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Opening the Gates to New Transportation Technologies

Implementation of the Alternative and Renewable Fuel and Vehicle Technology Program in Assembly Bill 118

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"When the legislature passed AB 32, last year's landmark global warming legislation, we were committed to making California the world's leader in combating the greatest crisis our generation faces. AB 118 continues in this fine tradition. Through the promotion of alternative fuels technology, the Golden State will soon be known as the Green State."

-- Fabian Nunez, June 2007

*"The Alternative and Renewable Fuel and Vehicle Technology Program is hereby created... The program shall provide...grants, [etc]...**to develop and deploy innovative technologies** that transform California's fuel and vehicle types to help attain the state's climate change policies. The emphasis of this program shall be to develop and deploy technology and alternative and renewable fuels in the marketplace, **without adopting any one preferred fuel or technology**."*

-- Assembly Bill 118

Executive Summary

In October 2007, the California legislature passed a major bill to supplement other state climate change efforts, Assembly Bill 118. This bill imposes small increases in various DMV fees to raise about $120 million per year, and uses the funds to create three programs aimed at reducing petroleum use, greenhouse gas emissions, and criteria pollutant emissions from the transportation sector through changing the technologies which run our transportation system. The topic of this paper is the largest of these programs, the Alternative and Renewable Fuels and Vehicles Technology Program (in this paper, "AB 118" refers to this program). The task at hand is to design this program so that the money available is invested effectively and according to clearly established funding priorities.

This analysis concludes that funding should be focused on projects that reduce market barriers to new vehicle and fuel technologies, thus enabling private investment and maximizing the impact of market systems implemented by other climate change policies. Market systems excel at encouraging the adoption of low-carbon technologies, but only once those technologies are available to compete in the market. AB 118's niche is helping make sure a variety of technologies are ready to compete with petroleum when market systems are implemented.

Support a Variety of Technologies, Don't "Pick Winners"

One natural model for AB 118 is the Carl Moyer Program. Carl Moyer funds projects to reduce criteria pollutant emissions. The program uses pre-defined projects and standardized measurement guidelines to determine the cost-effectiveness of each potential project. Implementing AB 118 in this way would maximize the greenhouse gas reductions obtained as a direct result of program spending, and would encourage competition among technologies to achieve better emissions-reducing characteristics as they seek funding from AB 118. However, this approach ignores the greater context of California climate policy; it pushes program managers to pick "winning" technologies as opposed to supporting all "promising" technologies.

The crucial problem with using cost-effectiveness with AB 118 is uncertainty. Experience with various technology fads over the past few years has taught policymakers that new technologies are unpredictable. Even using the best available information, we cannot know which technologies will ultimately become feasible, popular, and environmentally preferable. As opposed to trying to pick a single technology for support, the state alternative fuels plan charges

state agencies to support the development of a fuel-diverse transportation system. AB 118 language includes the requirement that its programs operate "without adopting any one preferred fuel or technology." In any case, the California climate policy toolbox includes better mechanisms to encourage adoption of low-carbon technologies: either cap-and-trade system or regulations will cause much more private investments than a voluntary program like AB 118.

Market Systems Cannot Decrease Emissions if Alternatives Do Not Exist

California is likely to implement one or more emissions market systems as a cornerstone of its climate change mitigation policy. The Low-Carbon Fuel Standard (LCFS) will use a system of tradable credits, similar to a market system, to require fuel suppliers to pump low-carbon fuels, such as biofuels, hydrogen, or electricity for transportation. The strength of market systems is that by imposing a cost for emissions, they can shift private investment towards low-carbon technologies without specifying particular technologies. This flexibility ensures least-cost reductions while leveraging billions of dollars of private capital.

Market systems cannot shift behavior, however, if lower-emitting alternatives are not available. A higher price for petroleum cannot cause a consumer to switch if the alternatives are costly, inconvenient and unproven! Research shows that pricing policies can encourage innovation in new technologies, but that process is slow. Innovators need assurance that when they bring their technologies to market, favorable policies will still be in place. What market systems can accomplish immediately, however, is adoption of currently-available low emitting technologies. The advantage of AB118 is that it has the flexibility to directly fund technologies which have not yet become established in the market. Once a technology gains a foothold in the market, a cap-and-trade system is a good way to encourage adoption.

Alternative Technologies Abound, But Face Significant Market Barriers

Persistent need to reduce oil dependence has led to a wide variety of vehicles, fuel production processes, and new technologies in the research and development pipeline. Clean technology businesses seem poised to introduce potentially game-changing alternatives, including cellulosic ethanol, algae biofuels, renewable diesel, green gasoline, hybrid trucks, hydrogen fuel-cell vehicles, plug-in hybrid vehicles and battery-electric vehicles. However, these technologies are currently unable to compete effectively with petroleum. For new technologies to be deployed by market systems, significant market barriers will have to be overcome.

The transportation fuel market is currently over 90% petroleum fuels. Incumbent status gives petroleum many advantages over emerging technologies including: huge production economies of scale, a broad network of fueling stations, a century of process efficiency improvements, communities built around gasoline car use, subsidies, and other helpful regulations.

RECOMMENDATION: Use AB 118 to Minimize Market Barriers

The most effective use of AB 118 funds is to conduct projects which enable private investment and knock down market barriers. Projects should help new technologies "into the ring" to compete with petroleum fuels. The success of future market systems, including the LCFS, depends on commercially ready alternative technologies.

Market Barrier Categories and Example Projects:

Given the recommendation to use AB118 funds to minimize market barriers, what projects should be funded? The following paragraphs present four different types of market barriers which low-carbon transportation technologies face, along with examples of good projects which address those barriers. These projects are small enough that they could be feasibly accomplished within the AB118 budget, but would also have important consequences in shifting the transportation system towards alternatives.

Barrier 1: Manufacturing Economies of Scale

In the past few years, delivery companies, utilities and garbage haulers have been experimenting with medium and heavy-duty hybrid trucks. In stop-and-go applications, these trucks have shown enormous fuel economy improvements, from 10-80%. Because the trucks are made in small quantities, however, they cost significantly more than standard vehicles. Mass production of these vehicles will reduce cost, resulting in a feedback loop which will increases sales volume. High production cost is the main barrier to widespread use of these vehicles. This situation justifies a temporary buy-down of medium and heavy-duty truck purchases in California, to drive economies of scale leading to fleet-wide fuel economy improvement. *AB118 should use targeted buy-down incentives for technologies in which the limited budget of the program could feasibly drive economies of scale.*

Barrier 2: Regulatory Hurdles Due to Environmental Risk

Ethanol has recently become a major industry. About 2,000 fueling stations across the country now supply E-85 fuel. Almost none of these stations are in California. This is partially due to the fact that pumping equipment for E-85 fueling has not yet been approved by the Air Resources Board. Measurements have indicated that E-85 used in standard pumps can lead to polluting evaporative emissions of volatile organic compounds (VOCs). Until equipment is available which can control these emissions, E-85 use in California will be stalled. This situation justifies state sponsorship for the development and testing of fueling equipment which can control these emissions, thus enabling private investment in E-85 infrastructure while protecting air quality. *AB118 should conduct research and testing on environmental risks of new technologies so that they can more quickly satisfy regulatory requirements and unintended consequences can be avoided.*

Barrier 3: Lack of Fueling Infrastructure

Alternative fuels present a chicken-and-egg problem: consumers won't buy alternative fuel vehicles until fueling infrastructure is available and convenient, while station owners won't install new equipment until there is a critical mass of vehicles to use it. Hydrogen currently faces this problem. Over the next few years, automakers will increase the size of their demonstration fleets of fuel-cell vehicles, but where will consumers fill up their cars? This situation justifies state sponsorship of strategically placed fueling infrastructure to enable alternative fuel fleets to gradually grow in size. Once alternative fuel fleets reach a critical mass, station owners will have an economic incentive to install new infrastructure without subsidy. *AB118 should fund infrastructure to support alternative fuel demonstration fleets and solve the chicken-and-egg problem. Ideally, infrastructure would be flexible enough to use various alternative fuels.*

Barrier 4: High Initial Cost of Emerging Technology Demonstration

Plug-in Hybrid vehicles will be commercialized in the next few years, but how will electricity companies ensure that their battery charging does not strain their system? Software and equipment could solve this problem, but will it work? New cellulosic and algae biofuel processes have been successful in the lab, but will they work at commercial scale? Projects to capture and purify methane from landfill gas could be a source of renewable natural gas, but how much methane can be produced, and at what cost? Well-designed demonstration projects can answer all these questions. For investors or lenders to fund projects, they need evidence that those projects can work. These initial projects are expensive, preventing small businesses from growing. This situation justifies state funding for demonstration projects that allow promising new technologies to prove themselves. To be most effective, these projects should be required to track performance. A proven record of performance will enable future private investment. Since these projects are state-funded, performance data should also be available for future policymaking decisions. *AB118 should fund demonstration projects of early-stage technologies with potential for significant emissions reductions, especially focusing on projects which can address integration problems or are first-of-kind projects.*

Table of Contents

Executive Summary i
Support a Variety of Technologies, Don't "Pick Winners" i
Market Systems Cannot Decrease Emissions if Alternatives Do Not Exist ii
Alternative Technologies Abound, But Face Significant Market Barriers ii
RECOMMENDATION: Use AB 118 to Minimize Market Barriers ii
Market Barrier Categories and Example Projects: iii
Barrier 1: Manufacturing Economies of Scale iii
Barrier 2: Regulatory Hurdles Due to Environmental Risk iii
Barrier 3: Lack of Fueling Infrastructure iii
Barrier 4: High Initial Cost of Emerging Technology Demonstration iv
Section I: Background and Legislative Framework 1
Framework of AB118 1
Landscape of Projects AB 118 Could Fund 1
Criteria for Deciding Between Projects 4
The Task at Hand 5
California's Climate Change Challenge 5
Transportation Emission Reductions Will Be Difficult to Achieve 6
Other California Climate Change Policies Impacting Transportation 8
Section II: Using AB 118 to Complement Other Policies 9
Economic Justifications for Climate Policy 9
Advancing Technology Without Picking Winners 11
Policies that Pick Winners Tend to Falter Due to Technology Risk 11
Cost-Effectiveness Framework Wouldn't Work for AB 118 11
Recommendation: Support a Range of Technologies with Potential Benefits 12
Demand-Pull Policies and Innovation 12
Model of the Innovation Process 13
Demand-Pull Policies Spur Investment, Achieve Low-Cost Reductions 14
Direct Funding of Demonstration Projects is Good for Driving Innovation 15
Recommendation: Use AB118 funds to address market barriers to innovative technologies 15
Reason for Optimism: Technologies Contending to Replace Petroleum 16
Electric Vehicles Are Being Reintroduced 16
Hybrid Medium and Heavy-Duty Truck Commercialization 17
Major Automakers Soon to Release Advanced Vehicles 17
Many New Biofuel Production Processes in the R&D Pipeline 17
Algae Fuel Start-ups May Start to Deliver 18
Section III: Market Barriers to New Transportation Technologies 18
Large Upfront Investments Needed to Achieve Economies of Scale 18
Sustainability and Air Quality Rules – Avoiding Unintended Consequences 21
Lack of Fueling Stations 23
Conclusion: Get More Technologies Ready to Compete 24
Appendix 26
Bibliography 30

Section I: Background and Legislative Framework

This section lays out the basic structure of the Alternative and Renewable Fuels and Vehicles Technology program, as described in the AB 118 legislation. It further describes the magnitude of the challenge required to reduce greenhouse gas emissions from transportation. Finally, in order to understand the potential role of AB 118 programs, other policies affecting greenhouse gas emissions from transportation are summarized.

