NEXT 10

EDUCATING, ENGAGING AND EMPOWERING CALIFORNIANS TO IMPROVE OUR STATE'S FUTURE

Driving Transportation Innovation

FINDINGS FROM DISCUSSIONS WITH VENTURE CAPITALISTS, ENTREPRENEURS & TRANSPORTATION EXPERTS

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NEXT 10

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About Next 10:

Next 10 (www.next10.org) is an independent, nonpartisan organization that educates, engages and empowers Californians to improve the state's future. Next 10 is focused on innovation and the intersection between the economy, the environment, and quality of life issues for all Californians. Next 10 funds research by leading experts on complex state issues and creates a portfolio of nonpartisan educational materials to foster a deeper understanding of the critical issues affecting our state.

EXECUTIVE SUMMARY

Transportation innovations that deliver near-zero emissions have a central role to play in mitigating climate change and bolstering energy security. With our nearly exclusive dependence on oil and internal-combustion engines, transforming transportation will be a heavy lift. Barriers standing in the way of industry, entrepreneurs, investors, and consumers make it difficult for the market alone to deliver sweeping greentech innovations.

A strategic, sustained policymaking effort will be needed to trigger technology and market transformations leading to near-zero emission transportation.

This report explores policy options for driving near-zero emission transportation innovation. It was developed with input from an array of experts. While this is not a consensus document, there is general agreement among experts that a multi-faceted solutions toolbox — a mix of rules, incentives, RD&D, and other complementary policies — will be needed to fully commercialize near-zero emission transportation innovations. Such policies include:

- **Regulations** to set the performance parameters and safeguard against unintended consequences;
- **Economic incentives** to align prices, rationalize markets, and stimulate supply and demand;
- **Research, development, and demonstration (RD&D)** to usher cutting-edge vehicle and fuel technologies from their pioneer to market stages; and
- **Education and outreach** to broadly distribute up-to-date, honestly-brokered information.

Historically, California has led the way on near-zero emission policies, including criteria air pollutants and greenhouse gas emissions. New strategies are now under development, including updated Zero Emission Vehicle rules, the second round of Pavley greenhouse gas tailpipe standards, implementation of Low Carbon Fuel Standards, and clean car incentives through a new feebate policy. What's more, the federal government is beginning to play an active role.

The next generation of near-zero emission transportation (NZET) policies is needed to advance innovation. It is likely that state and federal policymaking efforts over the next two years will drive transportation innovation for the next decade or more. The cost of transformational change will, no doubt, be high. But the overall benefits are likely to be even greater.

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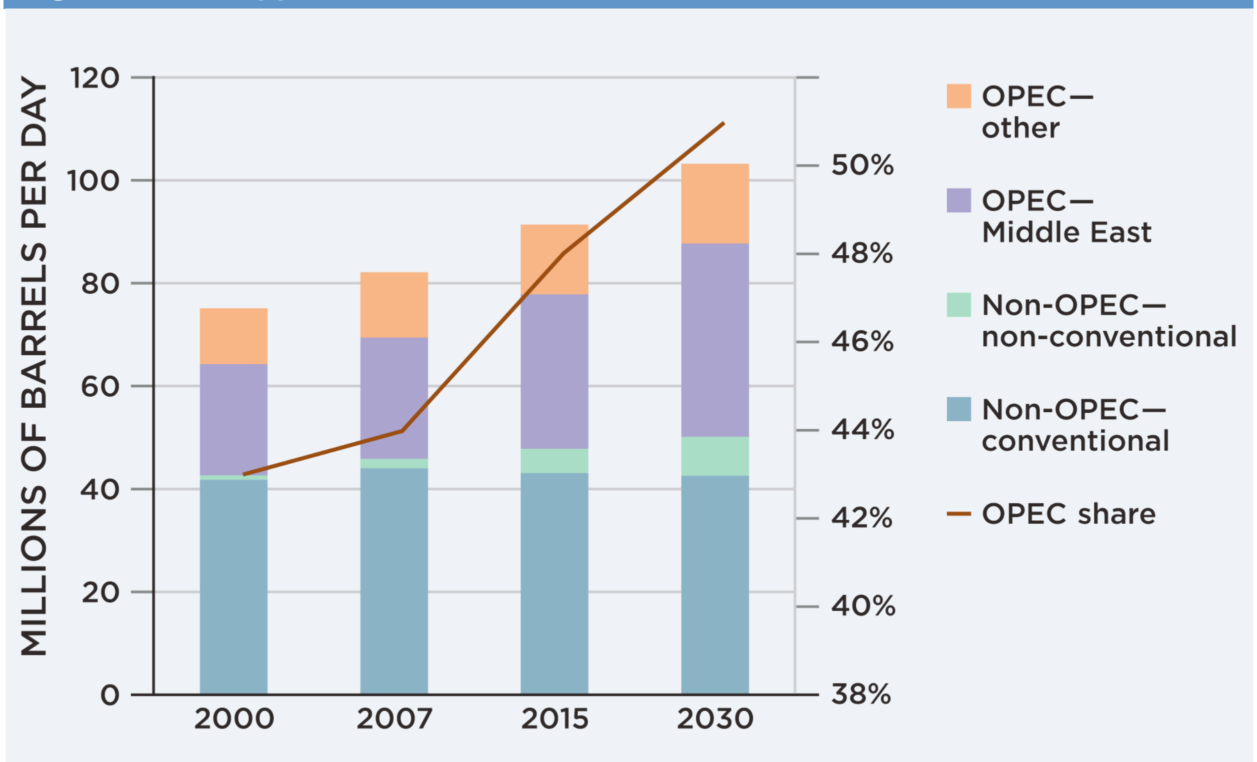
BACKGROUND

Today our transportation sector is powered by oil and laden with carbon. This situates our mobility at the precarious intersection of climate change and oil dependence. Low-carbon and green energy policies are needed to spur innovation and entrepreneurship in order to address these concerns.

Incentives have long been misaligned and rules lacking. Dependence on oil has grown due to policies that keep prices low. As a result, oil imports continue to grow because those nations with the least oil reserves have the world's greatest oil demand. This dubious distinction holds for the U.S., China, and India, among others. Even resource-rich California's oil imports are increasing rapidly. The U.S. and other net importers must turn to nationalized oil companies who now control over 80 percent of the world's oil reserves. Moreover, the Middle East is gaining control of global oil production at a time when conventional non-OPEC oil supplies are in decline (see ***Figure 1***). These conditions foster an unstable, dysfunctional market for one of the most sought after commodities needed to ensure global mobility.

