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CASE STUDY

California's climate and energy policy for transportation

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ABSTRACT

California has been a leader in advancing policy solutions to environmental and energy challenges since the 1960s. Many of those policy innovations have spread worldwide. Beginning with statutes passed by the California legislature starting in 2002 and continuing through today, California is adopting a comprehensive set of policies, regulations, and incentives to reduce greenhouse gas emissions, with particular emphasis on those associated with transportation—vehicles, fuels, and mobility. This paper reviews California's policy and regulatory approach related to transportation and highlights energy and climate policy lessons. The portfolio policy approach requires wise oversight, which will become more critical as California begins to adopt policies and rules to achieve more aggressive targets for 2030 and beyond. The shortcomings of a California-only policy approach will be overcome by expanding policy collaboration with other jurisdictions.

1. Introduction

California pioneered car-centric cities and lifestyles. By 1930, one of every five California residents owned a car, a level not reached in Western Europe until the 1970s, 40-years later. With motorization came increased mobility, economic activity, and suburban living. It also brought traffic congestion, high oil use, air pollution, and greenhouse gas (GHG) emissions. The downside of cars became visible, literally, by the mid-20th century, when brown smog started to blanket Los Angeles, heightening California residents' awareness of the health, economic, and esthetic problems of the car-dependent lifestyle.

Now as part of a larger effort to address climate change, California is building on earlier air pollution policies to devise broader approaches to tame motor vehicles, by reducing their energy use and GHG emissions. Whereas most of the international discussion of climate solutions until recently has focused on electricity and coal, in California greater emphasis has been given to transportation, where three-quarters of all oil consumed and over 40% of all greenhouse gases emitted are associated with the movement of goods and people. Because cars, oil, and environmental leadership are intertwined, any strategy to reduce oil consumption and greenhouse gas emissions must target transportation, especially in California.

A key agent in the design and implementation of climate policy is the California Air Resources Board (CARB), the agency most responsible for California's leadership in air pollution regulation and policy. Since its establishment in 1967 by Governor Ronald Reagan, CARB has been effective at regulating conventional air pollutants. Its clean air policies were imitated by the federal government and around the world, leading to the commercialization of catalytic converters, reformulated gasoline, zero emission vehicles, and many other technology innovations. As Daniel Yergin suggests *in The Quest: Energy, Security, and the Remaking of the Modern World*, CARB became the "de facto national authority" [1].[1] Now its mission is evolving and spreading as it extends this leadership to climate policy and regulation.

The agency oversees a budget of $300 million and a staff of over 1000 employees, and is governed by a 12-member board appointed by the governor and confirmed by the state Senate. The Board, with broad-ranging regulatory authority granted by the Legislature, operates in an independent manner through formal notice-and-comment rulemaking. Its decision-making is highly transparent, taking place in public at monthly board meetings, usually attended by hundreds of people and broadcast online.

CARB has adopted a far reaching set of climate rules and policies that cover virtually all aspects of the energy system, surpassing

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[1] As described later, CARB's authority emerged from the state's early and effective commitment to air pollution reduction.

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Europe in crafting the most comprehensive approach to climate policy in the world. Although the European Union adopted a carbon cap-and-trade program before California and has more aggressive greenhouse gas standards for vehicles, California's cap-and-trade covers more sectors, including transport, and the state has adopted a broad web of policies that range from deep energy efficiency standards for appliances and buildings, to reduced use of global warming gases by industry, to reduction of methane gases on farms.

Two political circumstances favor California's climate policy leadership. First, CARB has unique authority to regulate vehicles and fuels that are used within its borders. California suffered unusually severe air quality problems as early as the 1940s and adopted requirements for cleaner vehicles and fuels long before the federal government was moved to act. As a result of this leadership, the U.S. Congress has repeatedly preserved the state's authority to regulate vehicle emissions, as long as its rules are at least as strong as the federal ones. The California Legislature took advantage of this unique authority in 2002 when it directed CARB to pursue another first: to set standards on vehicular emissions of greenhouse gases.[2]

Second, California has more political space to maneuver than many other states. The Detroit car companies have relatively small investments in California and coal companies are absent. Plus, it benefits from a diverse resource base of solar, wind, ocean, and geothermal energy resources, which has created its own political constituencies. Lastly, the state is home to the largest high-tech venture capital industry in the world, which tends to favor clean energy and environmental policy. As a consequence, California politicians have greater public support to pursue aggressive energy and climate policies than their counterparts in many other states.

