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Why Hydrogen and Fuel Cells are Needed to Support California Climate Policy

Executive Summary

California has taken a leadership role on climate policy by adopting AB 32, the California Global Warming Solutions Act of 2006, which caps state greenhouse gas (GHG) emissions at 1990 levels by 2020, and by setting a follow-on goal of reducing GHG emissions 80% by 2050. Given that the transportation sector accounts for 40% of the state's GHG emissions, it will be difficult to meet the 2050 goal unless a portfolio of near-zero carbon transportation solutions is pursued in the very near future.[1] Consistent and durable public policy is needed at the state and federal levels to encourage the development of transportation alternatives with real market share. Because it takes decades for a new fuel or propulsion system to capture a large fraction of the light duty vehicle market, it is important to accelerate the introduction of low-carbon fuels and vehicles as soon as possible.

Hydrogen fuel cell vehicles (H2-FCVs), battery-electric vehicles (BEVs), and hybrid-electric vehicles (HEVs) with low carbon biofuels are the three most promising candidates for near-zero carbon transportation. All three are likely to play a major role in California and throughout the world, but all face a variety of challenges and risks. *California needs to pursue multiple near-zero carbon transportation options if it is to achieve major reductions in carbon in its transport sector.*

Hydrogen FCVs are making rapid technical progress, and offer zero tailpipe emissions, good performance, fast refueling, and the potential for competitive costs in mass production [4]. Most automakers are now developing and demonstrating prototypes of FCVs, several in response to the California ZEV Regulations and in partnership with the U.S. Department of Energy (DOE), and could be on a path to commercialization if supported by the appropriate policy mechanisms. Aggressive government policy including incentives, federal demonstration programs, and state vehicle regulations are necessary to overcome start-up barriers and ensure a timely, well-coordinated deployment of hydrogen fueling infrastructure and vehicles.

California can take the lead in collaboration with the federal government today to ensure the timely commercialization of hydrogen fuel cell vehicles. California's historic clean vehicle and alternative fuel policies have led the world. The state must expand upon its existing policies now to support the H2-FCV alternative in collaboration with the federal government. The automotive and energy industries, the state, and the federal government all support a national strategy that introduces H2-FCVs in select urban centers throughout the United States. The Los Angeles basin has been chosen as the most attractive urban center to first introduce this technology on a large scale, given its market demographics and as automotive manufacturers have a concentration of corporate activity and vehicle deployments in the area. Significant federal support for FCVs and hydrogen infrastructure in California could begin in 2010 if California establishes a strong regulatory signal that significant numbers of H2-FCVs will be sold in the 2015 to 2017 timeframe.

This report makes the following recommendations:

California Action

1) The California Air Resources Board (CARB) Zero Emission Vehicle (ZEV) Regulation should call for a major expansion of H2-FCVs, reaching a cumulative total of 50,000 or more by 2017, consistent with a viable product development path leading toward commercialization. This is necessary to send a clear signal to industry and the federal government, and to ensure sufficient vehicle volumes occur to meet cost reduction goals and market penetration needs by 2050. This policy will need to be coupled with a federal incentive program to offset vehicle purchase costs, until sufficient vehicle sales occur to bring costs down. Figure 1 compares the new ZEV Regulation vehicle volumes to the Oak Ridge National Laboratory (ORNL) FCV Scenario 2 [5], a level consistent with producing vehicles at

[1] A number of studies have shown that multiple solutions will be required to achieve the GHG reductions [1,2,3].

economies of scale.[2] The "Existing" ZEV Credit requirement could result in 50,000 FCVs depending on automotive industry product plans.

2) The state needs to enable the deployment of *three to five new* H2 stations by 2010 (refer to Figure 2) and provide financial support to enhance the accessibility and operation of a few of the 15 existing stations in the Los Angeles area. This early action will enable the next few years of demonstrations and provide a crucial bridge to 2010, when substantial federal funding could become available for hydrogen vehicles and infrastructure (see below). State funding decisions should *leverage* and *enhance* private investments, supporting stations that are strategically located.[3] By modifying existing state funding programs and partnering with the federal government, the cost to the state would be minimal.

Federal Action

3) Starting in 2010, the second phase of the U.S. DOE Hydrogen Learning Demonstration Program needs to be implemented to enable deployment of the H2-FCVs required under the ZEV Regulation and an additional 20 large-capacity stations in the Los Angeles basin prior to 2015 (refer to Figure 2). Existing Congressionally authorized funds (Section 808 of the Energy Policy Act of 2005 [6]) should be used for cost share grants with industry for infrastructure and vehicle subsidies between 2010 and 2017. To support this, a review of the progress of H2-FCVs in meeting the 2010 U.S. DOE targets needs to occur in 2009.[4]

4) The federal government can take a variety of actions to support the early stages of hydrogen transition for both vehicles and infrastructure. Because hydrogen fueling station investors are shouldering significant risk due to uncertainty in the long-term prospects, a variety of mechanisms to spread the risk between government and industry should be studied. One possibility is a federal tax credit for hydrogen fuel sales that could help improve the early business case for stations. Other mechanisms include but should not be limited to loan guarantees, accelerated depreciation, and station liability protection. Furthermore, institutional challenges, if not addressed, will restrict station infrastructure from growing at the pace required to meet the 2015 targets. Specifically, national codes and standards need to be further developed and closely coordinated with state officials to streamline the permitting process.

[2] An expanded explanation of our recommendation for 50,000 FCVs by 2017 and the ORNL Scenarios can be found on page 12.
[3] Elaborated upon in the expanded Recommendations section of the report in items #2 and #4.
[4] Recent studies [4] suggest that if H2-FCVs can achieve the 2010 DOE targets they would be competitive with other advanced technology vehicles (i.e. plug-in hybrid electric vehicles and battery electric vehicles) that are being considered under the ZEV Regulation.