Figure 1: Oil Supplies, 2000-2030

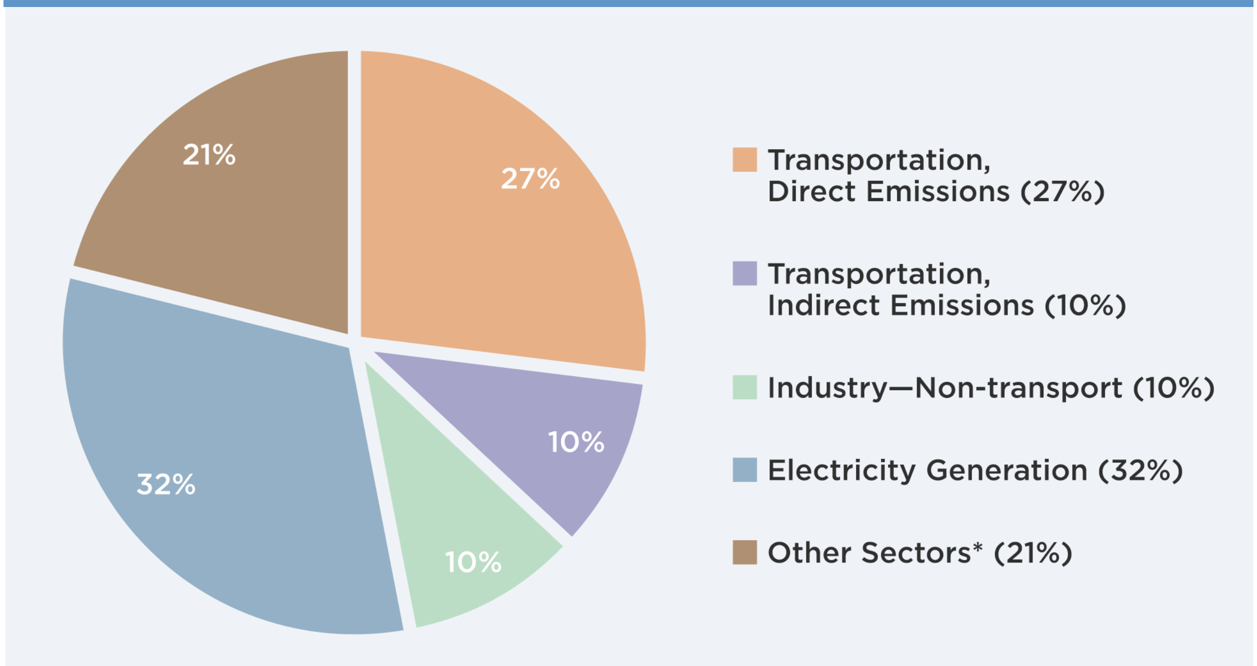


Source: International Energy Agency, *World Energy Outlook, 2008.*

Still, expectations continue for cheap, readily accessible oil. This invites market manipulation, price fluctuations, political clashes, and the push for unconventional oil development. Should unconventional oils – tar sands, shale oil, and coal – be used to meet growing global transportation energy demands, serious environmental impacts will likely result.

The U.S. transportation sector accounts for 27 percent of greenhouse gas (GHG) emissions from all vehicle sources. When *upstream* emissions are included into the fuel-cycle (to make and transport fuels and vehicles), America's share of transport CO_2 equivalent emissions is closer to one in every three pounds economy-wide[i] (see ***Figure 2***). Growing global motorization represents similar worldwide GHG shares from transport sources, with motor vehicles leading the charge.

Figure 2: U.S. Greenhouse Gas Emission Shares



** Other Sectors include Agriculture, Commercial, and Residential sectors in approximately equal shares.*
Source: US EPA, March 2006, page 6. (See full cite in ***footnote 2***).

Heat-trapping gas emissions rose rapidly in transportation between 1970 and 2004, up 120 percent. Future projections for CO_2 from energy use are forecast to increase 45 to 110 percent if fossil fuels continue to dominate through 2030.[ii] Much can be done with current technologies as shown in Socolow and Pacala's stabilization wedge approach. But this strategy was focused on maintaining an atmospheric CO_2 concentration of 550 parts per million (ppm).[iii]

What if we must go beyond this target? While the oft-stated goal is to keep global warming at less than two degrees Celsius (3.6 degrees Fahrenheit), many experts now estimate that we must collectively reduce atmospheric carbon dioxide levels to 350 ppm if we are to safeguard against climate crises.[iv] Today the atmospheric concentration of CO_2 is 385 ppm, and rising 2 ppm per year. Worst case projections from the IPCC indicate up to a 6 degree C rise in surface temperature and a 0.6 meter rise in sea levels by the end of the century if greenhouse gas emissions go unchecked. This further underscores the need for emission reductions in the transportation sector – the sector experiencing the greatest growth.

What role can the transportation sector play in achieving carbon reductions? The Intergovernmental Panel on Climate Change (IPCC) assigned only eight percent of the global GHG mitigation potential to the transportation sector.[v] They cited major challenges for the sector as "growth counteracting mitigation" and "consumer choices trumping best practices". In reality, many experts believe that the mitigation potential in transportation is much higher than the IPCC estimated. But timeframes are long, hurdles are high, and successful implementation of effective, complementary policies is crucial.

Climate protection and energy security ultimately mean achieving zero or near-zero emission levels in transportation (and all sectors of the economy). Achieving near-zero criteria and greenhouse gas emissions requires moving beyond fossil fuels to carbon-free energy sources.[vi] However, our existing policy tools and R&D efforts are not yielding technological progress at a pace commensurate with the climate and energy challenge. A huge, sustained effort in RD&D is needed to advance near-zero transportation technologies. There is also an urgent need for policy measures that establish clear, predictable, long-term performance standards. Companies, investors, and consumers also need long-term market signals that align incentives to cut carbon and save energy in transportation and throughout the market. The price-premium attached to NZET vehicles is currently too great for mass-market adoption. Policies are needed to balance affordability and value of first-generation near-zero emission vehicles.

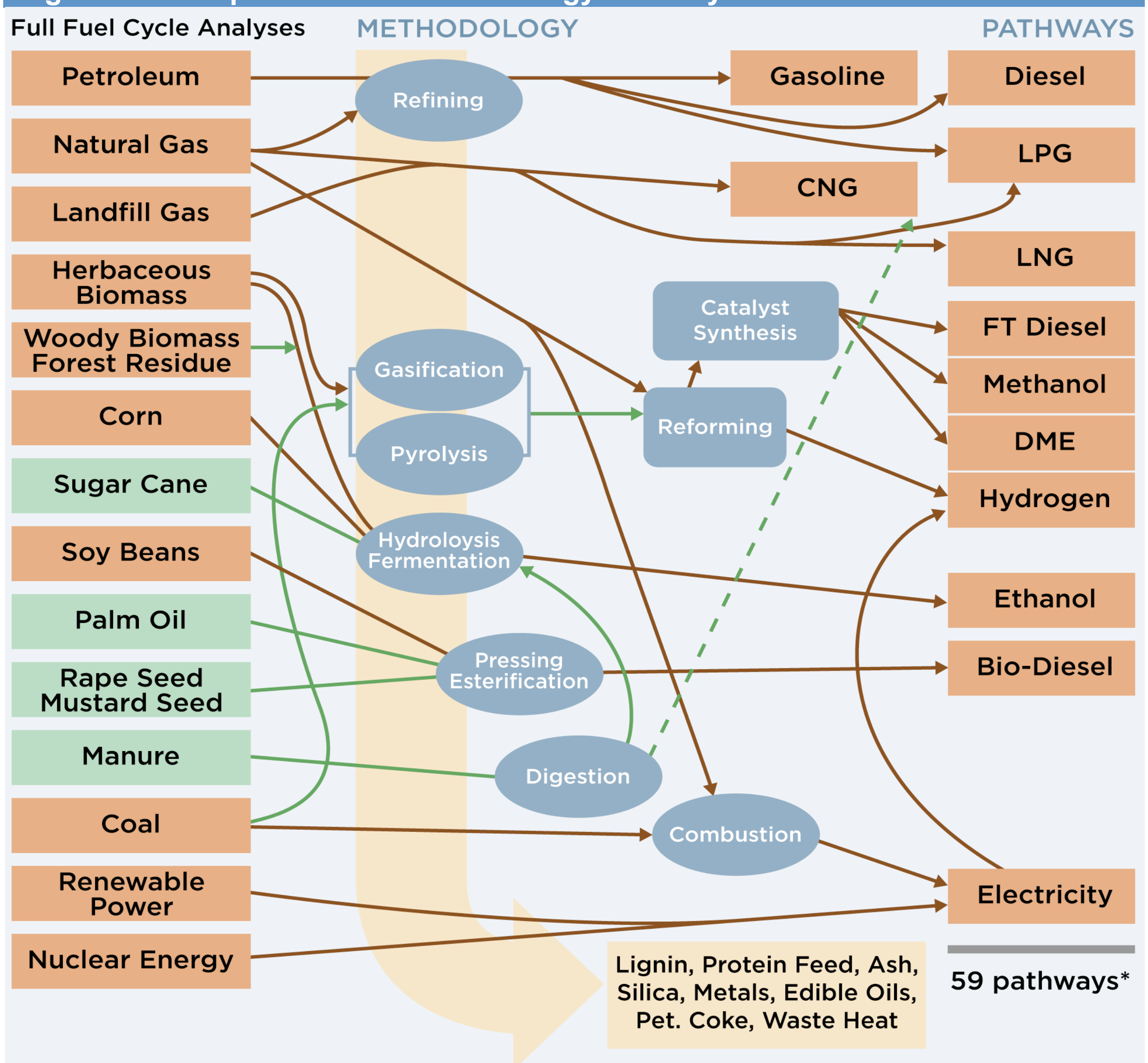
Given growing mobility and energy demands worldwide, the transition to near-zero emission transportation will have private and public dividends. A cleaner, efficient, more diversified transportation sector will benefit both developed and developing nations.