California's foundational climate law (AB32, the Global Solutions Act of 2006) set a specific target for annual state-wide emissions — to return to 1990 levels by the year 2020 and gave the Air Resources Board broad legal authority to set policy to achieve the target.

In this article we assess policies adopted by California and their effectiveness in stimulating innovation, encouraging changes in consumer behavior, and achieving large reductions in oil use and greenhouse gas emissions. The intent is to document California's policy innovations and explore its role as a policy model for the rest of the country and the world, recognizing that the next iteration of policies and rules will be more challenging in all ways.

2. Elements of the California transportation policy model

Good policy generally encompasses the following attributes: addresses both the short and long term, harnesses market forces, is performance based, equitable (across geographical regions, socioeconomic groups, and companies), transparent to all stakeholders, easy to administer, and economically efficient.[3]

Because climate change is a global problem, the solutions must eventually be pursued globally. No single country or state by itself can hope to stabilize the climate on its own. The international community, at past meetings of the United Nations Conference of Parties, has not yet succeeded in creating comprehensive climate protocols, financing programs, and binding mitigation policies.[4] Thus, California leadership is not only appropriate, but potentially of great value to the nation and the world.

Another widely held view is that the solution to our energy and climate problems is getting the prices right—sending the correct price signals to industry and consumers. In a general sense, internalizing the cost of climate change across the economy is essential and will make many of the other policies more efficient and less costly. But, at least for the foreseeable future, prices that are anticipated from existing or proposed carbon taxes, fuel taxes, or carbon cap and trade programs would not put us on a path toward deep reductions in transportation emissions without complementary policies. The explanation is behavioral and political: while the transport sector does respond to changes in fuel prices, especially over the long term, the response is insufficient to achieve large changes in vehicles, fuels, and driving behavior, at least in the range of prices that are politically acceptable. As we will see, California's initiatives are based on a broad set of policy instruments, with regulatory instruments expected to have a far greater effect in the near term in reducing energy use and GHG emissions than market instruments.

Europe provides an example of why pure market instruments are inadequate for the foreseeable future. It has gasoline taxes almost twice those of the US, and still finds the need to adopt aggressive performance standards for cars to reduce greenhouse gases and oil use. Europe's high fuel taxes certainly have an effect— on average vehicles are smaller, lighter, and people drive significantly less—but the resulting reductions in fuel use and greenhouse gases still fall far short of the climate goals of the European Union (and California). Large carbon (and fuel) taxes are efficient in an economic sense, but because consumer purchase and driving behavior is only moderately sensitive to fuel prices, the effect on vehicles, fuels, and driving are modest. The European experience suggests that, absent other policy, very large taxes would be needed to motivate changes in investments and consumer behavior consistent with climate goals. Economic research supports this finding [2]. Moreover, the effectiveness of taxes and other market instruments in reducing oil use and emissions are further inhibited by a long list of market failures and market conditions—new technology risk, technology spill-over and long development times, risk aversion by buyers who are not sure they will actually accrue the savings from more efficient vehicles, and more. As a result, a variety of policies are needed to overcome these various market failures and barriers.

In summary, the California policy model is a comprehensive mix of rules, incentives, and market instruments. Some economists would describe this approach as second best, since it does not rely on pure market instruments. Getting the prices right and adopting international climate agreements are clearly important, and will be instrumental in reducing GHG emissions, but progress can and will, be made within the transport sector in the next decade with regulatory instruments.

To describe and critique California's GHG policy model, the complexity of the transportation system is simplified into a three legged stool, with each leg representing a critical area of transformation: vehicles, fuels, and mobility (with mobility encompassing land use and infrastructure). The three legs are addressed below, beginning with the strategy that has the greatest potential for emissions reduction over the next few decades (for the US).

3. The first leg: vehicles

American vehicles stand apart from those of other major industrialized countries. They are much larger, more powerful, and driven further, and therefore consume much more

[2] In 2002, the legislature passed, and Governor Davis signed, AB1493, known as the Pavley Act. CARB adopted implementing regulations in 2004, but they were blocked until 2009 by lawsuits, as described later.

[3] For overview of policy options and strategies to reduce greenhouse gas emissions from transportation, see National Research Council, *Policy Options for Reducing Energy Use and Greenhouse Gas Emissions from U.S. Transportation*. Transportation Research Board of the National Academies, Special Report 307, Washington, DC, 2011.

