Hydrogen Fueling Infrastructure:
The USCAR Perspective

Environmental, societal, and political imperatives are driving the need for an unparalleled transition in transportation energy. Concerns about global climate change and the fear of reaching an environmental "tipping point" have intensified pressures to dramatically reduce fossil fuel emissions. Growing global demand for energy is driving concerns about energy supply. And geopolitical and geological factors affecting oil and natural gas supplies have given increased urgency to energy security. This perfect storm of converging forces is impelling the U.S. and the rest of the developed world to move aggressively to reduce the energy and environmental impacts of personal and commercial transportation.

In response to these pressures, all major manufacturers of passenger vehicles have committed to develop new automotive propulsion systems that can rely on diversified and, ultimately, cleaner energy sources. A compelling vision of a sustainable future rests on electrically driven automobiles. Whether energized from electric grid-charged batteries and/or hydrogen fuel cells, these systems offer substantial increases in efficiency, zero vehicle emissions, and the potential for development of a broad range of energy sources that can produce electricity and hydrogen with increasingly renewable content.

This paper focuses on fuel cell-electric vehicles (FCEVs) fueled by hydrogen that is conveniently accessible to the public through fueling stations like those used for gasoline. It examines, from a U.S. perspective, the deployment of such an infrastructure.

The commitment of the major vehicle developers to bring fuel cell-electric vehicles to maturity is undeniable. Several companies have already invested over a billion dollars each to develop FCEVs with performance and amenities comparable to conventional vehicles. A number of these vehicles are now in service in public demonstration programs; this includes routine use of the vehicles for mail and other delivery services as well as by government agencies and the general public.

While U.S. automakers continue to commit resources to complete the development of full-performance, affordable FCEVs, there appears to be comparatively little parallel investment in or development of hydrogen production, delivery, or dispensing technology. There has been no significant movement on equipment "proving grounds" to verify new fueling concepts and there are currently no public deployments of fueling stations planned for public demonstrations. In short, there are few market learnings to accompany the aggressive development and demonstration of FCEV technologies. As a result, accelerated investment by energy providers commensurate with the aggressive investment occurring in fuel cell-electric vehicle technologies is urgently required.

Early barriers to infrastructure have now been lowered. National Fire Protection Association (NFPA) and International Code Council (ICC) codes for fueling stations are ready for insertion into State Codes. The federal government has begun to train permitting officials who lack experience in granting permits for hydrogen facilities. Both the federal and state governments continue to show leadership in offering funding for installation of hydrogen fueling stations.

In addition to these actions, there is a need for policies targeting coordinated rollout of fuel cell-electric vehicles with an adequate number of fully capable and regionally dispersed hydrogen fueling stations in order to satisfy expected driver demand. Such policies must focus on both fuel quantity and fuel availability, i.e., the coverage required for drivers to feel secure about ready access to hydrogen.

Immediate action on fueling infrastructure development is urgently required. The near-term shift to FCEV deployment for pre-commercial "real world" validation of market acceptance requires a complementary shift in hydrogen fueling station deployment – because convincing and compelling demonstrations of the safety, convenience, and benefits of hydrogen are critical to market acceptance. Key requirements include increased fuel volume per station, larger numbers of stations for urban coverage, and customer-friendly accessibility.

Price is also key to customer and market acceptance of hydrogen and FCEVs. Numerous studies have shown that the near-term total cost-per-mile for hydrogen could be equivalent to $2.00 to $3.00 per gallon of gasoline ($4.00 to $6.00 per kilogram of hydrogen untaxed)* when fueling stations are well-utilized. And as more hydrogen becomes available for transportation, prices are projected to decrease. The U.S. Department of Energy (DOE) long-term target cost for producing, distributing, and dispensing hydrogen is equivalent to $1.00 to $1.50/gal of gasoline ($2-3/kg of hydrogen). DOE has identified several pathways in its Hydrogen Roadmap with the potential to meet this target.

The deployment and utilization of the next generation of hydrogen fueling stations will serve as public proof points that customer needs can be met in terms of fuel cost, availability, quality, ease of access, and convenient dispensing. These demonstrations will play a significant role prior to 2015 in determining the market readiness of both hydrogen vehicles and fuel.