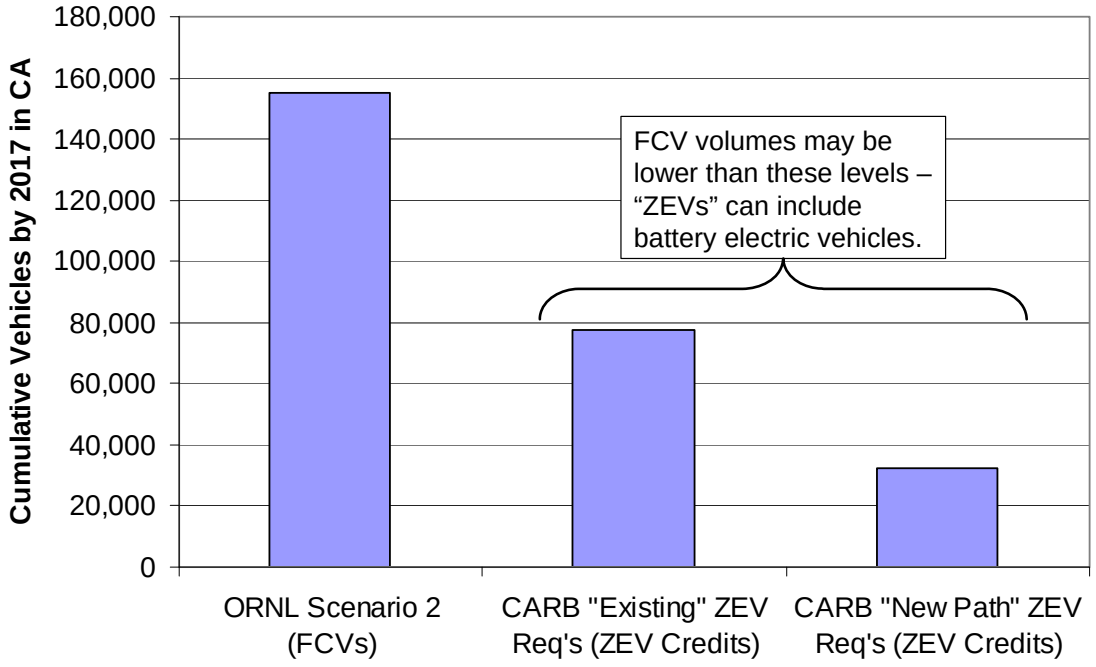

Figure 1: *Cumulative number of FCVs or ZEV Credits by 2017*
(Sources: ORNL [5] and CARB [7])
Refer to Figure 6 in Appendix B for a depiction of the annual vehicle sales for the cases in Figure 1

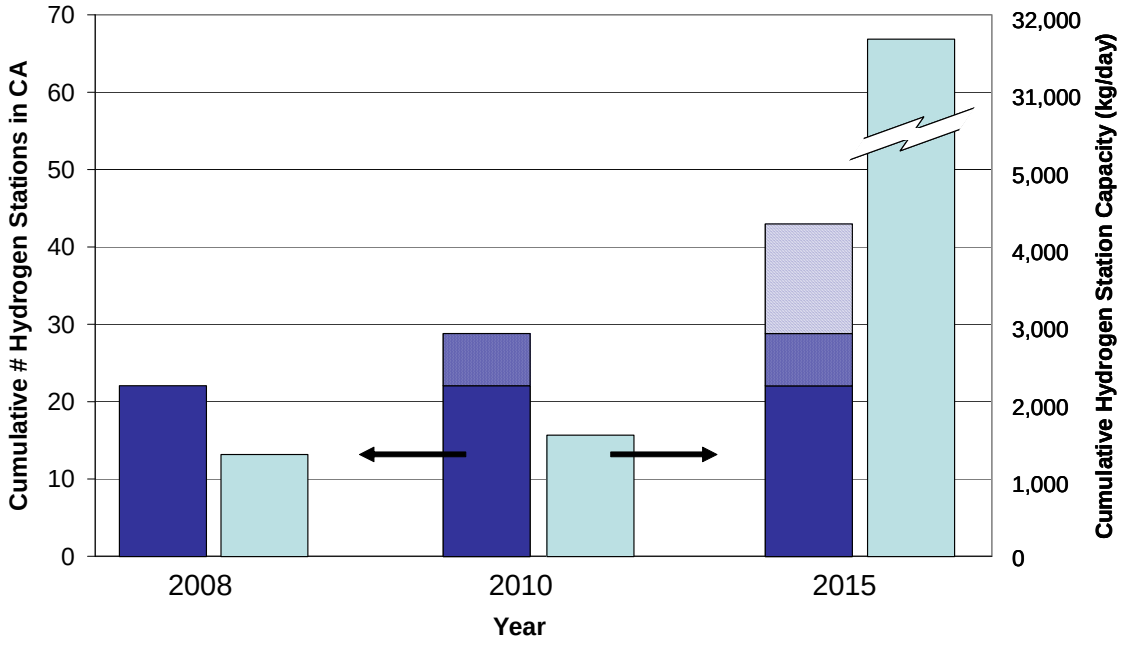

Figure 2: *Hydrogen Station Deployment Timeline in California,*
(Source, station numbers: CaFCP, ORNL [5])

Notes regarding station numbers and capacity:

- *2008: CaFCP station data*
- *2010: 3 additional stations at 100 kg/day each*
- *2015: 20 additional stations at 1,500 kg/day each*

Why Hydrogen and Fuel Cells are Needed to Support California Climate Policy

Meeting California's Long Term Greenhouse Gas Goals is a Monumental Challenge
The state of California has taken a leadership role through its innovative policies to address climate change, oil dependence and air pollution. California has recently adopted AB 32, the California Global Warming Solutions Act of 2006, which caps state GHG emissions at 1990 levels by 2020. The state also set a follow-on goal of reducing GHG emissions 80% by 2050, compared to the 1990 baseline [8,9].

Figure 3 below shows California's actual GHG emissions through 2004, projected emissions in 2020 and 2050, as well as the emissions reduction goals. Meeting 2020 goals will mean a 173 million metric ton (MMT) reduction of CO_2-equivalent emissions from projected 2020 levels (30%). For 2050, the graph shows an additional reduction of 340 million metric tons required to meet the goal, an 80% reduction compared to the 1990 baseline level. Compared to estimated "Business as Usual" emissions in 2050, the reduction is larger, approximately 710 million metric tons, or roughly a 90% reduction [10].