Framework of AB118

Assembly Bill 118 establishes three programs, the largest of which is called the "Alternative Fuels and Vehicles Technology Program." This program is the subject of this paper, and future references to AB 118 refer specifically to the Alternative and Renewable Fuels and Vehicles Technology Program. The purpose of this program is "to develop and deploy innovative technologies that transform California's fuel and vehicle types to help attain the state's climate change policies." Implementation of AB 118 requires balancing three goals: greenhouse gas reduction, petroleum reduction, and air quality improvement.

Lawmakers have afforded the California Energy Commission (the Commission, or CEC) significant leeway to decide how funds will be spent. The bill outlines eleven categories of possible projects types that can be supported. It describes several types of support, many possible applicants, and a long list of criteria to use in determining priorities. While the use of many criteria could ultimately be limiting, there are very few specifics included in the legislation, meaning that the Commission will be free to balance the criteria as it sees fit. The legislation creates an advisory committee to help find opportunities and set priorities for investment through a yearly public process.

The legislation imposes some key requirements on the decisions of the Commission. These requirements are:

- CEC must establish sustainability goals, using life-cycle analysis, to show projects are not negatively impacting state natural resources or lands.
- CEC must ensure emissions reductions and benefits can be measured and quantified.
- ARB must ensure projects maintain or improve air quality (also known as "anti-backsliding guidelines").
- CEC must ensure that projects are additional to that required by regulations.

Landscape of Projects AB 118 Could Fund

The AB 118 legislation lists eleven different project types eligible for funding: from technology development to improve the sustainability to installing alternative fuel infrastructure. In

addition, a wide range of alternative fuel technologies are eligible for funding. The total landscape of possible projects that could be funded is any combination of project type and fuel type.

Although petroleum is used for over (93%) of transportation energy in the U.S., the oil crises of the 1970s and the present oil and climate change crises have generated a number of nascent technologies vying to supplant petroleum. The legislation lists alternative fuels including "electricity, ethanol, dimethyl ether, renewable diesel, natural gas, hydrogen, and biomethane, among others." Many of these fuels can be generated in different ways, creating more possible options for new technologies.

To make a transition away from petroleum, many aspects of the transportation system will need to be replaced, possibly including fuel production, infrastructure and vehicles. For example, natural gas-powered vehicles exist, but in order to use these vehicles on a widespread basis, an extensive infrastructure of natural gas fueling facilities is needed, as well as increased production of natural gas. Essentially, to switch to alternative fuels, the entire supply chain must be transformed.

Possible recipients of AB 118 funding could include every possible combination of fuel and components involved in the transportation supply chain. Table 1, below, illustrates the supply chains for several alternative fuels. As mentioned above, there are many possible fuels, and the fuels in the chart are merely illustrative.

Different technologies have different challenges to address in order to become commercially viable. For example, companies already know how to produce electricity, but battery improvements are still needed before electric vehicles will be able to travel long distances. By contrast, it is fairly simple for manufacturers to produce economical flexible-fuel vehicles (FFV's) which can run on ethanol, but technical advances are needed to produce ethanol while consuming less land and producing fewer tons of greenhouse gases. To advance efficiency, the only relevant part of the transportation system is the vehicle itself.

Many projects types in AB118 specifically address different aspects of the transportation supply chain, including fuel feedstocks, fuel production, infrastructure, vehicles and retrofits. Workforce training and education programs are also specifically allowed, as well as certain types of research and development, including research on sustainability[1] and improving environmental performance.

[1] Assuming that clean-up language is adopted, this will be specifically mentioned.

Table 1: Illustrative Development Needs for Alternative Fuel Supply Chains

Type of Fuel → / Stage of Supply Chain↓	Efficiency	Electricity	Natural Gas	Cellulosic Ethanol	New Petro-like Fuels i.e. renewable diesel	Hydrogen
Feedstock Development	N / A	N / A	Landfills, waste-based sources	Lower-carbon crops, waste-based sources	Lower-carbon crops crops, waste-based sources	N/A
Fuel Production	N / A	Generation, need more renewables	Cryogenic processing Fischer-Trophe	Enzymes Biological or chemical research	Existing Refineries? Research?	Renewable sources, distributed generation
Fuel Distribution	N / A	Grid	Existing pipelines	Truck Improved method	Existing pipelines	Pipelines?
Storage	N / A	Batteries	LNG	Standard Fuel Tanks	Standard Fuel Tanks	New research, solid state, high-pressure
Fueling Infrastructure	N / A	Plug-in (parking garages, homes)	New Pumps	New Pumps	Existing Pumps	New Pumps
Vehicles	Hybrid Vehicles, Retrofits, Combustion Technologies	PHEVs, EVs	NG Vehicles	FFVs, standard vehicles certified for higher ethanol concentration	Standard	Fuel cell durability, cost, efficiency
Workforce	Driving Techniques, Mechanics, design engineers	Mechanics, Electricians, Renewables installers / technicians	Fuel Production, Mechanics	Farming, Fuel Production	Farming, Fuel Production	Mechanics, Electricians, Specialized technicians

Note: Highlighted boxes represent barriers where new breakthroughs are needed, or for which current technologies are particularly expensive. These assessments are based on general reading by the author.

Criteria for Deciding Between Projects

The core goal of the bill is to advance technology which will allow California to reduce petroleum dependence and greenhouse gas emissions from the transportation sector in the long term. The legislative language also encourages the Energy Commission to seek additional benefits where possible. The following language describes the criteria imposed by the legislation:

"The commission shall provide preferences to those projects that maximize the goals of the Alternative and Renewable Fuel and Vehicle Technology Program created by Section 44272, based on the following criteria, as appropriate:"

1) Measurable petroleum reduction and alternative fuel use
2) Consistency with state climate change policy and the LCFS
3) Reduction of air pollutants, air toxics, and multimedia environmental impacts
4) Decrease life-cycle water pollutants (compared to reformulated gasoline)
5) Does not adversely impact sustainability of natural resources, especially lands
6) Non-state matching funds
7) Economic benefits (CA-based jobs, firms and businesses)
8) Existing fueling infrastructure
9) Reduce life-cycle GHG emissions by at least 10% compared to gasoline
10) Alternative fuel blend of at least 20%
11) Drives new technology for vehicles, vessels, engines

The criteria originate from a number of different motivations. Criteria 1, 2, and 11 are the core goals of the program. Criteria 7 aligns AB118 with the overall strategy of addressing climate change while providing economic benefits to California. Criteria 3, 4, and 5 are intended to make sure that the programs avoid unintended consequences. Criteria 6 and 8 buttress the worth that taxpayers get for the program, since they help avoid costly and dead-end investments. Criteria 9 and 10 are designed to ensure that sufficiently large steps are made in advancing technology.

Table 2: Analysis of Criteria Used in the AB 118 Technology Program

Criteria	Motivation
Petroleum reduction	Core goal
Climate change policies	Core goal
Reduce air pollutants	Avoid unintended consequences
Reduce LCA water pollutants	Avoid unintended consequences
Sustainability of natural res.	Avoid unintended consequences
Non-state matching funds	Tax-payer value
Economic benefits	Tax-payer value
Existing fueling infrastructure	Tax-payer value
LCA GHG emissions – 10%	Significant advancement
Alternative fuel use – 20%	Significant advancement
Drives new technology	Core goal

One of the problems with the legislative requirements for the design of the Alternative and Renewable Fuel and Vehicles Technology program is that it imposes many criteria. With so many criteria, it is difficult to know how best to focus investments. This is particularly complicated as the criteria will look very different when implemented depending on the specifics of a given technology. Given this lack of clarity, a key objective should be to more clearly define the focus of AB 118, and how its criteria should be implemented.

The Task at Hand

The task at hand is to *define* the focus of the AB 118 technology program so that its funds maximize advances in efficient transportation and alternative fuel technologies. This in turn will help California to achieve its broader climate change, alternative fuel use, and air quality goals.

California's Climate Change Challenge

Climate change is a serious threat to natural resources in California and all over the world.[2] Scientists project that emissions reductions of 80-90% are needed by 2050 to avoid catastrophic outcomes. In California, we expect rising temperatures will make water supplies less reliable because of earlier snowmelts, making it more difficult to maintain agricultural production. Wildfires, droughts and heat waves are likely to become more extreme causing increased damage to property and health. Many important agricultural commodities in California may experience disruption, such as wine grapes, fruit, nut, and milk production. Worldwide, climate change may result in displacement of huge populations of people as sea levels rise, massive losses in biodiversity as ecosystems are disrupted, and severe impacts on health and food systems.

In response to the severe threat of climate change impacts in the state and worldwide, California has enacted an ambitious series of policies meant to reduce emissions of climate-change causing greenhouse gases like carbon dioxide. The most far-reaching of these is the Global Warming Solutions Act of 2006 (also known as AB32) which authorizes the California Air Resources Board (CARB) to design and implement a cap-and-trade program to limit greenhouse gas emissions in the state.

To complement AB32, many sector-specific policies are being enacted. In transportation, these policies included tailpipe greenhouse gas emissions standards, the low-carbon fuels standard, and various regulations encouraging individual technologies ranging from reflective paints, low-resistance tires, to retrofits for long-haul trucks. Achieving emissions reductions in the transportation sector is predicted to be more difficult than other sectors (discussed in detail in the following section), thus Assembly Bill 118 was passed to help achieve these policies.

