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Commercialization of Hydrogen Fuel Cell Technology in North America: Pathways to Success in Northeast Ohio

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COMMERCIALIZATION OF HYDROGEN FUEL CELL TECHNOLOGY IN NORTH AMERICA:

PATHWAYS TO SUCCESS IN NORTHEAST OHIO

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Commercialization of Hydrogen Fuel Cell Technology in North America

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PART ONE: OVERVIEW OF PRIMARY ACTIVITIES IN NORTH AMERICA

INTRODUCTION

The feasibility of hydrogen as a source of energy has been researched in one capacity or another for over a century. The first usage of the term 'hydrogen economy' is attributed to 11John Bockris in 1970. At the time, Dr. Bockris was a professor at the University of Pennsylvania. During a discussion at the General Motors technical center in Michigan he used this term to describe his vision of United States cities being supplied with energy derived from the sun. Typical of a disruptive technology, many years of laboratory testing have created a hydrogen fuel cell product that is ready for the consumer but no commercial markets exist to make the product cost competitive.

In North America hydrogen fuel cell development has continued to lead towards commercialization. An initial step, in North America and other parts of the world, has involved public transportation demonstration projects that raise public awareness of hydrogen fuel cell technology while simultaneously testing the market readiness of the technology[1]. The success of these projects has been documented through the gathering and analysis of technical data. Other indicators of success include the continued evolvement towards creating a hydrogen fueling infrastructure and the continued technological advancement in the hydrogen fuel cell industry.

The purpose of this paper is to identify areas in North America where hydrogen fuel cell technologies have been successful in demonstration projects across various applications. Particular attention is given to public transportation demonstration projects and the associated

[1] The National Renewable Energy Laboratory (NREL) was commissioned jointly by the U.S. Department of Energy (DOE) and The Federal Transit Administration (FTA) to evaluate both the DOE and FTA funded hydrogen fuel cell projects. The NREL began evaluating the projects in 2003 and is commissioned for projects through 2011. A publicly accessible database of the NREL evaluations can be found on the web at: http://www.nrel.gov/hydrogen/proj_fc_bus_eval.html

fueling infrastructure. The region(s) in which hydrogen fuel cell technologies are near commercialization are identified. Our attempts to document and analyze the factors that have contributed to successfully moving towards commercialization underlie the purpose of this research. The emergence of supply chains in support of a commercial hydrogen fuel cell market and the stakeholder sectors that have contributed to successful infrastructure and supply-chain development is documented.

The State of California and The Canadian Province of British Columbia have been identified as the North American leaders in hydrogen fuel cell technology usage. Within the State of California three transit agencies have been identified to have successful hydrogen fuel cell demonstration programs: SunLine Transit Agency, AC Transit Agency, and Santa Clara VTA. Hydrogen fuel cell development in the State of California and early market formation are based on and around these demonstration projects. Hydrogen Fuel Cell development in British Columbia has also been located near successful public transportation demonstration projects. Public sector and stakeholder involvement in development of the technology has differed in British Columbia from that in California, and these differences will be analyzed.

CALIFORNIA

The state of California has been an early worldwide leader in the development of hydrogen fuel cells for transportation applications. Regular use of hydrogen fuel cells buses is demonstrated by the SunLine Transit Agency, AC Transit Agency, and Santa Clara VTA.

As of October 2008 there were 66 hydrogen fueling stations in the United states, 32 of which are located in California.[2] Most stations in California have been built with a combination of public and private investment. Public Investment in hydrogen fuel cell transportation technologies has included both state and federal initiatives. The U.S. Department of Energy

[2] A comprehensive list of hydrogen fueling stations worldwide has been compiled by Fuel Cells 2000, and can be found at www.fuelcells.org

provided matching funds for four of California's fueling stations. The U.S. Department of Transportation built three hydrogen stations and deployed fuel cell busses through the Federal Transit Authority (FTA)[3], indicating that the Federal government has identified hydrogen fuel cell technology as an important piece of the future energy mix in the United States.

Public Policy has played an important role in hydrogen fuel cell market development in California. The California Air Resources Board (CARB) has contributed to the initial development of hydrogen fuel cells for transportation applications through its Zero Emission Vehicle (ZEV) Program. The ZEV Program requires at least 25,000 ZEV's to be produced during the 2012-14 time span and 50,000 ZEV's to be produced in the 2015-17 time span,[4] capturing a share of the automobile market.

Investment in hydrogen fuel cell technologies in California has largely been directed towards infrastructure development and the creation of a market for hydrogen fuel cell technologies for transportation applications. The California Fuel Cell Partnership (CaFCP) and CARB ZEV requirements have worked concurrently to promote commercialization in California. Fuel Cell proponents are calling for infrastructure investment in order to realize commercialization potential. Honda delivered its first five commercial vehicles in July 2008 to the Los Angeles area. The FCX Clarity is available for lease in Southern California for approximately $600 per month. Two hundred leases are planned for the next three years by the automaker, most of which will be in the greater Los Angeles area. Daimler will begin producing one fuel cell vehicle per day in its B-Class beginning in 2010. According to the CaFCP hydrogen fueling station map 16 operational hydrogen fueling stations exist in the greater Los Angeles area, which is about half of the total number in the state and nearly one-fourth of those in the U.S.

[3] Federal funding documentation retrieved from the California Fuel Cell Partnership web site at http://www.fuelcellpartnership.org/progress/stations/station-funding on 3/20/09.

[4] Details on the CARB ZEV Program can be found at http://www.arb.ca.gov/msprog/zevprog/zevprog.htm Due to flexibility in the ZEV program it is expected that 25,000 to 66,000 ZEV's will be produced in 2012-2014. At the end of 2009 the ZEV program will be redesigned to affect the 2015+ model years. The goal of this redesign is to strengthen requirements in order to contribute to moving low or no greenhouse gas emitting vehicles to commercialization so that The State of California can meet its greenhouse gas emission reduction goals.

The CaFCP organizes vehicle commercialization efforts within the State of California. Some of the members of the CaFCP include automobile manufacturers (Chrysler, Daimler, Ford, General Motors Nissan, Toyota, Volkswagen), energy companies (Chevron, Shell Hydrogen, United Technologies Corporation-Power), government entities (CARB, California Energy Commission, U.S. Department of Energy, U.S. Department of Transportation, U.S. Environmental Protection Agency), private firms (Air Products and Chemicals, Inc., Praxair, Powertech Labs, ISE Corporation, Proton Energy Systems, Inc. Ztek Corporation), public transit agencies (AC Transit, Santa Clara Valley Transportation Authority, SunLine Transit Agency), and academia (UC Davis Institute for Transportation Studies, UC Irvine National Fuel Cell Research Center).[5]

The CaFCP was established in January of 1999 to demonstrate the potential of fuel cell vehicles. The California Air Resources Board and The California Energy Commission joined with six private sector companies; Ballard Power Systems, Daimler Chrysler, Ford Motor Company, BP, Shell Hydrogen, and Chevron Texaco to form the CaFCP. Originally, a handful of vehicle manufacturers had their hydrogen fuel cell prototype cars located outside the CaFCP headquarters in Sacramento, where they had a hydrogen fueling station on site. The goal of the first project was to research the technical viability of the vehicles and fuel. The first phase was a success and the technologies proved viable. The CaFCP commercialization efforts, now in its third phase, will continue through 2012.[6] Due to the SunLine Transit Agencies leadership in hydrogen fuel cell demonstration projects and the emergence of a fueling infrastructure in greater Los Angeles, the effects of SunLine's demonstration projects deserve detailed analysis.

SUNLINE TRANSIT AGENCY

The SunLine Transit agency serves the Coachella Valley near Thousand Palms, California. It opened its alternative fueling station initially in 1994 in Thousand Palms. In April 2000 the station was opened to the public to demonstrate alternative fuel technologies. Between July

[5] A list of current CaFCP members can be found at http://www.fuelcellpartnership.org/about-us/members2
[6] A more detailed history of the CaFCP can be found on the collaboration's web site; http://www.fuelcellpartnership.org/node/82

2000 and September 2001 SunLine demonstrated ZEBus, the agencies first hydrogen fuel cell bus. The SunLine Transit agency continues to operate a hydrogen fuel cell bus, and has been a leader in demonstration technologies over the past decade. The current bus, put into service in January 2006 is a hydrogen fuel cell hybrid, and continues to fuel at the SunLine Transit fueling station. ISE corporation provided the fuel-cell hybrid drive system. Much of the funding for the demonstration buses has come from the Department of Energy through its Clean Cities Program. The fueling station developed out of a partnership between SunLine Transit, Hydorgenics[7], and Hyradix[8].

The first retail style hydrogen fueling station opened in October of 2004 in Los Angeles, California, and hydrogen fueling infrastructure continues to be built today. In May of 2009 CARB announced that it will grant funds to four new hydrogen fueling stations.[9] By documenting the technical viability of the hydrogen fuel cell bus and hydrogen as a transportation fuel source, the Sunline transit demo projects had a direct impact on infrastructure development in the greater Los Angeles region. Although Sunline Transit is not located within greater Los Angeles it is within close proximity. It demonstrated the feasibility of hydrogen as a transportation fuel and most importantly demonstrated the successful functioning of hydrogen fueling stations.

Following SunLine's first demo bus, the city of Los Angeles demonstrated a bus with a drive train provided by ISE Corporation which is located in southern California, just north of San Diego. ISE Corporation has also provided SunLine Transit with fuel cell busses. According to a report issued by the National Renewable Energy Laboratory in June of 2008, "the ISE Corp./New Flyer HHICE bus was purchased by SunLine as part of a joint Federal Transit Administration/

[7] Hydrogenics Corporation offers onsite hydrogen generation systems as well as fuel cell power systems and is headquartered in Ontario, Canada.

