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Regional Planning and Climate Change Mitigation in California

BY

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ABOUT THE JCCTRP

The Joint Clean Climate Transport Research Partnership (JCCTRP) is a new research partnership that brings together leading universities, private research institutes, businesses and non-profit organizations from Quebec, California, Ontario and Vermont working on transport and climate policy. The JCCTRP Secretariat is based at the *École des sciences de la gestion* at the *Université du Québec à Montréal (ESG-UQÀM)*. The ultimate goal of the JCCTRP is to identify technical, economic and political factors shaping the potential for environmentally effective, economically efficient, and politically viable low-carbon transport and climate mitigation policy, and understand their implications for emissions trading.

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ABSTRACT

This working paper presents an overview of regional planning and climate change mitigation in California. This paper is motivated by the unique success of California in developing and implementing a comprehensive program of policies to address global climate change. It traces the history of environmental regulation in California and shows how climate change policy is the outgrowth of decades of increasingly stringent and broad environmental policy. This paper is also motivated by JCCTRP's interest in the role of models. It shows how regional transportation modeling plays a critical role in meeting air pollution reduction targets, and how models can be used to achieve plans that meet the targets. The paper first presents the history of air quality regulation with focus on mobile sources. This is followed by a description of how air quality regulations have transitioned into more comprehensive greenhouse gas regulations in the 2000s with the introduction of Global Warming Solutions Act of 2006, also known as "AB32". The final section describes how federal and state regulation have affected regional transportation planning and discusses the role of models in the planning process. The paper closes with conclusions and some observations on what can be learned from California.

Ce document de travail présente un aperçu de la planification régionale et de la politique d'atténuation des changements climatiques en Californie. Ce document est motivé par le succès unique de la Californie dans l'élaboration et la mise en œuvre d'un programme complet de politiques pour lutter contre le changement climatique mondial. Il retrace l'histoire de la réglementation environnementale en Californie et montre comment la politique sur le changement climatique est le résultat de décennies de politique environnementale de plus en plus strictes et de plus en plus inclusives. Ce document est également motivé par l'intérêt du JCCTRP pour le rôle des modèles. Il montre comment la modélisation du transport régional joue un rôle essentiel dans la réalisation des objectifs de réduction de la pollution atmosphérique et comment les modèles peuvent être utilisés pour réaliser des plans qui atteignent ces objectifs. Le document présente d'abord l'histoire de la réglementation de la qualité de l'air en mettant l'accent sur les sources mobiles. Ceci est suivi d'une description de la façon dont les réglementations sur la qualité de l'air sont passées à des réglementations plus complètes sur les gaz à effet de serre dans les années 2000 avec l'introduction de la Global Warming Solutions Act de 2006, également connue sous le nom de «AB32». La dernière section décrit comment la réglementation fédérale et californienne a affecté la planification des transports régionaux et examine le rôle des modèles dans le processus de planification. Le document se termine par des conclusions et quelques observations sur ce qui peut être appris de la Californie.

INTRODUCTION

California has long played a leadership role in environmental regulation in the United States. Ever since the state enacted the country's first automobile emissions standards in the early 1960s as a response to acute smog in Los Angeles, it has led both other states and the federal government in environmental regulation. Today California is the home of the only comprehensive cap and trade program, has the highest share of zero emission new car sales in the US, and has achieved significant reductions in greenhouse gas emissions.

This paper is motivated by the unique success of California in developing and implementing a comprehensive program of policies to address global climate change. What explains California's climate change policy, and what can we learn from the California example? We trace the history of environmental regulation in California and show how climate change policy is the outgrowth of decades of increasingly stringent and broad environmental policy. This paper is also motivated by JCCTRP's interest in the role of models. How does transportation modeling fit into the climate change mitigation process? We show how regional transportation modeling plays a critical role in meeting air pollution reduction targets, and how models can be used to achieve plans that meet the targets.

The paper includes the following sections. Section 2 presents the history of air quality regulation with focus on mobile sources. Section 3 describes how air quality regulations have transitioned into more comprehensive greenhouse gas regulations in the 2000s with the introduction of AB32. Section 4 describes how federal and state regulation have affected regional transportation planning and discusses the role of models in the planning process. The paper closes with conclusions and some observations on what can be learned from California.

CALIFORNIA'S TRADITION OF STATE LEVEL ENVIRONMENTAL REGULATION

In order to understand how California became a national trendsetter, one needs to explore the past. As early as 1940, smog in Los Angeles was bad enough to reduce visibility to just a few blocks. While the exact scientific causality was unknown at the time, residents reported conditions of smarting eyes, burning lungs and nausea on some of the worst smog-days (CARB, 2019a) (Figure 1). In 1947, the Los Angeles County Air Pollution Control District - the first such body in the nation - was formed to tackle the issue.

The district regulated obvious culprits, like smoke-belching power plants and oil refineries, but still the smog persisted. When a scientific breakthrough in 1952 established that smog was caused by photochemical reactions involving motor vehicle exhaust, California began to take firmer and more far reaching regulatory actions targeting mobile sources (CARB, 2017b). This included the public health mandate to set controls on motor vehicle emissions (1961) and the nation's first tailpipe emissions standards (1966). In 1967, then governor Ronald Reagan signed legislation to establish the California Air Resources Board (CARB) as the state's main air quality regulatory institution (CARB, 2019a).

FIGURE 1. SMOG COVERING L.A. CIVIC CENTER ON JANUARY 6, 1948. (L.A. TIMES PHOTOGRAPHIC ARCHIVE 2019)



Early steps

The status of California as the national leader of air quality regulation was then cemented through Section 177 under the Federal Air Quality Act of 1967. Initially, automobile lobby groups and Democrats opposed giving any state an exemption and pushed for a uniform federal standard (Fern, 1997, Vogel, 2018). However, with help from Senator Robert Kennedy and reframing the act as a states' rights issue, the amendment to recognize California's earlier efforts and authorize the state to set its own separate regulations was approved (Vogel, 2018). Since then, CARB has received more than 100 waivers to adopt, implement and enforce a wide array of stricter-than-federal air pollution controls (Fern, 1997).

During the decades of the 1970s and especially towards the end of 1980s, there was a strong surge in the public interest on air quality issues, thanks to increased concerns related to acid rain, the ozone layer and air pollution. Correspondingly, regulatory agencies in California introduced various programs to address those public concerns. CARB issued a number of pollutant-specific vehicle emission regulations in accordance with the California Ambient Air Quality Standard (CAAQS) - California's own health-based air pollutant measurement covering ten pollutants, four more than the U.S. EPA's. The regulations introduced in this period include the nation's first tailpipe standard for carbon monoxide (1966), regulation for nitrogen oxide (NOX) (1971) and regulation for particulates (1982) (CARB, 2019a).

