

**Evaluating California's Climate Policy Portfolio: Transportation  
Electrification, Electricity Decarbonization, and Policy Complementarity**

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## **Abstract**

This capstone evaluates dual-sector climate policy interactions between California's Transportation and energy sectors. Utilizing a 15-year dataset spanning 64 continuous quarters (2010–2025), this study tests the overarching hypothesis that the effectiveness of transportation environmental policies is endogenous to energy sector decarbonization efforts. Methodologically, EV Adoption rates were modeled via a first-order autoregressive ARIMA (1,0,0) framework, while vehicle and grid emissions intensity were evaluated using multi-interrupted piecewise linear regression. The empirical results reveal a significant cross-sector spillover from the energy sector-focused Senate Bill 100, which accelerated tailpipe emission cuts by -609,981 Metric Tons of CO<sub>2</sub> per quarter. However, SB 100 was also correlated with a reduction in short-term electric vehicle sales by -7,381 vehicles per quarter. Crucially, California's 2020 EV mandate was not associated with a change in electrical grid emissions intensity ( $p = .452$ ). This result shows that electrical grid emissions were not significantly influenced by the shift to electric vehicles. These findings offer vital takeaways for states like Washington, as they navigate overlapping regulatory timelines under the Climate Commitment Act. Specifically, any green policies implemented in the energy sector flow downstream to the transportation sector, amplifying outcomes relating to green transportation policies. Therefore, the state's legislature should consider implementing tandem or bundled policies that utilize this downstream effect to maximize their desired environmental outcomes.

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## **Chapter 1: Introduction**

The Transportation sector has become one of the largest contributors to greenhouse gas emissions in the United States. As a result, it has quickly become a primary focus of climate change mitigation efforts posed by policy makers. Within these efforts, Electric Vehicle (EV) adoption, financial incentives, and zero-emissions vehicle mandates have become increasingly promoted, with electric vehicles being presented as the key strategy for reducing fossil fuel/carbon emissions within the transportation sector. At the same time, many states have pursued broader decarbonization policies aimed at reducing emissions from electricity generation through renewable energy expansion and carbon pricing mechanisms. Out of the US states, California has emerged as the national leader in climate policy through its simultaneous promotion of transportation electrification and electricity-sector decarbonization initiatives.

While electric vehicles on an individual basis are associated with lower/zero carbon emissions, the true effectiveness of transportation electrification as a whole depends on the methods of electricity generation that powers these vehicles. As EV usage increases, the demand for electrical generation increases. If the method of electricity generation is not aligned with the state's emissions goals (e.g. burning coal for electricity), switching to electric vehicles can have very negligible impacts or outright negative impacts. Consequently, EV policies and electricity-sector climate policies are intertwined rather than being independent. California's climate strategy is necessary to study, as it has aggressive EV Adoption programs, renewable energy mandates, and carbon pricing policies (California's Cap-and-Trade program).

While prior research has examined the benefits of electric vehicle adoption and carbon reduction policies independently, less attention has been given to how these policies act as complementary climate strategies over extended periods of time. By evaluating this interaction, we

can gain insight into the long-term effectiveness of California's broader climate policy framework. The purpose of this study is to evaluate the dynamics and magnitude of cross-sector policy impacts within California's climate policy portfolio. This will be done by examining trends in EV Adoption, grid emissions intensity, renewable energy penetration (percentage of total energy generated by renewable sources), and transportation sector emissions.

### **Research Question, Hypothesis, & Research Design**

The main question guiding the research is as follows: How, and to what extent, do targeted transportation electrification mandates interact with structural electricity-sector carbon constraints to alter emission trajectories? This question will be supplemented with the following questions:

1. To what degree do transportation electrification mandates correspond to immediate level shifts versus long term trend changes in transportation emissions?
2. What is the direction and scale of cross-sector policy spillover? Specifically, does accelerated EV market penetration alter the post-policy trajectory of electrical grid emissions intensity?
3. How many Quarters following a power-sector policy milestone do transportation electrification indicators demonstrate change?