A number of analyses have shown that deployment of a fueling infrastructure is within reach. A network of just 12,000 hydrogen stations would put hydrogen within two miles of 70 percent of the U.S. population (those living in the 100 largest metropolitan areas) and connect the major U.S. metro areas with a hydrogen refueling station every 25 miles. A practical first step would be to focus initial fueling coverage in concentrated regions. For example, 40 high-capacity stations in a large metropolitan area such as Los Angeles could be built with an initial investment of just $200 million and provide refueling for more than 40,000 FCEVs.

Going forward, vehicle manufacturers and fuel providers must pursue a consistent leadership commitment that brings hydrogen-fueled vehicles and fueling stations, and their associated infrastructures, to commercial maturity. In parallel, strong government leadership is crucial – to mitigate the investment risks of accelerated market entry, and to encourage customer acceptance through public recognition of the societal benefits that hydrogen and fuel cell-electric vehicles provide in terms of energy security and environmental sustainability.

It is important to make the transition to a hydrogen economy one of deliberate and accelerating progress, where hydrogen production pathways change over time and environmental benefits improve as technology advances. The momentum required to move the nation must continue – building to a pre-commercial stage of regional deployment. This buildup must include deployment of a mature generation of both fuel cell-electric vehicles and hydrogen fueling stations. In the meantime, today's deployments will continue to feed further learning, build confidence in the long-term vision, and create the necessary asset base for future growth.

In summary, fueling station deployment needs to satisfy driver demand for confidence in finding fuel outlets – so now is the time to demonstrate safe, convenient, and affordable accessibility to hydrogen. Numerous studies show hydrogen cost at the pump can be equivalent or better than gasoline in energy cost per-mile-driven. Vehicle deployment is broadening and moving to pre-commercial market readiness. Corresponding investment in fueling infrastructure has lagged behind, in terms of both new technology and deployment initiatives. An investment commensurate to FCEV investment is required to give the public comfortable, affordable, and regionally available access to hydrogen.

**A fuel cell-electric vehicle can generally travel twice as far on a kilogram of hydrogen as an internal-combustion-engine vehicle can travel on a gallon of gasoline.*

TEN THINGS YOU SHOULD KNOW ABOUT A HYDROGEN FUELING INFRASTRUCTURE FOR AUTOMOBILES

1. More than 40 billion kilograms of hydrogen* are produced globally each year, enough hydrogen to fuel over 150 million fuel cell-electric vehicles.

2. Half of the hydrogen produced in the United States (enough to fuel 13 million fuel cell-electric vehicles) is already dedicated to transportation – it is used in oil refineries.

3. A large hydrogen production site exists today near almost every major U.S. and European city.

4. Based on numerous studies, the near-term total cost (on a per-mile basis) of producing, distributing, and dispensing hydrogen at volume for use in fuel cell-electric vehicles is equivalent to $2.00 to $3.00 per gallon of gasoline (untaxed).

5. The U.S. Department of Energy (DOE) long-term target cost for producing, distributing, and dispensing hydrogen is equivalent to $1.00 to $1.50 per gallon of gasoline. Several pathways appear to have the potential to meet this target.

6. A U.S. network of 12,000 hydrogen stations would put hydrogen within two miles of 70 percent of the U.S. population (those living in the 100 largest cities). A focused regional approach in a major metropolitan area such as LA based on 40 large-capacity stations would require an investment of just $200 million and adequately kick-start the infrastructure as the fuel cell vehicle parc grows to 40,000 vehicles.

7. Natural gas, electricity, and water are widely distributed in the U.S., making virtually any location a potential site for hydrogen production (via natural gas reforming or water electrolysis) and vehicle fueling. Initial studies suggest "distributed" hydrogen production could be economically viable (approaching a cost equivalent to $1.50 per gallon).

8. A two percent increase in U.S. natural gas supply would support ten million fuel cell-electric vehicles annually and reduce the CO_2 emissions produced by the displaced gasoline vehicles by over 50 percent on a "well-to-wheels" basis. Natural gas is already proven as an affordable source of hydrogen (production cost roughly equivalent to $0.60/gal of gasoline, or $1.20/kg of hydrogen).

9. Balancing infrastructure availability with fuel cell-electric vehicle sales growth and concentrating initial sales in specific geographic regions will be essential to manage early capitalization risk.

10. Bottom line: The hydrogen infrastructure for automobiles is economically viable and doable but requires a collective will by automakers, energy suppliers, and governments to overcome initial capitalization risks and manage the transition.

*A *fuel cell-electric vehicle can generally travel twice as far on a kilogram of hydrogen as an internal-combustion-engine vehicle can travel on a gallon of gasoline.*