In 1989 the South Coast Air Quality Management District (SCAQMD) announced its three tier Air Quality Management Plan which applied through 2007. Tier 1 sought to promote a less auto-dependent lifestyle while encouraging the use of public transit. In Tier 2 and Tier 3, SCAQMD called for a progressive transition from gasoline to cleaner fuels such as methanol and electricity, with the ultimate goal of eliminating gasoline fuel vehicles by 2007. This was the first regulatory plan that explicitly identified electricity vehicle as an alternative to conventional gasoline vehicles (Collantes and Sperling 2008).

At the same time, the state legislature passed a number of acts aimed at reducing vehicle emissions. Two deserve particular mention for their roles in the inception of the ZEV mandate established in 1998. The first is the California Clean Air Act (CCAA), also known as Sher Act, introduced in 1988. The act mandated

CARB to take actions that are necessary, cost-effective and technologically feasible to “achieve the maximum degree of emission reduction possible from vehicular and other mobile sources” (Hanemann, 2007). Collantes and Sperling (2008) argue that this act provided CARB with a sense of urgency to take more drastic actions.

The second is AB234 introduced by Assembly Member Bill Leonard in 1987. This was the first bill that explicitly spelled out the need to promote ‘alternative fuels’ to achieve large reductions in emissions. The bill was also the first to suggest replacing the conventional uniform emission standards by the notion averaging, which provided the regulatory context for establishing separate technological standards for vehicle types, which became the hallmark of LEV and ZEV policy design (Collantes and Sperling 2008).

It can therefore be argued that two defining themes of vehicle emission regulation emerged in this early period. The first was an increased focus on technology-forcing mechanisms in program design. By enforcing standards that are not technically feasible at the time of adoption, the state sought to spur technological innovation by private actors, mainly automobile producers (ICCT, 2018, Next10, 2018). Reduction of smog forming vehicle emissions is one of the great success stories of such technology forcing (Table1). Automobile manufacturers developed a series of technologies to meet federal fuel efficiency and emissions standards for key criteria pollutants including but not limited to NOx, Sulphur Dioxide (SO2) and particulate matters (PM10 and PM2.5).

TABLE 1: CHANGES IN MEAN ANNUAL ATMOSPHERIC CONCENTRATION OF KEY POLLUTANTS IN CA

	1980	1984	1988	1992	1996	2000	2004	2008	2012	2016
NO_x¹	28.63	24.94	25.15	21.09	19.25	18.20	14.88	12.70	11.56	11.04
SO₂¹	5.56	3.71	3.38	1.92	2.75	2.50	2.00	1.36	0.73	0.83
PM10²	N/A	N/A	49.40	38.65	31.07	36.63	32.86	32.67	27.74	27.07
PM2.5²	N/A	N/A	N/A	N/A	N/A	14.74	12.03	12.13	10.26	9.55

Source: U.S. EPA (2019A)

Note 1 : NOX and SO2 are measured for 1 hour mean and expressed in Parts Per Billion (ppb)

Note 2: PM10 and PM2.5 are measured for 24 hours mean and expressed in Micrograms per Cubic Meter (ug/m3)

The second theme was a greater recognition of the need for alternative fuel vehicles. This was a result of a belief that further innovations in mainstream gasoline and diesel-based technologies would not be enough achieve such drastic level of emissions reduction as seemed necessary (Collantes and Sperling 2008). In other words, a consensus began to emerge that instead of pursuing just a lower emission in conventional vehicles, the state needs to pursue zero-emission vehicles (ZEV).

In summary, there was a gradual build-up of regulatory foundation towards the end of the 1980s which set the tone for more stringent and ambitious policy packages in the next decade. CARB clearly recognized that, at least internally, the only way to achieve clean-air goals was to have widespread adoption of vehicles running on alternative fuels with much less emissions. However, uncertainty and elusiveness surrounding availability of such technology prevented CARB and other state agencies from pushing ahead with such policy packages (Collantes and Sperling 2008). Eventually, the window of opportunity emerged in the early 1990s.

General Motors and the Zero-Emission Vehicle (ZEV) mandate

The impetus for new alternative fuel vehicles program came from an unlikely source. On January 3, 1990, at the Los Angeles Auto Show, General Motors (GM) unveiled the Impact, a prototype electric vehicle with a full-charge range of 128 miles. At the event, Roger Smith, then CEO of the GM, touted that, with expected innovations in battery technology and manufacturing technology, the company would be able to offer a marketable electric vehicle by 1996 (Bedsworth and Taylor, 2007). Clearly, there was an element of exaggeration and showmanship in Smith's presentation, and most of the experts treated it as wild optimism. In fact, the company later admitted that the event was more aimed at helping GM rebrand itself as a technological leader in the automobile industry in general (Collantes and Sperling 2008). Nonetheless, according to Collantes and Sperling (2008, p1306), this event was enough to give CARB "courage to push the ZEV requirements... if sufficient lead time was allowed and requirements were gradually phased in". Over the next few months, CARB held a series of seminars, workshops and meetings with industry stakeholders. Eventually, the Zero Emission Vehicle mandate was introduced as part of a bigger package of the Low Emissions Vehicle regulation in 1990.

Overall, the LEV regulation called for phased emission standards to achieve a 50% reduction in organic gas compounds (VOCs) and a 15% reduction in oxides of nitrogen (NOX) by 2000 (CARB, 2017b). The ZEV mandate required a minimum share of new car sales to be ZEV: 2% in 1998, 5% in 2001, and 10% in 2003 (CARB, 1998). The mandate had a number of features to provide flexibility to automobile makers. For instance, the mandate was enforced through a credit system with provisions of banking and pooling to allow manufacturers to more flexibly manage their production schedule (CARB, 2018a). CARB also set up the Battery Technology Advisory Panel (BTAP) in 1995 (CARB, 1998). This panel was tasked with engaging in regular talks with the automobile makers and producing a biennial review of the readiness of battery technologies to determine feasibility of achieving the short-term ZEV goals. In fact, observing the sluggish progress in battery innovation, the panel recommended replacing the percentage quota ZEV requirement with fixed quantity quota (3750 vehicles for all manufacturers) for the intervening period of 1998~2001, which was subsequently adopted by CARB (CARB, 2000).