[4] The two transportation activities where international agreements are needed and modest progress is being made are maritime and air transport, though these activities represent a small share of total transport emissions and energy use.

oil and emit far more greenhouse gases. One reason was policy, or lack thereof, as US national fuel economy standards remained stagnant for 30 years, while Japan, Europe, and China adopted increasingly aggressive standards to reduce oil use and greenhouse gases.

California played a leadership role in breaking the paralysis in the US. In 2002, California passed the so-called Pavley clean cars law that required a sharp reduction in average new vehicle greenhouse gas emissions—about 40% by 2016. The car companies filed lawsuits against California and other states that followed California's lead. When those lawsuits failed, the G.W. Bush Administration refused to grant a waiver to California to proceed, even though waivers were granted routinely for previous vehicle emissions regulations by California. In 2009, newly-elected President Obama not only agreed to grant a waiver, but, in partnership with California and the auto-industry, committed the entire country to a single national program based largely on the California standards.[5]

Then in July 2011, the US Department of Transportation, US Environmental Protection Agency, and the California Air Resources Board jointly announced a further agreement with the major automakers to sharply reduce fuel consumption and greenhouse gas emissions another 4–5% per year from 2017 to 2025. California, by maintaining its authority to adopt its own more stringent rules, was recognized as playing an instrumental role in the federal negotiations. Similarly, the automakers saw the uniform federal standards as preferable to a strategy where California (and other states who adopted California rules) pursued its own separate program.

These vehicle regulations are central to California's greenhouse gas reduction efforts. They are expected to elicit larger reductions than any other single policy or rule. The reductions are also expected to be cost-effective, with consumers earning back two to three times more from fuel savings over the life of their vehicle than they would be paying for the added cost of the efficiency improvements (even after discounting future fuel cost savings) [3].[6]

Another key vehicle technology strategy is the commercialization of zero emission vehicles (ZEVs) including plug-in electric and hydrogen fuel cell vehicles. It is widely accepted that these electric-drive technologies are central to continuing large reductions in oil use and GHG emissions. The federal government has recently pursued policies supporting ZEVs, with the Obama Administration offering tax credits of up to $7500 per car and billions of dollars in loans and credits to manufacturers of electric vehicles and batteries. The federal government also incorporated provisions into the national vehicle greenhouse gas standards to incentivize automakers to sell ZEVs (counting each electric vehicle as two initially and rating them as zero emissions per mile,[7] even though they do contribute emissions upstream where electricity is generated at power-plants).

California has had a much longer policy commitment to ZEVs. In 1990, the state adopted a zero emission vehicle (ZEV) mandate, requiring the seven largest automotive companies in California to "make available for sale" an increasing number of vehicles with zero tailpipe emissions. The initial sales requirement was 2 percent of car sales in 1998 (representing about 20,000 vehicles at the time), increasing to 5 percent in 2001 and 10 percent in 2003.

The intent was to accelerate the commercialization of electric and other advanced technology, including hydrogen fuel cells. Batteries and fuel cells did not initially advance as fast as regulators hoped, however, and CARB was forced to soften the ZEV rule. In 2012, for the first time since 1990, the ZEV program was strengthened, reflecting significant advances in battery and fuel cell technology and a more positive EV market environment. While some consider the ZEV mandate a policy failure, others credit it with significantly influencing the automakers, the ZEV component industry (batteries, motors, etc.), and launching a revolution in clean automotive technology.[8]

The initial numbers of vehicles sold to consumers as a result of the ZEV program fall well short of what CARB originally expected. Only a few thousand electric vehicles were sold in the US in the first decade of this century.[9] But 2011 was a breakthrough year. For the first time in over a century, major automakers made firm commercial commitments to the technology. Nissan began selling its all-electric Leaf and General Motors its Volt plug-in hybrid electric vehicle, and virtually all major car companies launched plug-in vehicle sales over the next few years. One start-up company, Tesla, made the biggest impression, thriving when all other newly formed vehicle companies had either failed or stagnated. Its second model, the Model S, was one of the best-selling full size luxury sedan in the US in 2013, including California. Total PEV sales were nearly 100,000 in the US in 2013 and California surpassed 100,000 cumulative sales in September of 2014 accounting for roughly 40% of all sales (California has 12% of the nation's population).

