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THE CASE FOR A CLEAN ENERGY SCIENCE
AND TECHNOLOGY INITIATIVE**

*Testimony Informational Hearing, Select Committee
on Air and Water Quality
February 25, 2004*

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Testimony
Informational Hearing
February 25, 2004

Select Committee on Air and Water Quality
Assemblymember Fran Pavley, Chair

**California's Hydrogen Highway:
The Case for a Clean Energy Science and Technology Initiative**

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Thank you for this opportunity to speak on such an important matter. We are at an important cusp of history. Should we pursue the creation of a hydrogen economy, and if so how do we proceed? That is the central question before us. A careful, balanced analysis would conclude that uncertainty is still too great along too many dimensions to arrive at a definitive conclusion. That indeed, was the finding of the just-published National Academies report.

But that National Academies report also concluded that the hydrogen economy was highly compelling -- that "A transition to hydrogen ... could fundamentally transform the US energy system, creating opportunities to increase energy security through the use of a variety of domestic energy sources for hydrogen production while reducing environmental impacts, including atmospheric CO₂ emissions and criteria pollutants." It called for an expansion in hydrogen R&D to create the opportunity to one day realize this potential.

My own personal conclusion, based on over two decades of research on alternative fuels and energy policy -- including the past 1½ years on that National Academies committee which examined exactly these questions -- is somewhat more ambitious. I have come to believe the following: even more initiative is appropriate and desirable, even broader benefits will likely result, and California is well positioned to be the international leader in moving toward hydrogen. The underlying premise of my conclusion is that hydrogen potentially provides far greater societal benefits than any other major long term option under serious consideration, namely battery vehicles and cellulosic ethanol.

The Transforming Challenge

This transition to a hydrogen economy is perhaps the most complex and far-reaching issue before us -- for California policymakers, California industry, and society as a whole.

We're not just talking about which fuel to put in our tanks. We're talking about much more.

We're talking of transforming the automotive and energy industries, the two largest industries in the world – transforming everything from upstream extraction and manufacturing, to downstream retailing and financing. We're talking about integrating stationary and mobile energy (including cars powering buildings), in effect merging electricity and hydrogen into one system. And we're talking about integrating a vast array of energy feedstocks into one system. About half the major corporations in America would play a significant role in the transition to hydrogen.

And yet, it is even more than that. We are speaking of transforming our society -- economically, socially, and environmentally, locally as well as globally. We are speaking of choices that impact almost everything – not only energy security and environmental quality, but also economic growth and social well-being. The point I'm making, that can't be overemphasized, is that this is *not a narrow, technical energy discussion*. It is much more. Indeed, as I indicate later, the transition to hydrogen provides the potential for huge economic benefits, including the creation of entirely new industries and many new jobs.

The magnitude of what we are contemplating is mind boggling. The challenges are daunting and the risks of wasted investment large. The recent National Academies report on hydrogen notes that “There are many hurdles on the path to achieving the vision of the hydrogen economy; the path will not be simple or straightforward.” If we deploy infrastructure and vehicles that no one buys, we risk substantial stranded investment and disillusionment in the new technology. If we do not ensure that the production and use of hydrogen offers environmental advantages, we risk trading one problem for another.

Hydrogen is not a “slam dunk.” Even the most ardent advocate, on closely examining the many challenges, will pause. The state must develop a coordinated plan for introducing hydrogen that recognizes the nature of technology development, markets, and business investment.

Hydrogen Vehicles

I focus the remainder of my comments on the transport sector, because that is where the long term energy issues are most confounding and where hydrogen is most promising. I note that the electricity sector already utilizes a broad array of resources, including natural gas, coal, hydropower, nuclear, wind, and biomass. Transportation uses only petroleum (97%). Moreover, the electricity sector can switch to hydrogen – using SOFC and molten carbonate fuel cells that produce hydrogen on-site from natural gas and other fuels – thus obviating the construction of a hydrogen infrastructure. Vehicles are different. They use PEM fuel cells, which run best on hydrogen. The hydrogen is best supplied from off-board sources, requiring hydrogen fuel stations.