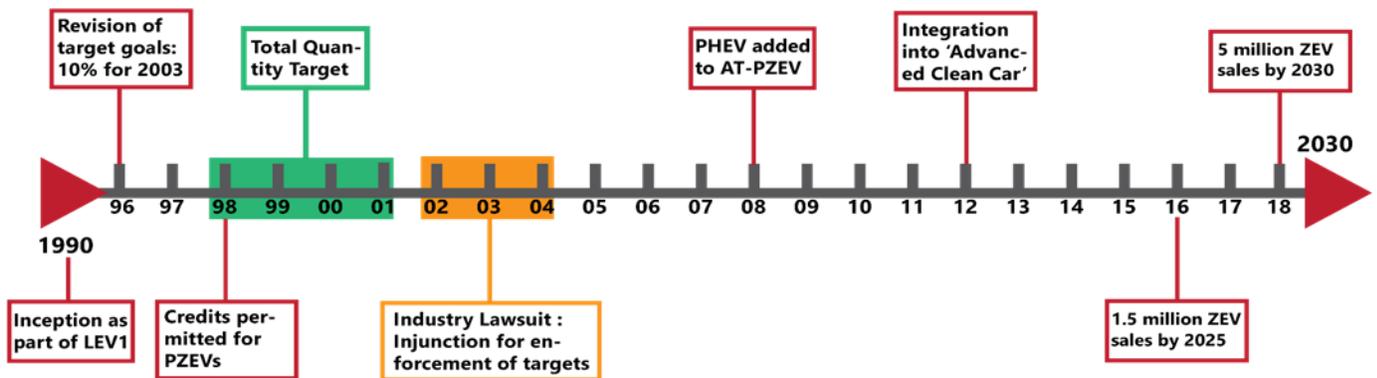
Overall, the initial phase of the ZEV mandate (1998~2003) proved its potency as a technology forcing mechanism. At the beginning of the mandate, there were only 2,300 ZEV credit applicable vehicles on road in California with just six automakers offering seven models (General Motors EV1 & S10 / Honda EV Plus / Toyota RAV 4 / Daimler-Chrysler EPIC / Ford Ranger EV / Nissan Altra) (CARB, 2000). Furthermore, the majority of these vehicles utilized lead-acid batteries which was considered to be far inferior in cost and efficiency compared to lithium-ion and nickel metal hydride batteries which were only proven under laboratory condition at the time (CARB, 2000). However, by 2003, breakthroughs were made on both battery technology and the development of hybrid vehicles. Eleven different automakers offered over 25 different ZEV and partial zero emission vehicle (PZEV) models (CARB, 2003). Introduced through 1998 amendment to give more flexibility to industries, PZEVs are those vehicles that meet the most stringent non-ZEV emission standard category of Super-Ultra LEV (SULEV) which means they are 90% cleaner than conventional vehicles. It was the PZEV sales that recorded particular success in the early 2000s with sales reaching 140,000 for the 2003 model year (CARB, 2003). Indeed, some observers argue that one of the most significant impact of the ZEV mandate was the emergence of diverse range of technologies with comparable benefits to ZEVs such as PZEV, AT-PZEV and plug-in hybrid electric vehicles. (Bedsworth and Taylor, 2007)

However, LEV regulation was not without controversies. Many changes were made to either eliminate provisions or lengthen the timeline for compliance. In 1996, the phase in targets were eliminated, and in 1998 the ZEV mandate was expanded to include PZEVs. Nonetheless, these changes were not enough to alleviate concerns and oppositions among automobile producers. In 2002, the US auto manufacturers filed a lawsuit, arguing that the mandate was both too costly and infeasible (Sperling and Eggert 2014). There are provisions in the law that regulations must be feasible and reasonably cost-effective. Consequently, a temporary injunction halted the mandate through 2004. The mandate was restructured and re-introduced for the 2005 model year. Over time, hostility among auto producers waned as fruits of R&D investments were realized. Each company began to pursue their own compliance strategy to mold ZEV more favorably towards its own competitive advantage. This made it easier for CARB to introduce and implement further amendments (Wesseling et al 2014).

Figure 2 presents a timeline of the major changes in the ZEV mandate. The program has become more sophisticated to reflect diversified types of ZEVs and PZEVs: Advanced Technology PZEV (AT-PZEV), Battery Electric Vehicles (BEV), Hydrogen Fuel Cell Vehicles (HFCV) and Plug-In Hybrids (PHEV). To allow automakers more flexibility in production and sales, the yearly target was replaced by a three-year phase system. In 2012 it was folded into the Advanced Clean Cars program which also includes LEV standards and GHG reduction rules (CARB, 2018b). The ZEV mandate has had a visible national impact: nine states have now evoked Section 177 and established ZEV targets of their own (CARB, 2017a).

CARB regulations have had an impact on car sales. As of 2017, the ZEV/PZEV share of new car sales was 4.5%, more than triple that of the national average of 1.1% (Next10, 2018). Targets have been increased twice: in 2016 to a ZEV fleet of 1.5 million by 2025 (CARB, 2016), and in 2018 to a ZEV fleet of 5 million by 2030 (Next10, 2018). CARB anticipates that battery improvements, falling prices, and increased infrastructure supply will make the current target attainable.

FIGURE 2: TIMELINE OF ZEV MANDATE AMENDMENTS AND KEY EVENTS SINCE 1990



FROM AIR QUALITY TO GREENHOUSE GAS (GHG) EMISSIONS REGULATION

If the focus of the 90s was the full establishment of mobile source regulation, the 2000s was a period marked by the expansion of scope and authority of CARB. In particular, there was a flurry of bills and regulations introduced to reduce greenhouse gas emissions, beginning in 2002 with AB 1493, the Pavley Bill. It was the first to designate CO₂ as a pollutant (CARB, 2017c). The bill applied to all vehicles beginning with the

2009 model year and directed CARB to adopt the maximum feasible and cost-effective reduction in four major GHGs - carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and hydrofluorocarbons (HFCs), which are collectively expressed in CO₂-equivalent tons (CARB, 2004). It was estimated that by 2020 the regulation would reduce GHG emission from the light duty passenger vehicle fleet by an estimated 87,700 CO₂-equivalent tons per day statewide and by 155,200 CO₂-equivalent tons per day in 2030 (CARB, 2004). The regulation was also expected to reduce “upstream” emissions coming from the production of vehicles approximately 6 tons per day in 2020 and 10 tons per day in 2030. As in the case of the ZEV mandate, other states have followed suit, evoking Section 177 and establishing GHG reduction targets (CARB, 2017c). Today 23 states have some form of GHG emission reduction target.

AB 32

The Pavley Bill was further reinforced by the landmark bill AB32 passed in 2006 (CARB, 2014a). The California Global Warming Solutions Act required the state’s GHGs to be reduced to 1990 levels by 2020 - a reduction of approximately 15% below emissions expected under a “business as usual” scenario (CARB 2014a). Implementation progress and goals of AB32 are updated every five years through action plans called Scoping Plans. The first scoping plan, published in December 2008, outlined a broad set of clean energy, clean transportation, efficiency, and other standards calculated to meet the 2020 emission goal (CARB, 2014b). Furthermore, the scoping plan clearly spelled out the two components of AB32 enforcement. Roughly 80% of reductions would be achieved through direct regulations such as mobile source emission regulations and fuel standards. The remaining 20% would be achieved through introduction of a cap and trade program (Hitzik, 2018).