[2] Impacts drawn from California Climate Change Center, 2006, "Our Changing Climate"

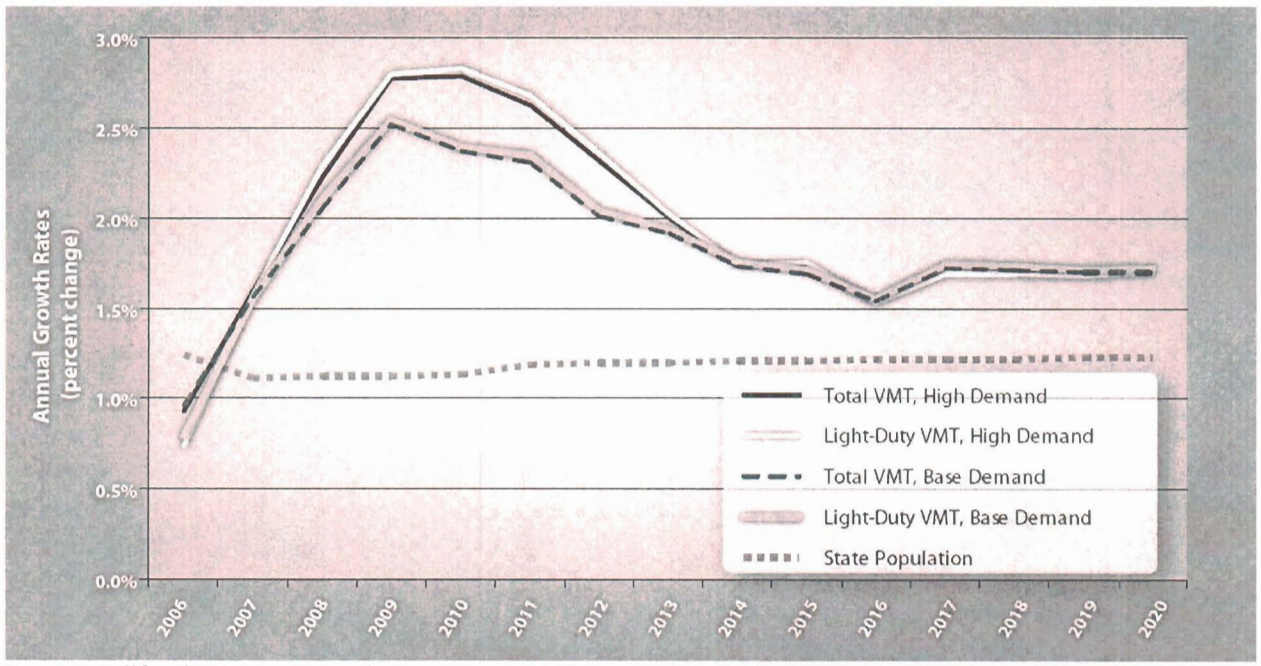
Transportation Emission Reductions Will Be Difficult to Achieve

The transportation sector will be resistant to emissions reduction efforts because cost-competitive low-carbon alternatives to gas and diesel-powered vehicles do not yet exist.[3] Car ownership and vehicle-miles traveled per car are both increasing, while vehicle efficiency has remained essentially stagnant for the past two decades. Fuel-efficiency policies have been effective, but lawsuits have delayed California attempts to tighten these policies. Even sharply increasing fuel prices have had a relatively minor impact on total driving.[4] News articles have noted some positive signals: smaller vehicles are increasing sales and homes near transit are gaining in value. It is too soon to know how significant these changes will be.

The state projects that vehicle-miles traveled will continue to grow faster than population until at least 2020, at a rate of about 1.5% per year (see Figure 1). The combination of these factors mean that we need to commercialize innovative new technologies – incremental improvements in existing technologies will not be enough.

Finding: Innovative new technologies are needed to achieve necessary reductions in the transportation sector.

Figure 1: Percentage Growth in Population and Vehicle-Miles Traveled



Source: California Energy Commission, Integrated Energy Policy Report 2007

[3] Corn ethanol has proved that it can be economically competitive under subsidy conditions, but even ethanol boosters do not anticipate this type of production can supply beyond 15 billion gallons. Skeptics think that the current production of corn ethanol already displaces too much food production.

[4] Over the period of 2000 to 2007, yearly growth in inflation-adjusted price was 6%, and gallons gasoline sold still increased by 1% per year. Gasoline sales have declined slightly since 2004, but this still represents a small effect in comparison the huge price increases. Source: State Board of Equalization tax data, EIA gas price data from CEC

One aspect of the state strategy to reduce greenhouse gas pollution from transportation is to encourage alternative fuels for consumer and commercial purposes. This is being done with a two-pronged approach: a low-carbon fuels standard, which will use market incentives to efficiently produce low-carbon fuels, and the State Alternative Fuels Plan, which has laid out a plan of action to displace 4 billion gallons of gasoline per year by 2020, or 20% of California fuels. To achieve this, the plan estimates that the private sector will need to invest $44 billion in new infrastructure, vehicles, and fuel production capacity (see Table 3).

The Alternative Fuels Plan calls for $100 million per year in state funding. AB118 is responsive to this request, and provides $120 million per year that can be used flexibly to support a wide variety of efficient vehicle and alternative fuel projects. This is the most state funding that has ever been dedicated to this task, and it is likely to remain stable since there is a dedicated funding source. The distance between state funding and the required private funding is enormous, however. To realize the total required investments, state funds will have to leverage federal funds and private investment by over 30:1 (see Table 3, below). While it is unlikely that AB 118 programs will receive this level of matching funds, the low-carbon fuel standard and AB32 have the potential to drive very significant private sector investments.

Table 3: Total Estimated Investments Needed, 2008-2020 (Million $)

Alternative Fuel	Market Investment	State Government Incentives and Co-Funding	Federal Government Incentives and Co-Funding
Ethanol	$9,000	$370	$1,800
Renewable / Biodiesel	$3,400	$284	$1,150
Propane	$276	$10	$8
Natural Gas	$3,600	$59	$48
Electric Drive Technologies	$10,700	$255	$200
Hydrogen	$17,200	$514	$500
TOTAL	**$44,176**	**$1,492**	**$3,706**
Annual Average (15 years)	**$3,000 / year**	**$100 / year**	**$250 / year**

Source: CEC, Alternative Fuels Plan

Perhaps the greatest risk to state climate change policies is that technologies may not be available in time to achieve the large reductions necessary without imposing enormous costs on California consumers. If the price of emissions reductions proves very costly, there could be a public backlash against climate change policies. Therefore the role of AB 118 is push an early start to the development and deployment of alternative fuel and efficient vehicle technologies, before market incentives like the low-carbon fuel standard or the possible AB32 market are in place. That way when these incentives are instituted, new technologies are ready to meet the demand.

Finding: Climate policy must leverage enormous private investment in new technologies

Other California Climate Change Policies Impacting Transportation

Targets for greenhouse gas reduction were set out by Governor Schwarzenegger in his Executive Order # S-3-05, announced in June 2005: 1990 emissions levels by 2020, and 80% below 1990 emissions levels by 2050. These goals broadly reflect the reductions necessary by developed countries to stabilize the climate. *The transportation sector accounts for 40% of California's present greenhouse gas emissions.* This comparison reveals the depth of emissions necessary from the transportation sector.

To be most effective, AB 118 should be implemented in a way that complements other climate policies which influence transportation, including the LCFS, AB32, and AB1493. Greenhouse gas reduction policies affecting transportation are often categorized according to three general strategies which each affect transportation emissions:

1. Reduce GHG emissions per gallon of fuel, such as switching to alternative fuels.
2. Increase miles traveled per gallon of fuel, such as vehicle efficiency standards.
3. Reduce total vehicle-miles traveled, such as smart growth or public transit infrastructure.

Global Warming Solutions Act, AB 32. This act legislates overall California emissions reduction targets by 2020 matching the governor's executive order. It authorizes the ARB to establish market-based mechanisms and regulations to reduce greenhouse gas emissions from all sectors. Transportation fuels may be included in a prospective market system, which would give low-carbon fuels a relative price advantage over higher-carbon fuels, but the advantage would be minor. A carbon price of $25/ton CO2 would increase the price of gasoline by just 21 cents.[5] This price alone could not achieve significant reductions from transportation. The ARB is considering several regulations affecting the transportation sector, including the LCFS, incentives for hybrid trucks, and a requirement for long-haul trucks to install retrofits to improve fuel economy. This policy uses all three overall strategies.

Low-Carbon Fuel Standard. The LCFS uses life-cycle analysis accounting to determine the total emissions of a fuel through its entire "life," including all stages of production through growing the feedstock, fuel production, distribution, and finally tailpipe emissions. The LCFS will require fuel providers to reduce the average fuel carbon intensity (AFCI) of the fuels they supply by 10% relative to gasoline by 2020.[6] The LCFS will use a system of tradable credits to reduce the economic cost of the measure. This market will provide a price incentive for the production and sales of low-carbon fuels not unlike the renewable portfolio standard. In particular, the price advantage it provides is proportional to the GHG emissions improvement of each fuel. This policy relates to strategy #1, reducing GHG emissions per gallon of fuel.

Tailpipe Emissions Standard, AB 1493. The standard requires that automakers reduce the fleet-average per-mile GHG emissions of the vehicles they sell. While this bill was passed in 2002 and rulemaking ended in 2005, its implementation has been delayed by lawsuits. So far, lawsuits

[5] Table 1-3 in Farrell, et al 2007a, UC technical analysis for the low-carbon fuels standard

[6] Description of the low-carbon fuel standard drawn from two UC reports on the technical and policy aspects of the LCFS, Farrell, Sperling et al, 2007a and 2007b.

have prevented California from implementing this law. Until this issue is resolved, it will be difficult for California to impact the efficiency of light-duty vehicles. This policy uses strategy #2, increasing vehicle efficiency per gallon.

AB 118 addresses an overlapping set of technologies, like the low-carbon fuel standard, AB32, and AB 1493, because it is meant to address both low-carbon fuels and vehicle efficiency. The LCFS directly impacts only alternative fuels. In order to provide these fuels, firms will have to invest in alternative fuel production and may also need new fueling station infrastructure. AB 118 can fill this need by directly funding fuel production or infrastructure, but it can also directly impact other aspects of low-carbon transportation such as: alternative fuel and efficient vehicles, workforce training and education, sustainability studies, retrofits of existing vehicles, etc. The flexibility of AB 118 allows it to work to fill the gaps created by the other pieces of CA Climate Change Legislation.