There are numerous transportation innovation pathways, each at different states of development, confronted by different technological and other barriers, with their own uncertainties, unintended consequences, and yet-to-be-determined real-world outcomes. Such complexity hampers innovation and underscores the need for public policy to drive innovation in NZET.

NEAR-ZERO EMISSION TRANSPORTATION TECHNOLOGY OPTIONS

There are many technological paths to power transportation in the future, some near-zero carbon and others not, and some reinforcing broader environmental goals and others competing. Future breakthroughs and trade offs will continue to modify these pathways and determine if technologies can deliver NZET and other societal benefits. At issue is how best to design policies to transform transportation. A brief discussion first of the current barriers facing candidate technologies is worthwhile before launching into the main discussion on policies to drive NZET.

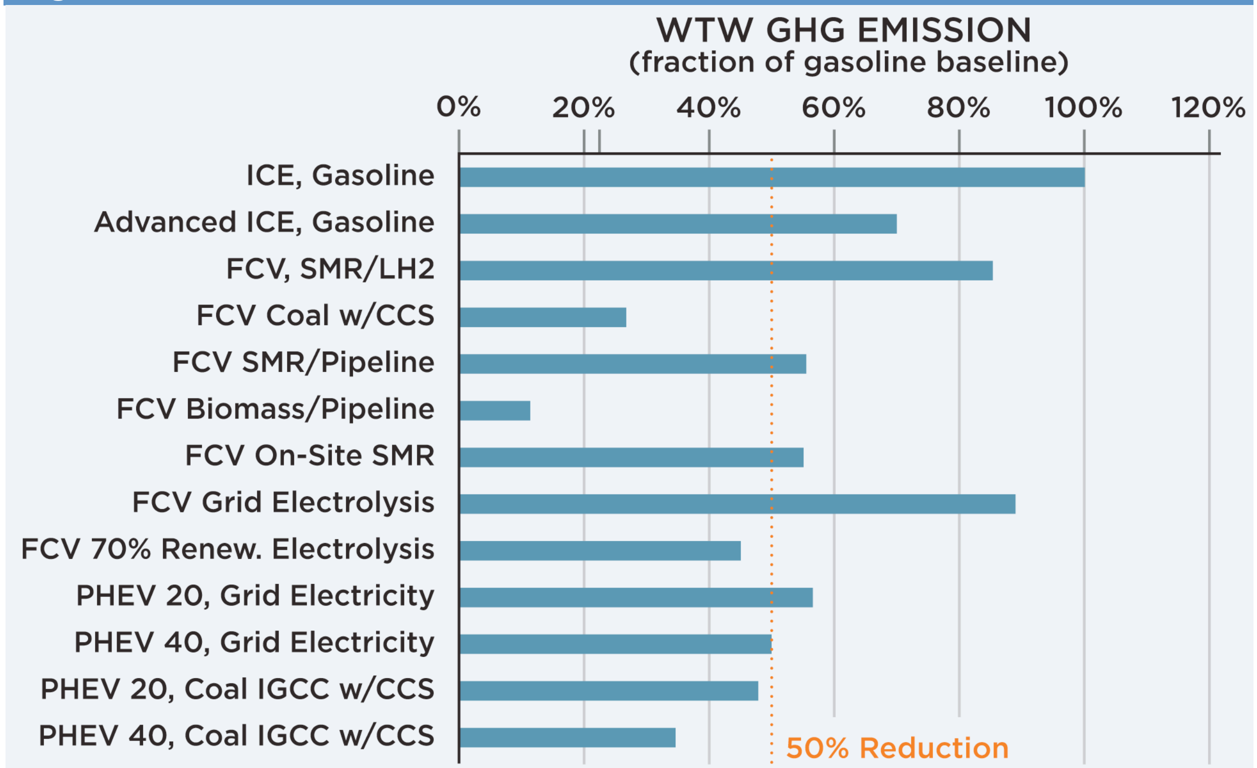
Figure 3: Transportation Fuel Technology Pathways



*The number of transportation-energy pathways is growing since this schematic was developed. Nanotechnology is under development for biomass separation processes to liquid fuels and algae can now provide new pathways to ethanol and bio diesel through photosynthesis or fermentation (without sun).
Source: Michael Jackson, TIAX, LLC, "Full Fuel Cycle Analyses for AB 1007," May 15, 2007.

Transportation technology innovation entails both fuel components (see ***Figure 3***) and vehicle design. Current analyses indicate that electricity, hydrogen, coal with carbon capture and sequestration (CCS), and cellulosic biomass are the transformative pathways capable of reducing wellhead-to-wheel (WTW) GHG emissions on the order of 50 percent or more (see ***Figure 4***).

Figure 4: Relative GHG Emissions: Wellhead to Wheel



Source: CARB/CEC, Development of the State Plan for Alternative Transportation Fuels (AB 1007), May 24, 2007. Key: ICE=internal combustion engine; FCV=fuel cell vehicle; CCS=carbon capture and storage; PHEV=partial hybrid electric vehicle; SMR=steam methane reforming; LH2=liquid hydrogen; IGCC=integrated gasification combined cycle.

Of the many different transportation vehicle and fuel innovations under development, several hold out the potential to reduce emissions to near-zero levels. Their current state of development and potential trade-offs are summarized below:

Electric Vehicles and Plug-In Hybrids: Batteries (specifically their cost, durability, and performance) are the main stumbling blocks for commercialization of battery-powered and plug-in hybrid electric vehicles (PHEVs). Commercial roadblocks also surround consumer acceptance of shorter driving distance between charges, high voltages, adequate infrastructure, and perceived safety concerns. The use of advanced lightweight materials can extend ranges for hybrids and battery electric vehicles.