The cap-and-trade program stands out as the only fully market-based policy within the family of AB32 compliance programs. The cap, which was initially set about 2% below the 2012 GHG emission level, is designed to gradually decline by 3% a year until 2020 (CARB, 2015). The combination of an increasingly more stringent cap and a trading mechanism incentivizes firms to reduce GHGs below allowable levels through increased efficiency, investments in clean technologies and other strategies. The first auction of allowances took place in 2012. Coverage of industry sectors has gradually increased and now includes about 450 entities in California (CARB, 2015).

The program has enjoyed notable success in building regional partnerships and expanding its scope. In 2014 California joined with Quebec, and in 2018 with the entire Ontario Region to form shared allowance trading and monitoring platform (CARB, 2019b). Under the agreement, all allowances can be used interchangeably (CARB, 2019b). It was argued that creating a larger market would allow more trading partners to join the auction, help keep compliance costs low and increase ambition to reduce emissions. A strong auction performance observed throughout 2018 after the joining of Ontario seems to attest such benefits are indeed coming from having a large connected market (EDF, 2018, Hitzik, 2018).

The program also plays an important role as a significant source of funding for innovation. As per implementing legislation, including AB1532, SB535, and SB1018, a portion of auction proceedings is allocated to the Greenhouse Gas Reduction Fund (GGGF). The GGGF is used to fund a variety of infrastructural and technology projects aimed at long-term reductions in GHG emissions (CARB, 2019c). The fund has received about \$8.5 billion dollars to date. The top three recipient programs by funding size are: Low Carbon Transportation (\$1.7 billion), High Speed Rail (\$1.6 billion) and Affordable Housing and Sustainable Communities program (\$1.2 billion) (CARB, 2019c).

SB 32

California was on track to reach the 2020 targets by 2017. This led to more ambitious targets being established with SB32 in 2016. The new targets were to reduce GHGs to 40% below the 1990 levels by 2030 and 80% by 2050 (CARB, 2017d). Accordingly, then Governor Brown ordered all state agencies with jurisdiction over GHG emissions to implement measures to achieve the targets. CARB was directed to update the AB 32 Scoping Plan to reflect the new targets set for 2030 (CARB, 2017e). The new plan included incentives for purchase of millions of zero-emission vehicles; 50% of electricity coming from renewables; and significant cuts in super-pollutants such as methane and HFC refrigerants. The bill also reaffirmed its support for the cap-and-trade program (CARB, 2017e).

The regulatory landscape today

In addition to cap and trade, the main programs related to transportation are Advanced Clean Cars and the Low Carbon Fuel Standard. As noted above, Advanced Clean Cars includes revised targets for the existing regulatory standards aimed at reducing long-term GHG emissions by 2025. These include reducing criteria pollutant emissions from mobile sources by 75%, a total 34% GHG reduction (or 4.6% reduction per year) and a target that 1 out of 7 new vehicles sold in the state is a ZEV (CARB, 2017a).

First adopted in 2009, the Low Carbon Fuel Standard (LCFS) seeks to reduce the carbon intensity of transport fuels 20% by 2030 (CARB, 2019e). The standard operates by setting an annual benchmark for petroleum fuels that suppliers must comply with, as expressed in carbon intensity (CI) which is a measure of carbon dioxide (in grams) produced per megajoule of energy (gCO₂/MJ). Suppliers unable to meet the target can make up the deficit by buying LCFS credits from other suppliers. Thus, the standard is essentially a fuel mandate that implicitly taxes gasoline and diesel while subsidizing qualifying renewable fuels (Yeh et al 2016). Overall, LCFS is widely considered a success. Between 2011 to 2015, reported total emission reductions from fuel suppliers was 16.8 million metric tons (MMT) CO₂, which was 81% higher than the required reduction of 9.2 MMT CO₂. For the same period, the average CI of all alternative fuels reported to the program declined 21%, from near 86 gCO₂/MJ to just over 68 gCO₂/MJ (Yeh et al 2016) To support the statewide goal of 40% reduction in GHG from 1990 levels by 2030, studies have shown that the average CI of transportation must be 12~20% lower than 2010 levels by 2030, and alternative fuels constitute at least 32% of the mix (CARB, 2019e). Overall, CARB's greenhouse gas inventory data, which shows a long-term decrease in transportation sector emission (Table 2), seem to support the successful operation of statewide vehicle emission regulations introduced thus far.

TABLE 2: TRANSPORTATION SECTOR GREENHOUSE GAS INVENTORY IN CA FOR 2000-2016, IN MTCO₂E

Year	2000	2002	2004	2006	2008	2010	2012	2014	2016
Total GHG Emission	183.86	191.59	191.21	193.31	182.64	170.16	166.16	167.14	174.01
CO ₂	173.39	181.08	180.65	182.87	172.74	160.75	157.33	158.64	165.87
N ₂ O	6.91	6.54	5.97	5.24	4.43	3.95	3.58	3.37	3.27
Methane	0.68	0.62	0.56	0.49	0.41	0.36	0.31	0.27	0.24

Source: CARB (2018D)

STATE REGULATION AND REGIONAL PLANNING

The expansion of state environmental legislation has had significant impacts on regional transportation planning. Regional transportation planning began in 1962 with the passage of the Federal-Aid Highway Act. Recognizing that travel demand is regional in nature, the act mandated that any metropolitan area with a population of greater than 50,000 inhabitants that seeks federal transportation dollars create a metropolitan planning organization (MPO) that would facilitate a “continuing, comprehensive, and cooperative” transportation planning process (Sciara, 2017). MPOs fulfill this mandate by creating regional transportation plans (RTP). RTPs are produced every five years and define the metropolitan area’s vision for transportation investments over the next twenty years (Sciara and Handy, 2017). Although the MPO process is a requirement for receipt of federal transportation funds, MPOs were given limited authority: they have no legislative or budget authority. As a result, transportation projects are incorporated into the planning process if a lead public agency (e.g., transit operators, cities, counties, etc.) submits a project for consideration. Thus, the bulk of day-to-day operation of MPOs involves assessing the impact of planned investments using mathematical transportation forecasting models and generating the RTP (Bollens, 1997, Sciara and Handy, 2017).