Section II: Using AB 118 to Complement Other Policies

The AB 118 Technology Program can accelerate the introduction of innovative technologies and the resulting emissions reductions. An emissions market system presents regulated entities with a choice: adopt low-carbon technologies or practices, or pay for credits on the open market. For this choice to work as intended, alternatives must be available, but petroleum fuels currently supply over 90% of the transportation system. If no alternatives are available, prices could increase to politically unacceptable levels. These high prices would induce innovation, but the innovation process works slowly, and depends on clear long-term market signals.

Fortunately, a variety of alternatives exist which could potentially displace petroleum: ethanol, biodiesel, electricity, natural gas and hydrogen are prominent examples. These alternatives technologies have been deployed on a very limited scale, however. They face significant market barriers to widespread deployment. Some even require further research before they are commercially feasible. The strategy of AB 118 should be to address these market barriers such that more fuels are ready to compete with petroleum when market systems are introduced.

Economic Justifications for Climate Policy

Economists justify public policies based on how they address problems in existing markets which lead to inefficient or inequitable outcomes. Several different problems affect transportation industries with respect to climate policy:

1. *Environmental impacts are not priced.* Firms and consumers do not face the costs of environmental damage related to the greenhouse gas emissions of their transportation choices. This means that petroleum fuels are "too cheap" relative to the societal costs they impose, which makes it more difficult for cleaner fuels to compete in the market.
2. *Innovation spillovers cannot be captured by innovators.* Innovation often creates new knowledge whose benefits cannot all be captured by the inventor. This means that firms

tend to under-invest in research and development, especially for environmentally beneficial technologies.

3. *Barriers to entry and necessary infrastructure*. Making changes in the technologies that we use for transportation in most cases requires very large up front investments in public or private infrastructure. For hydrogen vehicles to be successful, a wide network of hydrogen fueling stations must be built. For consumers to choose walking or biking, bike lanes or sidewalks should be available. The need for infrastructure and large networks makes it extremely difficult for new technologies to enter the market, especially in the presence of uncertainty.

All these problems are important, but they play out in different ways. The key problem inhibiting low-carbon technologies is economic: even recent high gas prices are relatively affordable in comparison to alternatives. Pricing environmental impacts is one way to address this disparity. Innovation spillovers affect all markets involving new technologies (not just energy and low-carbon technologies), so this problem is usually dealt with in a generalized innovation-policy frame, such as the R&D tax credit or patents. The innovation spillover problem can exacerbate other problems by reducing the incentive to invent environmentally-beneficial technologies. Barriers to entry are a more controversial market problem: once the first two problems are solved, barriers to entry should be surmountable. However, barriers to entry lessen the efficiency of the market response, increasing the delay between policy implementation and adoption of low-carbon technologies. The various problems affecting markets inspire different policy responses. The following table lists generalized policy responses paired with the market problems they are primarily designed to impact.

Table 4: Market Problems and Policy Responses

Market problem	Generalized Policy Responses
Environmental impacts not priced	• Carbon taxes or fees • Cap-and-trade programs • Maximum emissions standards • Best-available technology mandate • Incentives for environmentally beneficial technology adoption
Innovation spillovers	• Patent rights • Direct funding of R&D • R&D tax credits
Barriers to entry	• Antitrust law • Small business tax benefits • Technology demonstration and commercialization grants • Public infrastructure funding

Advancing Technology Without Picking Winners

Lessons from past experience with environmental technology policy and AB 118 language discourage program managers from picking winning technologies.[7] Although this mandate could be implemented by using a cost-effectiveness metric, the high degree of uncertainty inherent in technology development limits the usefulness of this approach. Instead, program managers should support a variety of technologies. This dovetails with state goals to commercialize multiple alternative fuels.

> "Policy makers and elected officials need to guide the creation of new transportation fuel and vehicle markets in California to begin transitioning the eighth largest economy in the world from a petroleum-based economy to a multi-fuel economy." (State Alt Fuels Plan)

Policies that Pick Winners Tend to Falter Due to Technology Risk

Lessons learned from past programs, such as the California Zero-Emissions Vehicle Program, the DOE Synfuels Corporation, or the state and national Hydrogen Highway Initiatives, show that technology uncertainty tends to trip up government programs. The Zero-Emissions Vehicle Program has stumbled twice by designing its requirements around the deployment of particular technologies: first battery electric vehicles and then fuel-cell vehicles (see box). Jimmy Carter started several research initiatives in solar thermal and synfuels which failed to result in technology breakthroughs, to the disillusionment of many. Initial pronouncements from leaders about the quick development of a hydrogen-fueled transportation infrastructure have proven premature. There is now wide consensus that picking winning technologies is too risky. A better approach is to invest in a portfolio of investments, thus reducing risk.

Cost-Effectiveness Framework Wouldn't Work for AB 118

The Carl Moyer Memorial Air Quality Improvement Program has successfully used a cost-effectiveness framework to improve air quality by funding technology deployment. Like the AB 118 Technology Program, the Carl Moyer Program has a series of different project types which are eligible for funding. Program administrators have developed clearly defined methodologies for measuring the benefits of any particular project. This often means that existing emissions standards are used as a baseline, so eligible benefits are those above that baseline.

Picking Winners and the Zero-Emissions Vehicle Program

In the 1990's, Air Resources Board regulators designed the compliance schedule for the zero-emissions vehicle program based on their estimates of the time that it would take to commercialize battery-electric vehicle technology. Although successful demonstration fleets were deployed, the technology remained expensive, and under intense pressure and changing technology fads, regulators rolled back the implementation schedule.

The ZEV program was popularly seen as a failure when battery-electric vehicles were abandoned, leading to the documentary, "Who Killed the Electric Car?" Research shows that the ZEV program achieved similar air quality improvements through incremental improvement as it would have through battery-electric vehicles, but technology uncertainty derailed the path picked by the regulation. This pattern has now repeated: when the electric vehicle schedule was rolled back, a new compliance path was created according to estimates of fuel cell vehicle commercialization timelines. Although FCV technology has improved, the implementation schedule was revised again, in March 2008, in favor of plug-in hybrid vehicle development.

Implementing an emissions reduction program according to cost-effectiveness has several advantages. First, rigorous measurement of emissions reductions due to funding means that program managers can easily justify the overall benefits of the program to the public and legislature. Second, danger of political influence or favoritism guiding project selection is decreased, because an unbiased metric is available to compare projects.

There are several important differences which make the model inappropriate for the AB 118 Technology Program, however. First, the policy context is different. The Carl Moyer Program is designed to be additional to criteria pollutant emissions performance standards. For example, new trucks for sale must certify their emissions below specific emissions rates for NOx and other pollutants. No such hard-line standards exist for GHG emissions. Instead, other GHG regulations flexibly seek to encourage least-cost reductions. Second, the AB 118 seeks to fund innovative and emerging technologies. The Carl Moyer program requires that funding be applied to technologies that have gone through rigorous certification processes to verify performance. Many new technologies are too early-stage to have certified emissions levels. For many applications, standardized test procedures do not even exist.

The most valuable benefits that AB 118 could bring is advancing new transportation technology to the point that price incentives are sufficient to cause widespread adoption. "Technology advancement" benefits are nearly impossible to quantify, even in retrospect.[8] To compare project benefits quantitatively ahead of time would require numerous unsupportable assumptions. Such a framework is untenable as a basis for funding decisions in an innovation program such as AB 118.

Recommendation: Support a Range of Technologies with Potential Benefits

AB 118 program managers should use a portfolio approach: support a range of technologies with potential to deliver GHG reduction, petroleum reduction, and air quality improvements. By supporting multiple technologies, risk due to uncertainty about how technologies will develop is reduced. Information about potential benefits should still be gathered, but this information should be used by the advisory committee in a flexible way, as opposed to a single maximization metric.

Demand-Pull Policies and Innovation

In order to achieve climate stabilization and long-term greenhouse gas reduction goals, deep reductions in emissions due to transportation are needed. To achieve this without curtailing mobility, innovation in low-carbon transportation technologies is needed. What policy tools can be used to drive this innovation?

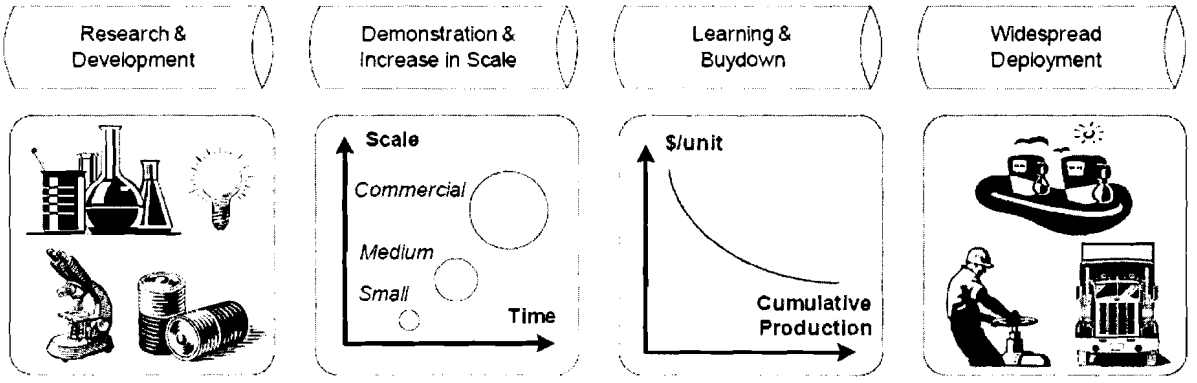
[8] Labored attempts have been made to quantify the benefits of DOE applied research programs by the National Academies of Science. Similar methodologies have been applied by the Department of Commerce to the now-defunct Advanced Technology Program.

Innovation happens in the presence of a cocktail of favorable circumstances: technology opportunity, capital availability for research, development and demonstration, and favorable markets for commercial products. Different policies are focused on different aspects of innovation. Broadly, policies focused on fostering markets for new technologies are "demand-pull" policies, whereas policies focused on uncovering technology opportunities and funding the development of those technologies are "technology-push" policies. The optimal environment for innovation requires both policy types.

In the context of developing low-carbon transportation technologies, market systems included in the LCFS and AB 32 are the demand-pull policies, whereas AB 118, the PIER transportation program, and DOE-funded research, development and demonstration are the technology-push policies. It is fortunate that we have both.

Model of the Innovation Process

The innovation process for new technologies is often portrayed as a linear process of research and development, demonstration, and deployment. Although real innovation is more complicated, this model is a good tool for understanding the role of different policy tools in advancing low-carbon technologies.