[8] Hyradix provides onsite generation systems and is headquarted in Des Plaines, Illinois

[9] Fuel Cell Today reported that the grants were awarded to Mebtahi Chevron in Harbor City, San Francisco International Airport in San Francisco, Shell Hydrogen in Newport Beach, and The University of California Los Angeles in Los Angeles. More information can be found at the fuel cell today web site; http://www.fuelcelltoday.com/online/news/articles/2009-03/New-Hydrogen-Refuelling-Stations

South Coast Air Quality Management District (FTA/SCAQMD) project in 2004. The bus went into service in December 2004. Soon after the HHICE bus started operation at SunLine, it was sent to Winnipeg, Manitoba, Canada for cold weather testing in February and March 2005, and then resumed operation at SunLine."[10]

Socio-economic factors also played a significant role in market development in greater Los Angeles. The region has been plagued with smog problems for many years and is highly automobile dependent. Three important factors make he region ideal for early adoption of hydrogen fuel cell vehicles: 1) the proven feasibility of hydrogen fuel cell technology throughout the state, 2) a strong need to decrease auto emissions as well as air pollution and 3) a high concentration of individuals with disposable income in greater Los Angeles. These socio-economic factors and the CARB ZEV requirement are contributing to the agglomeration of hydrogen fuel cell manufacturers nearby, in British Columbia.

BRITISH COLUMBIA

According to the 2007 Canadian Hydrogen and Fuel cell Sector Profile, Canada's hydrogen and fuel cell industry employed 2,043 Canadians in 2006. Canada invested $193 Million in research and development in 2006, bringing the total over the past five years over $1 billion. Canadian Hydrogen and Fuel Cell companies reported revenues totaling $133 million in 2006.[11] Contrary to the strong direction of the state of California's commercialization efforts towards automobile transportation, the Canadian province of British Columbia has taken a more balanced approach. While stakeholder organization is still seen as essential, public and private investment has been funding demonstrations of a wide variety of applications, rather than placing so much emphasis on transportation. This is not to say that transportation is not an important (possibly the most important) application in the mix, but Canada's investment has been across a wider range of

[10] The SunLine Transit Agency Hydrogen-Powered Transit buses third report can be found on the internet at: http://www.nrel.gov/hydrogen/pdfs/43741-2.pdf

[11] Taken from Canada's Hydrogen and Fuel Cell Industry Capabilities Guide 2008, published by Hydrogen & Fuel Cells Canada

applications. The seeming result is the early development of a fuel cell manufacturing cluster in British Columbia.

The hydrogen highway demonstration project is more than a highway with hydrogen infrastructure. According to the Hydrogen Highway website, "British Columbia's Hydrogen Highway is a voluntary network of Canadian technology providers[12], government partnerships[13] and technology users from participating organizations[14] who are working together to bring hydrogen and fuel cell products to the marketplace." The result of such targeted regional investment into such a diverse array of applications is that seventy-five percent of Canada's fuel cell and hydrogen-based research and development investments are in British Columbia. In turn, British Columbia accounts for sixty-nine percent of all sector employment.

British Columbia Transit Agency (BC Transit) is preparing to launch the worlds first hydrogen fuel cell bus fleet in 2010, which will be in use during the 2010 Olympic and Paralympic Winter Games. BC Transit will operate a fleet of 20 hydrogen fuel cell buses with financing from a federal-provincial partnership. The goal of the fleet is to be the first to integrate fuel cell buses into regular operational service in an urban environment over a sustained period. $89 million in public funding will support the entire program, including fueling stations. Two fueling stations are planned to be in operation by July 2009.

The National Research Council Canada (NRC) has been coordinating a strategic development strategy for the fuel cell industry in and around Vancouver. Vancouver accounts for nearly 70 percent of the roughly 1500 Canadian jobs in the fuel cell industry.[15] A key part of NRC's approach was the creation of a task force that determined how best to conduct fuel cell R&D in Canada, with Vancouver as the focal point. The plan sparked:

[12] For a list of technology providers involved in the British Columbia Hydrogen Highway project, visit http://www.hydrogenhighway.ca/code/navigate.asp?Id=214

[13] A number of provincial and Canadian federal government entities have contributed to the Hydrogen Highway project. A detailed list of government partners can be found at: http://www.hydrogenhighway.ca/code/navigate.asp?Id=216

[14] The 'technology users' have advanced the project by sponsoring the Hydrogen Highway or using hydrogen fuel cells in their daily operations. A complete list of participating organizations can be found on the web at http://www.hydrogenhighway.ca/code/navigate.asp?Id=216

[15] http://www.nrc-cnrc.gc.ca/aboutUs/corporatereports/fact_sheets/factsheet_vancouver_08_e.html

- The construction of a state-of-the-art NRC fuel cell research facility and the attraction of talent to build a hydrogen and fuel cell knowledge advantage.
- The creation of a national association, now called Hydrogen & Fuel Cells Canada, to accelerate this sector in Canada and foster private sector development.
- The development of the National Program on Fuel Cells and Hydrogen, a research initiative that taps the best minds at six of NRC's research facilities across Canada.

The Canadian government announced in May of 2008 a $13.6 million investment in the NRC's fuel cells and hydrogen research center. This funding is part of a larger effort by the Canadian government to invest in research and development of industries and technologies that will have a large impact in the future, such as biomedical and nanotechnologies. These efforts by the NRC and the Canadian government continue to work towards the creation of a hydrogen fuel cell industry cluster in Greater Vancouver.

Stakeholder coordination as well as targeted public investment has been the primary factors contributing to the development of a hydrogen fuel cell supply-chain in British Columbia. Hydrogen and Fuel Cells Canada, headquarter in Vancouver, British Columbia, is Canada's industry association for the hydrogen and fuel cell sector. The organization provides a "collective face" to the diverse set of stakeholders in the hydrogen and fuel cell industries. The leadership of this organization has proved invaluable to the fuel cell industry in British Columbia. Hydrogen and Fuel Cells Canada produced a "*capabilities guide*" in 2008[16], which provided profiles of all of the key organizations in the hydrogen and fuel cell sector. Ninety-eight organizations are represented in the capabilities guide. Each profile categorized the capabilities and market focus of the organization. Table 1 provides a breakdown of organizations by category of capabilities and market focus.[17]

[16] http://www.fuelcellscanada.ca/temp/20095649846/H2FC_CapGuide_08.pdf
[17] Table 1 is an analysis of data provided within the Hydrogen and Fuel Cells Canada *Capabilities Guide*

TABLE 1

Capabilities	**Market Focus**
Fueling – 18	Mobile – 50
Fuel Storage – 15	Stationary – 43
Fuel Cell Development – 26	Portable – 31
Systems Integration – 35	N/A - 22
Control Systems – 12	
H2 Production – 24	
Components – 22	
Test/Sensor Equipment – 11	
Services - 38	

OHIO

The State of Ohio has been a worldwide leader in hydrogen technology due to the location of Federal research laboratories in the state. NASA Glenn research center has been advancing hydrogen technology for use in aeronautics and has made Ohio a leader in hydrogen technologies research. Wright Patterson Air Force Base near Dayton has been an early adopter of hydrogen technologies for military applications helping to further technological developments and prepare hydrogen technologies to realize new market opportunities. These research centers make Ohio unique in the world in that the earliest and most innovative research on hydrogen as a fuel source began in Ohio. A strong investment in fuel cell technology by the Ohio Third Frontier has allowed Ohio to emerge as a leader in stationary fuel cell technology, but more work is to be done to assure the state capitalize on its technological advances and continue to build a fuel cell manufacturing industry. Of utmost importance, going forward, is the emergence of a hydrogen fuel cell manufacturing cluster that will support stationary, transportation and mobile technologies.

In order to continue to grow the hydrogen fuel cell industry Ohio must create strong partnerships between its manufacturing base and large number of research universities. A

better working relationship will allow Ohio's universities to serve as training grounds for highly skilled professionals in the fuel cell industry, giving engineering students potential jobs in the state. Additionally research and development efforts would be further expanded onto Universities easing the financial burden to some extent on the private sector and state. Community Colleges and Technical Schools will play the important role of retraining Ohio's manufacturing base and prepare a skilled labor force for the emerging fuel cell manufacturing sector.

The Ohio Fuel Cell Partnership (OFCP) has played a crucial role in organizing industry stakeholders and marketing the State of Ohio's fuel cell industry in order to attract a greater number of firms. The OFCP has additionally aided Third Frontier investments by coordinating research and development efforts and serving as liaison between industry professionals and Ohio's public sector. The creation of a statewide non-profit clearinghouse would benefit the fuel cell sector by creating linkages between potential markets, early adopters and the emerging fuel cell manufacturing industry. Additionally, this organization can drive state policy to encourage development of the fuel cell industry and most importantly, begin to broaden the scope of federal investment dollars into the states fuel cell sector. Ohio can benefit from the example set by California, in that state investment's continued to match federal investments to build an early hydrogen fueling infrastructure. Private sector investments naturally followed these public sector investments, as energy and auto companies made an effort to position themselves as leaders in the emerging markets. Strong state policy in the form of manufacturing mandates and tax incentives to consumers would allow Ohio to better position itself to capitalize off of Third Frontier investments and ensure manufacturing growth in the state. Highly visible demonstration projects of hydrogen fuel cell technologies (such as the Renewable Hydrogen Today project) will encourage consumers to embrace the new technologies, particularly when public education campaigns accompany the technical demonstrations.

Hydrogen fueling infrastructure growth has been shown to benefit from a hub and spoke development strategy (see examples in greater Los Angeles) and the Great Lakes Science Center is an ideal location for early fueling infrastructure. It's location near a major city center; waterway/seaport and expansive highway infrastructure can serve many different types of early adopters of hydrogen fuel cell technology. Many different types of early adopters and demonstration projects would benefit from locating an early fueling station at this location. Additionally, the station would be ideal for public education efforts due to its highly visible location and relationship with The Great Lakes Science Center.