The passage of the Intermodal Surface Transportation Efficiency Act in 1991 greatly changed the role of MPOs. For the first time, transportation planning was linked with air quality planning. Metropolitan areas were categorized into attainment areas defined by the severity of air pollution (Sciara, 2017). Any metro area that was out of attainment (e.g. at least one criteria pollutant above the federal standard) had to develop a transportation plan that would support attainment (CARB, 2017f). That is, ISTEA demanded that the regional transportation plan must be consistent with the air quality plan. MPOs must show that expected level of emission from RTP implementation would not exceed the maximum level of emissions required for the attainment of air quality targets (CARB, 2017f). Another important addition introduced by ISTEA was a budget constraint: all investments must have an identified revenue source. The MPO was now responsible for certifying conformity and the budget constraint (CARB, 2017f). These changes under ISTEA meant that, even without legislative or budget authority, MPOs now had substantive influence on the content of the RTP (Sciara 2017). For metro areas not in attainment, the ISTEA legislation also made the RTP process more difficult, as a plan had to be developed that would reduce pollution while accommodating expected regional growth. In practice conformity required more emphasis on transit and non-motorized modes (Nelson et al., 2004).

State regulation extends to the RTP

As part of the efforts to reach the AB32 targets, SB 375 The Sustainable Communities and Climate Protection Act was passed in 2008. SB 375 establishes regional GHG emissions targets. The targets are aimed at reducing passenger travel and increasing the fleet of ZEVs; they are expressed as a percent change in per capita passenger vehicle greenhouse gas emissions relative to 2005 (CARB, 2018c). That is, each of California’s 18 MPOs has a specific GHG reduction target determined by CARB. SB 375 also requires that a Sustainable Communities Strategy (SCS) be incorporated as an element in the RTP. The SCS requires: 1) a land use element that accommodates all forecast population growth, and 2) a transportation network to meet all regional needs (ILG, 2015). Some flexibility is offered in that, if the region is unable to meet its original SCS reduction targets, it has option to prepare an Alternative Planning Strategy (APS) which is free from some of the budgetary and political constraints applicable to the SCS (CARB, 2019d).

Table 3 provides summary information on California's four largest MPOs. The Los Angeles region is by far the largest in both population and geographic size. The GHG reduction targets for 2035 are the same for all four, but the 2020 targets differ, presumably due to different levels of difficulty in achieving near term reductions. As of 2018 the statewide 2020 targets were not expected to be met. VMT and associated GHGs declined from the 2008 baseline until 2012, and since then have increased (CARB, 2018e).

SB 375 has resulted in significant changes in the RTP process. It requires that the RTP must be consistent with the SCS, and both must be consistent with the regional housing plan. For the first time, land use and transportation planning are directly linked. Also, CARB determines SCS compliance, and hence for the first time has a direct role in the RTP process. All of California MPO's areas are under nonattainment for at least one criteria pollutant, and hence are subject to the federal conformity requirements as well as the GHG reduction targets (CARB, 2017f). We note that not meeting these requirements has high costs, as federal transportation funding is contingent upon an approved RTP. Although CARB has not yet imposed penalties for non-compliance, the lack of progress in VMT reduction may generate additional regulatory efforts such as, but not limited to, low-VMT housing rebate and new pricing policies (CARB, 2019d).

The challenge is how to meet these requirements. The California population is expected to continue to grow, which implies more travel demand, more pollution, and more GHG emissions. There are no easy technology strategies available. Criteria pollutants from tailpipe emissions have been reduced by 98-99% since 1970 which suggest that the marginal benefit of additional reduction would be small compared to cost required (U.S. EPA, 2019b). GHG emissions are tied closely to fossil fuels. Fuel efficiency improvements will continue, but the impact on the vehicle fleet will take many years. Similarly, shifting the vehicle fleet to ZEVs or near-ZEVs is a slow process (ICCT, 2018). Nor are there easy demand side strategies. Pricing strategies are gaining traction in California, yet broad schemes that could significantly affect demand (e.g. region-wide congestion pricing, VMT tax) continue to be politically difficult. Efforts to use transit investment to reduce vehicle travel has so far not been successful (SCAG, 2019). Policies to increase population density and redistribute growth to transit accessible areas will take decades to have an effect, and research shows that these shifts result in relatively small changes in travel behavior (Chapple et al, 2017, Stevens, 2017). Finally, transportation is experiencing massive disruption (e.g. ride hailing, P2P car sharing, AVs and CAVs), making any future forecasts highly uncertain.

TABLE 3: FOUR LARGEST MPOs IN CALIFORNIA

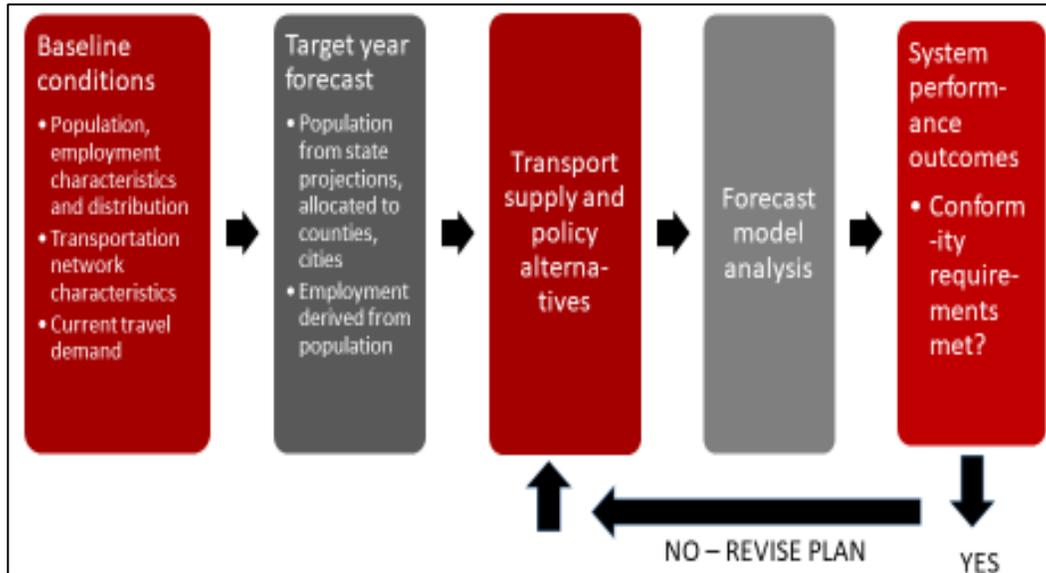
Metropolitan Region	Sacramento	San Diego	San Francisco	Los Angeles
MPO	Sacramento Area Council of Governments (SACOG)	San Diego Association of Governments (SANDAG)	San Francisco Bay Area Metropolitan Transportation Commission (MTC)	Southern California Association of Governments (SCAG)
Regional Population (Approx, 2010)	2,323,000	3,095,000	7,375,000	18,075,000
Regional Land Area	6,193 sq. mi.	4,230 sq. mi.	7,000 sq. mi.	38,000 sq. mi.
No of Counties in Region	6	1	9	6
No. of Cities in Region	22	7	101	191
Size of RTP-SCS (latest)	2016 MTP-SCS (\$35 billion)	San Diego Forward 2050 (\$204 billion)	Plan Bay Area 2040 (\$303 billion)	2016 RTP-SCS (\$556.5 billion)
CARB Approved GHG Emission Reduction Target	2020 : 7% 2035 : 19%	2020 : 15% 2035 : 19%	2020 : 10% 2035 : 19%	2020 : 8% 2035 : 19%