In addition to the ZEV mandate, California enacted various other programs and incentives in recent years to support the introduction of fuel-efficient and low-greenhouse gas vehicles, including ZEV rebates of between $1500 and $2500, access to carpool lanes by ZEVs, and subsidized hydrogen and PEV charging infrastructure. California also made a concerted effort to address all barriers to ZEV adoption, with Governor Jerry Brown enacting a ZEV Action Plan in 2013 that required all state agencies to work together to support ZEV commercialization and use [4].

One lesson is that no single policy, in this case the ZEV mandate, is generally sufficient to shift behavior and investment in a major way. So many barriers, market failures, and market conditions inhibit technology innovation and deployment in the public interest, that multiple policies and strategies are needed to overcome them.

4. The second leg: fuels

In some ways, the federal government has been a policy leader with alternative fuels. Its Renewable Fuel Standard (RFS), adopted in 2005 and then strengthened in 2007, required the production of 36 billion gallons of biofuels by 2022. It has serious shortcomings, however. This biofuel mandate has led to the production of more than 12 billion gallons per year of corn-based ethanol, but almost no low-carbon, non-food based biofuels. In 2013, the total quantity of advanced cellulosic biofuels was only 0.8 million gallons, 1% of the

[5] The administration pursued the regulation under the authority of the federal Clean Air Act, which the US Supreme Court had determined could apply to greenhouse gas emissions in Massachusetts vs. EPA (2007) subsequent to an 'endangerment' finding by the agency.

[6] The auto industry challenged these cost findings as too optimistic, but in the end all automakers except Volkswagen and Daimler agreed to support the aggressive standards proposed for 2017 to 2025.

[7] The electric-drive portion of plug-in hybrid electric (PHEV) and range extender battery electric vehicles (BEVx) also count as zero emissions for purposes of calculating GHG emissions.

[8] For the skeptical view, see L. Dixon, I. Porche, J. Kulick, Driving Emissions to Zero: Are the Benefits of California's Zero Emission Vehicle Program Worth the Costs? (Santa Monica, CA: Rand, 2002). For a positive view, see A. Burke, K. Kurani, E. J. Kenney, Study of the Secondary Benefits of the ZEV Mandate, Institute of Transportation Studies, University of California at Davis, Report UCD-ITS-RR-00–07 (2000) and S. Vergis, V. Mehta, Technology Innovation and Policy: A Case Study of the California ZEV Mandate, chapter 8 in Paving the Road to Sustainable Transport: Governance and Innovation in Low-Carbon Vehicles, 2012. For the historical origins, see G. Collantes and D. Sperling, The Origin of California's Zero Emission Vehicle Mandate, Transportation Research A,42 (2008) 1302–1313.

[9] ZEV sales in the ten other states that have adopted California's ZEV program all count toward meeting California ZEV requirement. In recent years, nearly half the ZEV sales in the US were in California.

mandated quantity in the 2007 law [5]. One problem with the RFS is the wording of the law. It tells the Environmental Protection Agency (EPA) to revise advanced biofuel requirements downward if the projected production volume of biofuel is less than the minimum required volume for a given year [6]. Oil companies and others sued successfully to force EPA to adopt fuel requirements that match how much is likely to be introduced. As a result, even though oil companies have vastly more financial resources and technical expertise than any other biofuel stakeholders, have little incentive to invest in advanced biofuels. If it is not available, they are not obligated to buy and sell it. And thus, advanced biofuels commercialization is proceeding slowly with greater emphasis on incremental advances in biofuel production processes [7].

California has pioneered a more flexible performance-based policy instrument, one that should provide a more durable framework for the transition to low-carbon fuel alternatives. Its Low Carbon Fuel Standard (LCFS), adopted in 2009, applies to all current and potential transportation fuels, unlike the biofuels-focused RFS. It also allows oil companies to trade credits among themselves and with other suppliers of low-carbon fuel alternatives (such as electric utilities) and, unlike the federal Renewable Fuel Standard, it provides incentives to make each step in the energy pathway, from the growing of biomass to the processing of oil sands in Canada, more efficient and less carbon-intensive. The LCFS provides a framework for stimulating innovation, harnessing market forces, and providing a framework for all alternatives to compete.