BARRIERS TO COMMERCIALIZATION

The National Renewable Energy Laboratory produced a list of barriers to commercialization in 2006[18] that are quite pertinent to the developing fuel cell industry in Ohio. Those barriers are:

1) Availability of infrastructure
2) High infrastructure construction costs
3) Inconsistent policy and leadership messages
4) Low oil prices
5) Poor perceived or actual performance of technology
6) Competition against conventional fuel economies of scale
7) High vehicle costs
8) Availability of vehicles
9) Lack of customer awareness or market acceptance
10) Lack of economic incentives
11) Lack of service and maintenance training and technicians
12) Lack of fuel station operators
13) Poor fuel properties

[18] M. Melendez authored a report titled *Transitioning to a Hydrogen Future: Learning from the Alternative Fuels Experience* in February , 2006. Research for the document was conducted by the National Renewable Energy Laboratory and the U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. The full report can be found online at http://www.osti.gov/bridge

14) Inconsistent codes and standards

The authors also outlined strategic considerations for overcoming the barriers to commercialization. Those considerations are:

1) Niche markets (manufacturing firms, airports, taxis, school buses, public transit)
2) Fleets (private, local, state, federal)
3) Outreach and education
4) Partnerships
5) Stakeholder coordination
6) Tax incentives
7) Policy
8) Grants and other financial incentives
9) Regulatory incentives
10) Research and development
11) Demonstration projects
12) Hybridization

SUMMARY AND CONCLUSIONS

The commercial production of Honda's fuel cell vehicle indicates that manufacturing, research and development, and hydrogen energy production will see growth sector wide. A global supply-chain will assemble to support the emerging industry. The United States government continues to invest significant amounts of money in hydrogen fuel cell technologies for transportation applications, indicating that the United States Department of Energy sees hydrogen fuel cells as an important part of the energy mix in the United States. In order to "accelerate the commercialization and deployment of fuel cells" the U.S. Department of Energy

invested $41.9 million dollars in fuel cell technology through the American Recovery and Reinvestment act.[19]

The west coast of North America, particularly British Columbia, is positioning itself as a worldwide leader in hydrogen fuel cell manufacturing. The region is home to many early adopter markets, with the greater Los Angeles area building a hydrogen fueling infrastructure. British Columbia has begun to develop a manufacturing cluster after more than ten years of targeted government investment in research and development. The coordination of public-private partnerships and the growing number of stakeholders in the greater Vancouver region has been integral to its success. Hydrogen and Fuel Cells Canada has been a crucial player to encourage market penetration and supply-chain development and agglomeration. Despite the cost savings and gains in research and development clustering has provided, hydrogen fuel cell markets have yet to experience significant growth. When market penetration occurs and significant market shares are captured regional clustering will significantly increase the competitiveness of firms in Greater Vancouver.

The state of California and the greater Los Angeles area are designated as the early market for Honda's hydrogen fuel cell vehicle. The process that has led to this occurrence began with strong public policy to mandate the production of "no-emission vehicles" to be sold in the State of California. To create the necessary infrastructure to support the early adopter market partnerships were formed to invest in fueling stations. These partnerships were between private firms (often energy companies and auto manufacturers) or were public-private partnerships. The poor air quality of the greater Los Angeles area has been a statewide political issue for many years, creating the socio-economic conditions for an early adopter market. When combined with the large number of households in the region with incomes near the top of the income distribution and the success of the public demonstration fuel cell bus projects in the state, the region has been able to make the necessary investments and begin to create a consumer market. The California Air Resource Board's zero emission vehicle public policy laid

[19] Details on this investment as well as other ways in which the U.S. Department of Energy is supporting hydrogen fuel cell development can be found at the Department of Energy's Hydrogen Program web page: http://www.hydrogen.energy.gov/

the necessary framework to create these early markets. A manufacturing region that can pool its resources, organize stakeholders to create strong partnerships and have the support of strong public policy that invests in research and development as well as market capture techniques will position itself to be part of the global supply-chain as the global hydrogen economy takes shape in the coming years.

PART TWO: SUMMARY OF INDUSTRY EXPERT INTERVIEWS

RESEARCH INTERVIEW WITH MR. GEORGE A. SATORNINO

President, SIERRA LOBO Inc.
August 2009

Thank you for meeting with Mr. Brandon Henneman, and myself as members of CSU Research Team regarding H2 Project and the impact to the economy. You focused on some key points and responded to specific questions. You provided us with a summary of your company and its involvement with hydrogen technology. You have stated that your company began with four former NASA Contractor engineers of the NASA Lewis Research Center at Plum brook Station. You have been involved with Cryogenic Fluids in the 1980s until present. Your company incorporated in 1993 as a Small Disadvantaged Business and you currently have over 400 employees. Your company is focused on High-Tech Engineering Services, Technologies and Products. You emphasized that your company has built in-house expertise on hydrogen technology. You referred the importance of training a highly skill technical workforce which includes providing challenging assignments on key technical projects. Your company's performance on project management and technical operations has led to successful awards of contracts from both the public and private sectors.

You said that your company initial role in the H2 Refueling Station Project was to provide a cost estimate. You offered the detail cost estimation to build the station as part of the proposal submitted by the H2 Project Team. You expressed that the project has the potential to be successful as a demonstration and could encourage other metropolitan cities in Ohio to replicate the initiative. You responded to one of our question involving commercialization. We asked you to answer the following question; what do you see as the logical process that should take place in order to commercialize fuel cell technologies as rapidly as possible? You have replied that there must be product roadmap and cost model to commercialize the fuel cell technologies that includes a price and profit margin and mass production for manufacturers and contracting. You mentioned the importance of identifying a 'tipping point' in production volume, where the emerging fuel cell technologies would reach scale economies and become cost competitive with the incumbent technologies they could potentially replace.

In terms of our question regarding public policy and its role on commercialization, you said that the focus should be government and making cities greener. Once technologies are identified that are economically feasible and more environmentally benign than current technologies, you mentioned that the role of government was to help bring emerging 'green' technologies to scale by incentivizing their early purchase. You could see cities adopting a policy that support a clean environment initiative such as H2 Project. You responded to our question regarding what might you view a hydrogen economy would look like and you said that the next step would be going greener which includes users' friendly fleet vehicles operated by fuel cell technology. You

also stated that the big cities would help resolve the "chicken and egg dilemma" regarding hydrogen (or other source of fuel) infrastructure and commercialization due to their high population density. Dense urban regions could make fuel easily accessible to large numbers of residents through carefully planned infrastructure. You said that public opinion would play a key role in commercialization and you must identify your supporters and fight your battles. You responded to questions about Ohio and Northeast Ohio comparative advantage and impact on job creation in fuel cell technologies. You stated that Ohio has a rich history of an educated population. You made reference to that fact that Ohio produced highly talented technical workforce. You said that you had met many individuals who were raised in Ohio and have contributed to advance technologies. You said that you could go anywhere in the United States and find someone from Ohio who has been involved with leading significant technical project. You stated that federal research institutions located in Ohio such as NASA Glenn Research Center and Wright Paterson Air Force Research Laboratory have produced talents. Your only concern was that more could be done to capitalize on this resource by both political officials and the federal research agencies to create a stronger commercial infrastructure in Ohio and retain jobs in support of the technological advances made in the region. We could learn from other states such as Texas and Alabama as to how to retain the educated population and the workforce and benefit the Ohio economy.

Respectfully Submitted By,
Robert Romero, Executive In Residence
Cleveland State University
Nance College of Business

RESEARCH INTERVIEW WITH DR. PAUL R. PROKOPIUS

President, Fuel Cell Consultants
April 2009

Thank you for meeting with Mr. Brandon Henneman, and myself as members of CSU Research Team. I have found the meeting to be really informative. I began by summarizing the diagram of the entire system for the Refueling Station prepared by Dr. Valerie Lyons, National Aeronautics Space Administration (NASA) Glenn Research Center (GRC) Chief, In-Space Power and Propulsion and presented me. You provided a historical perspective on fuel cell technology. You said that the in early 1970s, it was the beginning of fuel cell and battery technology due to the energy crisis. In the 1980s, emission regulations created the interest in federal agencies such as NASA and Department of Energy (DOE). NASA and DOE began working fuel cell hydrogen technology with DOE as part the Car Program. NASA/DOE involved General Motors (GM), United Technology Corporation (UTC), Ballard Power and others. You were a NASA Engineer during that time. In 1996, you retired and worked as a Fuel Cell Consultant with Proton Energy and Analex Corporation, EPRI, DOE and numerous venture capital firms.

Proton Energy worked to develop an electrolyzer and began to market the product with the government and industry. The electrolyzer was built hand made. There were significant interests in the electrolyzer. Proton Energy decided to invest in a building to manufacture the electrolyzer in Connecticut. The demand was due to Vice President Al Gore's Partnership for new Generation Vehicle Fuel Cell Program part of which was to develop the fuel cell and hydrogen generation industries leading to a "hydrogen economy". There were plans by Proton Energy to hire 400 employees who would work in Connecticut (30% Engineers). Proton Energy was traded in the US stock market during the late 1990s. However, President George Bush was elected and the interest for the hydrogen fuel cell technology declined due to the President's efforts to use Fossil Fuels. This had major impact on Proton Energy and they were forced to dissolve the company. However, they recently emerged from bankruptcy under private ownership.

You said that you continued to be involved with Fuel Cell Technologies and learned more regarding commercialization and cost. For instance, you have been able to conclude that the cost to build a refueling station is appropriately 1.5 million. The most expensive cost is the electrolyzer and it represents about 70 percent of the overall cost for the refueling station. Also, the cost would be substantially reduced based on the demand. The other major cost is the expense to build a Fuel Cell Plant for the industry. The projection for a plant could be 100 million for a high production, automated facility for manufacturing automotive fuel cells. However, niche markets such as various fleet applications could be addressed with the higher priced fuel cells such as those manufactured in low capacity pilot production facilities. You said that the Fleet Operators have an immediate interest in this technology such as Federal Express, UPS, as well as Lift truck manufacturers (Crown). In terms of government, port authorities would have the greatest interest.