Fuel Cells: Automotive fuel cell vehicles (FCV) have advanced significantly in recent years. Yet, technical developments are still necessary to achieve the performance and cost goals for commercialization. Needed improvements include simultaneously increasing the power density of the membrane-electrode assemblies to reduce the overall size of the fuel cell stack, reducing the catalyst loading and associated cost, increasing the operating life, and expanding the operational temperature range of the cell. The fuel used to power a fuel cell plays a large role in determining overall emissions as indicated in ***Figure 4*.**

Hydrogen: Whether used in a fuel cell or combusted, infrastructure – and fuel storage in particular – present the major barriers for hydrogen. Hydrogen cannot be stored, transported or dispensed using today's infrastructure. Present hydrogen storage concepts rely on compression which has difficulty achieving acceptable vehicle range within the targets for volume, weight, and cost, as set by the Department of Energy (DOE). Further development of liquid and alternative storage techniques (metal and chemical hydrides, activated carbon structures) will likely be required to achieve all the storage targets. However, cost will continue to be a factor for hydrogen as it is for many other oil alternatives.

Cellulosic Ethanol and Other Advanced Biofuels: Biofuels, like other oil alternatives, have the potential to emit near-zero emissions when the fuel cycle is taken into account. When only tailpipes are considered, this may not be the case. The goal for next-generation cellulosic biomass based ethanol fuels that reduce fuel cycle carbon emissions and avoid the use of food resources like corn has been limited by inadequate technological progress on microorganisms to ferment sugars and the high cost of enzymatic conversion technologies. Biofuels from algae and other organic feedstocks also have technological potential, especially those processes that use photosynthesis to produce hydrocarbon fuels. But the ability to produce next-generation biofuels on a large, industrial scale has yet to be done. These fuels could also face local roadblocks depending on land use, water, biodiversity, and other societal tradeoffs. Burning biofuels in vehicle engines may also increase toxic air emissions.

Renewable Electricity: In powering near-zero electrified vehicles, the biggest technical challenge associated with variable renewable electric power generation is energy storage. And while many current-generation renewable energy technologies are either market ready or competitive, the challenge is to scale them up and pursue breakthroughs in next-generation technologies such as solar thermal power and ocean energy.

Energy Production with Carbon Capture and Sequestration: Carbon capture and sequestration has the potential to remove carbon from electricity and fossil fuel production, making it near zero emitting. But this nascent major industry, similar in size to the oil industry, must be scaled up based on newly developing technologies to capture carbon and store, convert, or recycle it. Technological advances must further demonstrate large-scale capture. But the real barriers confronting this technology relate to storage and its legal, environmental, and societal impacts.

Nuclear Power: Nuclear power does not produce greenhouse gases, offering it up as a potential near-zero emitting electric fuel source that is likely to be pursued in the course of vehicle electrification. Existing barriers are part technical and part social, and reside in three areas: unresolved physical challenges in long-term management of nuclear wastes; perceived adverse safety, environmental, and health effects; and potential security risks stemming from proliferation of nuclear materials.

BARRIERS TO INNOVATION

Markets have the potential to work efficiently when ideal conditions exist. Such equilibrium between supply and demand, with few unintended consequences, is evident in certain parts of the U.S. economy. This is not the case when it comes to transportation, energy, and carbon markets, however. Here, numerous barriers stand in the way of innovative near-zero emission transportation products and practices.

While many promising revolutionary vehicle and fuel technologies are on the horizon, none are commercially viable on a large scale today. Each one faces major technological barriers, as well as other economic and market hurdles, infrastructure roadblocks, and political constraints.[vii] Electrification, for example, requires significant advances in energy storage (vehicle battery technology, ultracapacitors, and flywheels) and depends largely clean electric generating infrastructure. Plug-in hybrids require advances in battery technology in terms of cost and performance. Hydrogen requires fuel storage breakthroughs and extensive infrastructure development. Unconventional fossil fuels require carbon capture and sequestration development. Fuel cells require compact design and operating temperature advances. Next-generation biofuels require advances in conversion technologies and a better understanding of water and land use impacts.

Stakeholders at a fall 2008 dialogue convened by Next 10 identified four major barriers to mainstream adoption of near-zero emission vehicles, including technical, political, market, and infrastructure. (See Appendix A for a list of experts consulted in preparing this report.) Although the rank and order of these barriers differs among stakeholders, there is general agreement that certain barriers are blocking innovation (see ***Table 1***). Technical barriers rank high. Hurdles relate to cost, durability, and performance of batteries and other technologies. Market barriers, regarding fuel and vehicle cost, consumer demand, and fluctuating energy prices, are identified as secondary hurdles that innovation must overcome. Infrastructure and political barriers are also cited as secondary barriers. Infrastructure barriers revolve around electricity recharging and hydrogen refueling, while political barriers concern an overall lack of leadership.

Table 1
Survey Responses Ranking Barriers to Mainstream Adoption of NZET

BARRIERS	STAKEHOLDERS		
	Policymakers	***Venture Capitalists/Entrepreneurs***	***Industry***
Technical	1	1	2
Political	--	2	3
Market	2	3	--
Infrastructure	3	--	1

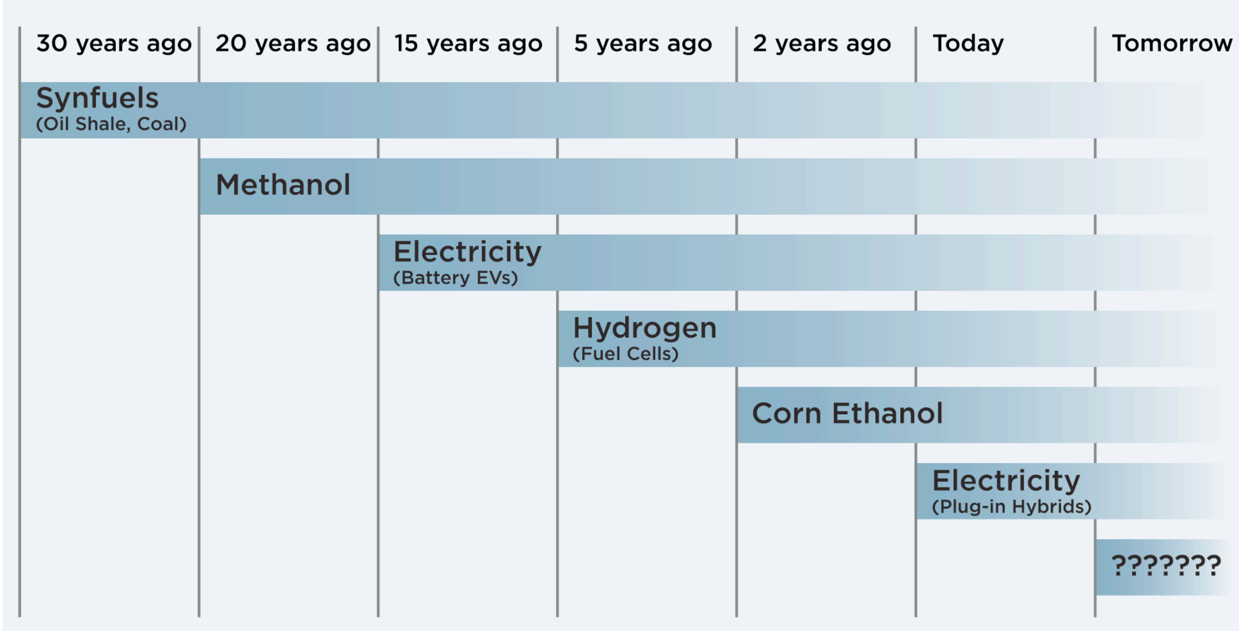
Source: September 3, 2008 Stakeholder Roundtable on Battery-Based Electric-Drive Vehicles, Next10.org
Key: 1 = Higher barrier; 3 = Lower barrier

Existing policies – subsidies, tax codes, regulations, legal systems, and other requirements – tend to serve the status quo. Agents for conventional technologies have a foothold in the market and can advocate for favorable policy treatment toward their investments. Consumers, who are often wedded to familiar ways, further reinforce policies that promote business-as-usual practices. Established industries producing conventional technologies enjoy economies-of-scale that pit market dynamics against small-scale innovators. Even public-sector electric utilities have not entirely embraced venturing into the transportation sector, which requires new infrastructure for feasible recharging, as well as incentives to create new markets.