If hydrogen vehicles (or any new vehicles) are to be successful, they must provide value to the customer. And for a hydrogen vehicle to displace the highly successful gasoline internal combustion vehicle, it will have to provide benefits above and beyond the

societal objectives of reduced pollution and greenhouse gas emissions. There are numerous historical examples of new vehicles and fuels that had substantial societal benefits but failed, because in the end they provided nothing new to the customer. There is one simple reason that automakers are investing so heavily in fuel cell vehicles – they truly believe it can be a better car for their customers. Fuel cell vehicles hold the promise of revolutionizing personal transportation by providing substantial design flexibility, smooth and powerful electric drive performance, and high quality, emissions-free on-board electricity.

However, we still have a ways to go before fuel cell vehicles can offer these value-added amenities at an affordable cost, and with sufficient reliability. Before a fuel cell vehicle is commercially viable, substantial research and development will be needed to reduce fuel cell stack and system materials costs, increase durability in all weather conditions, and improve hydrogen storage technology, just to name a few. And while automakers are making rapid and substantial progress on these challenges, even the most optimistic say that the decision to move into serious production will not occur until 2010 at the earliest. This commercial reality, coupled with the temporal realities of vehicle product development and market adoption, suggests that hydrogen vehicles will not likely begin to gain significant market share until 2015 or later. The National Academies report concurs, citing 2015 as the beginning of significant market penetration of hydrogen vehicles in its optimistic scenario.

Toward a California Agenda

Such a timescale should not imply that there is nothing for us to do today. In fact, there is substantial action that the state and other stakeholders can and must take if a transition is to be made in a timely manner to a cleaner and more sustainable energy system. We cannot divine the future, nor even the attributes of tomorrow's energy system. But there is a suite of promising technologies nearly on hand, with strong industrial support, and we have considerable insight into what new science and technology is needed. Hydrogen-related processes and technologies, including electrolyzers, renewable energy, fuel cells, and natural gas reformers, are core technologies of this future.

Demonstration Projects

A key step in the process toward an enhanced energy system is demonstration projects. These are often maligned as government waste. They often are. Too often demonstration projects are funded through politics, not merit. Too often they have little value and become “white elephants.” But demonstrations can and often are efficient and effective. Demonstration projects are essential for identifying and resolving real-world operating issues, and providing valuable lessons in siting and permitting infrastructure. They also can serve as pilot projects for introducing new technologies and fuels into early markets, including fleets and transit.

Research

The heart of a California Hydrogen Highway initiative must be research. While hydrogen is compelling, much is uncertain and unknown. The best way of producing, distributing and using hydrogen is still uncertain. And the timetable on how to proceed is uncertain.

Most importantly, the most promising means of producing, distributing, and using hydrogen still require huge improvements. Major advances are needed to develop renewable resources, store hydrogen efficiently, and develop cost-competitive fuel cells.

The principal role and value of government-funded research is to:

- Conduct exploratory and basic research
- Build a public knowledge base for policy-makers to make informed decisions
- Educate and train next generation of engineers, scientists, and policy makers
- Support public education
- Incubate new industries

The first step is to build an R&D foundation that will support accelerated commercial development. We do not yet have that foundation. California is perfectly positioned, though. California has world-class research capabilities in its university system, national energy labs, and industrial labs. These capabilities are unparalleled. A recent survey by *The Economist* magazine ranked six California universities in the top 15 in the world, and eleven in the top 44 in the world. If one also considers the presence of many corporate labs and the US Department of Energy labs (LBNL, LLNL, and Sandia), California's capabilities are unmatched in the world. Nothing similar exists anywhere. Many of these research capabilities are perfectly suited to the advancement of energy science and technology, and indeed are already engaged.

With more leadership from the State, these vast research capabilities can be further targeted, in part through stronger and more productive partnerships with industry. Indeed, a major science and technology initiative and a major hydrogen initiative need not mean a huge budget investment by the State.

California's university system is especially critical. It is uniquely positioned to provide basic and applied research and expert advice, and to perform perhaps its most important role: train the next generation of scientists, engineers, and leaders. State government agencies should be aggressive in supporting university-based research programs in hydrogen storage, production, distribution, and end use, with research directed at advanced materials and manufacturing techniques, nanotechnology, systems planning, and policy analysis. In addition, the state's universities can help educate the public on the complex issues surrounding hydrogen as a transportation fuel. Universities are perfectly suited to this role because we establish research collaborations, publicly share research results for the state's benefit, and train tomorrow's engineers, scientists, policymakers, educators and business leaders.