You emphasized that the fact the technology is presently ready now. The parts and equipment are available. The electrolyzer is the key component and can be built handmade. This is why Automobile Industry has an interest in the technology. Automobile companies have produced hydrogen vehicles. GM has 50 vehicles in California. A Refueling station must be available within a 30 miles radius of the vehicles. There are 120 stations around the world and 71 in California. Most, if not all refueling stations are operated with the electric grid. Our project will be the first to have the flexibility run solely on renewable such as wind, solar and other sources or in combination with the grid. Other applications for the technologies are portable generators to serve as back-up power supply for Hospitals, and Companies. In particular, computers are critical to many industries and power is required 24 hours a day.

We discussed other possible concerns with the technology such as policy restrictions imposed by state of Ohio and you stated that there are no current restrictions. Finally, I asked you if there were any other potential contacts that you would suggest for us to follow up regarding the project. You offered a couple of names, Mr. Bill Smith, former VP of Marketing for Pronto Energy, Mr. Eric White, former Station Development Manager of Pronto Energy and Mr. Tom Maloney, former Station Program Manager who handled manpower numbers to assemble a refueling station.

Respectfully Submitted By,
Robert Romero, Executive In Residence
Cleveland State University
Nance College of Business

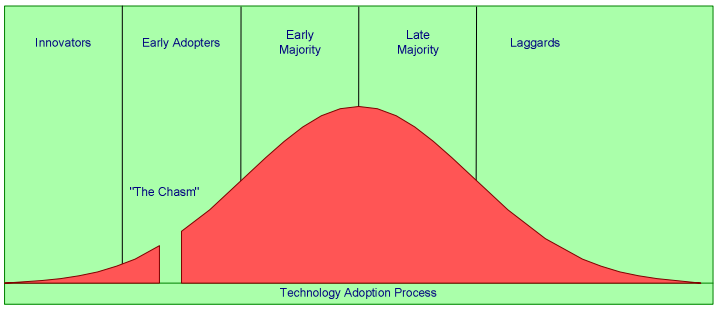
RESEARCH INTERVIEW WITH MR. BENSON P. LEE

President, Technology Management, Inc.
July 2009

Thank you for meeting with Mr. Brandon Henneman, and myself as members of CSU Research Team. I have found the meeting regarding H2 Project and the impact to the economy to be really informative. You focused on some key points rather than to respond to specific questions. You have stated that the largest early adopter customer for fuel cell technologies (of all types) is the US military and an emerging niche market for hydrogen fuel cells are to replace batteries on fleet vehicles such as forklifts, where the day begins and ends in the same location. This minimizes dependence on a dispersed hydrogen supply or delivery infrastructure.

You also discussed "missionary marketing" principles which are used to introduce game-changing or disruptive technologies and as an example identified important similarities of the hydrogen fuel cell technology to other technologies such as today's cell phones. An example is a focus on key features, not on the complete product. When first introduced mobile, phones were wireless and portable and not much else. They were imperfect products, but had new features never before available to the public that offered a value proposition. You recalled a time when the over-size wireless phone was expensive, had a limited battery life and was the size and weight of a brick, but it provided high value -- a method for you to communicate with your family when you had been on the lake with friends and colleagues. It presented a sense of security. These same principles -- demonstrating a value proposition even in an incomplete product – hold true today for hydrogen fuel cell products.

You cited several reading materials that address various concepts used in the commercialization of emerging or disruptive technologies. They all focus on the incremental stages of creating value propositions for early adopter customers and using this to generate market demands spread over time phases, i.e., Innovators, Early Adopters (feature sensitive), -- the "chasm" - Early Majority (Cost & Performance sensitive), Late Majority, and Laggards. These are shown in the chart.



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You recommended reading several books (all available in paperbacks): in importance, they were 1) "Innovator's Dilemma" by Mr. Clayton M. Christensen, 2) "Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers" and "Inside the Tornado", both by Mr. Geoffrey A. Moore and 3) "The Tipping Point: How Little Things Can Make a Big Difference" by Mr. Malcolm Gladwell. These would be basic readings for entrepreneurs who are presently interested in new businesses developing disruptive technologies.

You noted that hydrogen fuel cell technology is feasible now and must be managed as a disruptive technology. Hydrogen fuel cell technologies have many applications and the potential to change US economy by introducing an entirely new industry based on a unique set of American technology, workforce skills and industry. You also noted that within the world of "near-commercial" fuel cell systems, nearly all use one of two basic types (PEM and SOFC) and that there are a wide range of products being developed for different applications, customers and markets. Most can be differentiated from each other by the types of fuels they require and power output (<1kW, 1kW-100kW, >100kW). You mentioned that your company is commercializing a 1kW SOFC system which can operate on nearly all indigenous fuels found throughout the world, including jet fuel, diesel, biogas, and used vegetable (cooking) oils.

You believe fuel cells have the potential to impact every energy-dependent product or service today by providing an environmentally benign energy alternative to the utility grid, the internal combustion engine, and many types of batteries in applications such as stationary (distributed, point of use power), on board vehicles, and mobile electric power.

You emphasized the uniqueness of the H2 Refueling Station Project which has been structured as a public led and private funded commercialization model, separated into two initial phases. Phase I has NASA leading the technology and Phase II will have CSU leading the project from a commercialization standpoint. You stated that the private sector could begin to profit from the technology and build the local economy, but not in Phase 1. This introduces a "pay to play" concept. NASA Glenn Research Center plays a critical and significant role by applying its technological knowledge and leadership to validate the commercial use of a hydrogen refilling station. Private sector key collaborators have "paid" by offering hardware such as hydrogen bus, heavily discounted electrolyzer and business knowledge and capabilities such as project management and cost estimation.
The collective vision is a demonstration of a renewable hydrogen refueling station which can be replicated wherever renewable hydrogen is required or desirable as a fuel. The demonstration at the Great Lakes Science will use a (PEM) fuel cell-powered RTA bus that would operate in a highly visible venue in the Euclid corridor and could catalyst imaginative new ideas for products, services and businesses. The reasoning is that an "enabling technology" such as commercially available "On-site hydrogen production" would offer a value proposition never before available to entrepreneurs and businesses. As evidence of this, there has already been interest expressed for a refueling station at other locations. These include from the Great Lakes Science Center to provide sustainable power for the SS Mather, the County Commissioners for a sustainable north-south bus route through the Valley, and at the Cleveland-Cuyahoga Port Authority for clean power.

The proposed station has the ability to be movable and available for other initiatives. GLSC, Port Authority, and County Governments would be considered early adopters. For industry, niche markets such as lift trucks, forklifts, and golf club trucks manufacturers have already expressed interest, since it would provide a readily available source of renewable hydrogen for their various devices and vehicles.

You stated that as a result of NASA Glenn Research Center's involvement with the technology over the decades, there is currently a professional workforce in Northeast Ohio with the expertise to work with hydrogen fuel cell and can re-train others. If true, this gives Cleveland the most experienced hydrogen fuel cell workforce in the world. Other products and components necessary to build the refueling station currently exist as well in Northeast Ohio due to strong manufacturers' base, and that Case Western Reserve University is a world leader in the development of PEM fuel cells.

You emphasized the past and continuing role of the Cleveland Foundation being highly supportive of renewable power. To date, they have offered initial funds to begin the project and would be an important partner as the project matures and interest for the technology expands. You saw how intellectual properties and licensing fees from the project could be placed and used to fund an economic development trust administered by the Cleveland Foundation and a role for CSU Nance to serve as a distribution committee. You stated that having the cachet of the Cleveland Foundation managing the funds would add credibility and encourage the participation of business and industry.

Respectfully Submitted By,
Robert Romero, Executive In Residence
Cleveland State University
Nance College of Business

PART THREE: A FRAMEWORK FOR TAKING HYDROGEN FUEL CELL TECHNOLOGIES TO MARKET: POLICY, STAKEHOLDERS, FUNDING, INFRASTRUCTURE AND ASSETS

A STUDY OF CALIFORNIA AND OHIO

Prepared by:
The Center for Sustainable Business Practices,
Nance College of Business, Cleveland State University

