry partners that will focus on specific technological hurdles that must be overcome before fuel cells and hydrogen storage can be effectively used in commercial scale 	

Degrees of Government Intervention					
Flagship Components	Create Geographic Center of Hydrogen and Fuel Cell Commercialization	<ul style="list-style-type: none"> Market the state's centers to targeted firms in the industry 	<ul style="list-style-type: none"> Designate certain areas in the state as Energy Technology parks, each with a specialization (i.e., fuel cells, hydrogen storage, automotive) Encourage SCRA to fund hydrogen or fuel-cell related laboratory user facilities 	<ul style="list-style-type: none"> Offer tax advantages to corporations that locate in Energy Technology parks 	
	Create Risk Management Function to Support the Growth of the Hydrogen Economy		<ul style="list-style-type: none"> Install a hydrogen regulatory official who will cross-cut all agencies with an inventory of all the risks of hydrogen Allow use of hydrogen energy in a manner that uses the grid as backup without a fee 	<ul style="list-style-type: none"> Introduce mitigation bill that indemnifies lead adapters from using hydrogen energy Introduce finance underwriting bill that relieves state income tax obligations for employees in hydrogen start-up firms Designate hydrogen produced in the state (through electrolysis or reformation of biomass or waste) as tax exempt 	

Flagship 2 Development Components

Flagship 2: Development has six key components that provide a range of interventions essential to overcoming South Carolina’s historically low performance on commercialization and entrepreneurship, particularly in hydrogen and fuel cell related innovation.

Development Component 1: Build Entrepreneurial Talent—Launch an Entrepreneurship Accelerator Package

Goal: Increase the number of entrepreneurs in South Carolina, focusing on hydrogen and fuel cell innovation.

Structure: An entrepreneurship accelerator package is needed that addresses two different challenges:

- The need to induce faculty and staff of research institutions to produce the innovation content for new start-ups and
- The need to solicit and recruit entrepreneurs from out of state to work on growing new enterprise in South Carolina.

This package must recognize that entrepreneurship is a continuum that reaches from innovators who have ideas to managers who implement them.

Policy Options: The Entrepreneurship Accelerator Package will have two components. Each of which may be implemented by a team comprising the South Carolina Research Authority, local universities and national laboratory-affiliated partners:

- **The Innovator Package:** This would draw from the practices of leading universities and institutes (Purdue, University of Wisconsin, SRI) and would include: (1) Incentives to faculty and laboratory staff to identify existing intellectual property (rewards and promotional credit for disclosures or linking together several patents), (2) technical support for faculty or staff who wish to prepare a business plan based on their ideas, (3) equity in enterprises that meet review standards and successfully start-up. The goal is to retain faculty or staff and not encourage them leave to join ventures, but continue as technical advisors or consultants, through their university or laboratory. This may be linked to the patent tax exemption policy listed in this document.
- **The Jungle Guide Package:** A program would be established to seek out and recruit former citizens and alumni of South Carolina universities, or other seriously interested parties, as heads of new South Carolina enterprises in hydrogen and fuel cells. A recruitment package would be established that includes equity participation in each venture, pre-arranged match of seed capital, team building support and incubator facility access as well as linkages to other university, laboratory or industrial partners.

Development Component 2:

Enable Early Commercialization—Establish Pre-Seed and Seed Capital Fund for Hydrogen and Fuel Cell Innovation

Goal: Foster the creation of a steady stream of successful hydrogen and fuel cell start-ups by ensuring the availability of capital to bridge the gaps between scientific invention and proof of concept, between proof of concept and prototype stage, and between prototype stage and the manufacturing enterprise.

Structure: A growing number of states are recognizing one important way to increase the formation of technology-based enterprises is to provide very early-stage capital. This is funding that is often needed before a technological innovation can be turned into a start-up to prove that the idea has commercial value, and then, to finance the organization of the company that will produce the good or service. These categories of capital—pre-seed and seed—do not have consistent sources in the marketplace, as major investors prefer to fund companies that are further along their development path. Consequently, this stage of pre-seed and seed-funding are often provided by intermediate sources of capital who fall between traditional research funding agencies, such as federal SBIR programs and the formal investment marketplace, such as high net worth individuals who are interested in deeper involvement at the more risk-intensive stage of a new enterprise. However, state governments have now become more involved in filling this market gap and there are a number of seed capital funds that have been capitalized with general revenue bonds and agency specific program allocations. South Carolina, too, needs this bridging function if it is to grow the number of start-ups it produces—particularly in hydrogen and fuel cell innovation.

Policy Options: There are several possibilities for generating pre-seed and seed capital funds for hydrogen and fuel cell innovation in South Carolina:

- **Share Research Funds:** One option for meeting South Carolina’s needs for pre-seed and seed capital is to assign a portion of any funding raised to support hydrogen and fuel cell research (perhaps 10%) to this need. This could be structured in a model that parallels how the federal Small Business Innovation Research (SBIR) grant program, with incrementally growing, staged awards for innovations within key themes.
- **Separate Early Stage Fund:** A separate pool of funds for pre-seed and seed capital could be established, perhaps drawing from new and existing program sources, including SCRA resources, among others. While many states establish formal entities for screening, awarding and tracking pre-seed and seed funds, another alternative is to have any state funds allocated for this purpose placed under private management. In this way, one or more private managers can leverage their own capital, lowering their risk in any seed fund placement. Quite a few states now have altered their state legislation permitting a small portion of state employee pension funds to be invested in private funds that will, among other investments, consider early-stage placements inside the state. This prevents any conflicts that could otherwise arise between fiduciary trust obligations and economic development objectives. The pension fund investments would allow between 1%-to-4% of state employee pension funds already focused on alternative asset classes (such as venture capital) to be invested in ventures inside of South Carolina. The management of this should be put out to competitive bid with the requirement that money managers allocate specific percent of total assets to early stage capital in SC, emphasizing hydrogen technology deals that pass screening hurdles. In addition to the state pension funds, the state government could also encourage other pensions within the state to apply the same framework and rules to their pension funds. For example, pension funds from large companies or labor unions should be eligible to contribute to the fund (which would have a shared management). The state rules will have to spell out a set of rules which the funds would accept through their investment.

Development Component 3:

Increase Early Stage Deal Flow—Start a South Carolina Hydrogen and Fuel Cell Deal Generator Program

Goal: Dramatically increase the number, quality and readiness of candidate deals for early stage financing of hydrogen and fuel cell-related ventures.

Structure: Establish a panel of industrial and financial experts and “mentors” to work through SCRA or other intermediaries at technology innovation centers across South Carolina to identify, screen and prepare hydrogen and fuel cell start-ups to be introduced to angel networks, venture forums and direct ‘A’ round investors. This type of service has gained increasing recognition as an essential ingredient in enabling growth of technology-based enterprise nationally.

Policy Options: The Deal Generator program requires one or both of the following:

- **Harness Existing Resources:** Many states and cities have existing small business and economic development as well as technology commercialization programs that are now adding or enhancing their existing services through offering carefully structured deal preparation services. These programs work best when they link individual entrepreneurs with professional management advice. These efforts are often coordinated with chamber programs and professional association events. The majority of technology incubators now offer screening and preparation services, often using networks of experts.
- **Establish Volunteer Networks:** As angel networks and venture forums become established in a region they typically expand their activity to offering voluntary identification and

screening and preparation of deals for start-ups, before considering them, themselves or referring candidates to investors, often working together through quarterly venture or enterprise forums.

Development Component 4:

Foster Technology Co-Development—Induce Global Corporations to Conduct R&D with South Carolina Universities and Start-ups

Goal: Expand hydrogen and fuel cell innovation in South Carolina by inducing global corporations to locate R&D operations in the state and sponsor or contract for work with South Carolina universities and start-up firms.

Structure: To strengthen hydrogen and fuel cell technology development in South Carolina the state should more aggressively market and promote itself as a location for corporate R&D operations, systematically emphasizing the advantages it can offer global corporations. This will require developing a package of services, sites and incentives focused on the priorities of leading companies active in hydrogen and fuel cell-related technology development. This package should specify a continuum of services that help firms perceive the advantage of working in South Carolina. The elements might include the following.

Policy Options:

- **State R&D Attraction Package and Mechanism:** Establish an R&D attraction package which will be available to firms who move R&D operations to the state and to firms within the state who choose to establish R&D facilities focused on hydrogen and fuel cells. The package would include information on existing programs and research within the state and location services. The information on existing programs would specify the organizational structures that the state's universities and the national laboratory community can offer firms to support their R&D programs, such as existing hydrogen and fuel cell institutes, research centers or industrial liaison programs as well as competency matching services that can connect local suppliers to larger firms. The location services package should have well defined and prepared locations that can be used by corporations by their R&D operations at or adjacent to research or technology parks. As noted in the next component of this Flagship, South Carolina should maximize the use of its research parks to attract a growing "agglomeration" of hydrogen and fuel cell technology-focused companies.
- **R&D Incentives:** New or existing state policies that will leverage each dollar spent by corporations on South Carolina universities and laboratories. A good candidate policy for consideration may be to provide an R&D tax credit to companies (who have payroll or other taxes in South Carolina) for expenditures made at South Carolina universities or with South Carolina firms involving research and testing on hydrogen and fuel cell technologies. The goal of the R&D tax credit is to create an incentive for firms to site their testing and demonstration projects within the state. The tax credit would be available to companies for both the costs associated with purchasing equipment to set up the demonstration project (which may not be fuel cell or hydrogen technologies per se) as well as in some of the operational costs associated with conducting the research and development. The credit would initially be applied against the development costs but could be extended should the firm choose to further develop the product to commercialization inside the state. For example, if a firm spends \$800,000 on initial research and development, they would receive a tax credit over several years equivalent to that amount. However, if they continue to develop the product in the state and move towards commercialization, they would receive an

additional tax credit. These credits would fall into the manufacturing and production side credits described in the deployment phase. Combining the research credit with a deployment/commercialization credit is essential to prevent firms from accepting the initial research tax credit and then moving their facilities to another state for production.