Because the Low Carbon Fuel Standard is novel, casts a wide net, and requires major investments in low-carbon alternative fuels, it has been controversial. Economists argue that a carbon tax would be more economically efficient [8]. Energy security advocates and producers of high-carbon petroleum such as Canadian oil sands argue that the LCFS will discourage investments in unconventional energy sources and technologies that could extend the world's supply of oil. Many argue that the imposition of the LCFS in one state will encourage shuffling of high-carbon ethanol and petroleum to regions that don't discourage those fuels. Academics and many energy suppliers argue about the details of lifecycle emissions assumptions, especially related to indirect land use change for biofuels. Low-carbon biofuel suppliers (including biogas as a substitute for natural gas for vehicles) seek a price floor for credits to facilitate acquisition of bank loans. Others seek price caps to remove the possibility of higher fuel prices, market speculation, and political backlash. Fuel suppliers seek regulatory certainty, though some undermine that certainty by filing lawsuits. And program administrators outside California worry about the need for vast amounts of technical information and large numbers of staff to run the program.

Even with these teething challenges, the Low Carbon Fuel Standard is a powerful policy instrument. Some in the oil industry acknowledge that it has already motivated their companies to reduce the carbon footprint of their investments and to reassess their long-term commitment to high carbon fuels, such as oil sands. But to minimize fuel shuffling and reduce regulatory uncertainty and thereby realize the full benefits of an LCFS policy, more state and federal governments will need to adopt similar policies. To some degree this is happening. British Columbia, Canada and the European Union have adopted policies similar to California's LCFS, though in a more limited way. As of 2014, the states of Washington and Oregon were in the process of adopting their own version of an LCFS.

Greater benefits would also be realized, as with low-carbon vehicles, if additional complementary policies were adopted to target the many market failures and market conditions that inhibit the transition to low-carbon fuels. The case of hydrogen, a promising low-carbon transport fuel, illustrates the challenge. Fuel producers (including oil companies and other prospective fuel retailers) are generally unwilling to commit to building hydrogen stations until the demand is apparent in the form of vehicles sold, while car companies assert they can't take the multi-year risk of building hydrogen fuel cell cars unless they are confident the stations will be there. It is a classic chicken-and-egg dilemma. In fall 2013, California approved up to $20 million per year through 2023 to build a network of 100 hydrogen fuel stations across the state. As automakers roll out their new fuel cell cars, this level of infrastructure is expected to give initial customers enough confidence in the refueling network to purchase a vehicle. If the early market is strong and growing, station providers will in turn gain the confidence to invest in future stations.

5. The third leg: mobility

The third leg of the stool is vehicle users and their travel behavior, which is closely linked to transport infrastructure and land use. California pioneered car-dependent cities and living, creating an expensive and resource-intensive transportation system. Much of the world has pursued a similar car-dependent path, but later and slower and often superimposed on older and more established cities which still provide access to transit, biking and walking. The good news is that—perhaps because it has been so extreme—California is now showing policy leadership in reversing this pattern by pursuing programs to support "sustainable communities".

The goals of sustainable communities, defined here as more resource-efficient land use and transportation systems, are desirable, not only in terms of reduced GHG emissions but also because of reduced costs for road infrastructure and personal and business travel, as well as reduced local air and noise pollution and healthier lifestyles from walking and biking. The development patterns consistent with sustainable communities also result in less land consumption, which provides ecological benefits, preserves farmland, and reduces the need for a variety of public infrastructures.

The trend toward ever more driving had seemed inevitable until recently. However, starting around 2004, well before the recent economic recession, vehicle use per driver plateaued for the first time since the advent of mass produced cars (excluding World War II when gasoline was rationed), and then dropped. Vehicle use per capita dropped 7% in US from 2004 to 2013 before stabilizing [9], and similar reductions were observed in other OECD countries. While some of the later reduction was clearly due to the protracted economic recession of 2008–09, the fact that the reductions started before the recessions and continued for many years, suggests that the trend is strong.

There are a large set of policies and actions that could reduce vehicle use further. These include reducing sprawl, balancing the spatial match between jobs and housing, encouraging mixed use development, enhancing bike, walk, and public transportation infrastructure, and raising the price of travel (and parking) to incorporate externalities of carbon emissions, pollution, traffic congestion, and energy security. And then there are a large set of telecommunication and innovative mobility services that can be used to reduce the demand for vehicle travel. Other strategies to reduce GHG emissions associated with driving, without reducing vehicle use, include public education about eco-driving, whereby jack-rabbit stops and high-speed driving are discouraged and where tires are well inflated and roof racks that increase wind resistance are taken off vehicles when not in use. Still another strategy to reduce emissions is related to infrastructure management: reducing stop-and-go traffic through traffic management techniques, providing better information to drivers for instance by helping drivers find parking spots more quickly.