Source: Farrell, Sperling et al, 2007b and PCAST, 1999

Different aspects of the innovation process have different benefits regarding innovation. The introduction of fundamentally new technologies, or "radical innovation", requires investment in research and development first. Once concepts have been proven in a lab setting, they need to be demonstrated commercially, to prove that laboratory successes can be translated into real-world projects. For these types of innovation, direct funding is most successful. Important patents (those cited by other patents) are well correlated with funding of research and development[9].

When technologies are introduced, the innovation process does not stop, but it does change in character. As new technologies are deployed commercially, cost and quality improvements continue to occur. These changes can be attributed to economies of scale, learning-by-doing,

[9] Nemet and Kammen, 2007 "U.S. energy research and development: Declining investment, increasing need, and the feasibility of expansion"

and incremental technology improvements. For these types of innovation, demand-pull policies are most effective, such as technology subsidies, carbon taxes or cap-and-trade systems. Learning curves documented for many technologies have documented cost and performance improvements through deployment.[10] Technology deployment and incremental improvement are aligned with demand-pull policies.[11]

Demand-Pull Policies Spur Investment, Achieve Low-Cost Reductions

Demand-pull policies like cap-and-trade programs, consumer tax credits, and performance standards can completely reshape markets. The Federal Acid Rain SO2 cap-and-trade program reduced acid-rain causing emissions by nearly 50% ten years after implementation. Renewable energy production subsidies and state renewable performance standards have accelerated the growth of wind and solar thermal deployment, which now approach price-parity with natural gas electricity generation. Ethanol subsidies have grown ethanol to billions of barrels per year in the U.S. These programs shifted the investment decisions of many private firms with their implementation. This type of shift in investment is needed to reduce petroleum use and achieve a fuel-diverse transportation system.

Emissions markets can achieve reductions at low cost relative to regulations. This happens because of the flexibility that market systems allow. Instead of the government choosing the technology which industry must use to clean up emissions, firms choose the most cost-effective means of reducing emissions. Firms that can find cheap ways to reduce emissions do so, while firms with more difficulty reducing emissions purchase credits on the open market. Financial incentives drive the deployment of the best low-carbon technologies. And in the best of cases, unexpected low-cost reduction strategies are discovered after policies are implemented (see box, "Acid Rain SO2 Cap-and-Trade System").

Demand-pull policies have essential characteristics: they drive private investment in low-carbon technologies and achieve low-cost reductions. They create markets favorable to innovative technologies. Demand-pull policies do not directly drive new technology development, however. Innovation requires stable long-term market signals. Some scholars have worried that the volatility of emissions market pricing will discourage long-term innovation, in comparison to other policies such as a carbon tax[12]. Booms and busts in the wind, solar, and solar hot water heating industries have been connected to passage and abrupt expiration of renewable energy subsidies. This instability is believed to have inhibited investment in these technologies.

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[10] IEA, 2000. "Experience Curves for Energy Technology Policy"
[11] Nemet, 2008. "Demand pull, technology push, and government-led incentives for non-incremental technical change."
[12] Driessen, 2003. "The Economic Dynamics of Environmental Law"

Unexpected Solutions and the Federal Acid Rain SO2 Cap-and-Trade Program

Acid rain in the 1980's had been acidifying lakes, degrading air quality, and damaging sensitive forest and coastal ecosystems. In response to criticisms of traditional means of regulating SO2 emissions, the 1990 Clean Air Act introduced a novel cap-and-trade mechanism to reduce emissions. It was expected that by allowing flexibility, the cap-and-trade program would save money in the course of reducing emissions. It turned out that power plants were able to reduce emissions much more quickly and cheaply than had been anticipated.

One reason for the success of this policy was the emergence of an unexpected solution. In response to the new policy, power plants developed technologies so that they could switch to using a different type of coal lower in sulfur content. Previously, using this type of coal had been considered infeasible. Although fuel switching was not one of the original solutions expected, aligning the incentives correctly caused this option to be exploited.

Direct Funding of Demonstration Projects is Good for Driving Innovation

Successful innovation requires that capital be available in all stages of the innovation process. In a variety of energy technology areas, patenting activity (as a proxy for radical innovation) is well correlated with direct funding of research and development.[13] Funding of demonstration projects is the next step. Many technologies beyond research and development are still too early-stage for firms to invest. This lack of investment can be traced to the three market failures described at the beginning of this chapter, and uncertainty regarding policies to address these failures.

Technology entrepreneurs refer to the gap between research funding and project finance as the "Valley of Death." Once technologies are proven in a lab setting, research funds no longer help their advancement. But for risk-averse banks to fund the construction of new projects, technologies need to be thoroughly proven in a commercial setting. Venture capital has filled this gap in the electronics and biotechnology industries, but the investments necessary are much larger in the energy and transportation industry than they are in high-tech fields. While AB 118 alone is insufficient to move technologies all the way from lab to market, this gap is where funds should be used.

Recommendation: Use AB118 funds to address market barriers to innovative technologies, and move them past the "valley of death".

[13] Nemet and Kammen, 2007.

Reason for Optimism: Technologies Contending to Replace Petroleum

Although petroleum fuel and the internal combustion engine are currently the dominant transportation technologies, there is reason for optimism that new technologies could revolutionize the transportation system in California. A wide variety of new technologies at various stages of development are vying to replace traditional technologies. For the past decade there has been persistent interest from researchers to develop alternatives to oil. For nearly that long, venture capitalists have been investing in "cleantech," including some transportation technologies. Recently all the big oil and car companies have been making various investments to reduce petroleum use and GHG emissions. Some of the technologies first investigated in the reaction to energy crises in the 1970's are being reexamined. The combination of all this is a dizzying array of technologies and products in play. In the next few years, AB 118 could help the commercialization process of some to these technologies.

Electric Vehicles Are Being Reintroduced

A few short years ago, in 2000-2003 at the height of the first round of the zero-emissions vehicle program, hundreds of battery-electric vehicles drove on California's roadways. Since then, the presence of "full-function" electric vehicles has subsided, although there have been low-speed, short-range "neighborhood electric vehicles" for sale for several years. The next few years will see the reintroduction of electric vehicles meant to replace standard gasoline cars.

Among the companies planning to sell "full function" electric vehicles in 2008 are Tesla Motorcars and Phoenix Motorcars. Tesla has started commercial production of its high-end roadster,[14] planning to build about 100 vehicles per month by next year. They already have almost one thousand vehicles reserved. These cars give up nothing to gasoline vehicles: they out-accelerate other sports cars while achieving the equivalent of 135 MPG and a range over 200 miles, but with a hefty price tag above $100,000. Phoenix also plans to sell its vehicles soon, but production hasn't begun.

Norwegian electric car maker Think spun off a few years ago from the Ford efforts to comply with the zero-emissions vehicle program. They have sold about 1,200 cars in Norway, and now Silicon Valley venture capitalists will bring them back to market in North America in 2009.[15] Think will have the advantage that they have already been manufacturing and selling their car in Europe, thus they have already performed the necessary demonstration, performance and safety testing. While not as high-performance as the Tesla, a Think car should still exceed a 100 mile range on a charge and will be much more affordable.

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[14] From press release March 17, 2008 -- http://www.teslamotors.com/media/press_room.php?id=841

[15] Press release April 21, 2008 -- http://www.think.no/think/Press-Pictures/Press-releases/Kleiner-Perkins-and-RockPort-Capital-two-leading-US-Cleantech-investors-launch-joint-venture-with-Norwegian-electrical-vehicle-company-Think

Hybrid Medium and Heavy-Duty Truck Commercialization

Hybrids vehicles have become prominent in the light-duty vehicle market, but the opportunities for fuel savings from using hybrids in commercial applications may be even greater. Applications like parcel or beverage delivery, refuse pick-up, and utility maintenance involve extensive stop-and-go driving, where hybrids shine. Several manufacturers have conducted demonstrations over the past few years, including the original 2003 demonstration by FedEx and Environmental Defense Fund. Depending on the application, these trucks have shown fuel economy improvements of 10-80%. ARB regulators expect that they can achieve at least 35%, and pay for themselves over the course of 5 years once they achieve volume sales over 10,000 vehicles per year.[16]

Eaton, the leading producer of the hybrid powertrain, has recently started commercial production,[17] with several truck manufacturers incorporating the hybrid powertrain in their models, including Kenworth, Peterbilt and International.[18] Currently, low volume means high incremental cost for the hybrid vehicle, but these costs are likely to come down if manufacturing economies of scale can be reached, achieving significant fuel reduction.

Major Automakers Soon to Release Advanced Vehicles

The major automakers have made a range of announcements of various vehicles that they plan to offer in the 2010-2012 timeframe. This will include fuel cell vehicles like the Honda FCX, plug-in hybrid vehicles like the Chevy Volt, and a plug-in version of the Toyota Prius. These plans are partially in response to current requirements of the zero-emissions vehicle program, but also reflect a race to be the first to successfully sell the next generation of high-tech, environmentally friendly vehicles. American car makers have been highly criticized for their late arrival to the hybrid vehicle market, and seem intent on being quicker in the next round. If the commercial success of the Prius is any indication, other advanced vehicles may also bring profits to whatever company can bring it to the mass market.

Many New Biofuel Production Processes in the R&D Pipeline

Since introducing ethanol and biodiesel into the transportation fleet, a number of challenges to using these fuels have emerged. Ethanol absorbs water, which can rust pipelines, so it has to be transported by truck. Biodiesel can cause corrosion of certain components. Production of both fuels is relatively expensive.

In response to these problems, a wide variety of new biofuel production processes are being developed in universities and corporate research labs. Several processes are demonstrating that

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[16] Early Actions Report, Air Resources Board, 2007

[17] http://www.environmentalleader.com/2007/08/14/eaton-begins-commercial-production-of-hybrid-systems-for-medium-duty-trucks/

[18] http://www.peterbilt.com/newsdetails.aspx?id=215
http://www.truckinginfo.com/news/news-detail.asp?news_id=60095&news_category_id=20
http://www.internationaldelivers.com/site_layout/news/newsdetail.asp?id=930
http://www.nytimes.com/2008/04/27/automobiles/27TRUCK.html?ex=1366948800&en=dab18904956199bf&ei=5088&partner=rssnyt&emc=rss

plant materials can be used to produce liquid fuels that resemble gasoline[19] and diesel,[20] which should allow them to be distributed using normal infrastructure and used in standard engines. New processes are being developed to produce fuels more efficiently, using everything from modified bacteria from the Chesapeake Bay[21] to nanotechnology.[22] The proliferation of biofuels means that companies have a number of different processes to consider.