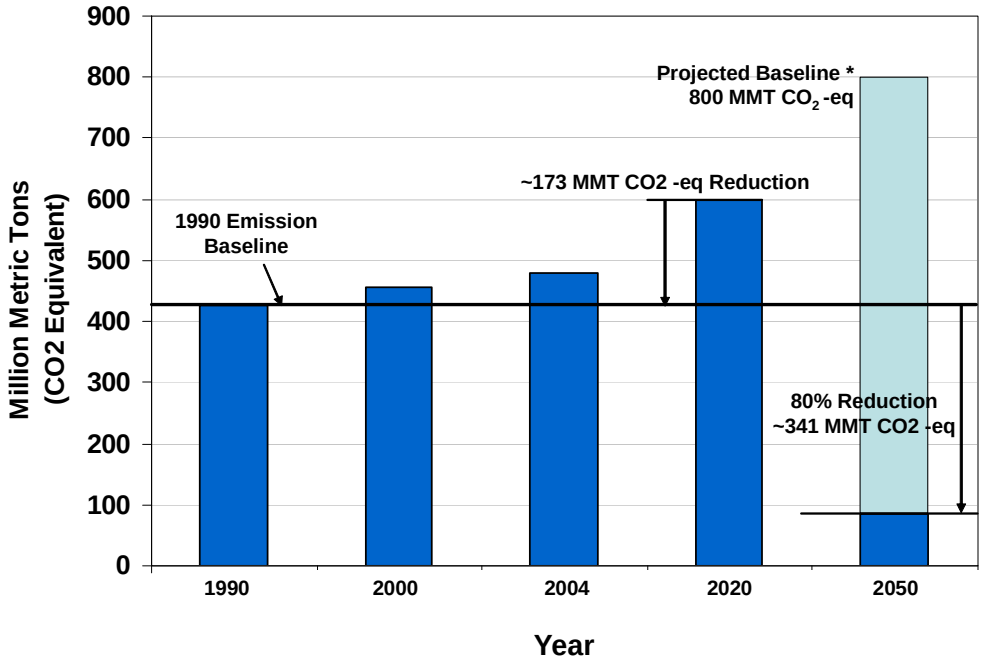

***Figure 3**: California GHG emissions (all sectors) - Actual and Projected with Reduction Goals*
(Source: CARB Scoping Plan presentation, Nov 30, 2007 [11])
*(*2050 baseline from reference [10] – based on 1% average annual growth from 1990)*

Meeting California's 2050 goal will require major changes to multiple sectors in the economy. In the transportation and electricity sectors, this will require adoption of alternatives with the potential for very large carbon reductions. The transportation sector is crucial: it accounts for more than 40% of total GHG emissions in California [3].

Achieving an 80% reduction in the transport sector will require a broad mix of solutions, including reduced vehicle miles traveled (VMT) per capita, increased use of transit, increased vehicle fuel efficiency, reduced fuel carbon content, and implementation of advanced vehicle technologies [3]. We focus on the critical role of alternative fuels and advanced vehicle technology in this low-carbon future.

Implementing Low Carbon Transportation Solutions on a Large Scale Will Take Time
California's 2050 goals require a series of actions, starting now, to develop long-term transportation solutions. Consistent and durable public policy is needed at the state and federal levels to encourage the emergence of near-zero carbon transportation alternatives with real market share, beginning with expanded demonstrations now and moving toward commercialization. As we describe below, for any new alternative to capture a large fraction of the light-duty vehicle (LDV) market by 2050, pre-commercial vehicle sales need to begin as early as 2015.

Figure 4 shows a representative market penetration curve for a "generic" alternative vehicle that achieves 50% market penetration by 2050. *To achieve this future market penetration,* ***new vehicle sales*** *of the alternative will need to begin by 2015 and increase to nearly* ***75%*** *of all vehicles sold in 2050*.[5] The shape of the curve in Figure 4 and the associated timescale is due to several factors.

- **Early market development**: During the first ten years of a new vehicle technology, there is substantial uncertainty (and risk) within the automotive industry about how consumers will accept the technology. Production volumes of the new alternative remain low during this period. After consumers signal market acceptance, larger production volumes and more competitive product lines emerge. (For example, gasoline HEVs were first introduced in compact vehicles and later emerged in larger platforms.)

- **Vehicle lifetime and stock turnover**: The average lifetime of a LDV in the United States is roughly 14 years. Theoretically, if all LDVs sold were the new alternative vehicle, it would take at least 14 years to "turn over" the stock of vehicles[6]. In practice the market diffusion is slower than this, resulting in several decades for a new technology to substantially replace older vehicles [12,13].

[5] The rate of market growth for the first ten years of this "generic" curve is assumed to match the historical market trends of the introduction of the gasoline HEV (1999-2007) in the United States. Absent policy, these trends may be optimistic for H2-FCVs or PHEVs, as they would need a different fuel infrastructure, unlike HEVs.
[6] Approximately 16 million new LDVs are sold in the U.S. each year, and the total U.S. LDV population is approximately 220 million [12].

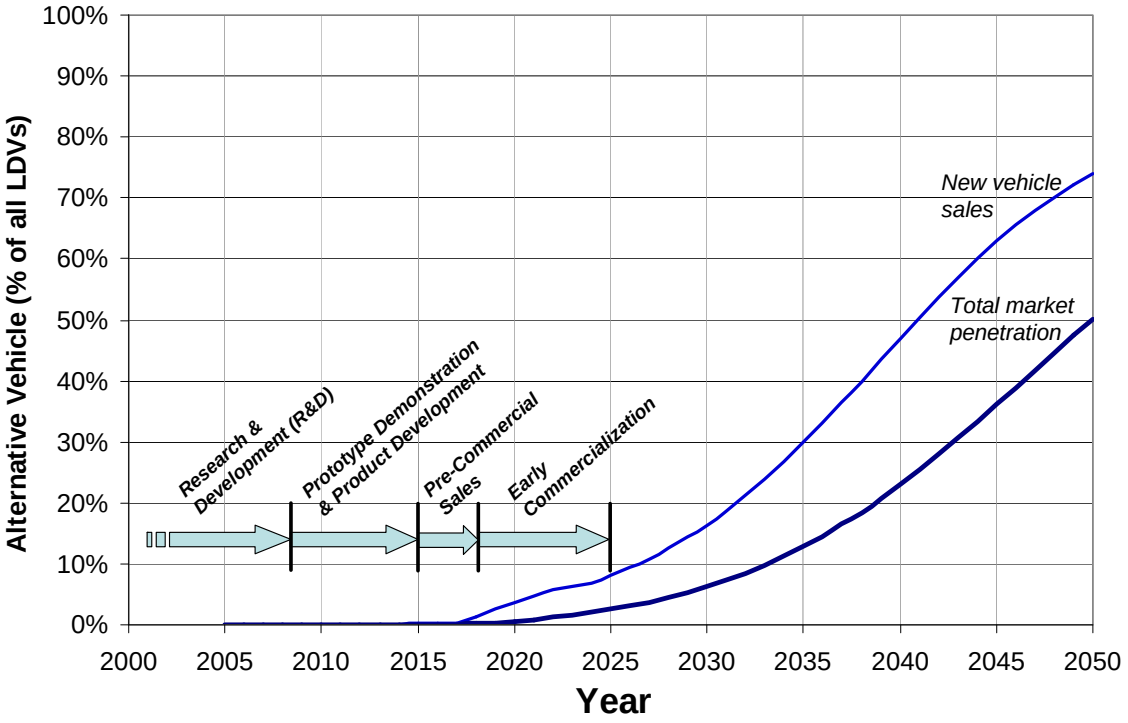

***Figure 4**: Alternative vehicle fleet growth curve, and stages of commercialization for the H2-FCV specifically*

Stages of commercialization

For an *evolutionary* new vehicle system (e.g. Gasoline Hybrid Electric Vehicles):