Until now, efforts to reduce vehicle use in California and the rest of the nation have had

limited success, and primarily only within cities that have aggressively pursued comprehensive policies.[10] Vehicle use increased steadily, despite a series of US government initiatives aimed at reducing vehicle use, dating back to the mid-1970s—including "Transportation System Management," "Transportation Control Measures," and "Transportation Demand Management," as well as constructing many hundreds of miles of carpool lanes and increasing subsidies for public transportation. Now, there are 1.1 vehicles per licensed driver, public transport accounts for less than 3% of passenger miles, and carpooling has shrunk [10]. Cars have become more central to daily life.

Reversing this trend on a large scale will require an unprecedented collaboration between federal, state and local governments that provide transportation funding and control land use. In many areas of the country it will require changes in land-use zoning policy, property tax policy, transportation funding formulas, parking policy, pricing of vehicle use, and much more. The private sector will also play a strong role, through developers who know how to provide cost-effective housing and services in walkable neighborhoods, and providers of innovative mobility services (such as demand-responsive transit and smart car sharing).

In 2008, California passed the Sustainable Communities law, known as SB375, to reduce land-use sprawl and vehicle use. It led to the creation of a new policy framework for cities to guide the transition to a less resource-intensive and car-intensive future. It provides a more robust and performance-based approach than previous efforts to reduce vehicle use.

In implementing the law, the California Air Resources Board established distinct targets for each metropolitan area in the state. Those targets range from 6 to 8% reduction in greenhouse gases per capita by 2020 for major metropolitan areas and 13–16% in 2035. The targets are applied to regional associations of governments (known as Metropolitan Planning Organizations), who develop Regional Transportation Plans (RTPs) consistent with the plan. Ultimately, the success of the policy relies on the individual cities and counties within their region. The local governments can utilize any tools at hand, including pricing of road use and parking, better land use management, building biking, walking and public transportation infrastructure, and managing traffic. The attraction of the Sustainable Communities targets is that they are performance-based and don't dictate to MPOs or local governments how they should comply. Cities can be innovative in ways that are locally most compelling.

The limitation of SB375 is that it imposes no real consequences for non-compliance and, so far, gives only weak incentives and rewards. Stronger carrots and sticks will likely be needed to achieve large reductions. The challenge is to provide incentives that are compelling enough to motivate new investment patterns and new behaviors by cities and project developers. Two options under consideration are diversion of cap and trade revenues to cities to pursue projects consistent with reduction targets, and restructuring of transport funding formulas to reward the cities that comply. In what now seems perverse, current transportation funding formulas are largely tied to population and vehicle use; more vehicle travel results in cities earning more money.

One lesson learned during early implementation of the SB375 program and development of greenhouse gas targets was that local politicians and transportation managers came to support the targets when they realized that strategies to achieve them are the same strategies they were already pursuing for other reasons, such as infrastructure cost reduction, livability, and public health. The cost reduction insight was particularly compelling. Regional economic and transportation modeling indicated embracing sustainable communities can have enormous financial benefits compared to business as usual. For example, the Southern California Association of Governments (SCAG) in their 2013 plan [11] claims the following benefits for the greater Los Angeles area: 1) Eight percent reduction in GHG and VMT per capita by 2020 and 16% by 2035; 2) Return on investment of $2.90 per $1 spent including the following savings – $6 billion in capital infrastructure and operating and maintenance costs, $4000 per acre in increased local revenues, $3000 per household in avoided costs for transport, energy, and water, $1.5 billion per year in avoided health costs; 3) Twice as many households living next to transit and 4) Reduced congestion, land-conversion, and air pollution, and increased safety.[11] While these are just modeled results and further research on this subject is needed, it is suggestive of what is possible. As evidence mounts that a focus on "sustainable" community development could be financially attractive, support for the policies and strategies that contribute to the goal will grow.

6. What about carbon cap and trade?

California adopted a carbon cap and trade rule as the capstone of its plan for meeting the goals of the overarching climate law (AB32). California is not the first to do so; the European Union preceded California by a few years, and northeast and Mid-Atlantic States began a carbon cap-and-trade program for their electric utilities in 2008. California benefited greatly by learning from these programs including their early successes and challenges. California pursued a program that is broader than the northeastern program because it includes large industrial emitters and broader than both the northeastern and European programs because it caps the carbon from transport fuels.