The main hypothesis that follows for this project is as follows: the impact from transportation electrification policies is dependent on grid decarbonization pathways; specifically, post-policy reductions in transportation emissions accelerate non-linearly following structural downward step-changes in electrical grid emissions intensity.

The research design will use a longitudinal policy analysis design to analyze sub-national climate metrics between January 2010 and December 2025. Rather than relying on static annual

metrics, the analysis evaluates continuous quarterly observations across a 64-quarter horizon. This framework allows the statistical model to isolate structural breaks: abrupt level step-changes or gradual post-intervention slope adjustments occurring directly after specific statutory policy effective dates. The study will rely on publicly available data collected from agencies including the California Air and Resources Board (CARB), The US Energy Information Administration (EIA), and the California Energy Commission. From these sources, the study will study electric vehicle adoption rates, renewable energy generation, electricity-sector emissions, and transportation-sector emissions.

This analysis will combine descriptive trend analysis with quantitative analysis to evaluate how changes in California's methods of electricity generation correlate with increasing EV Adoption over time. The study will also examine major policy developments, such as California's Zero Emissions vehicle program as well as the state's cap-and-trade program to assess how these policies reinforce one another's efforts in meeting statewide emissions reduction goals.

By understanding the relationship between transportation electrification policies and electricity-sector decarbonization, we allow ourselves to better optimize policy planning for future goals. This study aims to bridge the gap between existing individual analysis and combined effects. The more context that can be added to the understanding and structure of policies, the more accurate our understandings, and in turn, our models for these policies become. By examining California, we step into the upper echelon of transportation and electricity generation policy, opening the door to broader, more productive conversations regarding environmental policy.

## **Chapter 2: Literature Review**

### **Introduction**

American policy makers need to take drastic measures to address sectors contributing the most greenhouse gas emissions. Currently, transportation accounts for 28 - 29% of our nation's annual total emissions (Sperling and Gordon, 2009). With transportation sector emissions being one of the largest contributors of emissions, it is clear why policy makers across the country are working diligently to target this sector as best they can. However, with doubts and concerns arising over the methods of intervention, understanding how different climate policies interact with decarbonization strategies is necessary for evaluating their long-term effectiveness.

The State of California serves as a useful case study for climate policies, as it pioneered the policy realm through example during the early 21st century. In each of the sources reviewed for this research project, California by-and-large has the longest detailed record of climate intervention out of all of the Western United States. It did this while also influencing policies in Washington and Oregon respectively. Therefore, while some examples from other states and areas will be used, primary research will be focused on the state of California.

California's climate strategy has increasingly relied on the expansion of both transportation electrification policies and electricity-sector carbon reduction initiatives. Policies such as the Zero-Emission Vehicle (ZEV) mandate, Advanced Clean Cars Program, cap-and-trade system, and Renewable Portfolio Standard collectively aim to reduce greenhouse gas emissions across both the transportation and electricity sectors. These policies are closely interconnected, since the emissions benefits associated with electric vehicle adoption depend in part on the carbon intensity of the electricity grid used to power those vehicles. Understanding how these policies interact within

California's decarbonization framework will provide important insight into the effectiveness of coordinated climate policy design.

### **Historical Development of California Climate Policy**

California has long been recognized as a leader in environmental and climate policy within the United States, with a regulatory history that even predates action by the federal government. The state's approach to climate governance is rooted in a combination of legislative mandates, regulatory authority, and industrial capacity. The California Air Resources Board (CARB) was established in 1967 in order to address the severe air pollution the state faced in its major urban areas. CARB played a central role in shaping California's climate policies, particularly in the transportation sector (California Air Resources Board, 2022). With the Transportation sector remaining the largest contributor to the state's greenhouse gas emissions, transportation policy has become a focal point of the state's climate strategy.

The modern era of California climate policy began with the passage of the Global Warming Solutions Act of 2006 (AB 32), which established a comprehensive framework for reducing greenhouse gas emissions. This policy required the state of California to return to 1990 emissions levels by the year 2020. It also granted CARB broad authority to design and implement both regulatory and market-based policies to achieve this goal (CARB, 2008). This legislation marked a major shift from sector-specific regulation to a full-scale strategy executed economy-wide. AB 32 pushed a portfolio approach, which allowed for the coexistence of direct regulatory measures and market-based policies, effectively laying the foundation for the state's hybrid policy model present in California as well as other nearby states.