- **Spin-Off Tax Credit:** Corporations that have non-core technical operations or capabilities related to hydrogen and fuel cells can be encouraged to spin-off these units as South Carolina-based businesses by offering a “spin-off tax credit.” This will foster growth of new enterprise and raise the visibility of the state as a center for hydrogen and fuel cell innovation. However, this policy is a new concept that has yet to be widely used.
- **Skill Matching:** The state can offer workforce training services to prepare and match talents to company R&D and technical support needs, including arranging training at community colleges on a “just-in-time” basis.
- **State Purchase Guarantees:** The public sector can make commitments to purchase pre-commercial hydrogen and fuel cell products and technologies. These purchase commitments by state government entities will help move these products down the commercialization path more rapidly than otherwise possible through normal market mechanisms.

Development Component 5:

Establish Demonstrations and Technology Validation Initiatives

Goal: Position South Carolina institutions and companies as leaders in the demonstration and validation of hydrogen and fuel cell innovations as well as the early formation *and* attraction of hydrogen economy producers and suppliers, helping to build the foundation for South Carolina’s growing hydrogen and fuel cell economy.

Structure: There is strong interest among South Carolina universities, laboratories and agencies to undertake distinctive demonstrations and validations of hydrogen and fuel cell technology. Establish a statewide organizational network dedicated to the purpose of establishing demonstrations and technology validation initiatives that will showcase South Carolina innovation and competencies and foster associated up-stream and down-stream hydrogen and fuel cell industry supplier growth.

Policy Options: The active development of hydrogen and fuel cell demonstrations and technology validations will require some or all of the following capabilities:

- **Set Statewide Standards for Demonstrations:** Success in demonstrations and subsequent commercialization is often determined by having clear and consistent standards and regulations to guide operations. For example, in most states, hydrogen is regulated as a dangerous chemical which requires a special permit to be used. State rules and regulations must be adapted to permit legal use of such products. This is a critical element for success as many foreign countries have this objective on top of their list of things that government can and must do to facilitate the introduction of hydrogen into the commercial marketplace.
- **Statewide Network:** A statewide network or alliance for demonstrations and technology validations can be coordinated or administered by the South Carolina Research Authority (SCRA) working with a lead or anchor university, SRNL or technology centers in each case to execute specific initiatives as required. Having a statewide network with proven management capability will help ensure consistency of the development process and enhance coordination of implementation—even when initiatives are managed by a local anchor organization. This entity would plan, market/sell and administer efforts, as

appropriate, ensuring they meet hydrogen and fuel cell economy objectives, including fostering proof of concept, pilot scale operations, cost-benefit performance, and establishing of standards that will distinguish South Carolina. The network would also work to ensure that the above standards are established and followed.

- **Matching Fund:** To accelerate the planning, development and successful realization of sponsored demonstrations, there should be a mechanism for matching grant funds provided to firms. The initial pool of funds can come from the state's existing hydrogen and fuel cell research fund. The fund would be provided to companies or researchers for demonstration projects seeking to test the commercial potential of a technology. The grant would come in the form of a low or no-interest loan. These matching funds can be awarded on a competitive basis to projects proposed in any one year or on a rolling basis if the fund is a set amount that will be spent by a particular date. The fund will require an initial up-front company match of 25% which can be in the form of cash or certain in-kind contributions. There should be a maximum amount funded (such as \$500,000). In many cases, the companies will have to pay back the fund once their product achieves commercial success (which is based on an agreed-to level of annual sales discussed with successful applicants prior to receipt of the funds). One model is the recently announced Operational Demonstration Program as part of The Connecticut Clean Energy Fund (CCEF). This program will provide \$4 million through the end of 2006 for projects installed in Connecticut (the project will support many demonstrations with commercial potential within five years across a variety of renewable technologies including fuel cells). The requirement is for the projects to have a capacity of at least 1 kilowatt (or functional equivalent for hydrogen generation).
- **Tax Incentives for Green Building Demonstrations:** Establish corporate income tax credit for development or rehabilitation of buildings which meet "green building" standards (i.e. meet the U.S. Green Building Council criteria). This could be applied broadly to the development of the building plus specifically for the purchase and installation of renewable technologies (i.e. fuel cells, solar panels, wind turbine, etc.) or simply targeted only for the implementation of a fuel cell. Tax credit for the fuel cell should be 30% of the purchase and installation cost. For example, Maryland permits tax credits for the development of new green buildings or for tenant improvements in existing buildings by providing tax credits of 20-30% for wind, solar and fuel cells plus "6% of the allowable costs for the construction of or rehabilitation to a green base building or green tenant space <or> 8% of the allowable costs for the construction or rehabilitation of a green whole building." Maximum costs cannot be higher than \$120 per square foot for a whole building or \$60 per square foot for tenant improvements.

Development Component 6: Organize Industry Roadmap Technology Programs

Goal: Position South Carolina as a strategic location for industry R&D and commercial development focusing on strategic enabling technologies essential to the eventual commercial feasibility of hydrogen and fuel cells for motor vehicles (or other industries).

Structure: Establish a pre-competitive R&D consortium whose mission and objectives are defined by leading industry producers (such as car makers) and focus on specific technological hurdles that must be overcome before fuel cells and hydrogen storage can be effectively used in commercial scales. These pre-competitive consortiums must be organized and led BY industry, often with their own dedicated R&D facilities, with a very specific set of commercialization objectives. They are unlike Discovery pre-competitive initiatives anchored by universities, which focus on applied science problems. Development consortia are designed with a highly business-

defined objective of generating enabling technology that will advance progress along an industry-defined road map, leading to technology licenses and standards. This pre-competitive R&D consortium should have the University of South Carolina and Clemson as key partners but have a highly-market development structured agenda. Part of the mission of this consortium will be to effectively recruit company partners to set up R&D and engineering operations in South Carolina, and, hopefully also attract producers of more ready to go products (which would be part of a Deployment strategy). The key is differentiate South Carolina from other states as the right place to begin design, engineering and production of the vehicle of the future—or at least key components, such as drive motors, power electronics, drive systems and electro-mechanical transmissions—leading to next generation storage and fuel cells.

Policy Options:

- **Establish Consortium Team:** Form a core team of university and global industry partners to define the mission and structure of a dedicated globally focused pre-competitive consortium that will harness South Carolina competencies—from pre-fuel cell levels up. This initiative can be located at one or more sites in South Carolina, whether Clemson/ICAR or USC.
- **Define Agenda:** Work with industry partners to define the agenda for enabling technologies that maximize use of South Carolina R&D competencies across universities as well as SRNL and participating industries.
- **Raise Matching Funds:** Seek and draw from a state pre-competitive matching fund to leverage private sector sponsorship and federal support, drawing from models from the electronics industry (Sematech) as well as automotives (USCAR).
- **Aggressively Market:** Show that South Carolina understands the development road map for the future of key industries, such as motor vehicles, and use this to attract further partners as well as investors.

Development Component 7:

Create Geographic Centers of Hydrogen and Fuel Cell Commercialization

Goal: Maximize availability of required laboratory and supplier capacity and foster concentration of hydrogen and fuel cell-related technology research, development and supporting infrastructure to accelerate commercial development.

Structure: South Carolina has three technology/research parks. These sites can be used to good advantage to attract and concentrate specialized facilities for hydrogen and fuel cell-related technology development. Demonstrations and technology validation initiatives can and should be planned to be co-located within designated areas, such as *within* existing the research or technology parks at USC, Clemson and SRNL-Aiken perhaps labeled as “energy parks.” To maximize economic aggregation these sites could focus on accommodating co-location of: hydrogen and fuel cell-related demonstration and validation facilities, pilot test facilities, incubators, multi-tenant R&D buildings, existing or new university and laboratory operations, new corporate facilities, supplier operations as well as (where appropriate) shared hydrogen production, distribution and use-focused infrastructure.

Policy Options:

- **Energy Technology Park Plans:** SCRA can work with USC, Clemson and with the Savannah River Research Campus (SRS) to coordinate plans to foster and develop several carefully differentiated Energy Technology Parks that will help attract and link hydrogen and

fuel cell-technology assets. These parks would include a shared R&D infrastructure and significant tax advantages for location within the zone. The purpose of these zones is to establish a concentration of hydrogen and fuel cell related researchers and companies around a related theme area (such as fuel cells, hydrogen storage, or automotive).

- **Strategic Facilities:** SCRA can work with state partners to explore to how use its assets to provide funding for hydrogen or fuel cell-related laboratory user facilities that may not be in place but may be crucial to bids for demonstration projects and for attracting existing or newly formed companies to sites.
- **Market the State's Sites:** The state's commitment to hydrogen and fuel cell R&D and economic development should be reflected in a collaborative marketing effort to targeted firms in the hydrogen and fuel cell technology business.

Development Component 8:

Create Risk Management Function to Support the Growth of the Hydrogen Economy

Goal: To identify, quantify and manage the risks to the commercialization, production and use of hydrogen energy products and equipment.

Structure: A risk management specialist with experience in hydrogen energy will conduct an inventory of risks, including: technical, regulatory, marketing, finance and logistics. This inventory will then be studied by a team of hydrogen specialists for the purpose of rating the probability and consequence of these risks. A hybrid team will then address these risk ratings in order to derive a risk mitigation plan.

Policy Options:

- **Establish Office Position:** A hydrogen regulatory official with cross cutting access will be designated by the state with the portfolio of harmonizing all state agencies that have rule sets which effect hydrogen. This official will use a team of expert, volunteer advisors, who are industry representatives best positioned to analyze which regulations are barriers to hydrogen use.
- **Introduce Mitigation Bill:** A liability mitigation bill will be introduced to become state law that indemnifies lead adapters from using hydrogen energy. This law will also indemnify manufacturers and service providers, who reside in SC. The clear incentive is for existing and future industry leaders to locate in SC.
- **Offer Underwriting:** A finance underwriting bill will be introduced to become state law that offsets financial risk from investment in hydrogen by relieving state income tax obligations for employees of startup hydrogen firms.
- **Collaborate in Optimizing Hydrogen Use:** A state energy office and public utilities commission determination will be made which allows use of hydrogen energy in a manner that uses the grid as backup while eliminating any fees for mechanizing this use.
- **Incentives for Hydrogen Fuel Production:** The state will incentivize the creation of hydrogen fuel within the state by designating hydrogen produced by electrolysis or by reformation of biomass derived feedstocks or by reformation of waste derived feedstocks as a priority state product that is exempt from tax obligations applicable to the chain from production, through delivery to use.