Nevertheless, market barriers can be overcome by stabilizing erratic energy prices, implementing strategic policymaking that informs consumer demand, and allowing sufficient scale to be built. When energy prices reflect their true cost, consumer and supplier decisions are much more rational. Political barriers concerning a lack of leadership can be largely sidestepped by setting clear performance standards that provide long-term guidance to the marketplace. Government no longer has to debate the merits of specific technologies when performance parameters are established. Technical and infrastructure barriers are more of a challenge given their physical nature. Government purchase of NZET infrastructure and vehicles, along with ample funding of RD&D activities, are primary tactics. The development and maintenance of legal systems that support near-zero transportation technologies and their utilization is another important piece of a policy strategy.

It was noted by stakeholders in the Next 10 convening that America has a long history of selecting “winning” technologies (see ***Figure 5***) and that government is poor when it comes to picking winners. As we recycle alternative fuel technologies, the synfuel debacle of 30 years ago is now poised to repeat itself. A new approach is needed, one that employs durable transportation and energy policies that are technology neutral and performance based.

Figure 5: Evolution Transportation Fuel Development in the U.S.



Source: Deborah Gordon, "Two Billion Cars: Transforming a Culture," Keynote Address, 2009 Transportation, Land Use, and Air Quality Conference, Denver, Colorado, July 28.

Even when innovation policies are designed to be neutral, there are bound to be "winners" and "losers" in the marketplace. Less powerful start-up companies tend to be rewarded more by innovation policies than powerful, entrenched players. The role of policymakers is to set societal goals for near-zero emission transportation *without* picking winning technologies and *without* bowing to losers.

OVERVIEW OF POLICY TOOLS

Public policies are needed to advance transportation technology innovation to meet evolving consumer needs and solve our societal problems. The right policy design can further near-zero emission transportation goals by surmounting the technical, political, market, and infrastructure roadblocks discussed above.

The most politically popular policy strategies encompass ***regulations, standards, and mandates***. Performance standards, safety regulations, and technology mandates all play a role in advising the market and its investors on how to design, build, and sell products. Current regulations necessarily focus on conventional technologies, inadvertently standing in the way of innovative new approaches. For example, regulations prevent hydrogen vehicles from traveling through many of the nation's tunnels and bridges.

As a complement to standards, ***economic incentives and disincentives*** offer carrots and sticks to financially motivate consumers (stimulate demand) and producers (facilitate market build out). Federal incentives of up $2,500- $7,500 for plug-in electric drive vehicles are one example. These tools change the fundamental economics of decisionmaking while imparting quantitative information about what society values and how seriously it seeks to minimize certain problems.

Redistributive market programs direct public money to or away from specific stakeholders. Examples include grants and subsidies to public agencies or private ventures or individuals. For example, federal grants and loans have recently poured billions of dollars through the economic stimulus package into manufacturing electric vehicles, components, and batteries; as well as infrastructure. An oil price floor can be set to minimize wide fluctuations and steer profits away from OPEC. This policy tool can also be used to redirect targeted tax revenues to low-income individuals.

Direct government purchase or supply of targeted activities through Research Development and Demonstration (RD&D), technology transfer*, *and government procurement inserts the public sector into the innovation equation. RD&D provides pre-competitive innovations that can benefit all suppliers. And the transfer of technologies, especially from technologically advanced defense agencies to civilian government agencies and between developed and developing nations, could be a boon to clean tech innovation. (The defense sector is arguably where the government's most advanced technological thinking resides.) In terms of technology demonstrations, local, state, and national governments offer large markets for testing new products and practices. The practical information obtained from these sources can be used to better refine innovations before they are released to the larger marketplace.

The distribution of information through education and outreach offer the potential to honestly broker information, the key to sound decisionmaking. These strategies illuminate the unintended consequences attributed to current products and practices, influence innovations in the supply chain, and help consumers seek new products and change their behavior. The more transparent, immediate, and intuitive this information is, the greater its effect on innovation. Policies, for example, that advance common open communication platforms (such as the government policies of the 1990s to facilitate the "information superhighway") can serve to further NZET innovation goals.

Lastly, the ***development of legal systems*** plays a crucial role in guiding behavior in society. These rules often influence innovation in direct and indirect ways. For example, the relaxation of laws that govern public lands and the outer continental shelf facilitate fossil fuel development. Future ordinances that invoke low-carbon requirements, on the other hand, could influence land use in ways that promote NZET innovations. Regulatory and legal reforms may also be required in order for public utilities to assume responsibility for NZET technology deployment.

EVOLUTION OF TRANSPORTATION INNOVATION THROUGH POLICYMAKING

Past and present government policies have shaped technology pathways and market dynamics. Future policies can have the same effect (see ***Table 2***).

Looking back, numerous policies have worked in concert to wed Americans (and growing ranks of other countries) to internal combustion engine vehicles fueled almost entirely by fossil fuels. Some of these policies date back to the turn of the last century. Some policies are updated periodically while others remain in effect for long periods without modification.

Looking to the future, a new slate of promising public policies could benefit the green tech innovations supported by venture capitalists. In stark contrast, an entirely different future policy agenda – removing bans on offshore oil drilling and adopting incentives for tar sands, coal, and shale oil development –could steer transportation innovation in the wrong direction.