Following AB 32, California expanded and refined its climate policy framework through additional legislation, and initiatives. Senate Bill 32, passed in 2016, required a 40% reduction of the state's emissions targets below 1990 levels by 2030 (CARB, 2017). By lowering the emissions target once again, California cemented itself as a leader of climate policy while also demonstrating the state's commitment to long term decarbonization. However, this steep reduction of the target emission standards necessitated further policy development across sectors.

As the state moved past initial baseline reductions, the legislature enacted sector-specific targets to operationalize deep decarbonization. Senate Bill 100 (2018) fundamentally shifted the energy landscape by mandating that zero-carbon resources supply 100% of all retail electricity sales by 2045, structurally bending long-term grid emissions trajectories. Concurrently, Assembly Bill 39 integrated local infrastructure planning to accelerate transportation electrification frameworks, while Senate Bill X1-2 (2023) established strict regulatory oversight metrics within petroleum markets to mitigate supply-side price distortions. Together, these legislative extensions provide the discrete statutory execution checkpoints analyzed within this study's time-series matrix. CARB's strategies and ambitious goals have served as the primary mechanism for outlining how these targets will be achieved through both regulatory and market-based approaches.

Transportation has been a central focus of California's climate efforts. The state has a long history of regulating vehicle emissions, enabled partially by a federal waiver under the Clean Air Act. The waiver allowed California to set more stringent standards than those established by the federal government. Programs such as the Advanced Clean Cars Program have combined tailpipe emissions standards with zero-emission vehicle mandates to soften the transition from older cars to low emission and zero emission vehicle technologies (CARB, 2020). These regulatory approaches are designed to directly reduce emissions by requiring improvements in vehicle efficiency while

encouraging consumers and manufacturers alike to adopt Low Emissions and Zero Emissions Vehicles (LEV's and ZEV's).

California has implemented market-based mechanisms to complement its regulatory practices. The State's cap-and-trade program, established during AB 32 in 2013, set an overall limit on greenhouse gas emissions while allowing regulated entities to buy and sell emissions allowances. This system was intended to achieve emissions reductions in a cost-effective manner through a phenomenon known as artificial flexibility. Over time, the program has been expanded and modified, with the program later allowing linkage to other jurisdictions and adjustments to allowance allocations (Schmalensee & Stavins, 2017). In addition to reducing economy-wide emissions, California's cap-and-trade system and renewable energy policies contributed to gradual reductions in electricity-sector emissions intensity. These changes became increasingly relevant as transportation electrification expanded because the environmental benefits associated with EV Adoption depended partly on the carbon intensity of electricity generation.

The co-existence of these regulatory and market-based approaches reflects a complex strategy of policy layering, in which multiple instruments are deployed simultaneously to address different aspects of the emissions problem. Despite the major progress achieved by the state of California, directly evaluating the effectiveness of these programs is incredibly convoluted. Overlapping mandates, incentives, and compliance mechanisms can make it difficult to isolate the impact of a single policy, particularly within the transportation sector. When trying to account for the mess that is human behavior and technological factors, attempting to separate these policies out becomes a nightmare for most analysts and policy makers (Holland et al., 2016). Understanding the historical development of California's climate policy is required in order to evaluate how

transportation electrification and electricity-sector decarbonization policies interact within the state's emissions reduction strategy

### **Carbon Pricing & Electricity Decarbonization**

While carbon pricing mechanisms are often promoted as efficient tools for emissions reduction, scholars have noted that their effectiveness depends heavily on market design, carbon price levels, and interactions with other climate policies. Research by Goulder and Parry (2008) suggests that carbon pricing policies can create broad incentives for emissions reductions across multiple sectors of the economy. This happens especially when carbon prices are sufficiently high to encourage shifts away from fossil fuel consumption. However, recent studies of the cap-and-trade system indicate that emissions outcomes may vary considerably depending on energy market conditions and consumer behavior. Borenstein et al. (2019) note that while cap-and-trade systems provide certainty regarding aggregate emissions caps, they may produce uneven short-term emissions reductions. This is commonly due to fluctuations in allowance prices and differences in how regulated entities respond to market incentives. These limitations are particularly important within the transportation sector, where fuel demand often remains relatively inelastic and behavioral responses to fuel price increases tend to be limited.