Expected Outcomes of Flagship 2: Development

- Consistent growth in the number of South Carolina-based new entrepreneurs from within the state and attracted from out of state, in the field of hydrogen and fuel cells.
- Substantial rise in the number previously filed and awarded patents which are licensed to start-ups, and marketing to attract corporate partners to the state.
- Increase in the number of early-stage hydrogen and fuel cell-related enterprises that start and grow in South Carolina.
- Expanding number and quality of South Carolina-based hydrogen and fuel cell start-ups that area ready for venture stage investment.
- Growth in attraction of R&D firms to South Carolina working with universities and the national laboratory in special locations, such as energy parks.
- Accelerated South Carolina-based technology development *and* industry attraction focused on each stage of the value-chain of leading industries (such as vehicle energy systems), building the path to hydrogen and fuel cell use, creating businesses and jobs *earlier* that will enable near-term and longer-term clustering.

Flagship 2: Development—Delivery and Accountability

The collaborative “stewardship” group has agreed that the lead responsibility for championing Flagship 2: Development will be with the executive director of the South Carolina Research Authority, working with each of the universities as well as SRNL and the Savannah River Research Campus.

4.4. Flagship 3: Deployment—Hydrogen and Fuel Cell Enterprise Survival, Expansion and Attraction

Summary: Grow the Hydrogen and Fuel Cell Technology-based Industry Activities in South Carolina

Mission: Achieve a significant hydrogen and fuel cell industry cluster in South Carolina by providing the long-term economic development framework needed to sustain, and expand existing companies and attract new companies to locate here—by focusing on enterprises that are or will become hydrogen and fuel cell economy producers and suppliers..

Objectives: Build and support a continually improving business environment for the formation, growth and recruitment of hydrogen and fuel cell-related industry. Need to emphasize crucial economic inputs needed by an evolving industry, from financing (transition from negative to positive revenues), to obtaining skilled workforce and supporting facilities, to fiscal advantages that will make South Carolina a choice for industrial operations.. While a number of states are moving rapidly forward to be well positioned on many fronts, this marketplace has a long development path ahead and South Carolina can assert its own position of leadership, if it aligns state and local economic development policies to encourage and enable growth over time. This is an important Flagship on which the state department of commerce can work with key partners. There are four basic objectives that state and local policies and private practices need to focus-on to create advantages for the hydrogen and fuel cell economy:

- **Sustaining Start-ups:** Enabling hydrogen and fuel cell-related start-ups to survive from revenue negative to revenue positive status in South Carolina—particularly challenging for companies in industries that are just taking shape.
- **Expanding Suppliers:** As the hydrogen and fuel cell economy begins to take shape, South Carolina can enable companies to expand into these market segments as producers and suppliers, leveraging South Carolina assets whether innovation or industry experience, in chemicals or energy.
- **Attracting Producers:** Much of the knowledge and capital needed to build a hydrogen and fuel cell-based economy resides in major corporations who are active all along the continuum of research, development and deployment. For this reason, South Carolina needs to learn what is required and provide new advantages and incentives for these global companies to locate both their energy system related technology development and production as well as locate their hydrogen and fuel cell-related R&D as well as production operations in the state.
- **Reinforcing Clusters:** The state of South Carolina is committed to supporting cluster competitiveness among existing clusters and can also play a positive role in achieving a distinctive cluster focused on hydrogen and fuel cells. Cluster development creates additional economic value when industries find and share similar inputs in a geographic region and, through co-location and investment, help build and renew these inputs over time. In this way, clustering becomes a self-reinforcing economic generator because cluster producers, suppliers and supporting institutions are able to achieve positive and mutually beneficial inputs they need. The state of South Carolina and its local governments, chambers and institutions have the potential to begin early-on to set the stage for achieving and capturing the economic benefits that result from cluster development. However, sustaining this positive cycle requires continually learning and changing both public and private policies to provide new and improved sources of input advantage as this early industry takes shape and matures.

**Table 4-4. Policy Options, Flagship 3: Deployment—
Hydrogen and Fuel Cell Enterprise Survival, Expansion, and Attraction**
Grow the Hydrogen and Fuel Cell Technology-Based Industry Activities in South Carolina

Degrees of Government Intervention					
	Inform	Enable	Induce	Sustain	
Flagship Components	Enterprise Maturation Package	<ul style="list-style-type: none"> Identify and broker buyer-supplier relationships for early stage technology companies 	<ul style="list-style-type: none"> Devote demonstrations to fostering early-stage companies as much as possible Involve state and local transportation fleets in demonstrations 		
	Business Expansion Support	<ul style="list-style-type: none"> Require utilities to inform customers of renewable energy options 	<ul style="list-style-type: none"> Establish a green power purchasing nonprofit Encourage use of the provisions of the state net metering law that allows customers to sell excess energy back into the grid if they install their own renewable energy source and pay for access to distribution network. 	<ul style="list-style-type: none"> Establish a tax credit for the production of hydrogen fuel that is purchased by a renewable energy facility Offer tax credits or deductions for renewable energy use Offer tax credits for the purchases of hydrogen and fuel cell technologies. Mandate that state construction projects consider next energy technologies 	<ul style="list-style-type: none"> Make a State commitment to purchase a certain amount of renewable power
	Industry Attraction Incentives		<ul style="list-style-type: none"> Offer business relocation assistance Offer workforce preparation and retaining services 	<ul style="list-style-type: none"> Offer technology investment tax credits Offer property tax and corporate tax holidays Establish an incentive fund of several million dollars to pay out to companies that choose to locate fuel cell manufacturing facilities in SC Establish a tax incentive that applies to royalties from patents related to fuel cells or hydrogen 	<ul style="list-style-type: none"> Make a State commitment to purchase early-stage, pre-commercial technologies

Degrees of Government Intervention					
Flagship Components	Geographic Concentration— Hydrogen and Fuel Cell Innovation Zones		<ul style="list-style-type: none"> • Create targeted zones for hydrogen and fuel cell companies • Enable an organization that facilitates collaboration between companies in the zones 	<ul style="list-style-type: none"> • Provide R&D and production tax credits to firms in the zones that partner with universities and laboratories on innovation research 	

Flagship 3 Components

This third Flagship focuses on creating the “deployment” infrastructure for scaling up the economic development arising from hydrogen and fuel cell technology commercialization. This Flagship centers on meeting the needs of the emerging companies and focuses on building a supporting environment that will help producers, suppliers and their economic input institutions grow nearby to become an industrial cluster. There are four core elements of this Flagship:

Deployment Component 1: Enterprise Maturation Package

Goal: Enable South Carolina hydrogen and fuel cell-technology start-ups to survive through the critical period in their evolution when they can pass through from negative revenues through to positive revenues so they can emerge as successful companies to continue operation and to grow in the state.

Structure: Organize a next generation hydrogen and fuel cell economy enterprise package that identifies and brokers buyer-supplier relationships for early stage technology companies in this field and works to provide market opportunities for obtaining customers and revenue. The objective will be to find customers and create revenue that might sustain companies during their riskiest stage of growth.

Policy Options: This package may have at least two components:

- **Link to demonstration and validation projects:** All demonstrations and technology validation initiatives should be prepared to foster early-stage suppliers, as feasible. Early stage hydrogen or fuel cell companies should be screened and linked to major participants early on. Such efforts are undertaken as part of the hydrogen and fuel cell initiatives in states, such as Ohio, Massachusetts and California.
- **Leverage state and local procurement:** State (and local) agencies and authorities that have transportation fleets or procure energy equipment or energy should be induced and incented to set aside some portion of their budgets to participate in demonstrations (see above) and to be early adopters of hydrogen and fuel cell technologies. Through procurement set asides for small and renewable energy enterprises, state and local agencies may be able to create revenue streams that enable start-ups to reach sufficient revenue scale to continue operations and extend services to other markets. Many of the top 15 hydrogen and fuel cell states use state purchasing programs or dedicated alternative energy programs to directly finance use of hydrogen and fuel cell technologies (among others, such as photovoltaics and biomass).

Deployment Component 2: Business Expansion Support

Goals: Facilitate the growth of South Carolina firms serving the hydrogen and fuel cell technology marketplace by fostering demand for their products and services.

Structure: This component could comprise a set of supply and demand inducements/incentive policies designed to foster utilization of hydrogen and fuel cell-related technology in firms and the demand for hydrogen and fuel cell technology or output by power companies. While in some states there is a comprehensive set of state energy policies to stimulate adoption of renewable energy or to reduce carbon emissions, in the case of South Carolina, the focus, at this point, is on generating diversification of the economy and employment opportunities from the growth of the hydrogen and fuel cell economy.