- **R&D** (4+ yrs) – Core research in the laboratory of a new concept; high level of experimentation.
- **Production Development** (4-6 yrs) – Vehicle line and powertrain concept chosen in the beginning; focus is on specific system and vehicle design, durability testing, production planning, and marketing.
- **Early Market Development** (4-6 yrs) – Encourage sales and solicit consumer feedback on why they made the purchase decision; re-evaluate market projections; government subsidies may be present.
- **Expanding Markets** (4+ yrs) – If sales targets are exceeded, develop second generation vehicle; consider parallel expansion of production volumes of existing vehicle. If market appears strong, competitors will enter the market with additional product lines.

For a *revolutionary* new vehicle (e.g. FCVs; Dates below correspond to Figure 4 above):

- **R&D** (10+ yrs) – Core research in the laboratory of a new concept; high level of experimentation.
- **Production Development** (5-7 yrs) – Vehicle line and powertrain concept chosen in the beginning; focus is on specific system and vehicle design, durability testing, production planning, and marketing.
  - **Advanced Prototype Demonstration** (100's to 1,000's vehicles/yr, 2008 to 2015) – Typically, prototype testing is confidential, but for FCVs or PHEVs, early public feedback is necessary before commercial vehicle designs can be chosen. For FCVs, this period occurs in parallel to Production Development, and is carefully coordinated with hydrogen station deployment.
- **Early Market Development – "Pre-Commercial Sales"** (10,000's vehicles/yr, 2015 to 2018) – Vehicles placed into fleets or directly sold to consumers; vehicle costs are heavily subsidized by vehicle manufacturers and government cost share & tax incentive programs.
- **Expanding Markets – "Early Commercialization"** (100,000's vehicles/yr, 2018 to 2025) – Traditional sales and marketing of the vehicles emerge; vehicle tax subsidies reduced; multiple product lines emerge.

A Portfolio of Alternative Fuel and Vehicle Options Will be Required

Several recent studies suggest that a portfolio approach is required if we are to achieve the 2050 GHG reduction goals [2,3,14,15]. The best approach is to evaluate all viable alternatives for technical challenges, potential for GHG reductions, economic feasibility, and consumer acceptability. This section briefly describes the current suite of promising alternatives and how they have emerged over the past ten years. We focus on three fuel/vehicle pathways: hydrogen and fuel cells, plug-in hybrid electric vehicles, and biofuels with combustion engines.

Hydrogen has been identified in several authoritative studies as an alternative with a strong potential for long-term, deep reductions in GHGs [15,16,17]. Hydrogen can be produced from diverse resources and used in efficient fuel cell vehicles with zero tailpipe emissions. If hydrogen is produced from renewable energy or fossil sources with carbon capture and storage, the well-to-wheels GHG emissions are near zero. Even when produced from natural gas (the mostly likely near term source up to 2025), hydrogen used in FCVs results in >40% total GHG reductions compared to gasoline used in conventional vehicles [16]. The automotive industry is heavily investing in this alternative and government policies are critical to sustain and leverage this momentum. The rapid ongoing technical progress in H2-FCVs is discussed in the next section.

Challenges:
a) vehicle onboard H2 storage;
b) fuel cell system cost and durability;
c) hydrogen infrastructure expansion; and
d) cost-effective low-carbon hydrogen supply.

Plug-in hybrid electric vehicles (PHEVs) can play an important role in bridging the transportation and electricity sectors and can noticeably reduce GHGs. In the near term, with the current electric power grid mix, PHEV emissions will be comparable to FCVs using H2 from natural gas [4]. In the longer term, PHEVs can take advantage of new, low carbon electricity as renewable and other clean electricity capacity expands. In the future, PHEVs will bring emissions to near-zero, if coupled with a very low carbon liquid fuel such as renewable biofuel, or a fuel cell generator operating on low carbon hydrogen.

Challenges:
a) Lithium-ion battery cost and durability;
b) consumer acceptance of charging time;
c) meeting emission requirements with engine-off features; and
d) pace of low carbon electricity growth, including renewables and other clean energy.

Recent Alternative Fuel and Vehicle Trends

Over the past ten years, we have seen dramatic momentum in the automotive and fuels industries around these new alternatives. During the same time period, however, we have seen equally dramatic shifts in the view of the preferred alternative.

- **1998-2005**: Momentum towards hydrogen and fuel cell vehicles emerges, largely due to the demonstration of automotive fuel cell technology by Ballard and Daimler in the early 1990s. The CARB ZEV Regulation was a catalyst for automotive companies to develop FCVs as an alternative to BEVs, which industry opposed due to limited range and long battery charge time. HEVs emerge on the market and grow to 2% of LDV sales in the United States by 2005.
- **2005-2007:** Corn ethanol re-emerges as an alternative fuel and production skyrockets in the United States. This is largely due to its replacement of the phased-out MTBE as a gasoline additive, the 2005 Energy Policy Act that mandated blending 7.5 billion gallons per year of ethanol with gasoline by 2008, and the ethanol tax credit of $0.51/gallon. The federal government and energy firms invest heavily in advanced biofuels R&D.
- **2007-2008:** Attention to PHEVs increases dramatically due to a number of factors, including improved lithium-ion battery technology, electric utility support, established HEV platforms with which to experiment, and dedicated grassroots advocates.

Biofuels can play an important role and are more compatible than other alternative fuels with today's existing fuel distribution infrastructure. Biofuels can increase domestic energy production, offset petroleum consumption, and *may* reduce GHGs (depending on which biomass feedstock is used and how the fuel is produced [18]). But increased biofuel production has limitations due to biomass acreage restrictions, land-use changes, water availability, food price impacts (especially in developing nations), and a number of other sustainability factors [18].

It can be expected that over the next ten years, ethanol will be used in low blends with gasoline (10% on average nationally) and the nation will rely almost entirely on the traditional corn feedstock. In the longer term, there will be a need for next-generation ethanol (cellulosic feedstocks) and biomass-derived synthetic gasoline/diesel, but concerns similar to those affecting today's biofuels may still apply [19].