Table 2
Past, Present, and Future Public Policies Influencing NZET Innovation

Policy Category	Past	Present	Future
Regulation of market activities	• CAFE standards • Vehicle emission standards	• Next generation fuel economy and emission standards • LEV/ZEV mandates • Renewable fuel standards	• Fuel cycle ZEV mandates • GHG emission standards (Pavley II) • Carbon cap-and-trade • Low carbon fuel standards
Economic incentives	• Gas guzzler taxes	• Hybrid vehicle incentives • Electric-drive vehicle incentives	• Clean car feebates • NZET production incentives • Carbon tax
Redistributive market programs	• Oil industry subsidies	• Auto industry bail outs • Federal grants and loans for producing electric vehicles	• Fuel price floor • Targeted tax revenue expenditures (R&D, infrastructure, low income)

Policy Category	Past	Present	Future
Distribution of Information	• Labeling and advertising	• Social networking	• Hand-held, real-time, intuitive information devices • Open communication platforms • Honest broker information organizations (e.g., Office of Technology Assessment)
Development and maintenance of legal systems	• Anti trust • Property rights • Eminent domain	• Intellectual property rights • Environmental justice reforms	• Public lands moratoria • Binding carbon emission reductions • Low carbon land use and zoning
Direct government purchase or supply of particular activities	• Government RD&D (with defense and energy focus) • Interstate highway system	• Government RD&D (with added local environmental focus) • Government fleet vehicle purchases	• Government RD&D (with added global environmental focus) • Electricity infrastructure and technology development • Government financing and investment on NZET • Technology transfer from defense to civilian agencies and internationally

PUBLIC POLICIES THAT ADVANCE TRANSPORTATION INNOVATION

Each grouping of policy tools described below can be implemented using different approaches. A policy's design specifications will determine which goals can be achieved. The policies that hold out the most promise for advancing near-zero emission transportation innovations are summarized in ***Table 3***. This policy plan contains strategies that can be adopted individually, which is usually the most politically feasible course of action. However, a more comprehensive policy program, while politically challenging, is more likely to achieve overarching goals. Moreover, these policies can be implemented at the federal, state, and local levels in tandem or individually to reinforce near-zero emission innovations using both top-down and bottom-up approaches. (See Appendix B for a list of recent California Near Zero Emission Transportation policies.)

Table 3
Near-Zero Emission Transportation Policies

Regulations, Standards, & Mandates
Fuel Cycle ZEV Mandates: Early versions of this mandate simply required a set share of new vehicle sales to have zero emissions. Mid-course corrections have introduced regulatory inconsistencies creating challenges for industry. Nevertheless, this type of technology-neutral mandate can advance NZET innovation. Measures of compliance need to be clear-cut, however. The *number of cars sold* is likely not the single best achievement measure. Adding a measure for technological progress – such as high-quality demonstrations of certified vehicles – might spur innovation at a greater rate. Considerations for future elements of ZEV mandates include miles driven (through a pre-designated vehicle lifetime carbon burden and purchased carbon allowances), fuel-cycle emission allowances that take upstream emissions into account, advanced componentry allowances, credits for vehicle range and fast refueling, and credits for vehicle recyclability.
Greenhouse Gas Emission Standards: Vehicles emit numerous pollutants, the largest being carbon dioxide. Criteria air pollutants, air toxins, and other GHG emissions are also byproducts of vehicle fuel combustion. Current fuel economy standards consider fleet-average energy use, not individual vehicle total GHG footprints. They also only apply to new vehicles at the time of sale and not during their lifetimes. GHG vehicle performance standards have been adopted in California to address the shortcomings of CAFE standards while still achieving desired reductions in oil consumption. Vehicle manufacturers must certify GHG tailpipe standards in new vehicles, just as they currently do for criteria air pollutants. Pavley I standards set a benchmark of reducing the GHG emissions of a new passenger vehicle sold in 2020 by over 40 percent. Most importantly, NZET technologies should have the easiest time meeting these standards while gas guzzling conventional vehicles would have the hardest time complying.
Low Carbon Fuel Standard: A low-carbon fuel standard (LCFS) requires oil companies and other fuel providers to reduce carbon and other greenhouse gas emissions associated with transportation fuels. This policy specifies an allowable amount of carbon per unit of fuel produced. In order to comply, oil suppliers would decide how to meet the standard, whether by blending low-carbon biofuels into conventional gasoline, updating refineries to create low-carbon fuels, selling low-carbon fuels such as hydrogen, or buying credits from low-carbon energy suppliers such as electricity generators. Direct and indirect land use must be considered in the full fuel cycle analysis. This durable framework doesn't pick winners, encourages innovation, and sends a direct, fuel-neutral signal to suppliers.

Economic Incentives & Disincentives

NZET Technology Production Incentives: This policy funds production incentives for NZET-qualifying fuels and vehicles. An oversight authority would administer the program. Funds could be allocated through general revenues or through a targeted fee (e.g., on oil producers). Incentives would be used to purchase qualifying vehicles; encourage producers to supply qualifying fuels; create qualifying fuel infrastructure (fueling transmission and stations); and provide research grants and loans for alternative fuels and vehicles.

Clean Car Feebates: Financial incentives and disincentives can change manufacturing and purchasing decisions. The idea is simple: Impose fees to discourage the manufacture and/or purchase of vehicles that are gas guzzlers and polluters, and award rebates to those who make and/or buy fuel-efficient, low-emitting vehicles. It is also possible to create a revenue neutral feebate system that does not require general funds. Success is tied to three key factors. First, feebates are most effective when kept simple and linked with a specific regulatory goal such as greenhouse gas standards imposed on automakers. Second, dollar amounts must be set high enough to have a meaningful effect on consumer, manufacturer, fuel supplier, and car dealer behavior, but not so high that they provoke strong political opposition. And third, the policy design must be sensitive to equity implications. Feebates give automakers and their technology suppliers the certainty of knowing that near-zero emissions will be highly valued into the future. This inspires more innovation and more commitment to getting workable technologies into vehicles.

Fuel Price Floor: Purchase of NZET vehicles is tightly tied to the price of gasoline, which in turn is bound to the price of crude oil. High prices spur fuel efficient, hybrid, and other advanced vehicle sales and low prices shift consumer preference back to inefficient conventional vehicle technologies. The future price of fuel, however, is anything but certain. Such uncertainty creates irrationality in the vehicle market. For example, fuel prices rose to record levels of over $140 per barrel in July 2008 and then plummeted over 50 percent just three months later. By February 2009, a barrel of oil hovered between $30-$35, shooting back up to $70 by July. Such extreme fluctuations are a reminder that there are many factors beyond our control that render fuel prices unstable. Setting a “price floor” on a barrel of oil – or at the gas pump – would henceforth not allow the fuel prices to fall below a particular set point. A price floor on the order of $80 per barrel for oil, or $3.50 per gallon for gasoline and diesel fuel, has been suggested. If high fuel prices continue, this policy would have little impact, cost nothing, and steer manufacturers toward the vehicles consumers prefer. But as prices fall below that level, the government would intervene to keep the price stable, with the difference between the floor and the market price reverting to the state or federal government for targeted revenue recycling, funding incentives, R&D, and other related efforts.

RD&D, Technology Transfer, & Government Procurement

***Government Backed Battery Warranties*:** Manufacturers currently warrant conventional batteries typically over a 36-month free-replacement period and a 108-month pro-rated warranty period. But this is for lead acid batteries with which the industry has a long history. The new battery technologies developed for NZET vehicle applications could benefit from government backed battery warranties, at least until significant knowledge and confidence are built up over time and automakers regain market stability. This could help address consumers' fears over continued operation of large, expensive batteries. These public warranties could be designed as insurance or subsidy programs. On the other hand, government acceptance of liability for lower than expected performance could lead some companies and their financers to place a lower priority on achieving the highest quality standard. Product failures can damage markets for years such as diesel cars sold in the United States in the early 1980's.

Electricity Infrastructure and Technology Development: Utilities must focus beyond their traditional residential, commercial, and industrial customers if NZET technologies are to progress. These innovations require new transportation customers, including motorists themselves. The government could adopt a comprehensive strategy including R&D, demonstration programs and market support guided by long-term strategic plans. In Japan, for example, MITI has acted as the conductor in the development process supplying both R&D support and artificially created niche markets, and easing the way for targeted technologies by means of legislation and standards. CARB has taken similar approach to advance clean vehicle technologies. Both MITI and CARB have been criticized when the targeted technology (the battery-powered electric vehicle or BPEV) was not brought to market. However, the recent market success of the hybrid electric vehicle (HEV) can partly be attributed to these governments' support of the BPEV technology where the enabling component, the electric drivetrain, was developed for automotive use. CARB has focused more on ZEV policy redesigns that allow flexibility, adaptability and cooperation in terms of technical choice. The deployment of EV charging infrastructure can likewise be facilitated by local and state government policies.