Policy Options: Two basic policies are proposed for consideration:

- *Supply Side incentives:* These incentives encourage the production of hydrogen power or fuel cells within the state.
 - a. *Production Tax Credit:* Establish a tax credit for the production of hydrogen fuel which is purchased by an “eligible renewable energy facility” (as determined by the State’s Public Service Commission). For example, Iowa provides a tax credit (on personal income, business, sales, or use tax) of \$1.44 per thousand cubic feet of hydrogen fuel generated or sold to an eligible facility.
 - b. *Establish Green Power Purchasing Nonprofit:* Several states have established green power programs to encourage the production and use of renewable energy sources. One structure is to establish an independent nonprofit that works with energy producers to purchase power from renewable sources. The green power network enters into contracts with the green power producers and a utility to purchase a specified amount as well as provide a premium to the producer as an additional incentive (the amount of the premium to be determined based on the funding levels of the organization). The green power organization as a nonprofit can accept tax deductible contributions from individuals and businesses and use these funds to provide its premiums paid out to green power producers. A green power program would have to be created in partnership with state officials, the utilities and other stakeholders (such as renewable-energy advocates). The first statewide green power program in the US is North Carolina (NC GreenPower) which has been operational since 2003.
- *Demand side incentives:* These incentives encourage the purchase or use of hydrogen or fuel cell technologies by residential, government, or business consumers.
 - a. *Credit for hydrogen and fuel cell technology investments:* Establish a credit for purchases and use of hydrogen and fuel cell technologies. The credit would apply to a part, or all, of the price of hydrogen or fuel cell equipment purchase. The credit would be taken off of the company’s sales or property taxes and could be as high as 100% allocated over a set number of years. The credit would be available to businesses that conduct a certain percentage of their activities (such as 50%) in qualified research (such as hydrogen and fuel cell-related technologies) where the use of the equipment is necessary to conduct their work. The credit would decline each year starting at 35%, then 25%, 20%, 10%, 10%. The state could establish limits on the credit such as \$2 million total (or \$700,000 in the first year). The purpose of the credit is to encourage front-loaded investments and then allow the business to realize a tax credit over five years to recoup the totality of the investment. For example, Hawaii offers an equipment

tax exemption of 100% for the purchase of renewable energy equipment, including fuel cells.

- b. *State construction and design standards:* Mandates to look at cost and performance impacts of next energy technologies in state construction projects (from green buildings to renewable energy sources). The mandate could be a requirement to either consider the potential cost savings of the technology or for the actual purchase of the technology.
- c. *Extension Analysis to Spur Market:* Require utilities to provide customers with information on renewable energy options when there is a request for a line extension. Appropriate in rural areas far from the electric grid.
- d. *Expand Use of Net Metering Provisions:* Net metering laws allow individual customers (residential or business) to sell energy back into the grid if they install and maintain their own renewable energy source and (as required) pay fees for access to the distribution system. Typically a customer will install a specific technology (such as a fuel cell or photovoltaic cell) for their own use and then sell back some of the excess energy to the grid which is then credited to the customer on their subsequent bill. The utility can track and deduct fees for supplying access to the distribution grid. This can be combined with a green power program to allow for the excess renewable energy to be sold back to the utility and then sold under the state's green power program. Georgia is the only state with such a linkage. The Georgia system also allows customers to sell all of their power back to the grid (effectively making the customer a mini energy producer).

Deployment Component 3: Industry Attraction Incentives

Goal: Induce corporations to establish corporate R&D and production facilities focusing on hydrogen and fuel cells-related business in South Carolina.

Structure: The state of South Carolina can prepare a set of incentives that focus on this particular emerging market of business activity, with the goal of distinguishing South Carolina as a location of choice of industry in the hydrogen and fuel cell economy. The set of policies could start with the traditional industrial recruitment package but should craft these to emphasize the special needs of industry in this field. This component of the Deployment Flagship is designed to modernize recruitment by giving it a specific industry-cluster focus. The set of policies can be carried out in conjunction with participation from regions (Aiken, Midlands, and Upstate) that are most actively seeking companies.

Policy Options: The incentives the state could use can include the following, although there is an established array of incentives that states typically might draw from. Packaging this in a focused manner will help make them become more effective. It is best therefore to organize the policy options into two categories: financial incentives and institutional or relocation assistance.

- *Institutional or relocation assistance*
 - a. *Business relocation assistance grants:* Financial incentives for hydrogen and fuel cell-technology related companies, including help with securing industrial sites and workforce housing.
 - b. *Work force preparation and retraining services from technical and community colleges:* Technical and community colleges may be ready to define training programs for technicians working in specific segments of the hydrogen and fuel cell economy.
- *Financial incentives*

- a. *Technology investment tax credits*: Use these as means to promote hydrogen technology utilization by companies.
- b. *Property tax and corporate tax holidays*: Offer these for companies in designated categories of hydrogen and fuel cell-related technology.
- c. *Fuel cell manufacturing incentives*: Provide a direct payment to companies that manufacture fuel cells within South Carolina. Establish a set fund (of several million dollars) to be paid out to companies that choose to locate production facilities in the state. The incentive could be set up such that companies only receive the money based on sales within a single calendar year and receive a payment based on watts of energy sold. For example, Virginia's Solar Manufacturing Incentive Grant (SMIG) Program is a model that could be applied to fuel cells in South Carolina. It provides up to \$4.5 million per year (through 2007) to companies that produce photovoltaic panels in the state. For each watt of panels sold (up to a maximum of 6 MW) the company received up to \$0.75 per watt. The incentive is available for up to six years and the incentive amount declines each year (to \$0.50 and then \$0.25). This is the only state program that provides the incentive based on sales levels.
- d. *Patent exemption*: Establish a specific tax incentive that applies to royalties from patents in a designated area. For example Massachusetts provides a corporate and personal income tax deduction for sales or royalty income derived from a patent that benefits energy conservation or alternative energy development. The patent exemption also applies to fuel cells or hydrogen. South Carolina could establish the patent exemption to encourage firms with existing patents to move their facilities to the state and exempt a portion of these revenues. The state could also use the patent exemption as part of an attraction package for research (see Flagship 2).
- e. *State Purchase Guarantees*: The public sector can make commitments to purchase pre-commercial hydrogen and fuel cell products and technologies. These purchase commitments by state government entities will help move these products down the commercialization path more rapidly than otherwise possible through normal market mechanisms.

Deployment Component 4:

Geographic Concentration—Hydrogen and Fuel Cell Innovation Zones

Goals: Encourage and reinforce agglomeration of discovery, development and deployment of hydrogen and fuel cell industry activity in targeted zones to achieve clustering and associated economic multipliers.

Structure: South Carolina has a number of research parks that can serve as centers for hydrogen and fuel cell technology-related discovery and development activity. Today, states, such as Michigan and New Jersey are using state "innovation zone" policies that permit the concentration of a variety of incentives and related assets in geographic areas—which may encompass universities and technology parks—but can create a broader zone of activity, helping to foster development or redevelopment outside the core technology centers or parks. South Carolina should consider creation of a Hydrogen and Fuel Cell Innovation Zone policy to reinforce desired research, development and commercialization activities.

Policy Options: They Hydrogen and Fuel Cell Innovation Zones would encompass technology parks but extend their reach and connectivity through additional incentives and services:

- **Co-location of strategic facilities:** The zone policy would focus on attracting and directing university and laboratory R&D centers, corporate R&D partners, demonstrations and validation initiatives, federal program offices, commercialization centers, and start-ups as well as producers and suppliers to designated regions across South Carolina to achieve concentration of technology development, collaboration, synergies and downstream economic development.
- **Shared energy infrastructure:** The zone would solicit and work with South Carolina power companies and utilities (and national leaders) to provide advanced hydrogen and fuel cell power options (whether commercial scale or as part of demonstrations). The shared infrastructure would also permit the creation of centralized fleets which could use the site for refueling. If the zone is located in proximity to a university, the entire university car fleet (shuttles, carts, landscaping trucks, etc.) could be fueled at this centralized location.
- **R&D and Production tax credits:** Incentives to firms in the zone who will work with universities and laboratories on hydrogen and fuel cell technology innovation. For example, Michigan has designated a 700- acre state parcel a NextEnergy Zone that assesses no state or local taxes upon companies while located there. Employers located there also receive a tax credit based on the amount of compensation paid to employees. New Jersey also has similar policy called Innovation Zones. These are areas close to Universities which offer specific financial incentives to companies such as access to university facilities, “exchange programs” with university researchers, and qualification for state funded “proof of concept” commercialization work.
- **Hydrogen and fuel cell network:** The zone would provide an organizational and Internet based exchange that would help foster collaboration among companies, suppliers and research institutions—on R&D, workforce and services.

Expected Outcomes of Flagship 3: Deployment

- Survival of more start-ups to maturity and the retention of the associated growth of their operations in South Carolina.
- Expansion of South Carolina’s existing energy and chemical producers and distributors, component and system providers into the emerging hydrogen and fuel cell technology and product marketplace.
- Attraction of global corporate R&D and production operations related to hydrogen production, storage, distribution and conversion.
- Incremental development of the continuum of hydrogen and fuel cell-related producers and suppliers, enabling and contributing to a hydrogen and fuel cell cluster development in South Carolina over time.

Flagship 3: Deployment—Delivery and Accountability

The collaborative “stewardship” group has agreed that the lead responsibility for championing Flagship 3: Deployment should rest with George Wolfe and Fred Hume, Executive Director, Aiken Economic Development Partnership. However, responsibility for delivery over time will rest with the South Carolina Department of Commerce and South Carolina’s local economic development and chambers of commerce.

4.5. Conclusion: Flagships are Vital

The state of South Carolina will make progress in advancing its hydrogen and fuel cell economy because the state has important regional assets that have state and regional stakeholders are already working hard to support. None-the-less, given the competitiveness of the race to the hydrogen and fuel cell economy, unless the state of South Carolina decides to work within and across state agencies, legislature and its congressional delegation to provide a quantum leap forward in accelerating development, sustaining the current level of energy and commitment may become difficult. Careful thought about the structure and processes for building up a portfolio of Flagship initiatives and how to recognize their impact on reinforcing the state's regional strengths should be a cornerstone of this strategy.

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5. Ensuring Implementation: Organizational Realities of the Hydrogen & Fuel Cell Economy Strategy

5.1. Realistic Possibilities and a Necessary Path

The primary purpose of having a South Carolina Hydrogen and Fuel Cell Economy Strategy is to enable the state to create jobs and wealth for the citizens of South Carolina. This is a tall order. The hydrogen and fuel cell economy is still at its early stage of gestation and the specific directions that the emerging technologies will take are still uncertain. While the future directions that the actual hydrogen and fuel cell technologies will unfold over the next 10 to 15 years, South Carolina has the opportunity to position itself, early on, in a marketplace in which there will be more than one way to create jobs and earn a return for the state.