Challenges:
a) developing commercially viable advanced biorefinery technology with non-food feedstocks (avoiding food price impacts);
b) evaluating GHG emission reductions when land-use changes are taken into account; and
c) identifying advanced biofuel chemistries that allow for integration with the existing fuel distribution system.

Each of the alternatives discussed above could contribute to reductions in GHG emissions [3,15]. Given the severity of the issue and the uncertainties inherent in each alternative, a portfolio approach is warranted to ensure the most cost effective solutions are identified.[7] Policies should be designed with flexibility so that they are robust, yet adaptable to respond to future uncertainties as we learn more about each alternative's potential benefits and challenges.

Advances in Hydrogen and Fuel Cell Vehicle Technologies

Large advancements have occurred in fuel cell vehicle and hydrogen infrastructure technology over the past 15 years. Fuel cell technology has progressed substantially resulting in power density, efficiency, range, cost, and durability all improving each year. In another sign of progress, automotive developers are now demonstrating over 100 FCVs in California – several in the hands of the general public – with configurations designed to be attractive to buyers (see sidebar below). Cold-weather operation and vehicle range challenges are close to being solved [22], although vehicle cost and durability improvements are required before a commercial vehicle can be successful without incentives.

The pace of development is on track to approach pre-commercialization within the next decade. A number of the U.S. DOE 2010 milestones for FCV development and commercialization are expected to be met by 2010. Accounting for a five to six year production development cycle, the scenarios developed by the U.S. DOE suggest that 10,000s of vehicles per year from 2015 to

[7] Several comprehensive studies support the conclusion that no one alternative will meet energy and GHG goals.

- A joint U.S. Dept of Agriculture and U.S. DOE study [20] concluded that 30% of the nation's transportation fuel could be produced from biomass, but such a change would require a dramatic increase in ethanol and biodiesel from non-traditional biomass sources.
- An Electric Power Research Institute (EPRI) and Natural Resources Defense Council (NRDC) study [21] concluded that by 2050 PHEVs could comprise 60% of the total vehicle market (medium scenario), but that to achieve this goal 50% of new vehicle sales would need to be PHEVs by 2025.

2017 would be possible in a federal demonstration program[8], assuming large cost share grants by the government and industry are available to reduce the cost of production vehicles [5].

Advances have also been made with hydrogen infrastructure over the past 10 years. Various hydrogen fuel production technologies have demonstrated the potential for cost-effective hydrogen that, when used in a fuel cell vehicle, will result in reduced GHGs [16,17,23]. On a $/mile basis, a number of projections show that the cost of hydrogen used in an FCV could be lower than the cost of gasoline used with conventional vehicles [5]. Thanks to a concerted effort by many stakeholders, including the California Fuel Cell Partnership (CaFCP), CARB, U.S. DOE, and many private sector partners, there are now 23 hydrogen fueling stations in California and more nationwide. Today's hydrogen is made predominantly from natural gas, which provides approximately 40% well-to-wheels GHG reductions compared to conventional gasoline vehicles [16]. By 2020 and beyond, even cleaner hydrogen production sources are expected to become more prevalent.

- Honda's 2008 FCX Clarity, to be put in consumers' hands later this year, is the most recent example of advancements in fuel cell vehicles. Honda's new design demonstrates 270 miles of range, full cold-weather capability, and exceptional fuel economy – all with a mid-sized car platform [22].
- Daimler continues to expand upon its successful partnership with Ford and Ballard, and is preparing its launch of a new FCV on a B-class platform. Daimler's investments in fuel cells have resulted in the largest FCV fleet world wide, including more than 60 cars, 33 fuel cell buses, and three delivery vans.
- General Motors is proceeding with its "Operation Driveway" deploying more than 100 Chevrolet Equinox FCVs beginning this year, primarily in the Los Angeles area, enhancing the 2015 to 2017 timeframe for pre-commercial vehicles [23].

California's Leading Role on Hydrogen and Fuel Cells

California's historic policy actions on climate change and clean transportation systems have led the world. They include the ZEV Regulation, AB 1493 (2002), AB 32 (2006), and AB 1007 (2006). In addition, California has committed to adopting a low carbon fuel standard as an early action measure under AB 32. California has also enacted hydrogen specific measures, such as the Hydrogen Highway Network Executive Order S-7-04 and hydrogen fuel legislation (SB 76, SB 1505) providing infrastructure program funding and renewable hydrogen requirements. The world's foremost public private partnership, the California Fuel Cell Partnership, is located in the state. These actions have made California a focal point for hydrogen and fuel cell development. *It is important that the state expand upon these actions now to support the H2-FCV alternative*.

As part of the AB 32 regulatory process, in 2008 CARB is developing a Scoping Plan for meeting the 2020 reduction target along with a vision for how to achieve the 2050 goal, and is seeking stakeholder input throughout this process. Last year the state convened the Economic and Technology Advancement Advisory Committee (ETAAC) to provide expert advice. The committee's recently released final report reaffirms the need for both long-term and short-term solutions, and for public-private partnerships in meeting AB 32's goals [3].

While CARB is demonstrating leadership and vision in implementing AB 32, it is also sending mixed signals on the ZEV Regulation. It is important for CARB to return its focus to pure ZEV

[8] The ORNL FCV scenarios are based on reviewing the progress that industry is making in the laboratory in 2009 toward U.S. DOE 2010 targets.

technology and to signal its continuing commitment to accelerate the development and commercialization of advanced ZEV technology, based on both electricity and hydrogen.

H2-FCVs can meet relaxed 2010 DOE storage and fuel cell cost targets when competing against other low or zero emission vehicles [4]. The CARB ZEV Expert Panel [24] recommendations were based on meeting the more aggressive 2015 DOE cost targets. Based on a favorable review of H2-FCVs in 2009 on progress towards meeting the 2010 DOE targets, automakers could begin production in 2015. It is important that the ZEV Regulation be constructed in concert with a federal demonstration program with incentives, and to maintain sufficient vehicle volumes to ensure cost reductions occur by 2018. The current ZEV Regulation vehicle volumes do not accomplish this objective.

Several influential fuel cell companies are at risk of not surviving through to commercialization. Industry suppliers, consequently, are not developing mass production systems and facilities. For fuel cell vehicles to progress toward commercialization there needs to be clear government signals that will encourage long-term private industry investments. Specifically, continued strong FCV targets in the ZEV Regulation are needed.