Algae Fuel Start-ups May Start to Deliver

For years, one of the most elusive but promising sources for biofuels has been algae. Early experiments at the National Renewable Energy Laboratory showed that ponds used to grow algae produced 20 times more material for biofuels than crops on dry land. That means it is also pulling carbon dioxide out of the air twenty times faster. The trick is figuring out how to select for algae with good fuel properties and keeping them healthy and productive. A major milestone has been reached this year, as one commercial algae-fuel facility in Texas is starting commercial production.[23] If this facility is successful, it could mean that the engineers have figured out how to make algae work. California has its own algae-fuel startups, including Solazyme[24] in South San Francisco.

Finding: There are many exciting new technologies coming out, with news of more ideas and breakthroughs each week.

Section III: Market Barriers to New Transportation Technologies

New technologies in every industry face barriers which inhibit entry, but many characteristics of the transportation sector make it especially difficult for new technologies to enter. Alternative fuels have received government support since the 1970's, but they have yet to gain significant market share. The market barriers that have prevented the widespread adoption of alternative fuels and other new transportation technologies include:

- Manufacturing economies of scale
- Need for extensive network of fueling stations for convenience
- Restrictive environmental regulations due to environmental risks of petroleum
- High cost of developing and demonstrating new technologies

Large Upfront Investments Needed to Achieve Economies of Scale

In order to manufacture vehicles profitably, they must be built and sold in enormous quantities. Automakers require sales volume approaching 100,000 vehicles per year to reach economies of

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[19] "Green gasoline", http://www.sciencedaily.com/releases/2008/04/080407102812.htm

[20] "Renewable diesel" from Conoco and Tyson foods, http://www.marketwatch.com/news/story/renewable-diesel----next-best/story.aspx?guid=%7B153EB441-1D65-4759-AC23-8AD1D0A84FC8%7D

[21] http://www.upi.com/NewsTrack/Science/2008/03/13/new_biofuel_production_process_created/5820/

[22] http://www.public.iastate.edu/~nscentral/news/2007/jun/catilin.shtml

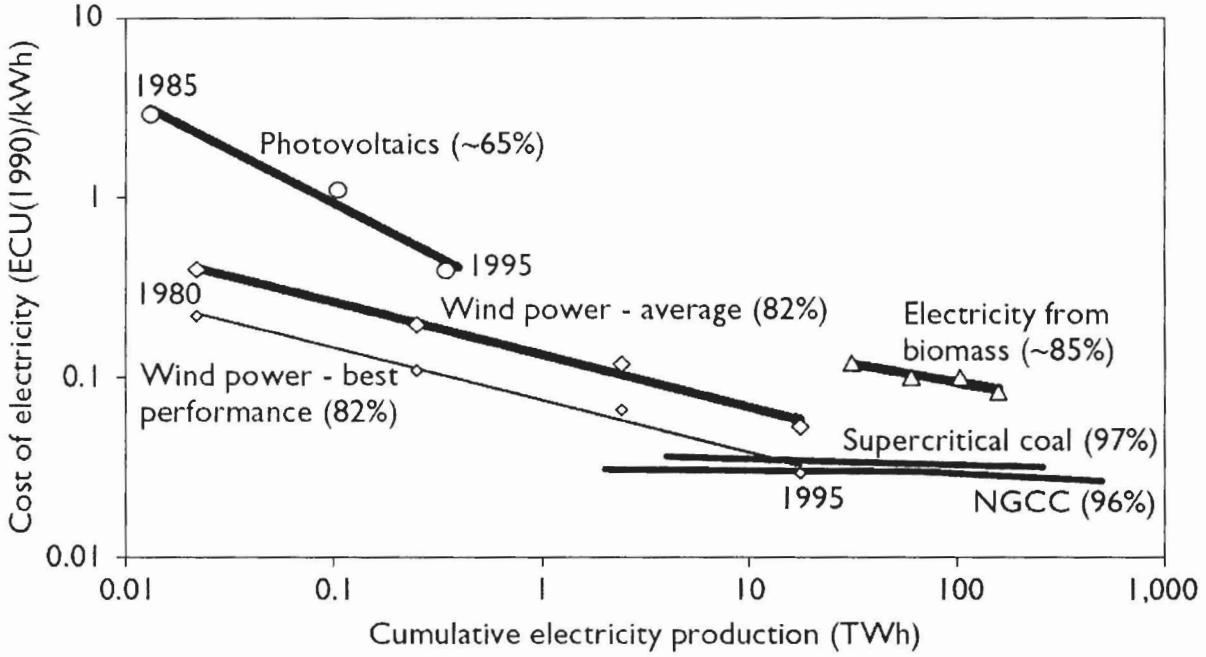
[23] http://earth2tech.com/2008/03/27/15-algae-startups-bringing-pond-scum-to-fuel-tanks/

[24] http://www.technologyreview.com/Biztech/20319/

scale. To get to the point of selling this many vehicles, a firm must make an enormous investment in research and development, and gradual scale-up of production. Even for a huge multinational corporation, such an investment is extremely difficult to justify.

Large scale manufacturing has several competitive benefits. First, large scale usually leads to cheaper production, which in turn increases sales. Second, researchers have documented learning effects in many technologies. The more a technology is used, the more gradual improvements can be made in the design, manufacture, and management of that technology. As a rule of thumb, this relationship means that a doubling of total output can be expected to result in cost improvements of 5-20%. The following figure represents learning rates documented for several energy technologies, on a logarithmic scale:[25]

Figure 2: Learning Rates for Energy Technologies in Europe



Economies of scale is one lens with which to view the failure of battery-electric vehicles to take hold in 2000 to 2003 despite the technology-forcing ZEV policy. Through the nineties and early 2000's, several thousand EVs were leased, but this never began to approach major automaker volumes. Electric vehicles are not yet popular enough to achieve high volumes necessary for large automakers to make a profit. In the past few years, several small companies have used very different business models and manufacturing systems to make small quantities of electric vehicles. These smaller companies may be able to achieve profitability at smaller sales volumes, allowing the slower scale-up necessary to make electric vehicles successful.
One of the eleven project types included in AB 118 is vehicle buy-downs. The purpose of such a technology is to encourage purchase, thus driving economies of scale. But available funds are relatively small compared to most markets. AB 118 funds may be sufficient to drive economies of scale in small or niche markets, but would be insufficient to drive demand in large markets,

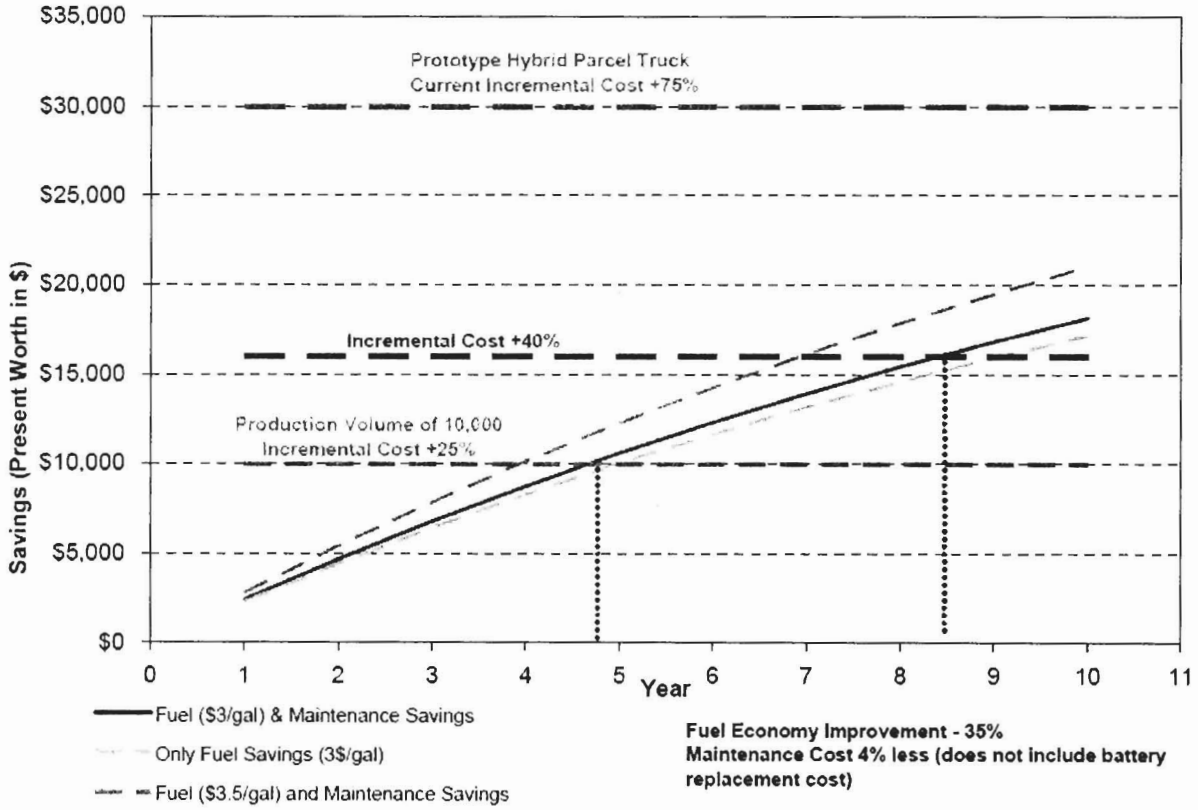
[25] IEA, 2000. "Experience Curves for Energy Technology Policy"

such as consumer vehicles or fuels. As reference, ethanol subsidies, which have driven nationwide ethanol production to about 5% of total transportation fuels, cost about $3 billion per year.

Medium-duty hybrid trucks are one technology where the market may be small enough that AB118 funds can drive economies of scale. These trucks are used in niche applications, such as parcel and beverage delivery trucks, garbage haulers, and utility cherry pickers. Depending on the application, applying hybrid technology can achieve significant fuel savings.

The Air Resources Board conducted an economic assessment of the potential for hybrid trucks.[26] The model showed that although pre-production trucks do not achieve sufficient fuel savings to offset high up-front costs, that when commercial production volume of 10,000 trucks is achieved, fuel savings will offset upfront costs over five years. This payback period is well under the expected vehicle lifetime.

Figure 3: ARB Medium-Duty Hybrid Truck Payback Model



AB 118 funds would be sufficient to make a significant contribution to achieving economies of scale in hybrid truck production. The Federal government offers a tax credit of $6,000 for several of these models. If California spent $10 million in AB 118 funds on hybrid truck buy-

[26] ARB Early Actions Report, May 2007. Standard vehicle assumptions: $40,000, 7mpg, 22K miles/year, 10 year vehicle life. Hybrid model assumptions: $70,000, 9.5mpg, same life and mileage, slightly lower maintenance costs.

downs of $5,000 per truck, it could drive the purchase of 2,000 trucks, a major step towards commercial production and economic competitiveness of this fuel-saving technology (for more details, see Appendix).