South Carolina does not need to pick specific winners at this point, instead it needs to adopt a portfolio management approach that will enable the state to spread its bets and ensure that it has a high prospect of success in one or more areas of this emerging technologically-driven economy. To do this, the state needs to focus on the core challenge that this strategy has outlined. Specifically, this challenge is to building the state's innovation pipeline for hydrogen and fuel cells discovery, development and deployment. If the state is able to ensure that the elements of this pipeline are in place and agile enough to adapt over time, at each level, the probability is that more desired economic outcomes will occur and remain in South Carolina. Failure to build an effective innovation pipeline will result in expenditure of a patchwork of funds possibly yielding useful results that will naturally emigrate any long lasting benefits to other states and regions.

South Carolina needs to learn how to build and manage its hydrogen and fuel cell innovation pipeline if it wants to draw close to and get ahead of competitors who are already out there aggressively investing in some or all of the elements needed to get and remain leaders. This is no easy task for South Carolina, but this state has assets that are strong enough to make a critical difference—if they are handled and supported effectively.

Therefore, in order for South Carolina to advance in the intensive competition for discovering, developing and deploying components of the hydrogen and fuel cell economy within its borders, the state must have an organized strategy. This strategy must be supported by the requisite public and private leadership to build and sustain commitments and momentum across all sectors of the community. If the state is then able to reach and exceed the minimum level of progress in building a critical mass of scientific discovery, energizing technology development, and concentrating industrial deployment of hydrogen and fuel cell innovation, there should be healthy near, medium and longer-term job growth and state revenue increases ahead.

South Carolina's Hydrogen & Fuel Cell Economy strategy needs to be supported by strategy at two levels:

- **State:** The architecture for crafting and sustaining statewide policy and programs and public-private initiatives for hydrogen and fuel cell strategy.
- **Region:** The anchor organizations for assembling and channeling resources to build and adapt competitive advantages in hydrogen and fuel cell strategy.

Recommendations for moving both structures forward are outlined next.

5.2. State Organization: Three Elements

Three basic recommendations are proposed pertaining to the structure and operations of any new state organization that will be established to advance the hydrogen and fuel cell economy. These address the question of what the organization should focus on, who should be part of this new organization (structure) and the importance of incorporating the state's regions in strategy design and implementation.

Recommendation S1: Build the Innovation Pipeline

The South Carolina hydrogen and fuel cell strategy has taken shape through a statewide collaborative process that has been analytic (informed by comparative benchmarking of the state's capabilities), bottom-up (driven by direct stakeholders) and market-driven (focusing on real competitive requirements). This effort has articulated challenges and actions that have found a common message across the state's major research institutions and industries. That message is "focus on building and reinforcing South Carolina's innovation pipeline for the hydrogen and fuel cell economy." The Flagships that have been defined draw from that common voice. They call for efforts focusing on these three needs:

- **Discovery: Build a critical mass in hydrogen and fuel cell research**—from increasing levels of science expenditures, to recruiting leading faculty, to creating more globally recognized pre-competitive R&D consortia, to generating more intellectual property from these efforts. Achieving a doubling of total research revenues (or more) will feed the innovation machinery of the state and lift South Carolina's visibility nationally.
- **Development: Expand the state's capacity for the entire value chain leading to and including hydrogen and fuel cell technology commercialization**—from growing entrepreneurs to mining intellectual property flowing from the discovery system, to financing the early stages of innovation, to attracting industrial R&D partners, and concentrating activities in regions to build synergies. Improving the scale and success rate in "technology capture" through improved entrepreneurship, expanded partnerships and rising volume and quality of deals will plant the seeds for hydrogen and fuel cell-related job growth.
- **Deployment: Enable enterprise survival, expansion and attraction in the emerging hydrogen and fuel cell industry**—from helping to sustain growth of early stage companies (demonstrations and procurement), to expanding South Carolina company entry into hydrogen and fuel cell production and supply (incentives for technology supply and demand), to creating incentives that will attract a concentration of global operations in South Carolina "energy zones". Strengthening how well the state retains and aggregates hydrogen and fuel cell-related industry activity—creating an eventual industry cluster—will be where the diversity of jobs and desired secondary economic multipliers will come from—over time.

These Flagships should become an ongoing agenda with metrics that of performance that can be tracked over time.

Recommendation S2: Three Dimensions of Statewide Partnership

South Carolina is ready to take its position on the global stage of competition for building the hydrogen and fuel cell economy. While the state lacks sufficient development infrastructure for commercialization, the state has sufficient assets at the discovery-end of the innovation pipeline to make a difference in the future. For this reason, now is the time to establish a statewide

organization that will be able to craft, finalize, advocate for, and sustain ongoing efforts across the public and private sectors to achieve advances in the state's hydrogen and fuel cell innovation pipeline.

The structure of a statewide organization should embrace two fundamentals essential to identifying and shaping a working hydrogen and fuel cell economy. These fundamentals are parallel what normally takes place in a high performing economy and can be seen in states that have effective cluster competitiveness strategies. There are three “dimensions” to these entities that should be represented—drawing from across the entire state:

- **Stewards:** “Servant leaders” as they are called, whose mission is to be the anchor for and champions of the overall organization’s mission. Stewards are individuals who are concerned about the well being of the state—the creation of jobs and wealth for citizens. Stewards should be selected because of their natural authority and influence, but also because, at the end of the day, they care about South Carolina’s performance and are not beholden to any narrow, non-economic development interests. Stewards are more than a board of directors, they must take ownership for specific initiatives and advocate for and drive these efforts forward (e.g., as a “champion”). Their leadership in motivating and sustaining the engagement of others is crucial to each element of the proposed strategy as it moves forward. These stewards must encompass regional representation, drawing from the ongoing collaborative efforts with whom this strategy process has worked. Each region will, no doubt, form and grow its own regional hydrogen and fuel cell strategy and their stewards should be delegates to the state level Stewardship group, without question.
- **Economic Foundations:** Lessons from high performing economies show that state leaders behave like dynamic companies. In high performing states, economic development is not compartmentalized but is, essentially, the mission of every state agency, public institution or authority, and major corporations. When a state wants to enhance competitive development and build their innovation pipeline, they ensure that representation at the table includes every public or private agency or entity that has any influence on the inputs that drive a given cluster, whatever its stage of development. For this reason, the organization established to pursue the South Carolina hydrogen and fuel cell strategy should include a panel of economic foundation representatives. These include industry leaders that influence inputs to each part of the hydrogen and fuel cell discovery, development and deployment pipeline, and insures representation and fairness in the evolving public policies that relate to the developing energy marketplace They are “suppliers” of resources that can be often used in new ways to better meet market needs and create advantages for the hydrogen and fuel cell economy over time:
 - **Human resources:** Technical schools, colleges and universities. (curriculum and training).
 - **Finance:** State department of commerce, state treasurer, major banks and investors, city and county economic development agencies.
 - **Innovation:** University chancellors for research, managers of intellectual property, deans and research center directors, laboratory management, and SCRA (including future innovation centers and incubators).
 - **Infrastructure:** State energy, transportation and environmental agencies, power utilities, transit authorities, university, SCRA and local real estate-related authorities.

- **Governance:** State comptroller, planning agency, environmental agencies, local permitting bodies as well federal agency representatives.
- **Marketing:** State agencies with marketing and communications responsibilities, leading private communications enterprises.
- **Economic Drivers and Users:** Lessons from high performing economies show that leading states are very proactive in engaging industry in the dialogue on how to build the innovation pipeline. Thinking ahead, leading states ensure that there is representation from a broad array of industries that might become the producers or suppliers as well as users of the future hydrogen and fuel cell cluster. This means the future South Carolina organization will need to reach out to industry leaders who may as yet not see the importance of South Carolina's efforts in hydrogen and fuel cells—either as producers, suppliers or users. None the less, South Carolina's leaders must work actively to make the case why the state's existing companies and institutions should help advise and support the South Carolina hydrogen and fuel cell strategy as it moves forward, as they will most certainly be affected in the near future. This may mean using knowledge of the emerging hydrogen and fuel cell supply chain to target and invite companies that could have a future interest in: (a) hydrogen production (nuclear and conventional power and chemical companies), (b) distribution (pipeline, valve, metering), (c) storage (metals and instrumentation), (d) conversion technologies, such as fuel cells (chemicals, catalysts, membranes, cooling, power controls), mobile power systems (autos and transportation equipment, transit authorities), and stationary systems (major power users, such as hospitals, municipal governments, corporate business parks, marine equipment) and so on. By engaging the stakeholders in the economic side of the South Carolina strategy early on (including out of state partners) the strategy will be sure to reflect both challenges and opportunities that might be missed if the strategy were to only focus on the scientific side of hydrogen and fuel cell development.

With a structure that presents necessary leadership (stewards), critical inputs (economic foundations) and market stakeholders (economic drivers and users), the proposed South Carolina hydrogen and fuel cell strategy will have a powerful base to argue and sustain its case over time.

Recommendation S3: Sustain Regional Initiatives

South Carolina is a state that has been known for the strength of its regionalism. Yet, in the global economy in which hydrogen and fuel cell technology industry will take shape, there is no room for cross state conflict. There are at least 15 US states, and many nations competing for their position in the hydrogen and fuel cell economy, and South Carolina must . The Next Energy Initiative (now known as the South Carolina Hydrogen and Fuel Cell Initiative) invested significant effort in convening and listening to regional stakeholders with the goal of understanding what makes them and South Carolina different from current competition and to build the case for a bottom-up set of common strategies based on shared needs. This has been accomplished. The common strategies are embedded in the three proposed Flagship initiatives. If these are pursued, their implementation will benefit each of the state's regions.

Beyond this, however, there is an important opportunity to reflect on the importance of regionalization. Regions have historically taken shape because of differences in configuration of assets and how they are used. South Carolina has three regions which have much in common, but also have differences in their areas of hydrogen and fuel cell concentration. Reinforcing and leveraging these differences will help, rather than hinder South Carolina's progress in building an innovation pipeline for hydrogen and fuel cells. In fact, participants in the collaborative strategy

process often attended meetings in the other regions, acknowledging that their region's efforts shared substantial interdependencies with one another. This is an excellent indication of the beginnings of cross-region collaboration. While Aiken has an aggressive program of activity focusing on hydrogen production, storage and distribution, anchored by SRNL, university faculty from USC, Clemson and South Carolina State University have active engagement there as well. This is true of activities in Columbia and in Clemson as well. Having nodes or hubs of specialized activity, linked to other state regions, is helpful to building a strong case for the state's hydrogen and fuel cell economy. Taking these specializations forward, and helping them to become better defined will help South Carolina recruit industry R&D partners and promote the state's position in competition for federal grants and pre-competitive R&D consortia with other states.