State and Federal Policies

California Policies

- **AB 1493** (2002) – *CA Motor Vehicle GHG Emission Reduction Regulation*. Requires a 30% reduction in CO2-equivalent emissions from LDV sector by 2016. To be implemented by CARB.
- **AB 32** (2006) – *CA Global Warming Solutions Act*. Requires CA GHG emission reductions to 1990 levels by 2020. To be implemented by CARB.
- **AB 1007** (2006) – *Alternative Fuels Plan*, evaluating pathways for reducing CA's petroleum usage. Scenarios and report developed by California Energy Commission (CEC).
- **SB 76, Chapter 91** (2005) – *CA Hydrogen Funding*, appropriated $6.5M for hydrogen stations and vehicle leases with oversight under CARB. Additional authorizations at same level in 2007 & 2008.
- **SB 1505** (2006) – *Environmental Standards for Hydrogen Production* (applies to state funded stations only). Requires a 30% well-to-wheel reduction in GHGs compared to the conventional gasoline/vehicle pathway, and 33% well-to-tank energy requirements from renewable energy.
- **Low Carbon Fuel Standard** (2007) – Requires a 10% reduction in carbon intensity of all transportation energy in California by 2020. Enacted as an "early action" under AB 32 and under development by CARB.
- **AB 118 (2007) –** *Alternative fuels and vehicle technologies funding programs*, provides roughly $120M/yr to CEC and $80M/yr to CARB over seven years. Funded by new vehicle fees.

Federal Policies

- **Energy Policy Act of 2005** (Congress) – Section 808: Hydrogen Demonstration programs. Authorizes cost-share grants for vehicle demonstrations, and stipulates a review of technical requirements after 2010. $375M authorized for 2010 FY for all programs in this section.
- **Energy Independence and Security Act of 2007** (Congress) – Establishes first major increase in LDV fuel economy in several decades, requiring a combined 35 mpg by 2020.

Recommendations

This section expands upon the four recommendations outlined in the Executive Summary. These recommendations are similar to those made in previous authoritative energy policy studies [15,16,17], and are focused on ensuring the H2-FCV option is seriously evaluated. Generally speaking, hydrogen and fuel cells need to be appropriately considered as low carbon, cost effective options are evaluated in broad-based climate change policies.

California Action
 # 1: Strengthen the ZEV Regulation for pure ZEV vehicles, including H2-FCVs

The California Air Resources Board (CARB) Zero Emission Vehicle (ZEV) Regulation should call for a major expansion of H2-FCVs, reaching a cumulative total of 50,000 or more by 2017, consistent with a viable product development path leading toward commercialization. This is necessary to send a clear signal to industry and the federal government, and to ensure sufficient vehicle volumes occur to meet cost reduction goals and market penetration needs by 2050. This policy will need to be coupled with a federal incentive program to offset vehicle purchase costs, until sufficient vehicle sales occur to bring costs down.

We chose targets for FCV sales based on a series of scenario analyses conducted by the U.S. DOE with industry, academia, the National Renewable Energy Laboratory and ORNL [5]. An ORNL scenario (Scenario 2) that seeks to achieve pre-commercial introduction of H2-FCVs by 2015 is compared to the new CARB ZEV Regulation (approved March 27, 2008) in Figure 1 and Figure 6 (Appendix B). The ORNL scenario seeks to achieve full commercialization by 2025 based on the deployment of several million H2-FCVs nationally, recognizing that market penetration needs to begin in the next decade if H2-FCVs are to play an important role in the 2050 GHG reduction targets.

The ORNL scenario, with an initial deployment of a few thousand FCVs, followed by rapidly increasing sales starting in 2015, reflects how the auto industry could proceed to fully commercialize FCVs by 2025. To meet this accelerated schedule, the auto industry would need to finalize core research, freeze basic design targets in 2009-2010, and move into a five to six year "production development" phase for the production of 10,000s of FCVs per year in the 2015 to 2017 timeframe. To support this, a review of the progress of H2-FCVs in meeting the 2010 U.S. DOE targets needs to occur in 2009. Recent studies [4] suggest that if H2-FCVs can achieve the 2010 U.S. DOE targets they would be competitive with other advanced technology vehicles (i.e. plug-in hybrid electric vehicles and battery electric vehicles) that are being considered under the ZEV Regulation. Specifically, the study showed H2-FCVs could be competitive while assuming hydrogen storage and fuel cell costs are higher than the 2010 targets.

A key message of this paper is that setting a rapidly advancing FCV sales target (as part of a federal demonstration program) is necessary to effectively launch the pre-commercial FCV market within 10 years, which in turn is necessary to ensure FCVs are available as one of the vehicle technology paths in the portfolio of solutions critical to helping California meet the 2050 GHG goal. The new CARB ZEV Regulation [7] retreats from requiring a substantial number of pure ZEVs in the 2015 to 2017 timeframe, and will stall the momentum toward commercialization of FCVs (large cost reductions are expected to occur with volumes in the 100,000's [5]). Additionally, as we applaud the extensive effort by the ZEV Technology Assessment team convened by CARB for the ZEV Regulation review [24], we disagree with the conclusion that FCV commercialization will not occur until post-2020.

<u># 2</u>: Support new stations in the Los Angeles area over the next two years and use H2 funding strategically

The state needs to enable the deployment of three to five new H2 stations by 2010 (refer to Figure 2) and provide financial support to enhance the accessibility and operation of a few of the fifteen existing stations in the Los Angeles area. This early action will enable the next few years of demonstrations and provide a crucial bridge to 2010, when substantial federal funding could become available for hydrogen vehicles and infrastructure (see below). State funding decisions should leverage and enhance private investments, supporting stations that are strategically located where vehicle deployments will occur (closely aligned with Recommendation #4 below). By modifying existing state funding programs and partnering with the federal government, the cost to the state would be minimal.

Recent studies have shown that a sparse network of hydrogen stations, placed appropriately, can serve a large number of vehicles and provide fuel accessibility to a large number of Californians [25]. The Los Angeles demonstration activities should be leveraged with both the U.S. DOE Hydrogen Demonstration Program and with South Coast Air Quality Management District's hydrogen activities.