Government's Leadership Role

The State of California is recognized as a leader when it comes to environmental policy innovation. Government leadership is necessary in creating a more socially-beneficial energy and transportation system. It is widely recognized that policy innovations in California, and resulting technical innovations, spread to the rest of the country and the rest of the world. But leadership can be fleeting. Other states are already challenging California's leadership in hydrogen, including Michigan, Florida, Ohio, and Texas.

Government needs to lead with consistent vision, as a strong first customer, and with policy mechanisms that maximize leverage and investment from industry

Summary

In summary, California is a crossroad. How should it proceed and how fast? There are no definitive answers; there is too much uncertainty. Much needs to be done.

But I do want to make the following points:

1. The hydrogen option should be pursued. The bottom line for the transport sector is: If not hydrogen, then what? Many argue that the highest priority policy should be energy efficiency – improving the fuel economy of today’s technology, and accelerating the use of hybrid vehicles. I fully agree. That indeed should be the primary policy focus. But efficiency is not enough. Efficient petroleum-burning vehicles still means continued dependence on precarious oil supplies, and continued emissions of large amounts of CO₂. Given the long time lag involved in transitioning to new energy supplies and systems, means the transition needs to start very soon. In my mind, the question is not if or even when – it is how. One can legitimately argue about how fast we should proceed, how to do so, and how much to invest in the near term, but it seems bad policy and irresponsible not to initiate a transition.

2. California is uniquely positioned to be a leader in the transition to hydrogen California has one of the largest economies in the world, is home to two automakers leading the development of fuel cell vehicles, the strongest university system in the world, perhaps the most entrepreneurial economy in the world, an open consumer market, and the last two industrial revolutions (information technologies and bio-technology). Indeed, it is an opportunity, and perhaps even a prerequisite to continued prosperity.

3. The minimum strategy for California is to launch a major clean energy science and technology initiative. Hydrogen and fuel cells might be the centerpiece, but would share the focus with a vast array of scientific and technologic opportunities to produce, move, store, and use energy. The PIER program of CEC, focused on electricity, would be an important part of this initiative. For California to thrive, it needs to be at the cutting edge of technology development. Information technologies provided an earlier boost to our economy. The next big technology revolution was and is biotech. It will play out for some time. Hydrogen and, more broadly, clean energy technology, may well be the next big industrial transformation.

4. California also needs to address the following questions:

- How will California work with the rest of the nation and developing countries?
- How important is it to keep small innovative companies in business, and how will this be accomplished? Many innovative hydrogen and fuel cell companies are on the verge of disappearing. It appears that most companies, small and large, are starting to conclude that the business case for hydrogen carries huge risks into the foreseeable future.
- How will California partner with small and large companies, including automakers, from basic R&D to demonstrations?

- How will oil companies be engaged? For a variety of reasons, they appear to have less incentive to be pioneers with hydrogen than do automakers with fuel cells. But they are key to the transition, and must be engaged.
- How assertively will government lead and how will it perceive its role in serving the public interest? A more passive approach would be to defer to consumer sovereignty, and not lead.

Let me draw this testimony to a close with an observation about experts and leadership. I come from a world that values expertise and knowledge. We speak in terms of metrics, analytical frameworks, statistics. But I can't help quoting Henry Kissinger who once said, "Most foreign policies that history has marked highly, in whatever country, have been originated by leaders who were opposed by experts. It is, after all, the responsibility of the expert to operate the familiar and that of the leader to transcend it." I have to agree. I think of Rachel Carson regarding environmental awareness (*Silent Spring*), Jane Jacobs regarding urban planning (*Death and Life of American cities*), and Betty Freidan on role of women (*The Feminine Mystique*). None were experts. All were leaders.