For this reason, any organization that is proposed to plan and manage South Carolina's statewide hydrogen and fuel cell strategy needs to recognize and take into consideration how best to respect and make the most of the state's regional differences. To this point, there has been uneven development of regional leadership around the hydrogen and fuel cell economy theme. While three regions were "convened" to work together in defining their challenges and actions, there is as yet no formal regional structure that a state entity could call upon to anchor innovation pipeline strategy efforts. None-the-less, there is good reason to promote this process, recognizing that that over time there are natural tendencies for economic agglomeration to take shape in these regions and perhaps others. This emergence of differentiated by complementary regional centers will be a fundamental aspect of the emerging hydrogen and fuel cell economy in South Carolina in coming years.

5.3. Regional Organizations: Three Recommendations

Much has been said in this strategy concerning the importance of bottom-up, collaborative, market-driven action—it is the key to South Carolina's success. In this process at the regional level the key unit of analysis are the set of public and private institutions that existing within the "commutershed" of a metropolitan area and are willing to work together to carry out hydrogen and fuel cell strategy. Regional strategy is not about jurisdictional boundaries, it is about achieving a critical mass of advantages in a geographically concentrated area that will help form, expand and attract industry—creating jobs and wealth over time. For this reason, the South Carolina Hydrogen & Fuel Cell Economy Strategy needs to encompass regionally-based groups that are able to work together on a shared business plan that will make their region's innovation pipeline as strong and adaptive as possible. For this to occur there are three recommendations for organizational development and implementation that should be considered by regional leaders:

Recommendation R1: Build a Permanent Collaborative Leadership Group

To advance the development of the hydrogen and fuel cell economy each of South Carolina's regions needs to have their own dedicated public-private leadership group that will serve to catalyze and enable the delivery of the ingredients that may be currently missing from the region to help form, expand and attract industry. Regions are like "holding companies" with multiple divisions of economic activity that earn the region's livelihood. Every region has a continually changing portfolio of industries and, under the best circumstances, industry clusters naturally take shape. These are groups of similar companies, serving related market segments, sharing similar

technology, skills, finance, and infrastructure drawn from responsive regional institutions. However, in many regions there is need for an intermediary organization to help the region create the business environment needed for a given industry. These organizations serve the role of defining challenges, identifying actions and marshalling collaborative solutions focused on their emerging and existing industry stakeholders. These organizations may deliver services directly or broker resources to achieve the solutions required to enable growth—but they get the job done. What characterizes such leadership groups is that their goal is to create distinctive advantages that enable industry formation, expansion and attraction better than their competitors.

While good leadership groups know how to use find money when it is needed they also are very good at using existing resources in new ways. By having an organization that is dedicated to making sure that innovation is accessible, financing available, skills adaptable, physical infrastructure sufficiently advanced and business climate acceptable, they can tip the balance in their growth and maintain it over time. Some regions have a cluster organization for every industry with a presence others have them strategically for new and emerging industries. South Carolina may fall into the second category. Each region needs a group to catalyze and accelerate desired actions to bring the state closer to its future. These organizations are typically non-profits that bring together their own stewards, economic foundation representatives and current (existing industry) and future economic drivers (entrepreneurs) to work together to produce and implement their own regional strategy and business plan for collaborative solutions. Most leading states are organizing and maintaining state hydrogen and fuel cell cluster groups and many are fostering regional hydrogen and fuel cell clusters. In the case of South Carolina this approach is an essential way to harness and activate regional assets.

Recommendation R2: Integrate the Innovation Pipeline into Ongoing Economic Development

Each region should organize a regional leadership organization to develop and sustain implementation of a regional hydrogen and fuel cell strategy. These organizations cannot simply be booster clubs. They need to have a demand-driven strategy themselves to enable the group set priorities. The innovation pipeline framework provides a very simple guideline for organizing such groups. In any of South Carolina's regions potential regional organizations need to assess how well their region is able to create distinctive advantages at each level of the innovation pipeline and from there determine the shortcomings or missing ingredients on which they should focus:

- **Regional Discovery Infrastructure:** In regions of South Carolina the discovery system, which focuses on generating basic and applied research, is growing well towards building a critical mass of hydrogen and fuel cell basic and applied science activity. In fact, universities or the federal laboratory may be doing well in winning new federal awards or new industry sponsored pre-competitive R&D. In such cases, the responsibility for sustaining this activity should logically remain where it is—with the performing institutions—with the regional leadership organization playing an ongoing supporting role—perhaps in recruiting faculty, building support for endowments or recruiting industry partners for new R&D consortia.
- **Regional Development Infrastructure:** South Carolina's regions have uneven ability to support technology development and commercialization. However, there may be emerging resources that may be increasingly accessible that can be coordinated, leveraged or brokered by the regional organization. For example, management of intellectual property identification and packaging for commercialization may not be a current strength of universities nor of the federal laboratory, more over, too date pre-seed and seed capital may not have been available

to assist technology start-ups and spin-offs. However, as the state makes the resources of the South Carolina Research Authority (SCRA) available to support innovation centers, there should be a modest amount of funding available for pre-seed and seed capital. There may even be capacity to help improve commercialization services until university or laboratory capabilities are able to expand capacity or expertise. Moreover, the leadership group and its members may have the ability to foster growth of regional angel networks and access to the new state venture fund and new private investment. Similarly, while early stage companies may require incubation space, there may be facility spaces (wet or dry labs) that are being built that can be made available for lease at competitive prices, perhaps brokered through the leadership organization in conjunction with other partners who own or are developing facilities. So, in this case, the regional leadership organization should concentrate on functions that the state or private marketplace have yet to fully offer. This might take the form of the intermediary in defining market demand or helping to underwrite the initial costs of projects to accommodate needs of early stage enterprise or incoming corporations—whether generating new deals or meeting incubation and pilot testing facility needs.

- **Regional Deployment Infrastructure:** South Carolina's regions have limited resources to channel into economic development, although some counties have used bond funding to capitalize new facilities. Often there is a patchwork of economic development resources available to help retain, expand and attract industry, but very often this exists in a fragmented array of services—between city, county, local and regional chambers, utilities, banks and state agencies. An effective regional leadership organization in hydrogen and fuel cells should incorporate into its organizational structure, from the start, representatives of key economic development stakeholders and ensure that they not only understand the hydrogen and fuel cell agenda, but can see where their capabilities can best be focused on strategic needs—whether services or investments. The goal of the regional organization should be to create the best possible package of public and private resources to focus on two key dimensions of deployment:
 - **Promoting Clustering:** The regional leadership organization should have a strategy that shows how to create the best possible business environment for the operation of hydrogen and fuel cell enterprise. This might mean establishing an innovation zone or technology park project that helps focus regional land, financing and infrastructure on this emerging industry. All three of South Carolina's regions already have university or federal laboratory associated research or technology park sites. These all can become the geographic focus of an associated set of industrial formation, expansion and attraction incentives and services. This approach, which should not be exclusive, can help multiple agencies and providers concentrate their activities, ensuring that each region is always ready to receive and enhance hydrogen and fuel cell-based economic development. Each regional package should be different, complementary to one another if possible and linked as much as feasible, but they should definitely have their own identity.
 - **Fulfilling Marketing:** Communicating the story of South Carolina's distinctive regional competencies and attractiveness as a center for research, development and growth is crucial. To educate regional stakeholders and promote the region at the state, national and international level to retain, expand and attract resources and companies is a crucial regional task. The regional leadership organization should have an integrated game plan focused on today's industry education and marketing opportunities (deployment), and how to accomplish these objectives. The leadership organization may decide to do so by either producing or procuring the services needed. If there are no existing providers—whether

another agency or a private vendor—who can deliver the marketing and recruitment services needed, this organization can directly deliver the services. If there are suitable providers, the leadership organization will reach out to them and either fund them or channel funds to them to get the job done.

Recommendation R3: Establish a Formal Implementation Mechanism to Enable Regional Actions

In many regions regional leadership organizations remain ad hoc committees and sometimes a non-profit organization that advocate but do not have the capacity to take responsibility for action. For cluster development—whether for emerging or established clusters—there is often the need for a formal capacity to implement action. Each region in South Carolina will have a different size and range of stakeholders with whom to work. None-the-less, at the heart of successfully advancing a hydrogen and fuel cell economy will be a sufficiently active and empowered development organization.

Many cluster-type organizations across North America find that without a formal organization with budget and authority that they cannot often execute needed initiatives when there are no external providers or resources available—this is often the case even when there are statewide organizations, such as the South Carolina Research Authority, will be providing resources in the future. For this reason, a basic collaboratively-focused development corporation model might be desirable for use as the vehicle to sustain implementation activities in each region in South Carolina.

The charter of a regional development corporation dedicated to providing what the marketplace has not as yet or cannot provide may be an important interim means for advancing each region's agenda for action. A development corporation should be able to be established with a focused mission that can change as requirements demand. This entity might have a small scale of operation with a limited core budget that permits the entity to directly offer services, induce their production (through coordination or brokering) or procure them to meet needs—using its own core resources (if it has them) or funding from external sources (federal, state agencies, universities, local government and chambers, industry sponsors, partners and affiliates). Ideally, the entity might have its own assets (land, buildings, endowment), but even without these, the corporation can serve its sponsors and affiliates by systematically building bridges and creating advantages where others may not be able to—whether in fostering helping arrange R&D partnerships, conduct intellectual property packaging and enterprise development, enabling early stage funding, arranging for incubation or collaborative R&D facilities for industry, matching R&D partners, or recruiting and attracting industry investment. A formal intermediary mechanism does not need to be large and its mission can be subject to “sunset” provisions by its sponsors, so that its role is always matched to changing market needs in the region of South Carolina in which it operates. Many of South Carolina's regions may have existing entities that can undertake the role of being a development corporation. As long as the organization is collaborative and reaches out to both its regional and statewide counterparts in fulfilling its mission, the form of the entity can be flexible.