A cap-and-trade program—whereby carbon emissions from factories, oil refineries, cement producers, electricity generating facilities, and other large greenhouse gas sources are capped—is important in injecting a carbon price into the economy. If companies cannot shrink their emissions, or choose not to because it is more expensive than purchasing "allowances", they can purchase those allowances either from the State or from other companies that can reduce emissions at a lower cost. With carbon trading, a market is created to incent carbon reductions, thus providing a financial signal for efficiency and low-carbon energy. The price of carbon is determined by the cost or difficulty of achieving reductions. If everyone is successful in reducing their emissions at low cost, the carbon price will be low. If they are not successful or reductions prove to be expensive, prices will be high. When carbon has a market value, polluters know how much it costs them to pollute, and they can make economically rational decisions about how to reduce their greenhouse gas emissions.

The California cap-and-trade program is relevant to transportation in that it covers oil refineries and, in 2015, is extended to cover the carbon content of the fuels themselves. The program is designed with a floor price of $10 indexed to inflation and reserve prices of $50–70 per ton of carbon through 2020.[12] The price had not yet reached $13 by early 2014. Consider that $10 per ton equates to about $0.09–0.10 per gallon of gasoline, including both refinery and vehicle emissions. A price increase of $0.10 would likely have limited effect in the short-run, since people have limited ability to shift driving patterns or buy a new car, and companies have long lag times in building capacity for new lower-carbon fuels.

[10] For an overview of the challenges of reducing greenhouse gas emissions through land use changes, see National Research Council, Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions. Transportation Research Board of the National Academies, Special Report 298, Washington, DC, 2009.

[11] Benefit calculations are based on the time period of the 'project' (25 years) with a 3% discount rate using the Regional Economic Models, Inc. (REMI).

[12] Reserve prices indicate the price when, if achieved, the state will make additional allowances available to the market. This is generally expected to reduce volatility.

The focus on the short-term is misguided, however. The purpose of pricing carbon is to put in place a durable signal to guide investment by both producers and consumers. Long-run demand elasticities are difficult to calculate but a recent review of the literature suggests they could be in the range of −0.8 [12]. At carbon prices of $10 and today's price of fuel (~$3.50) this would result in a ~2% reduction in demand[13] and, all things equal, each additional $10 in carbon price would reduce fuel demand an additional 2%. While this is not sufficient on its own to meet the greenhouse gas goals, it can play an important complementary role in encouraging more efficient driving and altering vehicle purchase decisions. A price on carbon can also accelerate the time by which some low-carbon fuels become cost-competitive (e.g. advanced biofuels) and provide further benefit to use those that are near the cost or even cheaper than petroleum today (e.g. electricity).

7. Assessing California's policy model going forward

California has crafted a mix of regulations, incentives and market instruments that together comprise a sophisticated and largely coherent policy model to guide the transformation. California's program includes zero emissions vehicle requirements, mandatory vehicle greenhouse gas standards, a low carbon fuel standard, a price on carbon, and metropolitan-wide GHG targets for transportation. California drew many lessons from other jurisdictions in crafting these policies but few, if any, are as comprehensive and ambitious.

Economists would argue that California's approach is second best, since it does not rely principally on market instruments. But many market failures and market conditions limit the impact of pure market instruments, such as carbon and fuel taxes. Even Europe, with its large fuel taxes, feels the need to also enact very aggressive regulatory requirements. And thus, California is not relying solely or even principally on a simple carbon tax or cap-and-trade program. Instead, it uses targeted incentives and rules to address the myriad market failures and market barriers hindering the transformation of the transportation system—and to evade political reluctance to impose large fees and taxes.

This set of integrated policies and regulations is unique in the world. It includes an array of policy instruments that target specific vehicle, fuel, and mobility activities. They cannot be simply categorized. While most are regulatory, they are largely performance-based, and many have a market or pricing component to them, such as the credit trading provisions of the Low Carbon Fuel Standard and Zero Emission Vehicle program.

The California model to date imposes limited cost burdens to taxpayers, makes extensive use of performance-based standards, and partially harnesses market forces. It has survived numerous political and legal challenges, including a 2010 state-wide vote to suspend implementation of the AB32 climate policy law (by a vote of 61%–38%, the widest margin of any issue on the ballot); and numerous state and federal lawsuits.