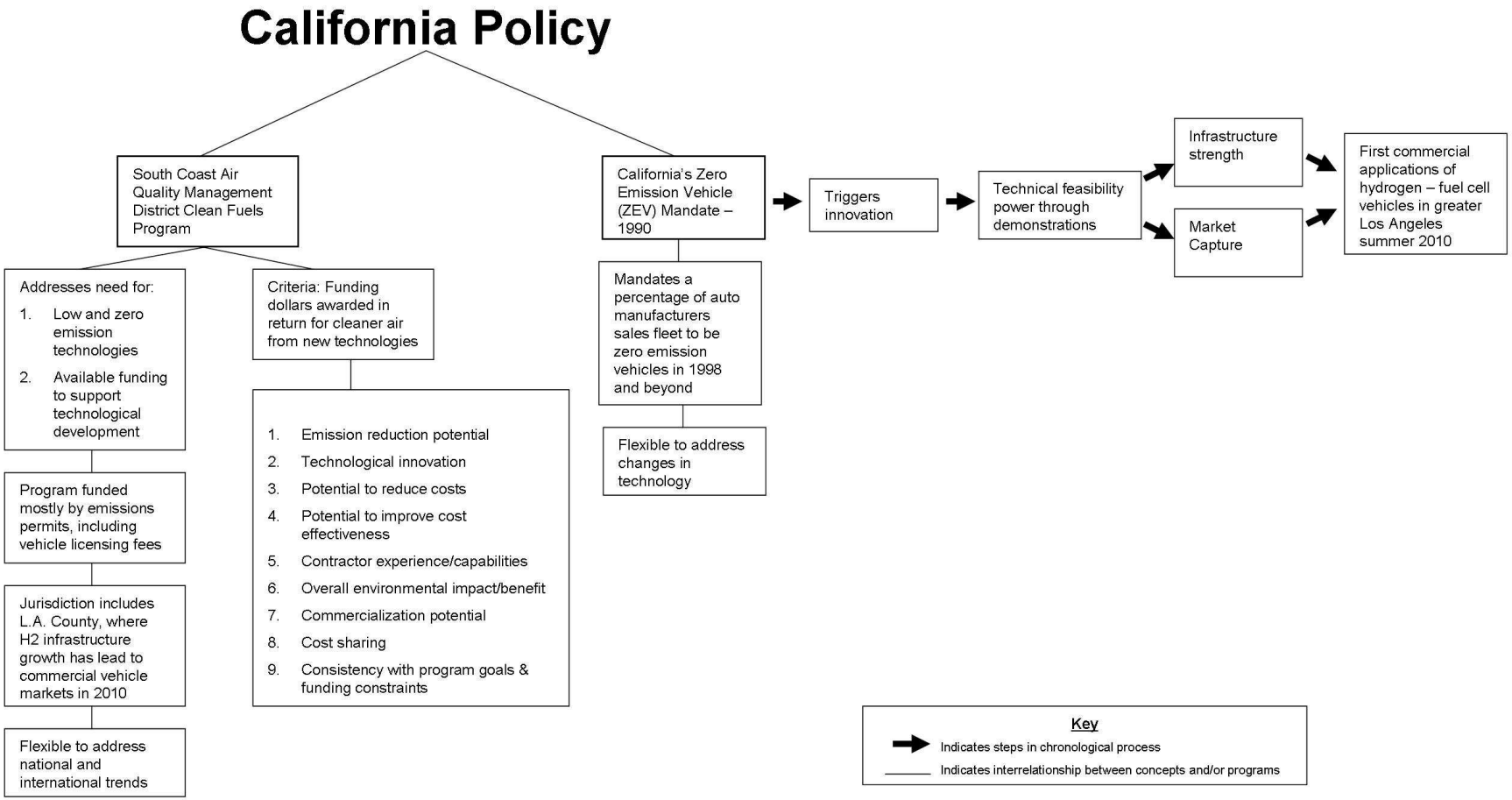
The Center for Economic Development,
Maxine Goodman Levin College of Urban Affairs, Cleveland State University

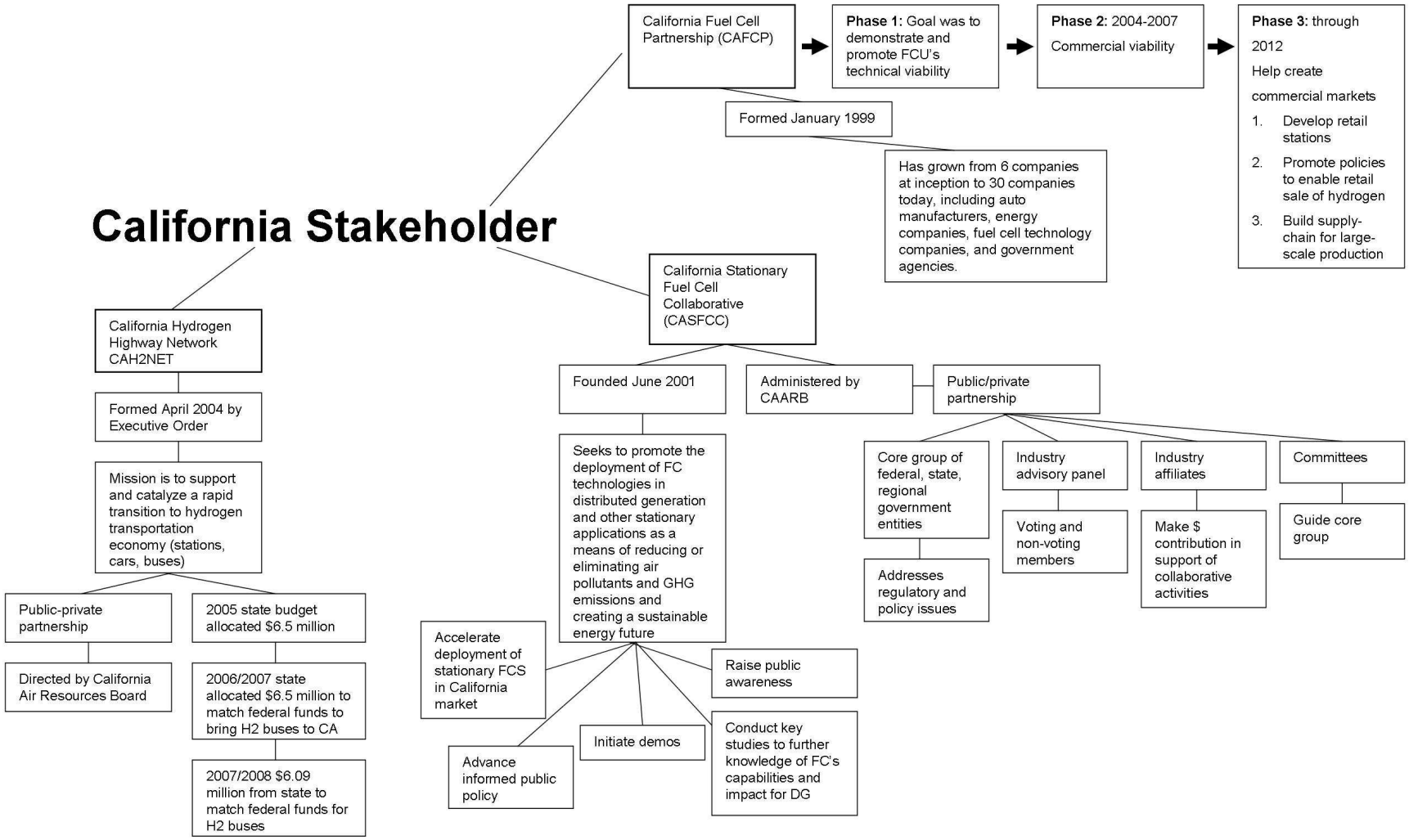
As part of:
"A Clean Energy Program for Economic Development"
Construction of a Renewably-Generated-Hydrogen

Fueling Station as a Template to be Duplicated for Commercialization
funded by The Cleveland Foundation

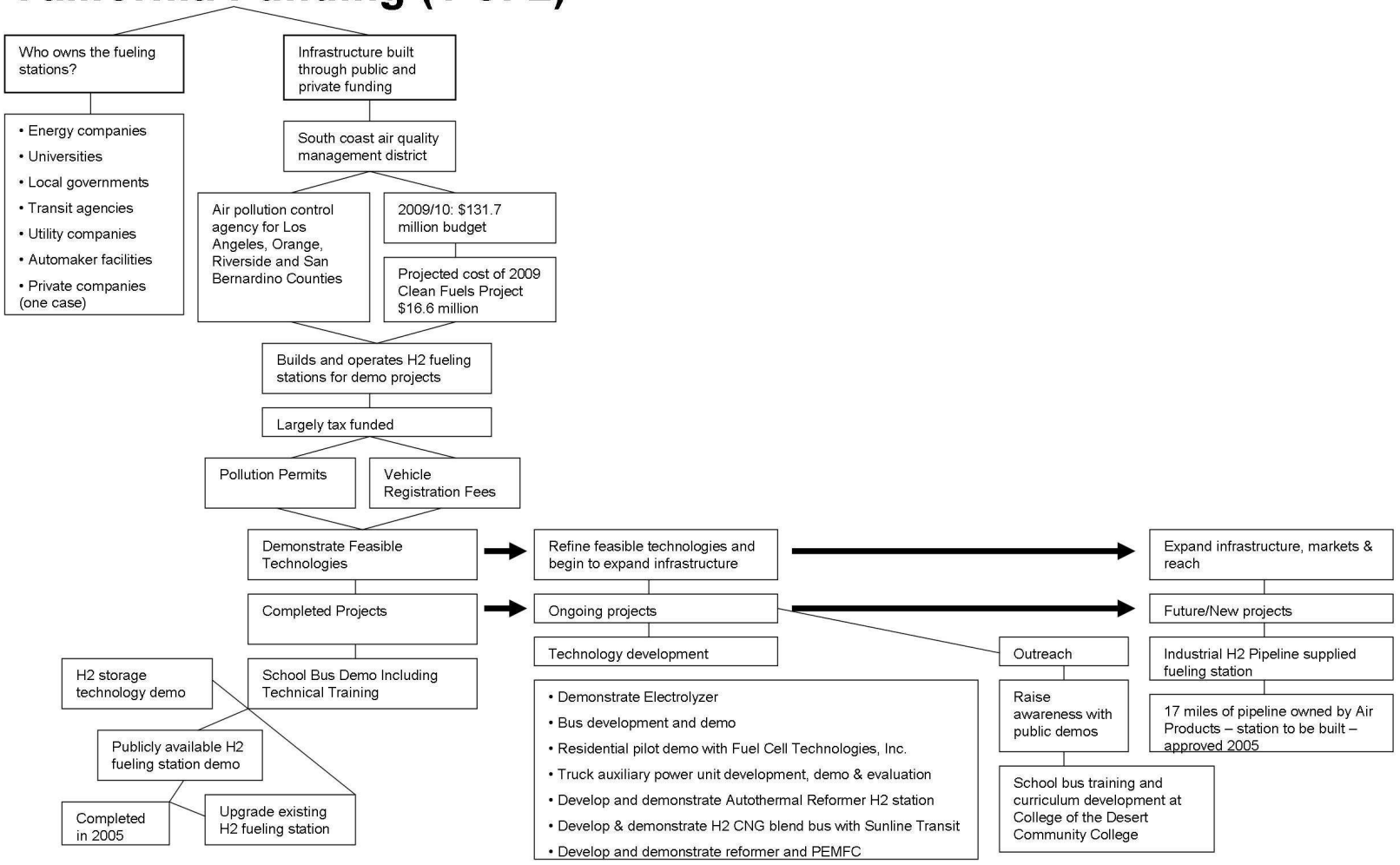
ACRONYM KEY

- CAARB: California Air Resources Board
- CAFCP: California Fuel Cell Partnership
- CAH2NET: California Hydrogen Highway Network
- CASFCC: California Stationary Fuel Cell Collaborative
- CNG: Compressed Natural Gas
- DG: Distributed Generation
- DOT: Department of Transportation
- DOE: Department of Energy
- EERE: Energy Efficiency and Renewable Energy
- FC: Fuel Cell
- FCS: Fuel Cell System
- FCV: Fuel Cell Vehicle
- GHG: Greenhouse Gas
- GLSC: Great Lakes Science Center
- NEO: Northeast Ohio
- OHFCP: Ohio Fuel Cell Partnership
- PEMFC: Polymer Electrolyte Membrane Fuel Cell
- U.S. DOE: United States Department of Energy
- U.S. DOT/FTA: United States Department of Transportation Federal Transit Administration
- ZEV: Zero Emission Vehicle