6. South Carolina’s Vision of the Hydrogen & Fuel Cell Economy Future

6.1. Getting on the Path of History

While today’s energy marketplace is still dominated by conventional sources—oil and gas, coal, hydropower and nuclear—the speed of change to other sources and methods of generation is accelerating.

There are important parallels in how this change is taking place that speak to what we might expect. Corporations, for example, have been able to become increasingly decentralized due to the impact of global telecommunications and the Internet on global supply chain, and by the readiness of global regions to respond to corporate and market needs. So too is the production and distribution of power likely to become increasingly geographically distributed as the technologies for production and distribution become more efficient and cost effective.

Figure 6-1. Timeline for Future of South Carolina’s Hydrogen and Fuel Cell Economy

	2005–2010 Build the Pipeline	2011–2015 Accelerate Growth	2016–2025 Full Cluster Realization
Vision	<ul style="list-style-type: none"> Statewide and regional SC hydrogen and fuel cell leadership in place. 	<ul style="list-style-type: none"> SC becomes a top center for hydrogen and fuel cell innovation in the U.S. 	<ul style="list-style-type: none"> SC has built a self-renewing innovation pipeline for the hydrogen economy.
Discovery	<ul style="list-style-type: none"> Discovery “engine” doubles research funding with new chairs. H2/fuel cell patent and innovation output jumps. 	<ul style="list-style-type: none"> Ranked in the top 10 of world class leaders in research. 20 endowed chairs and leading R&D facilities to match in place. 	<ul style="list-style-type: none"> Evolving and diversifying portfolio of research assets. Specialized faculty and endowed chair leads to new institutes, centers, and labs.
Development	<ul style="list-style-type: none"> Commercialization capacity in place; more pre-seed, seed capital, more IP packaged; leads to first generation of H2/fuel cell deals. 	<ul style="list-style-type: none"> Commercialization culture takes hold: Start-ups and spin-offs ramp up. Deal volume increases, attracting venture funds, investment, entrepreneurs, and corporate partners. 	<ul style="list-style-type: none"> Major headquarters for commercial energy innovation. A recognized generator of start-ups, spin-offs, and entrepreneurs.
Deployment	<ul style="list-style-type: none"> New incentive policies attract and retain companies to new “SC Energy Zones”—including a major producer of power systems. 	<ul style="list-style-type: none"> Maturing R&D partners expand into production in state—building cluster. SC energy zones become nationally visible. 	<ul style="list-style-type: none"> First generation of real hydrogen and/or fuel cell producers, suppliers, and related services in and around regional centers.
Results	<ul style="list-style-type: none"> Increase in faculty and staff R&D jobs. More corporate R&D operations. First H2/fuel cell start-ups. 	<ul style="list-style-type: none"> 2,000 to 3,000 jobs created. Job growth increases for companies founded in first 5 years. 40–50 new company formations. Many demonstration and validation projects underway. 	<ul style="list-style-type: none"> South Carolina’s hydrogen and fuel cell cluster matures and advances. 8,000 to 12,000 primary jobs. Equal number of jobs from supply-chain and secondary services.

However, while energy is an industry, its distinctive dynamics have fundamentals that are complex with a long-term structure that remains quite uncertain due to many factors—natural, environmental, political and technological. However, as has occurred in the past, there are certain periods when the form of change to come is in flux and there is an opportunity to place oneself on the path of history. In doing so, there is a risk to an individual or company of being wrong. But *for a state*, there is the ability to spread one’s risks, getting in early and building a portfolio of activities rather than narrow industry choices, some of which will have a good

chance of yielding a very substantial economic payoff. The period for realizing the full benefits has already started and will continue over time, maturing over the coming 15 to 20 years.

South Carolina can create and achieve a vision of the future in which the state is an active participant in each stage of its development, maximizing the economic payoff to the state's citizens at each step. This is not a short-term initiative, but there are clear payoffs at every stage that will be valuable to the state, with return on investment escalating over time.

6.2. The Next Five Years—Building the Hydrogen & Fuel Cell Innovation Pipeline

Establishing the Statewide Mechanism

South Carolina breaks new ground in building a collaborative statewide organization dedicated to the mission of achieving the economic potential of the hydrogen and fuel cell economy. This entity has state support and a charter to move the state forward, shaped through strong leadership by stewards and representation of key economic input foundations, as well as the commitment of current and future industry stakeholders. This entity also demonstrates the readiness of regions to work together at the state level to pursue national and global markets, while pursuing distinctive nodes of activity on their own.

Growing Regional Hydrogen and Fuel Cell Initiatives

Within a short time, each of the leading regions in South Carolina that have important hydrogen and fuel cell-related assets will have established formal organizations to sustain the development and implementation of their own regional strategy—each region with its own distinctive identity, participating in the statewide organization showing that the state knows how to collaborate regionally and work at the state level to compete nationally.

Building the Discovery Engine

Having raised new sources of funding to support building a critical mass of scientific capability, the partners in the new state collaborative must aggressively and successfully pursue a series of new federal research programs around new faculty chairs, as well as national pre-competitive R&D consortia that focus on an energy “road map” defining the enabling technologies crucial to facilitate hydrogen and fuel cell commercialization. Traditional university research expenditures double, as does intellectual property output, and new revenues are generated from consortia with over 100 companies and federal agency sponsors working at research centers of excellence in South Carolina that link universities and SRNL. Scores of new jobs in research and technical support are created and there are many corporate scientists and engineers now in state working side-by-side with university staff and laboratory staff.

Setting in Place Development Infrastructure

South Carolina formalizes a statewide technology development capacity building from SCRA resources and adding strong programs to build entrepreneurial innovators with pre-seed and seed capital, and management support to scale up new company formation. A number of automotive energy system consortium initiatives take shape—steps on the technology road map to fuel cells and hydrogen storage. The first generation of fuel cell deals emerges from the state's improved

commercialization infrastructure. South Carolina now can claim to produce new start-ups for the hydrogen and fuel cell economy. These companies produce 15 to 20 jobs each, but also attract management from out of state, some returning to South Carolina because of its business opportunities. The good news is that South Carolina's entrepreneurial climate is already changing and there are already signs of new enterprise formation in hydrogen and fuel cells.

Preparing Policies for Deployment

The statewide hydrogen and fuel cell organization reviewed the policies and practice of state agencies as well as public and private institutions and has prepared a package of incentives designed to retain and attract companies to three designated "energy zones" and "energy parks" founded across South Carolina. These policies took time to prepare and pass in the legislature but now distinguish South Carolina as being ready and able to support the growth and attraction of companies ready to produce or supply for the hydrogen and fuel cell economy. Initially, successful recruits come to South Carolina to collaborate in R&D initiatives with universities, but an increasing number expand their presence to participate in the centers of activity that are taking shape. At least one major industrial producer is successfully recruited to South Carolina to produce advanced technology for automotive energy systems, still pre-fuel cell and hydrogen, but setting the stage for continuing development of the value chain around next generation energy technology.

Economic Return: First Round of Discovery Driven Growth

Over the coming five years South Carolina will achieve a substantial return on investment from its public matching funds support of research and faculty, through the rising success rate in obtaining a growing share of federal research dollars. The investment in public research infrastructure, such as the hydrogen and fuel cell portion of the Horizon Center and projects at the National Center for Hydrogen Research, will also begin to pay off as corporate tenants come to the state to participate in research projects and consortia. While there will be a few spin-offs, generating relative few jobs, they may bring new capital into the state. The effort of positioning the state will, however, enhance recruitment of at least one major producer eager to locate near South Carolina's range of materials, systems engineering and energy competencies—a future partner for the emerging innovation from the state. All of the investment at this stage will start generating higher multipliers as the output of the discovery work is "captured" in the improved development system in the coming years.

6.3. 6 to 10 Years—Accelerating Growth of Hydrogen & Fuel Cell Commercialization

An Emerging Energy Innovator

Six to ten years from the start of new efforts South Carolina will have become one of the top centers for hydrogen and fuel cell innovation in the United States. Whereas other states have focused narrowly on one segment of hydrogen technology and often found themselves outside the race, South Carolina will have multiple lines of innovation working—serving as a seed bed for the more commercially viable segments of technology. Moreover, the state will continue to feed its portfolio with a rising volume of intellectual property that is carefully managed with the intention of commercialization at all times. The combination of strong research and improved development infrastructure will draw more producers to set up both engineering and production operations in South Carolina.

Outstanding Leadership in Discovery

South Carolina has, relative to its population and its other fields of science, become a world class leader in hydrogen and fuel cell-related research across the board with the state's universities in the top 5 to 10 in total research expenditures. With attention to maintaining and leveraging each subsequent research program by adding new endowed chairs and associated facilities, South Carolina is easily recognized as a top knowledge generator and center of innovation. As has occurred nationally with such centers, global corporations have co-located laboratories in South Carolina so that they can work with faculty, recruit graduates and capture ideas. South Carolina has maintained strong incentives for partners that ensure that the economic value they derive from university and national laboratory collaboration is captured as much as possible on the ground in the state through new offices and operations, helping to expand research park occupancy, and growing the local workforce, sourced from both outside and within the state.

Accelerating Growth of Enterprise

After five years of building up the technology commercialization support infrastructure in South Carolina, the volume of hydrogen and fuel cell-related start-ups and spin offs begins to rise to ten a year, distributed across the state. This growth in deal volume attracts branches of the rising number of venture funds that are focusing on new energy technologies to the state. The availability of a replenished pre-seed and seed capital fund combined with effective spin-off and start-up management has created a new energy pump-priming capacity in South Carolina, missing in most other states. After five years, the surviving start-ups from the first years have generated 50 to 100 jobs themselves, have been merged into operations of larger companies, or have spun off new start ups themselves. Now the state will see as many as 50 new companies and their rising number of employees. Though not all will survive, they will bring in out of state investment and transfer their technology to other firms and entrepreneurs.