The role of models

How then do MPOs manage to submit RTPs that meet the federal conformity and state GHG reduction requirements? The transportation forecasting model has become critical in the compliance process. Figure 3 shows a simplified flowchart of the long-range planning process. It begins with calibrating the model parameters with current data on population, employment, network characteristics, and travel demand. The target year forecast starts from a population projection generated at the state level. Employment is typically derived from the population forecast and anticipated sector growth rates. Population and employment characteristics are then allocated throughout a region, giving estimated patterns of land use and, in turn, necessary inputs to generate future travel demand. Transportation supply and policy alternatives are then generated to accommodate or manage travel demand. The alternatives are fed into the transportation model to evaluate their performance with respect to traffic conditions, modal shares, etc. After the process of

validation, the output of the transportation model is then fed into an emissions model to generate emissions estimates. If the alternative meets conformity and SCS requirements, it can be considered for approval. If not, revised alternatives must be tested until an acceptable plan is achieved. It can be seen that the transportation forecast model is at the core of the RTP process, as it determines what alternatives may go forward for further consideration.

FIGURE 3. THE LONG-RANGE PROCESS



Regional transportation forecasting is as much art as science. Forecasting travel demand decades into the future has many uncertainties. Population growth has the least uncertainty, because birth, death and migration rates are relatively well known. However, the distribution of population at the level of small geographic units called Transportation Analysis Zones (TAZs) – required for demand forecasting – is notably more uncertain. Employment forecasts require assumptions about the future industry mix, labor productivity changes, labor force participation, etc. The population and employment distributions depend on land prices, transport prices, agglomeration economies, and the built environment.

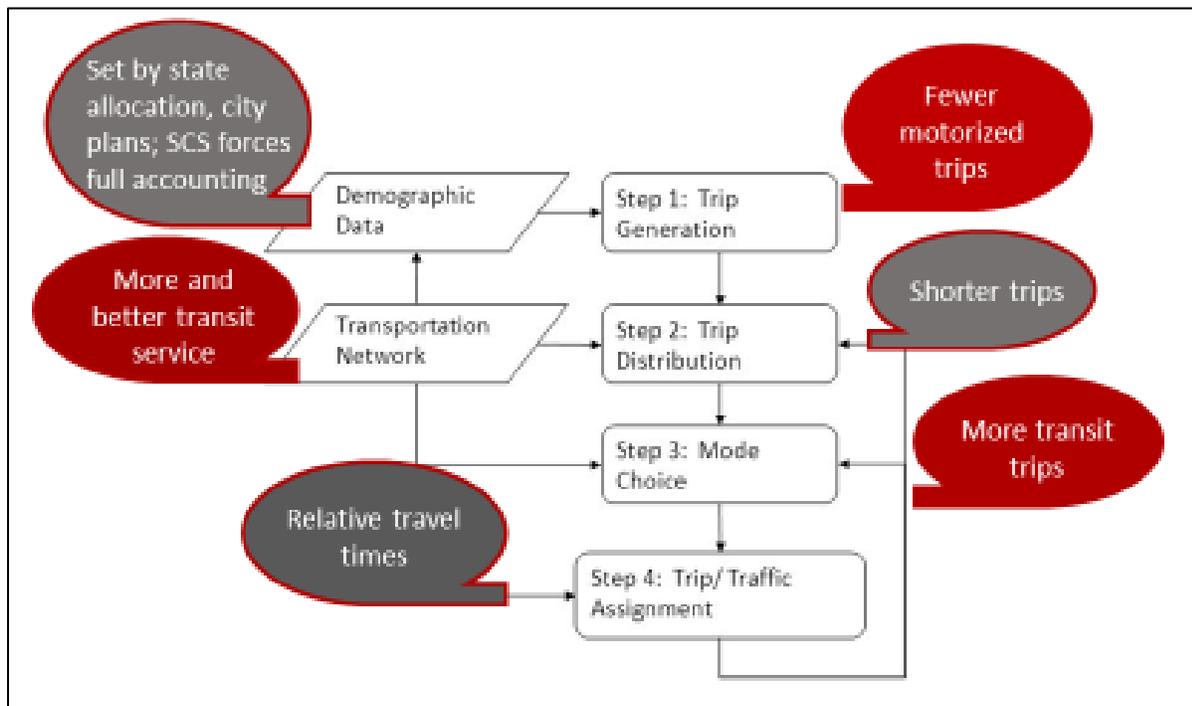
A second dimension of uncertainty is that we use current behavior as the basis of our models. Models are typically calibrated using baseline (current) data and then used for forecasting. Implicit in this approach is the assumption that the drivers of travel behavior do not change. For example, the price elasticity of demand for fuel will be the same in 2040 as it is in 2020. The same is true for residential or firm location choice. It seems reasonable to assume that the choice process is likely to change in the future. Automated vehicles may change preferences regarding vehicle ownership. The resulting reduction in parking demand may attract more firms to central core locations. None of these potentially significant changes are captured in the forecasting model.

Increased computing speed and capacity, together with the availability of new data sources, have enabled the development of more complex forecasting models. The traditional “trip-based” model is being replaced with “activity based” models. The trip-based model predicts trips as the unit of demand and express travel behavior as a function of population groups (e.g. single or multi-person households, income level, car

ownership). On the other hand, activity-based models generate patterns of individual daily activities based on their socio-demographic and economic traits, with travel demand derived from activity patterns. Individual level results are then aggregated to predict trip demands per given geographic unit. Activity models, therefore, recognize that an individual's trips are interdependent and a function of a daily sequence of activities taking place in different locations. However, the fundamental problems of initial assumptions, uncertainty, and constant behavioral preferences over time are not solved.