To date, the California state legislature has passed two laws that address funding for hydrogen. SB 76 (2005) and SB 1505 (2006) established guidelines and environmental standards for state-funded hydrogen infrastructure. Both were important milestones, but both should be reviewed. We recommend that future California legislative funding for hydrogen allow for more flexibility in spending priorities. State hydrogen funding will be most useful when it augments and enhances privately funded stations with federal program support and is part of a broader strategic infrastructure plan. Recommendations include:

- Use public funds for new station construction if it encourages major energy firms, hydrogen gas providers, or entrepreneurs to construct an otherwise unplanned station in a location identified to be strategic for the Los Angeles demonstrations. Three to five new stations placed in the Los Angeles area could ensure an effective demonstration in the next few years. This activity is expected to be initiated with CARB's forthcoming RFP that will distribute $7.7 million for new and existing station enhancements in the LA area.
- Use public funds to increase access to existing hydrogen stations (see Figure 5 in Appendix B). Currently, access to a number of stations is restricted to a single automotive company. This is a straightforward and inexpensive way to quickly expand the infrastructure.
- Use public funds to support specific activities with which private energy firms need help, including permitting procedures, training local officials and community leaders, and enhancing station accessibility (refer to Recommendation #4). This will not require substantial funding, but represents a critical role for the state to ensure private investments are maximized. This was not part of the original SB 76 funded program, but should be the basis for a review of the state's hydrogen program.
- The SB 1505 requirement that hydrogen fuel reduce vehicular GHG emissions by at least 30% compared to gasoline vehicles is achievable since hydrogen produced from natural gas exceeds that target. However, the requirement that at least 33% of the hydrogen dispensed for transportation comes from renewable energy should be relaxed until 2010 to encourage the infrastructure expansion. Relaxing the requirement until 2010 would allow California funds to enable three to five new stations in the next few years during a critical station deployment phase.

Automotive developers are moving aggressively in developing FCVs, but energy firms currently have less incentive to establish hydrogen stations until there is a larger demand. Therefore, stronger government action is necessary to help clarify a roadmap for the H2 infrastructure during the demonstration and transition periods to provide more certainty for energy firms.

Federal Action

 # 3: Starting in 2010, U.S. DOE should fund an expanded network of stations in Los Angeles and provide incentives for vehicles.

Starting in 2010, the second phase of the U.S. DOE Hydrogen Learning Demonstration Program needs to be implemented to enable deployment of the H2-FCVs required under the ZEV Regulation and an additional 20 large-capacity stations in the Los Angeles basin prior to 2015 (refer to Figure 2. Existing Congressionally authorized funds (Section 808 of the Energy Policy Act of 2005) should be used for cost share grants with industry for infrastructure and vehicle subsidies between 2010 and 2017. To support this, a review of the progress of H2-FCVs in meeting the 2010 U.S. DOE targets needs to occur in 2009. Figure 2 in the Executive Summary outlines the pace of station infrastructure growth.

The funding for a federal Hydrogen Learning Demonstration Program, described in Section 808 of the Energy Policy Act of 2005 [6], has been authorized, but not yet appropriated or planned. The following are this paper's recommendations for the demonstration program:

- Total FCV capital costs are expected to exceed hydrogen infrastructure costs by more than 9 to 1 [5]. Therefore a fraction of the federal funding should be appropriated to the automotive industry to reduce their fleet costs. This creates a "market pull" policy that helps to ensure a large number of FCVs will be deployed. Without a market pull policy (as vehicle costs are still high), automotive manufacturers cannot justify producing the vehicles. This policy could take several forms, including government incentives that offset the incremental vehicle cost to consumers, or direct government vehicle procurement for government fleets. The latter may be a means to ensure vehicles are centrally located near limited H2 stations.
- Stations receiving funds should be part of a planned network. Specifically, there should be a coordinated strategy assuring placement of stations where they are most needed. There will need to be some flexibility as fuel providers will have their own priorities on where to place stations.
- It may be appropriate to provide incentives (higher proposal weighting) to energy companies that will construct multiple stations. This ensures that the federal funding helps specific companies reduce costs and learn from the demonstrations.

 # 4: Institutional challenges need to be addressed for infrastructure investments

The federal government can take a variety of actions to enable the early stages of the hydrogen transition for both vehicles and infrastructure. Because hydrogen fueling station investors are shouldering significant risk due to uncertainty in the long-term prospects, a variety of mechanisms to spread the risk between government and industry should be studied. One possibility is a federal tax credit for hydrogen fuel sales that could help improve the early business case for stations. Other mechanisms include but should not be limited to loan guarantees, accelerated depreciation, and station liability protection. Furthermore, institutional challenges, if not addressed, will restrict station infrastructure from growing at the pace required to meet the 2015 targets. Specifically, national codes and standards need to be further developed and closely coordinated with state officials to streamline the permitting process.

The policy mechanisms mentioned above are important "foundation building" activities that commonly are overlooked, but have been clearly emphasized in major authoritative studies [3,16,17,23]. Emphasizing a major recommendation in [17], these policies need to be

coordinated by a national Interagency Task Force because more than one agency oversees these policies. This national effort needs to clearly depict the role of H2 in the broader energy strategy, and ensure consistent, long-term support during the transition period of the H2 infrastructure.

National codes and standards need to be further developed, and states need to help ensure these codes are implemented locally. Consistent standards and a streamlined permitting process will allow stations to be designed to common requirements, saving time and money. States can facilitate hydrogen infrastructure development by supporting training modules and providing outreach to local officials, thus increasing community awareness of the benefits of H2 and FCVs. In California, this activity should be led by CARB's CaH2Net program with support from the CaFCP. One study [23] recommends that states should cultivate hydrogen-supportive communities (not solely customers) for early demonstration locations, and to coordinate support in addressing NIMBY concerns.

The feasibility of a national hydrogen tax credit should be studied to understand its impact on motivating early infrastructure developers to enter the market. Such an incentive could improve the early infrastructure business model by reducing the developer's fuel price, and increasing profit potential to levels that would offset the risk. In addition, policies that allow for accelerated depreciation and/or loan guarantees for hydrogen station capital to compensate for investor risk in this emerging market should be considered.

Because station ownership will range from major energy firms to smaller industry stakeholders, liability insurance will be critically important. The federal government should conduct a risk study that examines the multiple decades of industry experience with handling hydrogen. A prime audience for this risk assessment should be the insurance industry. The study would underscore the experiences to date to build confidence among insurers and ease concerns about liability.

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Appendix B – Infrastructure and Vehicle Sales Details

Hydrogen Stations in Los Angeles, California

The map below shows the existing and planned hydrogen stations in the Los Angeles area. There are a total of 15 operational stations in this part of Southern California (not including the San Diego and Palm Desert locations). Approximately half of these stations are restricted to only one automotive OEM. As a result, customers wishing to receive fuel have a network of only seven stations from which to choose.