The defects of the California model are both theoretical and practical. One concern is that the focus on regulations, with only modest reliance on market instruments, has the potential to create inefficiencies and increase the costs of compliance. For transportation, there is still a need to provide stronger market signals to vehicle consumers. One idea is to impose a system of revenue-neutral "feebates", whereby car buyers pay an additional fee for vehicles that consume more oil and produce more greenhouse gases, and receive a rebate for those that consume and emit less. A feebate can partially reconcile regulations with market signals and, designed appropriately, can do so without requiring government expenditures. Feebates have been adopted in France (known as "bonus-malus") and in more limited ways in other European countries.

Still another weakness of a California-only policy is emissions leakage and fuel shuffling—whereby fuel suppliers send their "good" fuel to California and their high-carbon fuel elsewhere. This shuffling is a particular challenge for California and other sub-national governments, whether the policies are based on market or regulatory instruments. The only way to fully address this issue is by expanding the coverage of climate policies to these other jurisdictions, thus reducing the incentives for this behavior.

Perhaps the biggest challenge to California is managing the complex interplay of many regulations and incentives, and the involvement by various governmental bodies. For example, the benefits of large-scale adoption of electric vehicles depends on the design of the cap-and-trade program and renewable energy requirements of the California Air Resources Board and Public Utilities Commission (PUC). It also depends on the PUC enacting rules regarding the role of investor-owned utilities in providing electricity to vehicles and who receives the LCFS benefits from electricity sales. Meanwhile, the federal government and CARB determine how much credit electric vehicles receive as part of vehicle performance standards, including emissions upstream of the vehicle (currently they are rated incorrectly as zero). It is important to make sure that the many rules are aligned and send consistent and durable signals. It's a challenging task, exacerbated by the involvement by numerous government agencies and legislative bodies. It requires wise and conscientious oversight and a willingness to adapt to changing conditions. This concern for wise oversight will grow when the next tier of more aggressive targets are put in place for 2030 and beyond.

Another limitation of the California model is the absence of policies addressing most air, maritime, and some freight activities, leaving significant chunks of the transport system untouched by carbon policy. The explanation is largely that California is legally limited from restraining interstate commerce. In these cases, the US government needs to play a lead role, and in some cases international agreements are needed (especially with aviation and ocean shipping).

8. Implications for others

In the end, the key question is whether California policy is having an impact. California policy has stimulated investments in and sales of plug-in electric vehicles (PEV) and low-carbon biofuels. To date, over a third of US PEV sales are in California even though California accounts for only 12% of the population. PEV GHG emissions in California are less than half those of conventional combustion engines on a lifecycle basis, in large part because of the state's success requiring more renewable energy in electricity generation. California's low carbon fuel standard has contributed to lowering the carbon intensity of biofuels by encouraging the use of waste materials and other low-carbon materials. The LCFS also encourages energy efficiency improvements along the entire biofuel and fossil energy chains. So far, in terms of actual GHG reductions, these GHG reductions through the California fuel system are small and, in a global context, likely always will be (if only because California contributes less than 2% of the world's total greenhouse gas emissions), but they serve as a starting point for demonstrating viable, market responsive climate policy approaches.

In this regard, California's policies have had two major influences in decarbonizing the transport sector that offer significant lessons for policy makers in Washington, D.C. and globally: 1) California's climate and energy policies are stimulating innovations and investments in low-carbon technologies and behaviors and 2) California's climate policies are serving as a beacon and model for others. It may be impossible to quantify these two effects for some time to come.

California policy played an important role in the success of companies like Tesla (which

[13] For example, at $3.50/gallon, a price of carbon that equates to $0.10 per gallon would represent about a 3% increase. At an elasticity of 0.8, consumers would reduce their consumption by 2.1% (=0.8 × 3%).

sells ZEV credits to other automakers) and the launch of many startup biofuel companies. California's LCFS has also surely motivated investments in a wider variety of biofuels, especially fuels originating from waste materials—across the country and even in other nations.

Some of the technologies and strategies developed to meet California's program are being shared and copied around the world, including China which has recently signed collaboration agreements with California institutions on climate and advanced vehicle policies. It is an iterative process. California continues to learn not only from its own experiences but also from the experiences of other states and countries that are finding their own way.

While top-down approaches via international treaties and even national rules will clearly be needed to achieve meaningful climate change mitigation in an efficient and large scale manner, there is still substantial room for a bottom-up approach that more directly engages individuals and businesses. California is providing a compelling model for encouraging businesses and individuals to act sustainably.[14] Other states and provinces, and the United States and other countries, would benefit from considering the California case study in developing a national climate and transportation strategy.

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