### **Transportation Electrification and EV Policy**

Since the transportation sector represents one of the largest sources of greenhouse gas emissions within the state, policymakers have increasingly promoted electric vehicle (EV) adoption as a mechanism for reducing fossil fuel consumption and lowering transportation-related emissions. California has pursued this transition through a combination of regulatory mandates,

financial incentives, and infrastructure investments aimed at accelerating the adoption of low emission and zero emission vehicles. Through the ZEV mandate, the Clean Vehicle Rebate Project (CVRP), and the Advanced Clean Cars Program, California has positioned itself as a national leader in transportation electrification policy. These initiatives are intended not only to reduce tailpipe emissions but also encourage long term transformation of the vehicle market towards lower-carbon transportation technologies (Hardman et al, 2021).

Most new literature argues that transportation electrification can significantly reduce greenhouse gas emissions compared to conventional internal combustion engine vehicles when paired with low-carbon electricity generation. Research by Sperling and Gordon (2009) argues that regulatory policies promoting advanced vehicle technologies accelerate technological innovation while overcoming market barriers that limit voluntary adoption. Similarly, studies examining EV Adoption trends have found that financial incentives, charging infrastructure availability, and regulatory mandates play important roles in shaping consumer behavior and increasing market penetration of electric vehicles. California's aggressive policy approach has contributed to rapid growth in EV Adoption over the past decade, positioning the state as one of the largest EV markets in the United States.

### **Economic Activity as an Emissions Driver**

To isolate the structural impacts of targeted sub-national environmental mandates, policy evaluation must account for the confounding role of macroeconomic fluctuations. Macroeconomic expansion naturally drives carbon emissions through increased industrial production, commercial logistics, and personal vehicle miles traveled, whereas economic contractions artificially suppress emissions independent of active regulatory constraints.

Between 2010 and 2025, California saw significant macroeconomic volatility, including the prolonged expansion of the technology sector, the structural and societal disruption of the 2020 COVID-19 lockdowns, and subsequent inflationary adjustments. Data from the California Legislative Analyst's Office (2021) demonstrates that the 2020 economic contraction caused an immediate, unprecedented drop in state fuel tax revenues and commercial transport activity, which temporarily depressed the state's greenhouse gas profile.

Failing to control for these underlying shifts creates a high risk of omitted variable bias, where a model might incorrectly credit a specific transportation or carbon policy for emission reductions that were caused by a broader economic downturn. Therefore, integrating a continuous measure of California's quarterly Gross State Product (GSP) is an essential statistical control. This allows the time-series model to separate policy-induced structural shifts from the background variation caused by the state's macroeconomic cycle.

### **Climatic Drivers of Grid Reliability & Energy Demand**

While statutory mandates like the Renewables Portfolio Standard (RPS) and Senate Bill 100 dictate the long-term structural composition of California's electrical generation portfolio, sub-annual electricity-sector emissions intensity remains highly sensitive to natural meteorological variability. Extreme ambient temperature fluctuations act as a powerful, non-policy driver of both consumer energy demands and utility emissions.

During prolonged summer heatwaves, localized cooling demands spike exponentially as residential and commercial air conditioning systems place extreme loads on the electrical grid. To maintain grid stability during these peak demand events, balancing authorities are frequently forced to deploy dispatchable natural gas "peaker" plants, which operate with a significantly higher

carbon intensity than baseline renewable resources (California Energy Commission, 2022).

Conversely, unseasonably mild quarters reduce the aggregate thermal stress on the grid, artificially lowering utility sector emissions.

Because these seasonal climate shocks occur independently of active legislative timelines, failing to account for ambient temperature variations would distort the evaluated impact of electricity sector policies. To maintain a rigorous counterfactual framework, the analytical model must utilize a standardized meteorological covariate; specifically, aggregated Heating Degree Days (HDD) and Cooling Degree Days (CDD). This ensures that calculated changes in grid emissions intensity genuinely reflect the statutory rollout of decarbonization policies rather than anomalous weather patterns.