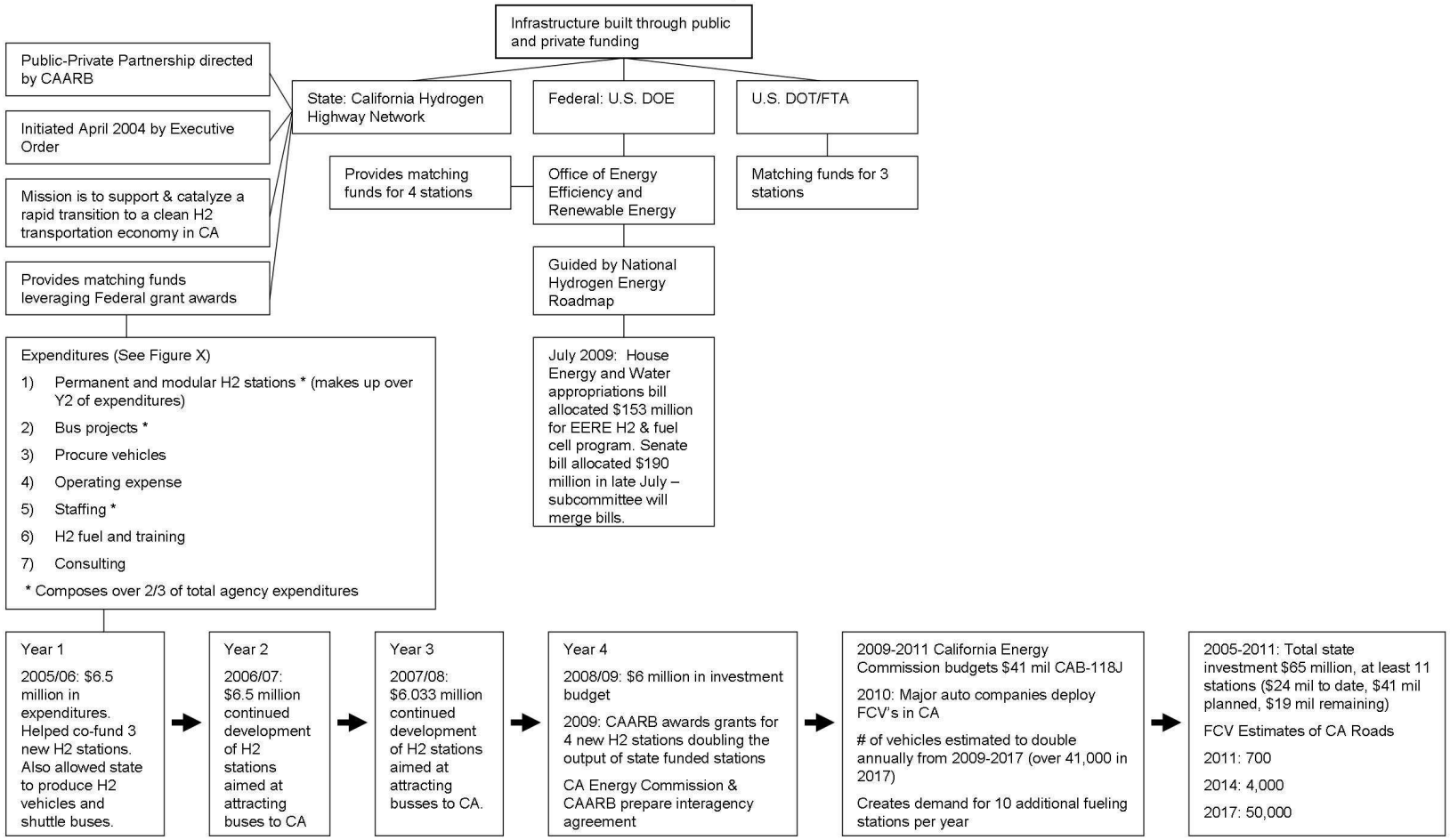

California Policy
South Coast Air Quality Management District Clean Fuels Program
Addresses need for:
1. Low and zero emission technologies
2. Available funding to support technological development
Program funded mostly by emissions permits, including vehicle licensing fees
Jurisdiction includes L.A. County, where H2 infrastructure growth has lead to commercial vehicle markets in 2010
Flexible to address national and international trends
Criteria: Funding dollars awarded in return for cleaner air from new technologies
1. Emission reduction potential
2. Technological innovation
3. Potential to reduce costs
4. Potential to improve cost effectiveness
5. Contractor experience/capabilities
6. Overall environmental impact/benefit
7. Commercialization potential
8. Cost sharing
9. Consistency with program goals & funding constraints
California's Zero Emission Vehicle (ZEV) Mandate – 1990
Mandates a percentage of auto manufacturers sales fleet to be zero emission vehicles in 1998 and beyond
Flexible to address changes in technology
Triggers innovation
Technical feasibility power through demonstrations
Infrastructure strength
Market Capture
First commercial applications of hydrogen – fuel cell vehicles in greater Los Angeles summer 2010
Key
Indicates steps in chronological process
Indicates interrelationship between concepts and/or programs


California Stakeholder
California Fuel Cell Partnership (CAFCP)
Phase 1: Goal was to demonstrate and promote FCU's technical viability
Phase 2: 2004-2007
Commercial viability
Phase 3: through 2012
Help create commercial markets
1. Develop retail stations
2. Promote policies to enable retail sale of hydrogen
3. Build supply-chain for large-scale production
Formed January 1999
Has grown from 6 companies at inception to 30 companies today, including auto manufacturers, energy companies, fuel cell technology companies, and government agencies.
California Hydrogen Highway Network CAH2NET
Formed April 2004 by Executive Order
Mission is to support and catalyze a rapid transition to hydrogen transportation economy (stations, cars, buses)
Public-private partnership
Directed by California Air Resources Board
2005 state budget allocated $6.5 million
2006/2007 state allocated $6.5 million to match federal funds to bring H2 buses to CA
2007/2008 $6.09 million from state to match federal funds for H2 buses
California Stationary Fuel Cell Collaborative (CASFCC)
Founded June 2001
Administered by CAARB
Public/private partnership
Seeks to promote the deployment of FC technologies in distributed generation and other stationary applications as a means of reducing or eliminating air pollutants and GHG emissions and creating a sustainable energy future
Accelerate deployment of stationary FCS in California market
Advance informed public policy
Initiate demos
Raise public awareness
Conduct key studies to further knowledge of FC's capabilities and impact for DG
Core group of federal, state, regional government entities
Addresses regulatory and policy issues
Industry advisory panel
Voting and non-voting members
Industry affiliates
Make $ contribution in support of collaborative activities
Committees
Guide core group

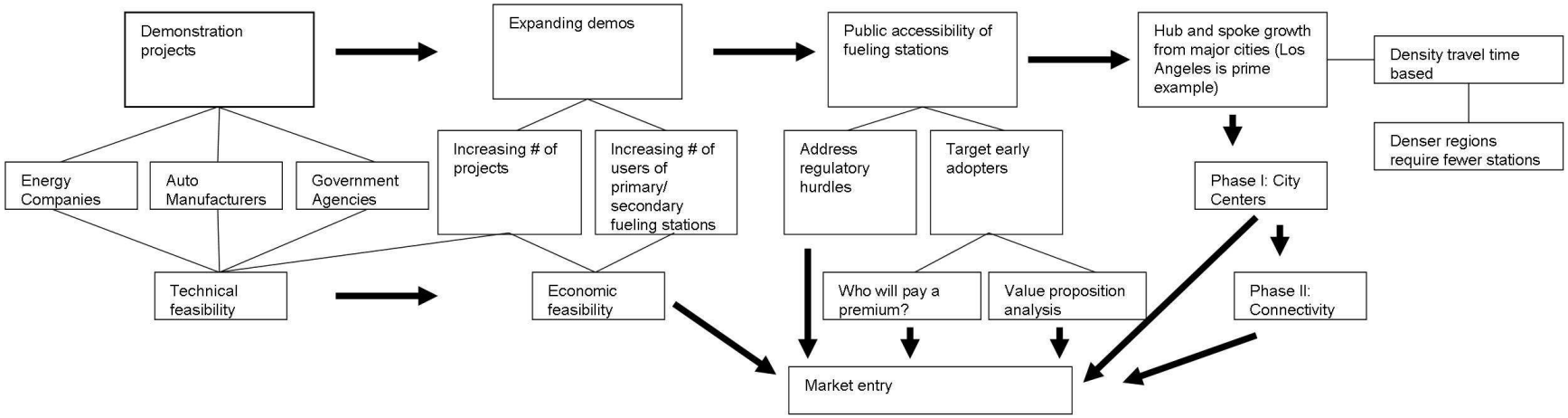
California Funding (1 of 2)