The combination of complexity and uncertainty means that the specific value of any model parameter is also uncertain, and choices may depend on judgement. Model assumptions and parameters determine forecast results, and hence changes in these factors will lead to different results. The potential for model adjustments is illustrated in Figure 4. We use a trip-based model to illustrate, but the principle, if not the process, is the same for activity-based models. For the purpose of modeling, the region is divided into small geographic zones (TAZs). The primary inputs to the model are the population and employment forecasts and the future transportation system, including anticipated transit networks and demand management policies, as well as the road network system. Regional population forecasts are exogenous to the region, as noted above. Population and employment at the sub-regional level may be forecast in a number of ways but must be consistent with local long-range plans (Sciara, 2017).

FIGURE 4: THE TRANSPORTATION FORECASTING PROCESS



Once the distribution of population and employment is established, attributes of both are used for trip generation. Because most non-motorized trips are short and hence do not cross zone boundaries, the focus of trip generation is motorized trips. If the transportation plan includes extensive pedestrian improvements, or if one of the plan goals is to greatly increase bicycle use, modelers may assume or estimate a larger proportion of non-motorized trips, reducing the motorized trip generation rate. Many plans have targets

that go far beyond observed rates of non-motorized travel, and hence there is no source of data to determine whether these rates are reasonable. It must also be noted that most models only predict motorized trips by passenger vehicles and do not include freight trips. As a result, demand for freight trips is usually predicted separately and added on to the main model at a later stage.

The next step is to link trip origins and destinations to produce an origin-destination matrix. The typical method is to use some type of gravity model formulation between TAZs. The higher the cost of travel, the shorter trips will be, all else equal. Thus, if extensive congestion or high fuel costs are assumed, the gravity model will generate shorter trips.

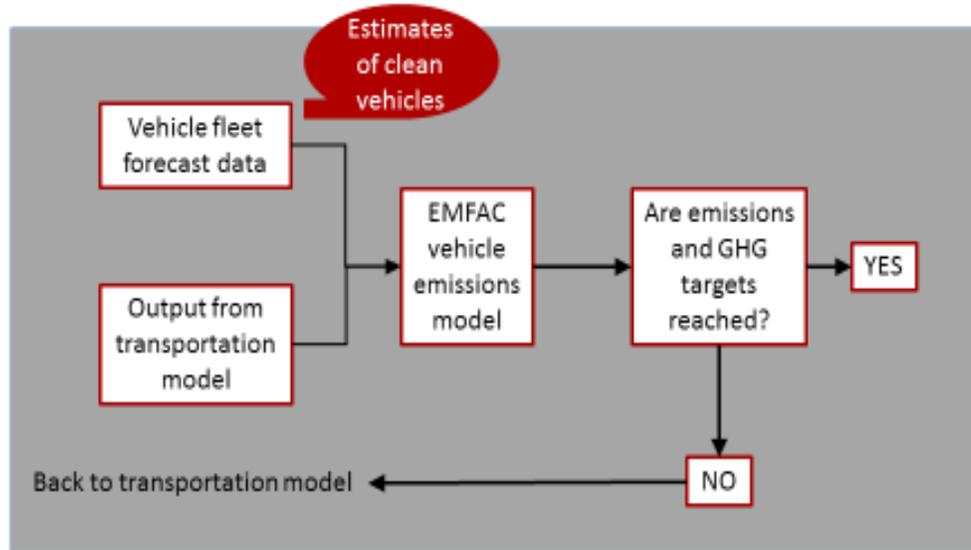
In the next step trips are allocated to modes. Mode choice is a function of relative travel time and cost, car access, comfort, safety, and attributes of the individual (income, employment status, etc.). Differences in travel time and cost affect choices between driving alone, carpooling, or using public transit. There are many parameters to be generated, e.g. average speed of car travel, average wait time for transit, average transit travel speed, etc., and these parameters often rest on assumptions. Mode choice becomes even more complicated because of the emergence of new modes, for which very little information exists. If the forecasting model is to incorporate ride hailing or car sharing, how should these modes be expressed? More optimistic assumptions could lead to much higher rates of ride sharing, hence reducing VMT.

Finally, the resulting trips by mode are assigned to the transportation supply. Transportation supply is essentially the road and transit network infrastructures that exist right now as well as those that have been planned or anticipated by the target year. If demand far exceeds supply, the result is extensive congestion, which then makes modes with separate right of the way relatively more attractive. By feeding these results back into trip distribution and mode choice, there will be a further effect on mode shares and VMT.

Conformity requires that the plan forecast be consistent with air pollution reduction targets. The SCS requires that the plan be consistent with the GHG reduction targets. Therefore, the results of the transportation forecasts must be evaluated via emissions modeling (Figure 5). There are two main inputs to the emissions model: the output from the transportation forecast (e.g. VMT and speed), and information on the future vehicle fleet (e.g. age, vehicle type, fuel type). The emissions model then calculates the total amount of the various criteria pollutants, including CO₂. It can be seen that the cleaner the future fleet, the fewer emissions, hence another point in the process where assumptions can be adjusted. If the forecast emissions meet the targets, the plan can be moved forward. If not, the plan must be adjusted, and the transportation forecasting process repeated.

This brief description shows the many ways that model parameters can be adjusted to meet conformity and SCS requirements. Are there incentives to adjust models to meet these requirements? Our answer is yes. First, as noted earlier, the cost of producing a plan that does not meet requirements is high. For conformity, a non-conforming plan cannot be approved by the state or EPA, and without such approval federal funds can be frozen. For SCS, CARB's authority allows it to increase regulations if required to reach AB 32 goals. Local governments want to avoid regulations that would reduce their autonomy or affect their economies. Thus it is far better strategy to submit a compliant plan. Second, targets are established for the future; the accuracy of the forecast can only be evaluated after the target year. If the targets are not reached, any number of factors may have occurred, from unanticipated per capita income growth to slower than expected battery technology improvements. In essence, it would be very difficult to claim that the forecast was misleading given all the changes taking place over the forecast period.

FIGURE 5: ESTIMATING CRITERIA POLLUTANTS AND GHG EMISSIONS



CONCLUSIONS

Why California?