Sustainability and Air Quality Rules – Avoiding Unintended Consequences

From gasoline additives to refrigerant gases, the introduction of new technologies often causes unintended environmental consequences. [27] Petroleum use, in particular, has caused serious environmental problems in the past, including air quality degradation and groundwater pollution. In response to these past problems, we now have strict environmental regulations and certification procedures for fuels and vehicles. These rules protect our environment, but they also represent significant barriers to new technologies. It is not always possible for small businesses advancing new technologies to pay for the necessary testing procedures. In these cases, conducting testing of promising new technologies through AB 118 would enable private investment, while protecting environmental quality.

Even when regulations are not in place, it is important to mitigate negative unintended consequences that could result from new technology. When significant risks are ignored, otherwise valuable policy initiatives can be sabotaged. Current debates around biofuels currently threaten to set back climate change policy because potentially unsustainable grain consumption of biofuels was not addressed prior to widespread introduction.

Negative side-effects of biofuels have recently gained national prominence.[28] Increased ethanol and biodiesel have been blamed by the media for food shortages,[29] accelerated deforestation of the tropics, and increased greenhouse gas emissions[30]. Stakeholders are aware that the potential for climate change policy to yield unintended consequences is important, thus the inclusion of language in AB 118 to try to avoid causing new environmental problems.

There are several immediate examples of situations where we know of possible environmental risks associated with alternative fuel and vehicle technologies. Tests of tailpipe emissions due to biodiesel have found decreased levels of several pollutants, but modestly increased levels of NOx emissions. The ARB is currently sponsoring research meant to investigate technologies that may be able to mitigate this effect. Similar problems have been uncovered related to E-85. There is currently no fueling equipment certified in California to dispense E-85. Until last fall, part of the delay was due to safety concerns: Underwriters Laboratories was concerned about that the caustic qualities of ethanol would cause it to degrade pumps and cause dangerous spills. Although UL has now approved some equipment for use with E-85 on safety grounds, there are still concerns regarding increased evaporative emissions due to dispensing E-85 from standard fueling infrastructure.

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[27] "Late Lessons from Early Warnings", Stikkers 2001 and Davis 2006.
[28] For example, Time Magazine cover story, Krugman in the NYT, SF Chronicle, International Herald Tribune. Google search for 'biofuels unintended consequences' yields 27,600 results in the past three months.
[29] UN-Energy Report, "Sustainable Bioenergy", Runge in Foreign Affairs, "How Biofuels Could Starve the Poor"
[30] Searchinger, et al and Fargione, et al in Science, 2008.

E-85 pump deployment in California has been delayed by a lack of approved fueling equipment. A good use of AB 118 funds would be to do testing and research to develop equipment which can dispense E-85 while avoiding the possibility of evaporative emissions. In general, where sustainability or environmental impact risks stand in the way of alternative fuel deployment, AB 118 is an appropriate source of funds to research those risks and develop equipment to mitigate risks.

Unintended Consequences and Environmental Policy

Environmental policy has numerous examples of situations where information was known about potential hazards well before regulatory decisions were made, but regulators were not made aware of results early enough or warnings were discounted for one reason or another. If regulators use a precautionary framework, they could anticipate many of these risks and gather the necessary information.

Revisions to the 1990 Clean Air Act required oxygenation of gasoline to reduce carbon monoxide emissions. This requirement was needed, in part, because of the phase-out of lead in the 1980's for health reasons. About two-thirds of the oxygenation requirement was met with MTBE, about one-third with ethanol. In retrospect, the use of MTBE was a very expensive mistake. One cost-benefit analysis calculated that the air quality benefits of oxygenation were worth between $14 and $78 million, whereas the combined costs of groundwater clean-up, fuel cost to consumers, and lost recreational areas would be between $700 million and $3 billion. Making matters worse, there was information available before the introduction of MTBE that could have averted this outcome.

The problem could have been avoided. Prior to 1990, MTBE persistence and mobility were known, as well as its impacts on water taste and smell. Noteworthy is that at the time there were no specific health problems for which MTBE was implicated. It turned out, however, that peoples' ability to taste MTBE in their water was sufficient reason to avoid drinking contaminated water. New evidence now shows that MTBE is a suspected carcinogen, and other possible negative health impacts continue to accumulate.

The history of refrigerants is another technology area littered with unintended consequences. In the 1920's, as refrigeration was becoming widespread, toxic gases like ammonia were used as refrigerants. Chemist Thomas Midgeley invented Freon, which greatly improved human health from ammonia leaks. In the 1970's, the ozone hole was discovered, and CFC's like Freon were identified as one of the causes. International negotiations led to the Montreal Protocol, which has largely phased out CFC's. These chemicals were replaced by another set of chemicals, HCFC's, which do not deplete the ozone, but have since been discovered to be potent greenhouse gases. Huge sums of international climate change mitigation funds have been put into destruction of HCFC's, and now these chemicals are being phased out.

Lack of Fueling Stations

Many alternative fuel vehicles require special fueling stations. In order for a consumer to use a hydrogen, natural gas, or propane vehicle, they need convenient places to buy necessary fuel. Fueling stations have characteristics of public infrastructure: whether a city has many or few alternative fuel vehicles, a similar number of fueling stations are needed. This means that early adopting drivers will have to endure considerable inconvenience, and that early station owners will have a hard time selling fuel profitably. In addition, selling fuel is not very profitable. Most fuel station profits are made in the snack shop. Spending $50K-$300K on new alternative fuel infrastructure does not increase snack shop profits.

Hydrogen fuel cell vehicles currently a face lack of fueling infrastructure. Several years ago, the state undertook a plan for a "California Hydrogen Highway," meaning that hydrogen fueling stations would be placed along major state highway routes at fifty-mile increments. Hydrogen stations have proven very expensive to implement, costing several million in government funding to establish per station. The current plan is being reshaped to concentrate fueling infrastructure in a few metropolitan areas, particularly in Southern California.[31] Public funding for initial infrastructure deployment is necessary to allow further development of hydrogen vehicle technology.

Hydrogen technology is at an early stage, and needs technical advances in several areas. One idea for low-carbon production which needs to be more fully explored is on-site hydrogen production. Currently, hydrogen is often trucked from refineries where it is reformed from natural gas. We do not yet know what technology will be used to produce hydrogen in the long run. This uncertainty means that infrastructure investments should be made cautiously so that a large initial investment is not stranded by technology change.

Some fuels are able to avoid problems related to expensive infrastructure deployment. Because of its similarity to gasoline, millions of flexible-fuel vehicles have been sold already, which can use either gasoline or ethanol. Although most of these vehicles are not currently using ethanol, for a fuel station owner who chooses to install E-85 infrastructure, there is already a customer base ready to use the fuel.

[31] http://hydrogenhighway.ca.gov/update/spring08.pdf

Conclusion: Get More Technologies Ready to Compete

At a base level, reducing greenhouse gas emissions requires that we either reduce the amount of driving that we do, or switch to lower-carbon technologies. A cap-and-trade program adds a financial incentive to the equation. This has the effect of integrating environmental concerns in our overall economic system. The choice remains, however, reduce consumption, or switch to lower-carbon alternatives.

In the case of the transportation sector, credible alternatives to petroleum do not yet exist. A number of technologies exist in early-stage form, but they have not yet proven that they can displace major percentages of the transportation fuels we use. Contrast this with the electricity sector, which, although highly emitting, has a number of established low-carbon technologies: hydropower, nuclear, wind, solar and geothermal generation.

Cap-and-trade systems create an incentive for innovation, to develop and deploy new technologies, but the strength of that incentive is not sufficient to develop new technologies quickly. The carbon price in a cap-and-trade market may not be as high as the damage caused by emissions. Innovators are often unable to capture all the benefits from their inventions. Lastly, innovation is inherently risky, and it can be difficult to get the necessary capital for the big upfront investments necessary to bring new ideas from the laboratory into the marketplace.

The role of AB 118 is to help smooth the path for the deployment of new technologies in the transportation sector. The barriers faced by each technology are different, but through expert consultation and economic analysis, AB 118 managers should be able to isolate the pressing barriers preventing the deployment of new technologies. Among these, they can select the barriers for which AB118 funds can make a difference.

AB 118 is one funding source among a field of different sources: the federal government is pouring billions of dollars a year into biofuels and vehicle technologies; the private sector is investing hundreds of millions in research and development. The niche of AB 118, as set out in the legislation, is to address demonstration and deployment. This niche is not unique, as the Department of Energy also spends significant funds on demonstrating and deploying new technologies, but this gives California a tool to push its own priorities, and jump-start alternative transportation technologies in California.

Recommendations:

The Task at Hand

The task at hand is to define the focus of the AB 118 technology program so that its funds maximize advances in efficient transportation and alternative fuel technologies. This in turn will help California to achieve its broader climate change, alternative fuel use, and air quality goals.

Finding 1: Innovative new technologies are needed to achieve necessary reductions in the transportation sector

Finding 2: Climate policy must leverage enormous private investment in new technologies

Recommendation 1: Support a Range of Technologies with Potential Benefits

AB 118 program managers should use a portfolio approach: support a range of technologies with potential to deliver GHG reduction, petroleum reduction, and air quality improvements. By supporting multiple technologies, risk due to uncertainty about how technologies will develop is reduced. Information about potential benefits should still be gathered, but this information should be used by the advisory committee in a flexible way, as opposed to a single maximization metric.

Recommendation 2: Use AB 118 to Minimize Market Barriers

The most effective use of AB 118 funds is to conduct projects which enable private investment and knock down market barriers. Projects should help new technologies "into the ring" to compete with petroleum fuels. The success of future market systems, including the LCFS, depends on commercially ready alternative technologies.

Finding 3: There are a lot of exciting new technologies coming out, with news of more ideas and breakthroughs each week.