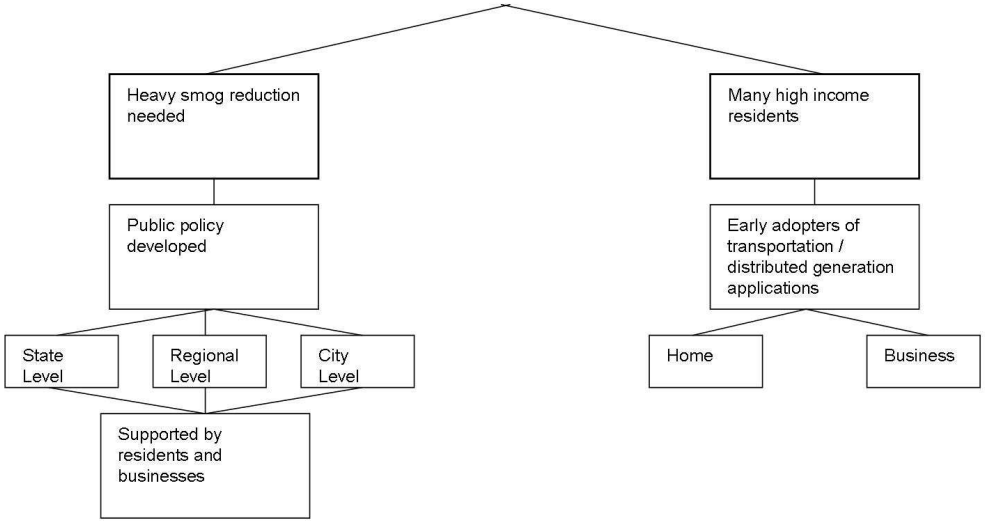
California Funding (2 of 2)

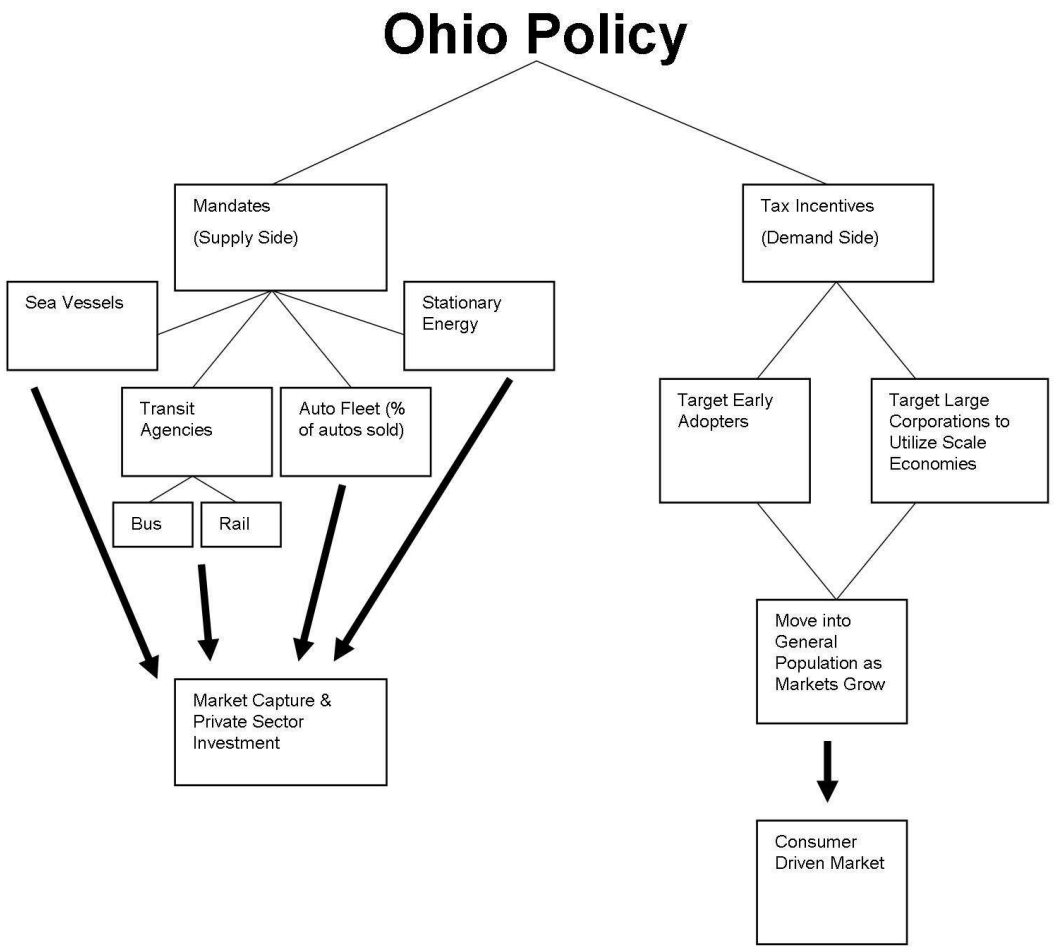


California Infrastructure

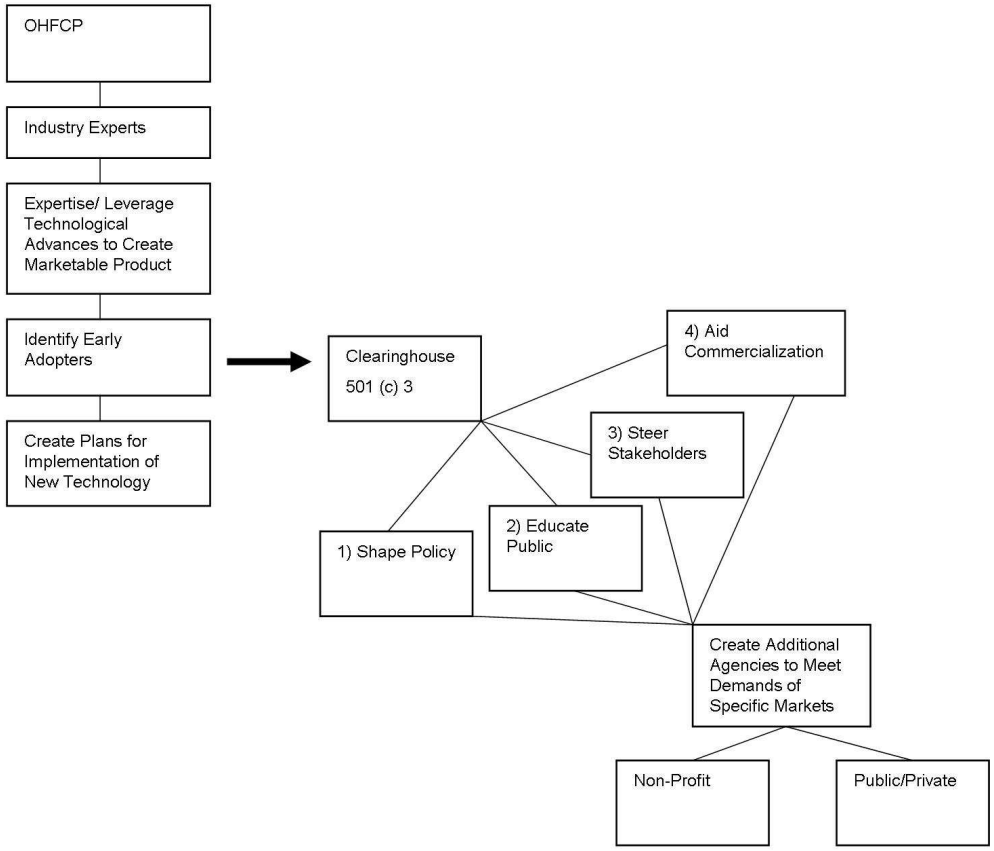


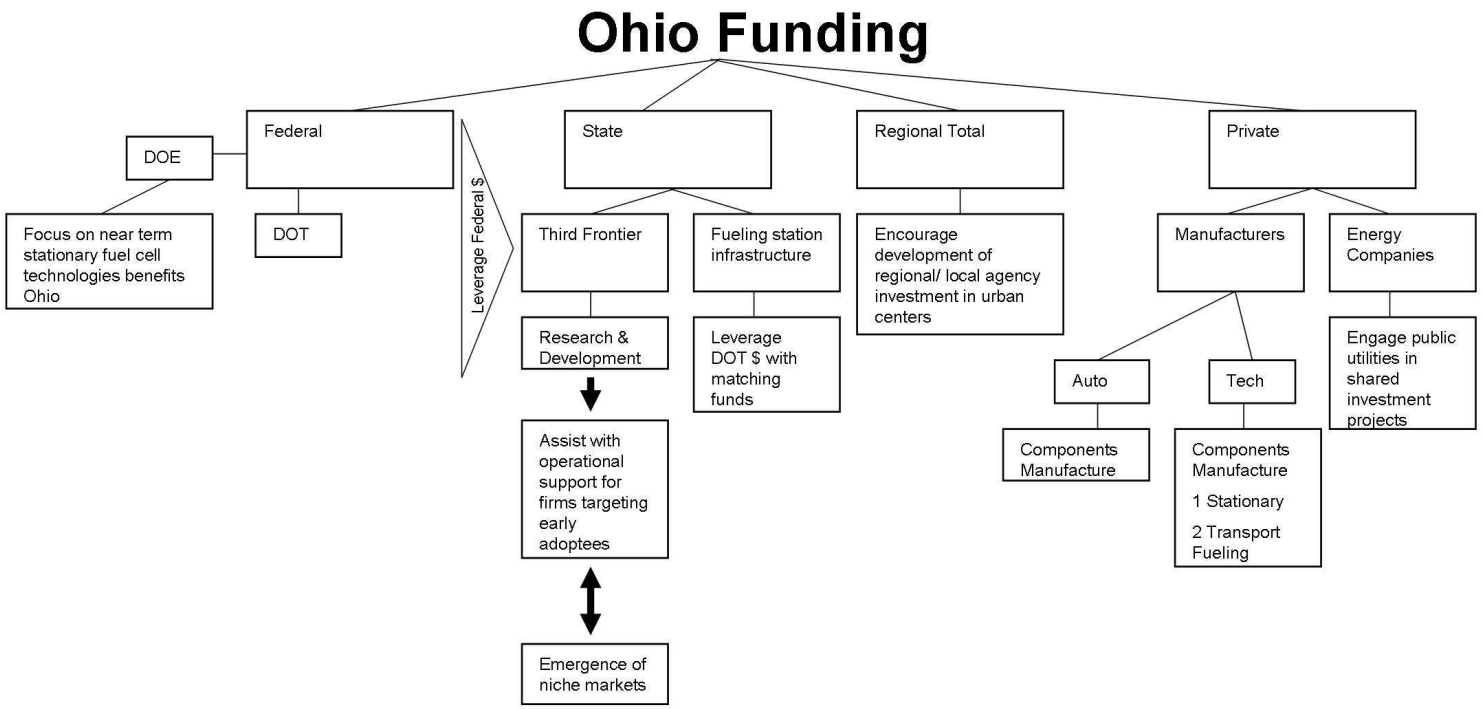
California Economics / Consumer Preferences