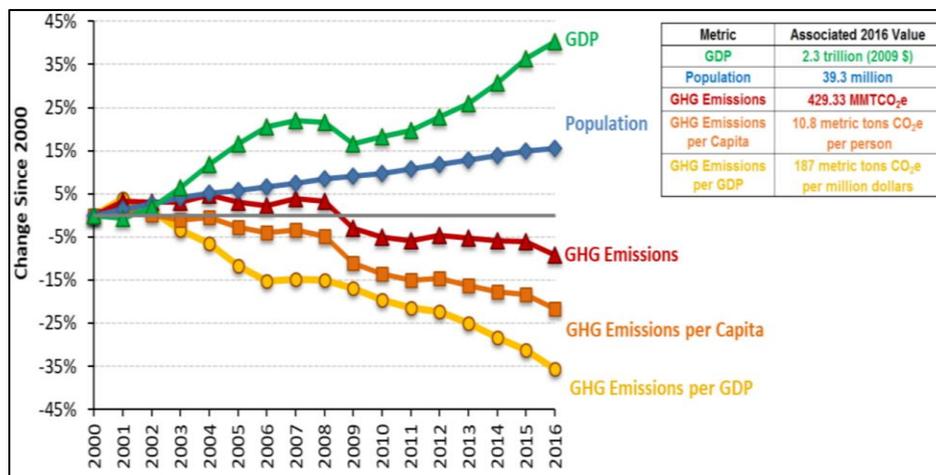
California's leadership in global climate change mitigation policy is the result of a long tradition of environmental regulation, originally motivated by severe air pollution problems in Southern California that emerged in the 1940s. Air pollution was not nearly as critical an issue in other parts of the country, and the national environmental movement leading to the landmark environmental legislation of the Clean Air Act of 1970 didn't get started until the 1960s (Fern, 1997). California chose to act before the Federal Air Quality Act of 1967, and obtained a waiver that allowed it to maintain its own more stringent standards.

California has led environmental regulation ever since, adopting its own air quality standards (CAAQS) and its own environmental review process (CEQA). Emissions regulation was and is based on technology forcing: impose standards not technically feasible at the time of adoption. The success of technology forcing emissions regulation emboldened the state to expand to new areas, notably the ZEV mandate of 1990 and the most recent version of the ZEV mandate in the Advanced Clean Cars program that has a target of 5 million ZEVs in the fleet by 2030 (CARB, 2018a). To place the target in perspective, 5 million vehicles is about 20% of the current passenger vehicle fleet (CA DMV, 2018). In 2016, ZEV policy was expanded to the truck fleet through the California Sustainable Freight Action Plan (CADOT, 2016).

Although the state relies heavily on technology forcing regulations and mandates, California's leadership was reinforced by AB 32 and its establishment of the most comprehensive cap and trade system in the US. The cap and trade program has largely been a success. It expanded with the participation of Quebec and Ontario, and it has generated billions in revenue that in part are used to support the various GHG reduction programs (CARB, 2019c). These efforts have successfully reduced the state's GHG emission over the years even though its GDP and population has steadily increased. (Figure 6). These reductions are largely due to

the electricity sector, which decreased its emissions by nearly 36% since 2000 (Table 3). Transportation sector emissions declined during the Great Recession, but have increased since 2014.

FIGURE 6: CHANGE IN CALIFORNIA GDP, POPULATION AND GHG EMISSIONS SINCE 2000



Source: CARB (2018D)

TABLE 4: CHANGE IN CALIFORNIA GHG EMISSIONS PER SECTOR SINCE 2000, IN MTCO₂E

	2000	2002	2004	2006	2008	2010	2012	2014
Emissions	471.69	485.83	493.71	482.74	487.34	448.11	450.38	444.10
Electricity	105.35	109.09	115.59	104.86	120.43	90.58	95.33	88.37
Transportation	183.86	191.59	191.21	193.31	182.64	170.16	166.16	167.14
Industrial	104.55	104.15	106.08	101.82	99.47	100.93	100.89	104.23
Commercial	14.16	16.10	15.83	16.54	17.68	20.09	21.11	21.37
Residential	30.96	30.15	30.70	29.91	30.48	31.26	30.04	26.26
Culture & Recreation	31.60	33.82	33.42	35.41	35.79	34.27	36.08	35.95
Unspecified	1.20	0.94	0.87	0.89	0.85	0.82	0.78	0.78

Source: CARB (2018D)

Some Observations

The strength of the California approach is in its coordination and comprehensiveness. The many programs together form a suite of supportive policies. For example, cap and trade revenues support subsidies and incentive programs to promote purchase of EVs. Introduction of ZEV trucks and buses is being facilitated by CARB’s funding of demonstration projects. The SCS forces links between the RTP, state GHG reduction targets, and regional housing plans. A portion of cap and trade funding is allocated to the development of higher density, transit accessible affordable housing. The Low Carbon Fuel Standard tackles conventional fuels. This broad array of interlinking policies increases the likelihood of success of the entire program.

California has steadily and consistently broadened its authority through the California Air Resources Board. CARB is authorized to carry out most of the provisions of AB 32 and SB 32, and to date has had a relatively free hand in doing so. The voting membership of CARB include 12 members appointed by the Governor and confirmed by the Senate, and 2 members appointed by the Senate Rules Committee and the Assembly Speaker respectively. CARB has enjoyed strong political support from both the Governor's Office and the state legislature. It was able to expand its authority to regional transportation planning through the SCS requirement despite concerns from local governments and MPOs.

With the RTP now subject to both federal conformity and state SCS target requirements, the models that produce the transportation forecasts have become a more critical element in the transportation planning process. Model results determine whether conformity and GHG reduction targets are met. Given the challenge of accommodating more population and jobs while at the same time reducing emissions, models and model results become ever more important. The complexity and uncertainty of transportation forecasting allows for flexibility in model assumptions and parameter values, hence making it an important tool in achieving these targets in transportation plans.

Can we replicate California?

The final question that motivated this paper was replicability. California has moved faster and further in climate change policy and GHG reductions than any other state or country. Many of California's policies have been replicated. Many states have followed California's lead and used S 177 to impose more stringent air quality standards, and later ZEV mandates. As noted earlier, 23 states now have some form of GHG reduction target. However, no other state has programs of the scale and scope of California.

California is known for its exceptionalism in many areas. The term goes back to Carey McWilliams who argued in 1949 that California developed in isolation, allowing it to function more like a nation-state. It had vast natural resources that attracted "risk-takers" from the East. These were migrants willing to experiment with new ideas. This tradition of risk-taking and innovation is a continuing theme in California history, from the mid-nineteenth century Gold Rush to the movie industry in the 1920s to Silicon Valley today. One explanation for California's environmental policy leadership is therefore that it is another example of California exceptionalism at work.

A second explanation is the size of California: a population of 40 million, and a GDP of about \$2.7 trillion, making it the fifth largest economy in the world. California has the financial resources to invest in green technology and is able to maintain a vibrant economy despite the added costs associated with GHG reduction policies. A third explanation is the famously liberal political climate of California. Public support for protecting the environment, cleaning up the air, and avoiding the worst consequences of global change is strong and enduring. Combining this commitment with California exceptionalism helps us to understand the state's leadership.

As for replication, two essential ingredients seem to be public support and broad regulatory authority. States like Oregon, Vermont and New York are examples, and each already has in place strong environmental programs. The question is to what extent they could implement a California style program.

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