Accommodating New Partners

The success of the universities and SRNL in making a quantum jump in scale of both federal and pre-competitive consortia revenues, and the rising visibility of South Carolina as a source of energy start-ups, will have attracted R&D operations of major corporations to the state. By this time (five years later), these firms will have matured and expanded their in-state operations, often doubling or tripling in size, sometimes expanding into production for specific new lines of technology, thanks to the deployment package long in place and continuing to improve. By ten years, South Carolina's energy zones and energy parks are now becoming nationally visible, not dissimilar to other major centers, such as North Carolina's Research Triangle. Within five years several energy zone or energy parks (such as those in Aiken and Clemson) have become the sites for development of hydrogen production and distribution infrastructure and have attracted, through ongoing demonstration and validation projects with energy distribution partners as well as related hydrogen energy end-users attracted to the park sites, generating several hundred new jobs. The pre-fuel cell stage producers will have continued to expand production and South Carolina will have gained attraction as a location for Tier 1 producers in the radically changing automobile industry.

Economic Return: Commercialization and Attraction Ramp Up

Ten years into the strategy South Carolina has achieved stature as a highly focused player in the global hydrogen and fuel cell economy. This position is merited by the coherency of state policies and their emphasis on leveraging all public and private players to continually create advantages in the innovation pipeline. This position is also reinforced by the positive feedback loop in development and deployment that is being achieved at regional centers around the state as their science application activities attract partners and major demonstrations that in turn attract innovative producers and suppliers that in turn use services from the state's surrounding communities. By ten years South Carolina has generated new jobs from its strong scientific research base and their partners, from growing number the technology start-ups and their partners, and from the attraction of established companies in energy production, storage and distribution and use who have located operations at hubs of activity across the state. There are now conservatively 1,000 to 2,000 net new jobs directly associated with hydrogen and fuel cell economy in the state and perhaps twice this number related to secondary support. These jobs are separate from the perhaps 1,000 jobs related to transitioning technologies in automotive energy systems that new producers will have located in South Carolina.

6.4. 11 to 20 Years—Full Cluster Realization in the New Energy Economy

Reaping the Harvest of Ideas

The second decade of South Carolina's concerted focus on hydrogen and fuel cell technology will be one of diversifying outwards from the portfolio of assets established during the first five years. Some of the scientific innovations or results of pre-competitive consortia, will have not only addressed critical questions on the technology road map for hydrogen or fuel cell technology, they will have also become the basis for licensing deals and/or South Carolina production ventures, whether for hydrogen storage materials, pipeline structures or optimized fuel cell engineering for various scales and fuels. The implication of success in having managed a diversified portfolio of research across the universities and laboratory will mean that South Carolina will have had its collective eye on the downstream commercial production or licensing opportunities arising from this innovation early on. In the 10 years after the hydrogen and fuel cell strategy has been in effect, the state's innovation pipeline business model will still be paying off by having produced at least part of key components to the world's future energy system. More importantly, having built a stable and sustainable innovation pipeline, the state has also started generating an increasing flow of innovations in areas related to hydrogen and fuel cells, a natural and appropriate outcome, whether vertically along the value chain of energy systems from generation to conversion, or laterally, in areas of new distinction, such as power technologies or bioconversion. This vital cycle of innovation and economic generation will change how South Carolina works, making the state a stronger player in the future technology-driven economy, and increasing its positive image to industry and the marketplace. All this will have built on a complementary growth in the value-chain of automotive and energy-system related producers and suppliers who will have developed and grown in South Carolina prior to the maturation of fuel cells and hydrogen systems.

Next Generation Foundry of Discovery

The prospects for expanding basic and applied science related to energy are excellent in the coming 20 years. However, universities that succeed in the short term will need to renew themselves. Through having recruited scores of new faculty, setting up endowed chairs and working actively to win federal science and consortia initiatives, South Carolina's universities will have effectively replenished itself and remained ready to compete as a knowledge generator. If USC builds a critical mass of scientists and research funding over the first decade of the hydrogen and fuel cell economy, this will easily enable the university to explore and grow new areas in the following decades. With its suitable size, the university may find that it wishes to establish a "college or institute of energy" that provides a major multidisciplinary center of education and research, and supports a multitude of consortia for a field that will be on the center stage of the global economic concerns.

A Headquarters for Commercial Energy Innovation

Once South Carolina aggressively begins to foster or recruit entrepreneurs into the state, it will establish (as others states have done) a "generator" of start-ups and spin-offs, positioning the state into a higher business-friendly ranking. After a decade or more, the state will now have established a proven track record in energy-related entrepreneurship and become a center for energy technology commercial innovation, attracting both students, inventors, and, of course, investors. While the total number of enterprises formed in hydrogen and fuel cells and related energy innovation may not necessarily rise exponentially, the level will double while other related areas may grow as well. This will lead to an important shift in regional economic dynamics, as the quality of deals will have improved with maturity of the state's base of entrepreneurship so that the size and impact of commercialization ventures will be more substantial. South Carolina's population would have very likely grown during this development period so that the state's culture will now be more likely to produce entrepreneurs of various kinds.

Clusters Come of Age

The most important measure of innovation pipeline success is the achievement of a viable industry cluster in hydrogen and fuel cell technology. Within 15 to 20 years, if the state has effectively pursued the strengthening of its innovation pipeline, South Carolina should have witnessed the agglomeration of the first generation of real hydrogen and/or fuel cell producers, suppliers and related services in and around its regional centers. Regional centers will have found distinctive emphases in their role in the cluster process. Depending on the path that the state's portfolio of hydrogen and fuel cell technologies take, Aiken may become a center for hydrogen power engineering and production, with nuclear and or other power producers, and intermediate hydrogen users, connected to national hubs with next generation distribution infrastructure. Columbia may, for example, become a center for the business headquarters and R&D segments of fuel cell and integrated power system production. The Upstate region might become a design, engineering and production center for automotive and transportation equipment components and assembly that use the first and second generation of new hydrogen and fuel cell systems. In each case the agglomeration of producers, suppliers and economic inputs, from skills to financing and infrastructure, will constitute industry clusters, presumably with some degree (though not necessarily) of mutually reinforcing linkages across regions. These clusters will generate two or more times their employment numbers in secondary employment, and foster ongoing innovation and exchange among companies and associated institutions.

Economic Return 2025: The Renewable Resource

Over twenty years South Carolina could establish multiple centers of hydrogen and fuel cell-related industrial activity, generating a *minimum* of 8,000 to 12,000 primary jobs, which could possibly be doubled if production facilities, that include but extend beyond the actual design, engineering and manufacturing of hydrogen or fuel cells are included. These jobs will echo through the state economy helping to generate at least two times their numbers. What will be important for South Carolina is that having invested now in building a strong innovation infrastructure, the state will have created not only the capacity to prepare for and shape the emerging hydrogen and fuel cell economy, but will also be ready to apply these same competencies to many related economic segments that are, to this point, still unknown.

Like any battle, the win is achieved by readiness. The hydrogen and fuel cell economy are major opportunities for tapping into the major economic possibilities of the many fields required for their development, including advanced materials and chemical engineering, and computer science and systems, among others. Pursuing hydrogen and fuel cells is vital, but the rewards will extend beyond any one technological innovation. The pay off is the economic transformation of South Carolina, and its growth and sustainability in the 21st Century.

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7. Conclusion: Setting the Stage and Staying the Course

South Carolina represents one of the rare instances in the United States where state assets in an emerging field of science and technology are sufficiently advanced as to provide a natural case for concerted public policy to leverage those capabilities into economic growth of a distinctive and powerful nature. Hydrogen and fuel cell technology is as yet early enough in its developmental path as to provide a window of opportunity for the state to choose to lay the groundwork for generating and capturing substantial future potential for job growth and state revenue. Moreover, in choosing to pursue and assist the development of a hydrogen and fuel cell economy in South Carolina, the state will not only be increasing the probability of near, medium and longer-term returns to the state, but will also be, concurrently, positioning South Carolina to benefit in any future technology-based economic development opportunities. For by improving the state's innovation pipeline for hydrogen and fuel cell development there will be many natural benefits that will strengthen the state's research engines, its technology commercialization structure and the state's ability to form, expand and attract companies.

Each stage of the forthcoming development of the hydrogen and fuel cell economy will have uncertainties, as technologies and markets resolve and mature. Yet the approach proposed for adoption in South Carolina does not choose individual winners, the strategy emphasizes a portfolio management perspective—a choice, fortunately, that other states may not have but South Carolina does. This approach means that the set of public and private policies set in place by the state to accelerate growth in these fields will foster development of a diverse range of important seeds for the future, as well as elements that will be used along the emerging value-chain of these industries. South Carolina will witness some of the creation of its research laboratories and start-ups survive into full commercial viability while others will not survive. Yet, the framework and array of policies and programs proposed will ensure that there is growing quantity and quality of innovation flowing into technology, valid technology flowing into business deals, and strong deals maturing into growing concentrations of businesses.

As shown, the results of this strategy require a long-term view. The outcomes will not occur all at once. Over the first five years key state and regional decisions and investments will be made and policies set in place. These will generate new jobs, primarily in the discovery system with growth in researchers and their business partners. Over the second five years growth will begin to take shape as the number and rate of start-ups and in-coming companies grows. After a decade or more South Carolina will have clearly demonstrated the viability and leadership of its new economic generator—hydrogen and fuel cell industries. By this time the state will begin reaping the harvest of economic multipliers arising from formation, expansion and attraction of the continuum of companies as they create clusters of distinctive competency and associated job and wealth generation.

This bottom-up, collaborative, market-driven strategy for enabling the growth of South Carolina's hydrogen and fuel cell economy is not only about building the competitive industry for the future, this strategy is about strengthening how South Carolina grows and takes care of business to create a continuing and renewable base of jobs and economic growth for this generation of citizens and the next at the regionally level and statewide. There are rewards at every step, but the commitment over time is essential.

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8. Appendix

South Carolina Next Energy Participants

Upstate

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