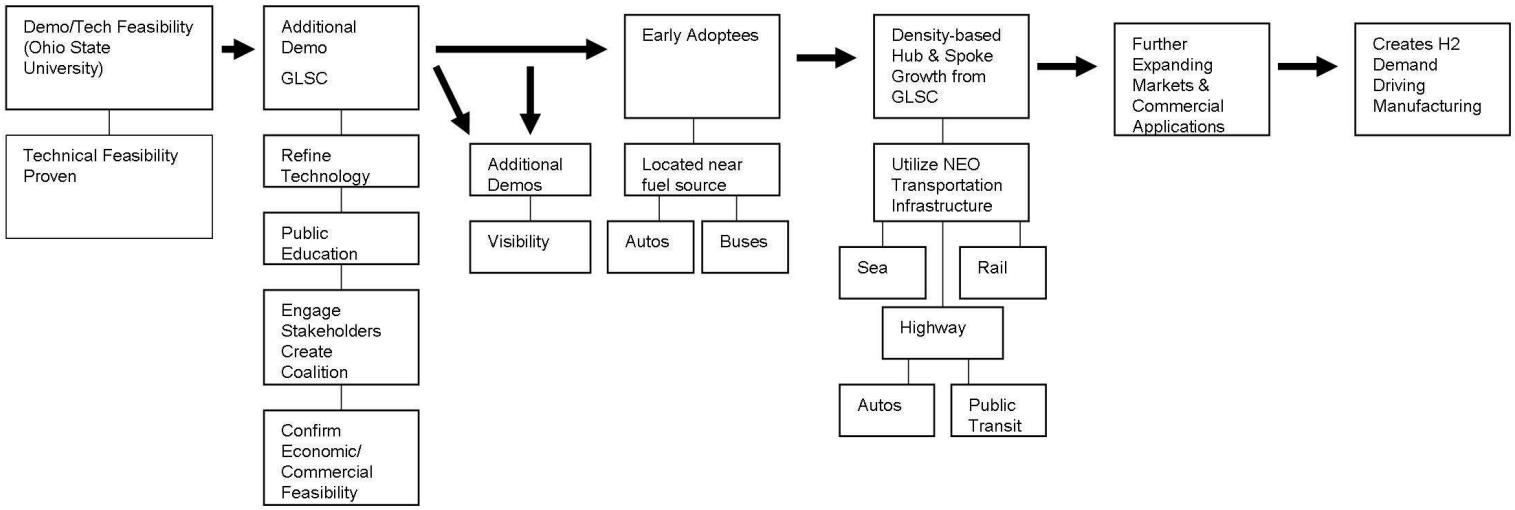

Ohio Policy
Mandates
(Supply Side)
Tax Incentives
(Demand Side)
Sea Vessels
Stationary Energy
Transit Agencies
Auto Fleet (% of autos sold)
Bus
Rail
Target Early Adopters
Target Large Corporations to Utilize Scale Economies
Market Capture & Private Sector Investment
Move into General Population as Markets Grow
Consumer Driven Market

Ohio Stakeholder

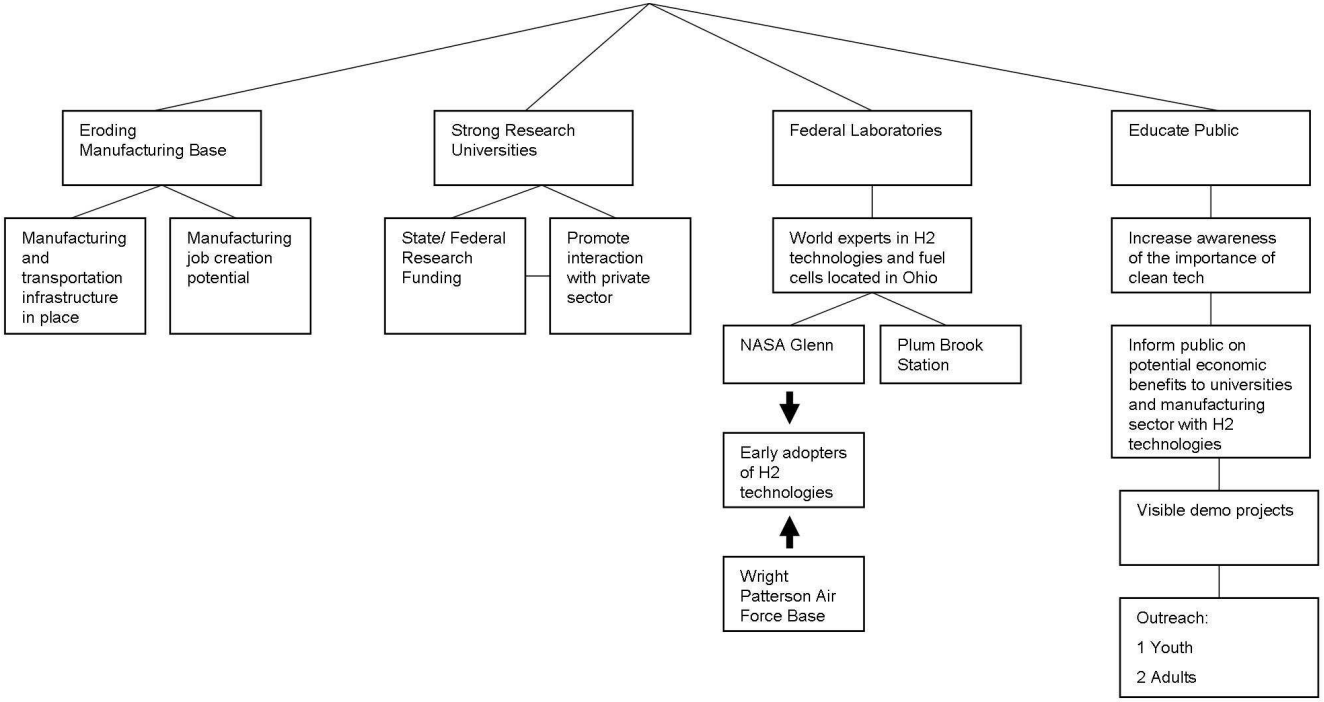



Ohio Funding
Federal
DOE
Focus on near term stationary fuel cell technologies benefits Ohio
DOT
Leverage Federal $
State
Third Frontier
Research & Development
Assist with operational support for firms targeting early adoptees
Emergence of niche markets
Fueling station infrastructure
Leverage DOT $ with matching funds
Regional Total
Encourage development of regional/ local agency investment in urban centers
Private
Manufacturers
Auto
Components Manufacture
Tech
Components Manufacture
1 Stationary
2 Transport Fueling
Energy Companies
Engage public utilities in shared investment projects

Ohio Infrastructure



Ohio Economics / Consumer Preferences



PART FOUR: MATERIALS FOR PUBLIC EDUCATION AND STAKEHOLDER ENGAGEMENT

Renewable

A Public/Private Model

A Template for Economic Development and Jobs

Cleveland Foundation

Cleveland State University
Nance College of Business Administration

National Aeronautics and Space Administration
Glenn Research Center
Cleveland • Ohio

BEST SYSTEM

OAI
Ohio Aerospace Institute

GREAT LAKES Science Center

Parker

TMI Fuel Cell Systems

SIERRA LOBO

THE UNIVERSITY OF TOLEDO 1872

earth DAY COALITION

CSU

Phase I: Publicly Led, Privately Funded

NASA-led collaboration will develop a renewable hydrogen refueling station at the Great Lakes Science Center with a hydrogen fuel cell powered RTA bus as a technical and business demonstration project.

Phase II: Led by CSU

CSU will be creating a road map detailing the process of using the Hydrogen fueling station as a catalyst for economic development and job creation.

Renewable Hydrogen Today

This clean energy program for economic development was funded by the Cleveland Foundation.

Phase I: Publicly Led, Privately Funded

Phase I is a NASA-led collaboration that will develop a renewable hydrogen refueling station at the Great Lakes Science Center with a hydrogen fuel cell powered RTA bus as a technical and business demonstration project.

Phase II: Led by CSU

Cleveland State University will create a road map detailing the process of using the Hydrogen fueling station as a catalyst for economic development and job creation.