The future of some stations is uncertain. Although a few stations are retiring because they were originally designed for a limited timeframe, others may be at risk of closure prematurely. At the LAX station, for instance, BP is looking for a new operator to take over control of the station. Other stations could benefit from improvements or enhancements. The Santa Monica station could use an upgrade to 700 bar pressure for improved support for vehicle fuel requirements. UC Irvine's station is already 700 bar, but fuel capacity (kg/day) is very low and could use an enhancement to support larger fleets.

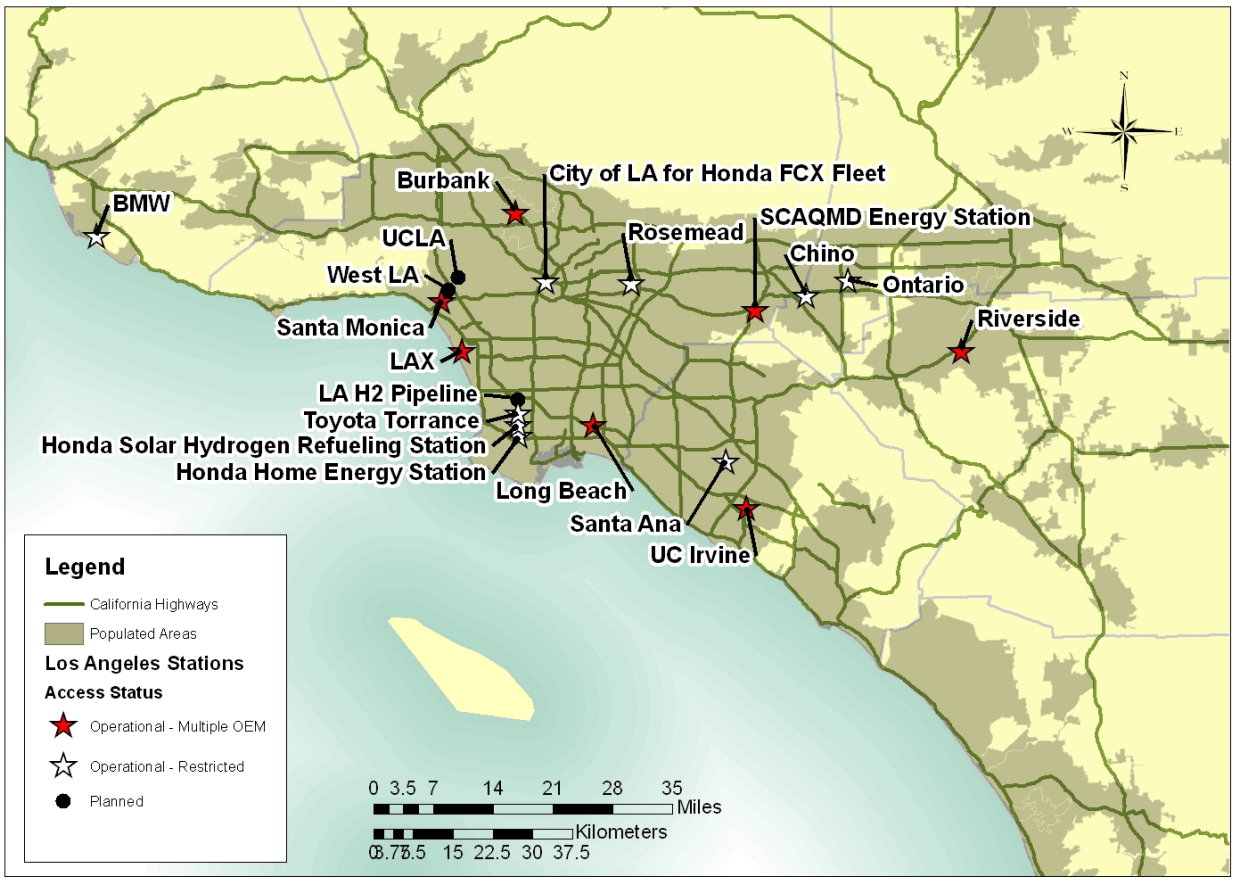

***Figure 5**: Existing and planned hydrogen stations in the Los Angeles area (Source: CaFCP data, GIS map developed by Mike Nicholas)*

Annual FCV Sales in ZEV Regulation and ORNL Scenario

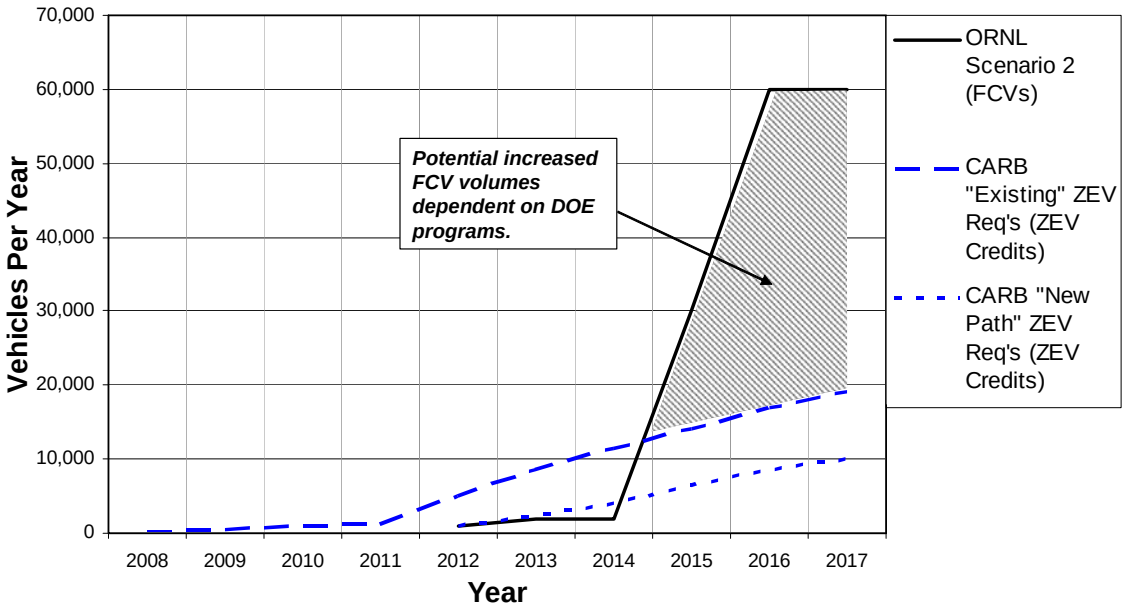

Figure 6: *Cumulative number of FCVs or ZEV Credits by 2017*
Minimum number of FCVs recommended in this report – 50,000 cumulative by 2017
(Sources: ORNL [5] and CARB [7])