Government Purchase of NZET vehicles: Government procurement programs can facilitate the NZET transition. Federal, state, and local governments purchase large volumes of vehicles for a diverse array of public activities. Many of these are currently conventional cars and SUVs. Such large fleet operations can increase volume production in burgeoning markets and provide early experience new vehicle maintenance protocols. Programs such as the US General Service *Administration's Energy Efficient Federal Motor Vehicle Fleet Procurement* program that has appropriated $300 million to acquire motor vehicles with higher fuel economy, including hybrid and electric vehicles are expected to save up to $42 million and 10 million gallons in fuel and 24 million pounds of carbon over the vehicles' lifetimes.

Information, Education, & Outreach

***Hand Held, Real Time, Intuitive Information Devices*: ** Black boxes are the first generation of information technology. If deployed widely, they would facilitate policies like emission fees and user charges to help transform vehicles and fuels. The second generation of such IT devices is the collection and distribution of real-time data to inform users about the all facets of the conditions affecting their own transportation, energy, and environment systems. Navigation systems are a limited application of this technology. Armed with information, travelers can best select which vehicle modes, routes, budgets, and schedules fits their particular situation. The third generation of these IT devices could be intuitive machines that decide – like a personal travel agent who knows your preferences – when, where, and how individuals' travel decisions are optimized.

Legal Systems

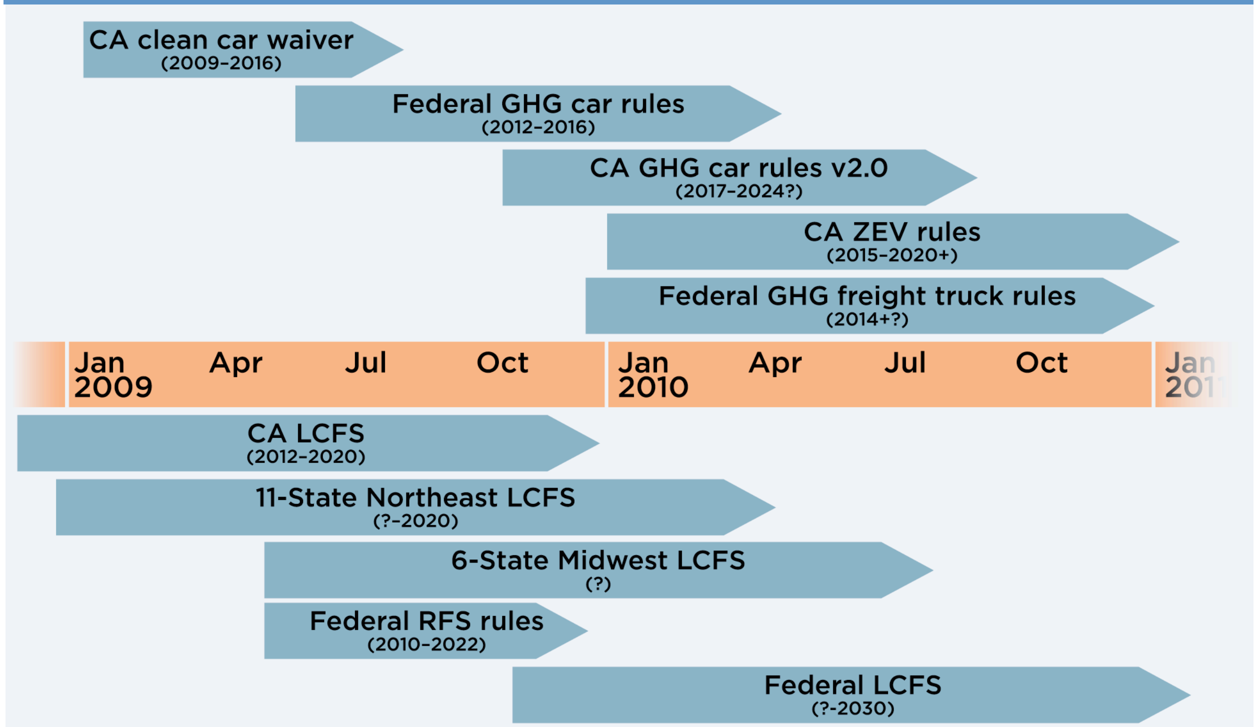
***Electric Utility Reforms Facilitating NZET*:** Utilities are regulated by local, state, and federal authorities and organized in many different ways, each with their own characteristics that may encourage or limit their involvement in electric vehicle technology innovations. Utilities are generally well positioned to make the kind of supporting investments required by electric drive, and can do so in a manner that conditions the market for broad consumer demand for electric cars. For example, utility programs could create incentives to charge during off-peak hours, increasing the cost-competitiveness of electric cars; provide renewable power to electric vehicles; demonstrate and deploy distribution-level technologies to optimize grid interconnection, including smart charging and local wire upgrades; fund battery technology; own the battery; and leverage utility customer relationships as a tool in marketing electric vehicles. Reforms that create a smart grid with advanced communications, sensors, and diagnostics could also further other technological developments throughout the utility grid.

Low Carbon Land Use Planning and Zoning: Carbon emissions can be factored into government budgets, transportation planning, and land use development. This would give local governments new incentives to factor greenhouse gas emission reductions into their decision making on issues like infill development, greater density around transit stations, and land development patterns that support the use of neighborhood electric vehicles. In practice, local government decisions, whether to build a new road or approve a new subdivision, would be assigned a carbon unit. If the city exceeded its carbon budget, it would have to buy credits from others. Initially, credits might be tradable only between local governments. But eventually the carbon units could be bought from and sold to all other holders of carbon credits, including companies subject to industry caps or to more specialized programs such as low-carbon fuel standards and vehicle greenhouse gas standards. Historically, development decisions and zoning rules have been tied to tax considerations and developers' influence. California is just now developing site-specific models for each county in the state that measure the greenhouse gas associated with each type of land use and include details on floor space, roads, and travel (as advanced in SB 375, the nation's first law to control greenhouse gas emissions by curbing sprawl).

Policy decisions over the next two years will influence more than a decade of transportation and energy technology development. Public policy can help chart this course toward a cogent near-zero emission transportation future. California's Clean Car Standards and Low Carbon Fuel Standards are the first step. Next is the extension of low-carbon vehicle and fuel policies to other states and to national adoption (see ***Figure 6***).

A strategic, sustained policymaking effort will be needed to facilitate the transformation to near-zero emission transportation. This will take decades to realize, but it must start now.

Figure 6: Strategic Near-Zero Emission Policymaking Opportunities



Key: ZEV = Zero Emission Vehicle; LCFS = Low-Carbon Fuel Standard; RFS = Renewable Fuel Standard

CONCLUSION

Near-zero emission transportation innovations hold out the promise of enhancing our economy, security, and environment. Policy decisions made today will likely influence transportation and energy systems over the next several decades.