The expert in me tells me to calculate the costs and benefits of investments in hydrogen and fuel cells to quantify uncertainty and risk. I will. But I wonder if this isn't the time to take off my professor's hat. Are we talking about something so fundamental about our future, and so important, that we need to reach out beyond our narrow interests and reductionist approaches, to take a few more chances? Experts are conservative and cautious. That's our culture and profession. But maybe that approach is insufficient in this case. In the end, ideas do matter. We've got a big one here. It involves huge risks, and potentially huge costs. But the cost of not doing something ambitious could be even greater. The benefits of moving forward decisively could be huge. The world is not a healthy place these days. As members of the richest and most powerful country in the world, and the country that consumes far more oil and emits far more GHGs than any other country in the world, I wonder if we shouldn't be providing more leadership. I praise Governor Schwarzenegger, Secretary Tamminem, and Chair Alan Lloyd for leading California forward, and offer my encouragement and praise. California is fortunate to be blessed with such leadership on this issue. Thank you.

Background on How UC Davis Is Contributing to the National Effort to Develop a Hydrogen Fuel Economy

I want to share with you the ways that UC Davis is making a difference in developing the technology, infrastructure and people to advance the state of the art with respect to hydrogen for transportation. Due to the long transitional time associated with vehicle turnover and fuel infrastructure introduction, business and policy decisions like those being considered here are being made today. These near-term decisions will affect the transportation sector for many years to come. It is very important that state energy policy be shaped by the best available current knowledge and that future policy be shaped by objective future research.

Brief Description of related ITS-Davis Research

About 35 graduate students and ten faculty members are involved in advanced environmental vehicle and fuels research on the UC Davis campus. Graduates of our interdisciplinary Transportation Technology and Policy (TTP) program have obtained positions within the automotive and energy industries, academia, environmental NGOs, and government. The following is a sampling of our larger programs:

Hydrogen Pathways Research Program

The Hydrogen Pathways Research Program is a multi-year program designed to look at the near to mid-term introduction of hydrogen as a transportation fuel from a technical, economic and policy perspective. Bringing together people already working on these issues, the ITS-Davis Hydrogen Pathways Research Program has already engaged a broad consortium of leading industry partners, federal stakeholders and state agencies.

Fuel Cell APUs: A \$3 million project is developing and testing fuel cell auxiliary power units (APUs) that power truck-trailer refrigeration and other auxiliary systems. The new APUs could eliminate the need for idling big-rig diesel engines, which is inefficient, expensive, noisy, and polluting and could power electric systems in aircraft, leading to fuel savings in the nation's future commercial aircraft fleet.

Advanced Vehicle Modeling: ITS-Davis researchers conduct extensive computer modeling of vehicle and heavy-duty truck emissions, fuel economy and performance. ITS-Davis is completing a five-year, \$3 million fuel-cell-vehicle modeling program that was sponsored by 20 companies and three government agencies.

Advanced Vehicle Power System Evaluations: Researchers at ITS-Davis study energy storage and conversion technologies (including ultracapacitors) for electric, hybrid-electric and fuel cell vehicle applications for a variety of government and industry sponsors.

Hybrid Vehicle Prototypes and Component Evaluations: The UC Davis Hybrid Vehicle Driveline Research and Design Center designs and builds vehicles that demonstrate improved overall efficiency, high fuel economy and low emissions. The HEV

Center's current efforts focus on plug-in hybrid-electric vehicles (HEVs) and continuously variable transmissions (CVTs).

New Advanced Environmental Vehicle Laboratories: The UC Davis College of Engineering and ITS-Davis are planning to build a new advanced environmental vehicle facility. This project would create large synergies by clustering UC Davis clean-vehicle research and education programs. The facility would include high-bay vehicle laboratory space, a distributed computing facility and a hydrogen refueling station. Co-funding by public and private sources is currently being sought.

Graduate Education

We are especially proud of the success of our expanding graduate education and research program – much of it directed at electric-drive vehicles. The National Science Foundation awarded ITS-Davis a \$2.6 million Integrative Graduate Education and Research Traineeship (IGERT) grant for our innovative Transportation Technology and Policy graduate program, the only transportation institute in the country to be funded. In addition, the U.S. Department of Energy awarded UC Davis two (of ten nationally) Graduate Automotive Technology Education (GATE) Centers – to ITS-Davis for fuel cell vehicles and to the Department of Mechanical and Aeronautical Engineering for Hybrid Electric Vehicles. UC Davis won the first two (1998 and 2001) FutureCar and FutureTruck competitions sponsored by the U.S. Department of Energy and the USCAR program of the U.S. auto makers, and placed third overall in the 2002 FutureTruck competition.