Recommendation 3: Choose projects which address one of these market barriers:

1) Economies of scale
2) Environmental risks / regulatory barriers
3) Availability of fueling infrastructure
4) Demonstration projects, especially those using first-of –kind technology or addressing integration problems

Appendix

Medium-Duty Hybrid Trucks

Medium-duty hybrid truck technology has significant promise to significantly increase fuel economy and decrease greenhouse gas emissions from medium and heavy-duty trucks used in stop-and-go applications. The most beneficial applications include delivery vehicles, utility trucks, and garbage collection. The technology has already been proven in several demonstration projects starting in 2001, but currently has a high incremental cost. A large portion of this cost is due to extremely low-volume production; today there are fewer than 600 of these trucks on the road. Medium-duty hybrid technology has developed without the very large government subsidies that have been afforded to biofuels or other alternative fuels, and is likely to be price competitive without subsidy when mass production and market stabilization is achieved. This presents an attractive opportunity for a publicly sponsored buy-down program to accelerate the market penetration of this environmentally-beneficial technology. By increasing efficiency, this technology can simultaneously advance California's multiple policy goals: reduced greenhouse gas emissions, reduced petroleum use, and improved air quality.

Among possible projects, this is one whose technology is fairly near-term; it could achieve wide deployment within the next ten years. It can achieve a high percentage greenhouse-gas reduction, since the fuel savings is substantial, but the number of medium-duty trucks being used in stop-and-go applications is relatively few compared to light-duty vehicles and long-haul trucks, so the maximum reductions available from this strategy are less than those that affect those aspects of transportation. It makes excellent sense within a business development sphere, however, as hybrid trucks are a natural step towards building either plug-in hybrid trucks, battery electric trucks, or hydrogen fuel cell trucks.

Demonstration Vehicles Have Significantly Reduced Greenhouse Gas Emissions

A number of demonstration projects have been conducted which show significant fuel improvements over standard vehicles, including ones conducted by Purolator, Fedex and Environmental Defense Fund. Laboratory testing conducted by the Southwest Research Institute for Fedex and Environmental Defense Fund has shown fuel economy improvements of 45-57%. On-road testing conducted by Purolator in 2007 showed a fuel economy improvement of 49%, though this was confounded by a switch from gasoline to diesel fuel.

A reasonable but conservative estimate is that hybrid technology could increase medium-duty truck fuel economy by 35%, equivalent to a 26% reduction in GHG emissions. Air Resources Board calculations[32] estimate that over a ten-year lifetime, one hybrid medium-duty truck saves about 7,500 gallons of fuel and 21 tons CO2 reduced.

Total Reduction Potential is Significant, But Much More is Needed

In 2020, California is likely to have nearly 300,000 trucks which could benefit from this technology. If 20% of that fleet were hybrids, that would mean a reduction of nearly 200 million

[32] ARB assumptions from early action report: ten year truck lifetime, base mileage of 7 mpg, 35% improvement to 9.2 mpg, 22,000 miles per year driven.

gallons of diesel and 0.5 MMT in 2020, compared to total reductions needed of over (100 MMT). If adoption were total among urban trucks by 2020, reductions would be 1.7 MMT.

Technology Could Be Advanced Through Economies of Scale

Despite fuel savings and environmental benefits, current market penetration of hybrid trucks is very low, perhaps 600 total trucks in operation. This results in very high cost, since many parts are custom-made. Current preproduction incremental cost of hybrid technology is $30,000 (over the cost of a standard truck), but hybrid truck builders say that at commercial production of 10,000 trucks / year, the incremental cost will be only $10,000. This cost premium would be more than compensated by the fuel savings. Public incentive funds could advance this technology by overcoming initial risk and cost barriers of scaling production, but the technology is likely to be cost-competitive even without a price for carbon within a few years of reaching mass production.

Pushing Hybrid Truck Technology to Scale Would Not Be Cost-Prohibitive

The entire incremental cost ($30,000) of 10,000 preproduction trucks would be $300 million. Compare this to the costs of the federal ethanol tax credit in 2006: about $3 billion. In reality, California would not need to cover the entire cost of 10,000 preproduction vehicles. Fuel savings provides about half this cost over a ten-year lifetime. Federal incentives for these trucks are about $4,000 per truck. This means that an additional incentive of about $11,000 would make a preproduction truck fully cost-competitive (not counting possible replacement of the battery). In reality, California would not need to spend even this much, however, since costs are likely to come down as production scales up, and other states will also support part of the hybrid truck market. If California spent $10-15 million per year for four years from AB 118 funds to advance hybrid truck technology, there would be a reasonable chance of driving production to scale pre-regulation.

Federal Investments in this Technology Have Been Modest

The Federal government has made previous major investments in hybrid technologies through the Partnership for a New Generation of Vehicles in the late 1990's, but presently the vast majority of funding is focused on ethanol and other alternative fuels as opposed to improvements in vehicle efficiency. Small investments have been made in hybrid heavy-duty trucks and transit buses. The Energy Policy Act of 2007 established a purchase incentive for hybrid trucks, but the amount is small in comparison to that given to alternative fuel technologies and small in relation to the incremental cost.

Hybrid Trucks Present Fewer Sustainability Risks than Other Options

Hybrids trucks could present sustainability risks in the production and disposal of batteries, including possible malfunction of some battery technologies leading to safety risks. Light-duty hybrid vehicles face all the same risks, however, and are being used widely without obvious problems. There are also no obvious risks to public lands, displacement of food, water use or contamination, or air quality. Since they use less fuel, it is possible that hybrid trucks

could further improve air quality, especially since they are used in urban settings close to residents.

Every technology should continue to undergo testing as it matures. Life-cycle assessments should be conducted to calculate the emissions due to the production of the hybrid powertrain and battery, which may partially offset the in-use fuel savings. On-road fuel savings may vary by application. Driver training courses may allow higher fuel savings to be reached.

Relationship to Other Policies in California

This measure could advance the goals of AB32, the State Alternative Fuels Plan, and the Low-Carbon Fuels Standard by reducing greenhouse gas emissions and petroleum fuel use in California. The ARB has approved Medium-Duty Hybrid Trucks as an early action measure for possible consideration in 2011, at which point either incentives or mandates may be instituted. This measure could make a mandate possible at that time by allowing these technologies to prove themselves at a commercial scale for several years. By that time, medium-duty hybrid trucks may already be cost-competitive, minimizing the cost and resistance that the ARB would encounter to such a regulation.

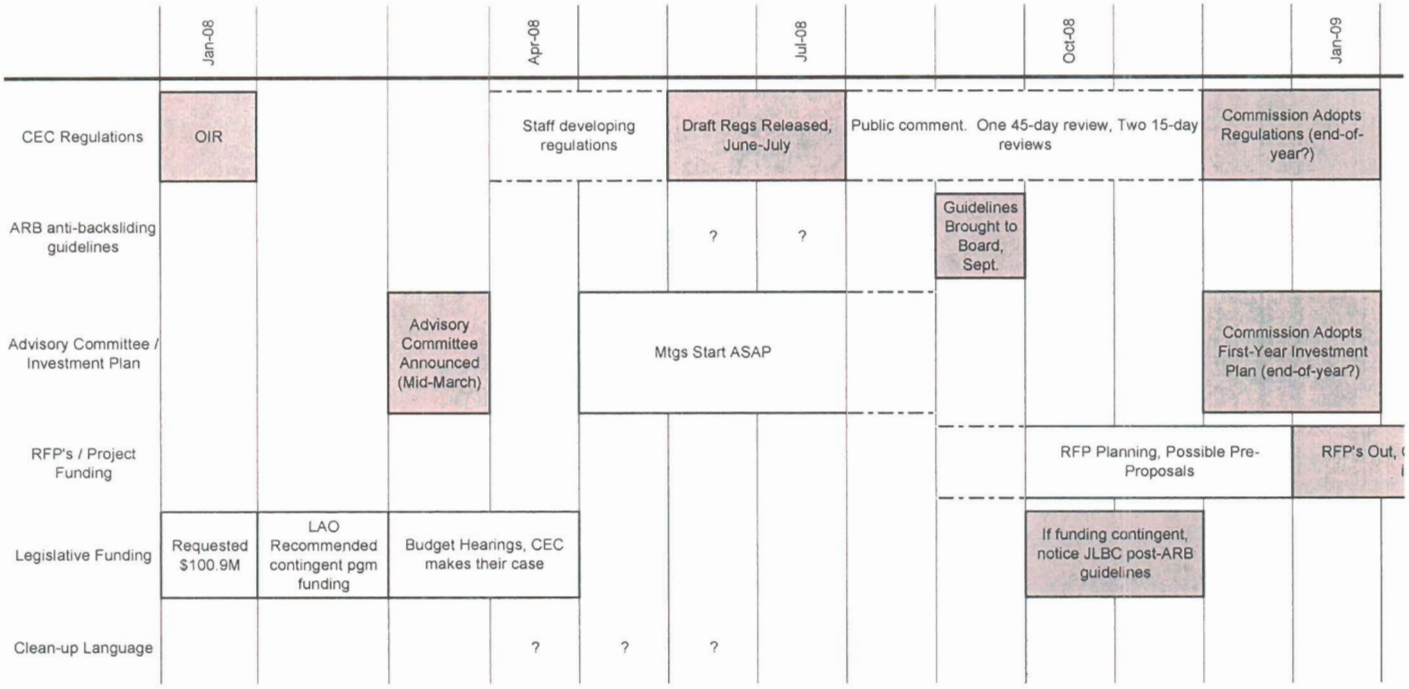
A Buy-Down Program for Hybrid Trucks Would be Cost-Effective

Calculating the cost-effectiveness of innovative technologies like medium-duty hybrids is uncertain. Suppose California were to award buy-down incentives for medium-duty hybrid trucks of $10,000 per truck, and used as an emissions baseline the fuel use of a comparable standard truck. In the short term, each $10,000 incentive awarded to a medium-duty hybrid truck purchase would achieve immediate cost-effectiveness to California state funds of about $480 / ton CO2. While expensive, this is comparatively little for a new technology. If a total of $50 million were spent on these incentives over several years to scale up hybrid truck production, and this effort were to cause the medium-duty truck fleet to turn over to hybrid technology just two years before it would have otherwise, then the overall program would achieve cost-effectiveness of about $15 / ton. This difference is because the main benefits due to funding the buy-down program are economies of scale. If the buy-down program can help manufacturers achieve cost reductions, then the benefits go far beyond the emissions benefits of the actual trucks funded by the program.

Schedule for Implementation

There are several separate threads happening simultaneously, which will later be combined into the final program. Of immediate concern is the development of the regulations at the Energy Commission and Air Resources Board. Later on, the advisory committee process will take precedence. There are some interdependencies to this process: the Energy Commission may not receive funding appropriations for 2008-2009 until regulations have been adopted. Requests-for-proposals can not be circulated until the investment plan has been adopted. Discussion of the investment plan will take place before the regulations have been fully developed, but the regulations will affect what projects are funded, thus interacting with the advisory committee process.

Estimated Implementation Schedule*



* based on conversation with CEC staff

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