Policymakers have never fully imagined, let alone devised, a comprehensive transportation, energy, and climate plan. A near-zero emission transportation innovation strategy must, at the very least, address carbon reduction and energy security. It should also protect the gains made reducing criteria pollutants and toxic emissions.

Information technology, personal computers, electronic social networking, and pervasive computing were a futuristic dream a generation ago. Biotechnology came next, followed by innovations in personalized medicine and biomarkers for health. Breakthroughs in nanotechnology are happening. Near-zero emission transportation and energy technologies are the next *greentech* innovation wave. Distributed energy, material and energy storage breakthroughs, advanced manufacturing, carbon management, and new mobility options are all on the frontier.

There is tremendous opportunity and cause for hope. But there are also many potential pitfalls that must be avoided. Roadblocks stand in our way and we will spend resources and time maneuvering around them. Cheap gasoline prices have contributed to the dominance of SUVs in the vehicle fleet. Immense public subsidies have been devoted to conventional oil over the past century and, more recently, corn-based ethanol. Tar sands and other unconventional oils have made market inroads despite their mammoth environmental costs. These are just a few examples of misguided decisionmaking.

Public policy must help chart the course toward a cogent near-zero emission transportation future. A strategic, sustained policymaking effort will be needed to facilitate the transformation to near-zero emission transportation. No doubt, the cost of action will be high. But the cost of inaction could be far higher.

What commitments will it take to make this a reality? The political fortitude to advance balanced macroeconomic pricing and targeted incentive policies. The commitment to establish and tighten well-designed performance standards over the long-term. The ability to manage the dynamic nature of technology mandates. The capacity to address unintended consequences as they arise. And a long-term vision to invest substantial public and private funds in near-zero emission research, development, demonstration, and deployment.

Transportation and energy technologies are at a crossroads. Policies that transform the marketplace to near-zero carbon emission, highly energy-efficient vehicles must replace business-as-usual policies that promote inefficient vehicles burning high-carbon fuels.

Appendix A

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Appendix B

History of Near-Zero Emission Transportation Policies

In 1967, the California Air Resources Board was created from the merging of the Motor Vehicle Pollution Control Board and the Bureau of Air Sanitation. In a move that would set California apart forever, the U.S. Congress granted the State the right to set and enforce its own emission standards for new vehicles, as long as the standards were at least as stringent as the federal standards. In amending the Clean Air Act in 1977, Congress went still further, giving all other states two choices: follow federal rules, or follow the more stringent California standards. All states followed the federal rules until the early 1990s, when for the first time an increasing number began to follow California.

In 1990, California adopted its new Low-Emission Vehicle Program (known as LEV I). It not only mandated reduction of tailpipe emissions to well below federal standards but also required reformulated gasoline and a certain percentage of zero-emission vehicles (ZEV). In 1998, CARB adopted still another round of even more stringent vehicle standards known as LEV II. LEV regulations evolved to ultimately include, in addition to LEVs and ZEVs: TLEV (transitional low-emission vehicle); ULEV (ultra low-emission vehicle), SULEV (super low-emission vehicle), PZEV (partial zero-emission vehicle), and AT-PZEV (advanced technology partial zero-emission vehicle).

ZEV Mandate

The California zero-emission vehicle (ZEV) mandate was adopted as part of the 1990 LEV I program. As originally formulated, it required the seven largest automotive companies in California to "make available for sale" an increasing number of vehicles with zero tailpipe emissions (ignoring other vehicle emission sources and emissions from upstream energy production and refueling facilities). The initial sales requirement was 2 percent of car sales in 1998, increasing to 5 percent in 2001 and 10 percent in 2003.

After undergoing industry lawsuits and continuous modifications, the ZEV rule now bears little resemblance to the original 1990 rule. Under mandated biennial reviews, ZEV policy continues to be hammered out. The simple 2, 5, 10 percent requirements have given way to a complex set of rules premised on a series of assumptions about categories of certified ZEVs, which vary in practice. Estimates from 2008 put ZEV production in the range of 7,500 fuel cell vehicles or 12,500 battery electric vehicles (or some combination thereof) between 2012 and 2014, along with 58,000 plug-in hybrids. To date, CARB estimates that the ZEV program has resulted in over 750,000 Californians are driving cleaner vehicles with extended warranties of 15 years or 150,000 miles. This includes cleaner conventional gasoline (internal combustion) vehicles. Regulations have resulted in new vehicles that are 80 percent cleaner than the average 2002 model year car.

CARB is slated to overhaul the ZEV program for 2015 vehicles to coordinate with other Board tailpipe emission programs (such as the Pavley regulations addressing greenhouse gas emissions) and the low emission vehicle program.

The Pavley Act, California's Clean Cars Law of 2002

In 2002, California enacted the Pavley Act (AB 1493) to reduce greenhouse gas emissions from new vehicles by 30 percent by 2016. After being challenged on its right to enact its own emissions standards, the Supreme Court subsequently upheld California's right for carbon dioxide. Still, California cannot proceed with implementing AB 1493 until the U.S. Environmental Protection Agency (EPA) formally issues a waiver. Initially, the EPA simply ignored CARB's waiver request submitted in December 2005 along with follow up requests in April and October 2006. The Governor formally notified EPA in April 2007 that the State would file a lawsuit under the Clean Air Act if the agency didn't address California's request within six months. The EPA didn't act and California filed the suit in November 2007. One month later, the EPA rejected California's waiver request with the argument that the just-passed federal Energy Act, with its new fuel economy standards, preempted the need for California's greenhouse gas standards. Congress launched an investigation and California, along with 17 other states, filed a lawsuit in March 2008. On June 30, 2009, the U.S. EPA approved California's waiver enabling the state to enact its Pavley GHG emission standards beginning with the 2009 vehicle model year. The development of a second round of Pavley vehicle greenhouse gas emission standards will soon be underway.

The Global Warming Solutions Act

In the fall of 2006, the California legislature passed the California Global Warming Solutions Act (AB 32), lead by Assemblywoman Fran Pavley. This policy orders CARB to initiate regulations and market policies to reduce total greenhouse gas emissions in the state back to 1990 levels by 2020 – about a 28 percent reduction below forecasted levels. The implementation process is under way, with all rules to be adopted by 2010 and taking effect no later than January 2012.

Low-Carbon Fuel Standard

On January 19, 2007, Governor Schwarzenegger issued an executive order for a low-carbon fuel standard calling for at least a 10-percent reduction in carbon emissions in transport fuels by 2020. (Weeks later, the European Union proposed similar but a somewhat more limited program.)

The low-carbon fuel standard, adopted by the California Air Resources Board in 2009, encourages the use of alternative fuels that reduce greenhouse gas emissions, not just from the tailpipe, but also throughout the entire energy cycle of production, distribution, and use. The standard is imposed on oil refiners because it is far easier to regulate a few large companies than it is to regulate every fuel station, every household, or every vehicle tailpipe. As the standard is initially designed, an oil company can comply in one of four ways, it can: (1) improve the efficiency of its refineries and upstream production, (2) mix low-carbon biofuels into its gasoline, (3) sell low-carbon fuels such as hydrogen, or (4) buy credits from companies selling biofuels, electricity, natural gas, and hydrogen for use in vehicles.

This new standard is fuel neutral in that it does not set mandates or quotas. It blends command-and-control regulations and market based rules by imposing a 10-percent reduction while creating marketable allowances for trading. Importantly, the low-carbon fuel standard codifies the concept of life-cycle emissions.

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