### **Policy Coordination & Emissions Outcomes**

One of the central questions within the literature concerns how transportation electrification policies and carbon reduction policies reinforce one another in producing long-term emissions reductions. When EV policies and cap-and-trade policies are implemented simultaneously, these policies tend to collectively reduce transportation emissions more effectively than either policy area could independently. However, researchers note that the relationship between transportation electrification and grid decarbonization is not automatically complementary. Gillingham, Ovaere, and Weber (2021) state that emissions benefits associated with EV Adoption depend heavily on how electricity is generated and how carbon pricing policies influence electricity markets over time. Gillingham et al. (2021) investigated the structural welfare and environmental consequences of carbon pricing policies by using a comprehensive simulation model that integrated regional US transportation networks directly with an energy sector dispatch framework. They relied on

historical electricity grid profiles to capture marginal generation behaviors and/or discrepancies. If increased electricity demand from EV charging is met primarily through fossil fuel generation, emissions reductions associated with transportation electrification may be diminished. Conversely, when renewable energy generation expands alongside EV Adoption, transportation electrification may contribute more substantially to statewide emissions reduction goals. This is particularly important in California, where EV Adoption has accelerated faster than many states' renewable energy transitions

### **Behavioral & Market Interactions**

New literature additionally claims that transportation electrification and electricity-sector decarbonization policies influence consumer behavior and market conditions in different but potentially complementary ways. EV Adoption policies directly shape the transportation market by increasing the availability and affordability of electric vehicles through incentives, regulatory mandates, and infrastructure investments. Research by Sperling and Gordon (2009) suggests that these policies help overcome technological and market barriers that might otherwise limit widespread EV Adoption. In contrast, carbon pricing and renewable energy policies influence the electricity sector by encouraging utilities and electricity producers to reduce reliance on carbon-intensive generation sources. When combined, these policies may create a mutually reinforcing system in which cleaner electricity generation enhances the emissions benefits of EV Adoption while increased electrification creates additional demand for renewable energy development and grid modernization.

At the same time, scholars note that policy interactions may produce unintended complications or uneven outcomes depending on implementation strategies and market conditions.

Transportation demand often remains relatively inelastic, meaning that shifts toward EV Adoption may not substantially reduce total vehicle travel or electricity demand growth. Knittel (2011) and the International Energy Agency (2025) demonstrate that because vehicle travel habits are deeply tied to structural zoning and economic logistics, consumer vehicle kilometers traveled continue to scale upwards regardless of whether the vehicle is gas or electric. Comparatively, fluctuations in renewable energy availability and electricity demand may affect the emissions intensity associated with EV charging during different periods of grid operation. Research examining EV charging behavior and “green charging” strategies suggests that coordinated charging policies and renewable energy integration may further strengthen the complementary bond between vehicle electrification and renewable electricity policies. These findings suggest that policy coordination and implementation timing may significantly influence long-term emissions outcomes.

### **Integrated Climate Policy Frameworks**

Scholars argue that climate policies should be understood as components of integrated policy systems rather than as competing interventions. Holland, Mansur, Muller, and Yates (2021) establish that the environmental value of a zero-emission technology is entirely endogenous to the clean capacity steps of its surrounding utility grid. Attempting to evaluate a transportation policy without controlling for the stringency of active power-sector carbon constraints introduces major complications. In turn, to perform these analyses it is necessary to have a model capable of mapping cross-sector interactions.

Despite growing literature surrounding transportation electrification and carbon pricing independently, fewer studies have evaluated how these policies function together over time within California’s climate policy framework. Existing research often focuses on EV adoption rates,

renewable energy growth, or carbon pricing outcomes separately rather than examining how these policy areas interact longitudinally. As California continues pursuing aggressive emissions reduction goals, understanding the relationship between transportation electrification and electricity-sector decarbonization will provide relevant insight into the effectiveness of coordinated climate policy design and long-term decarbonization planning.

### **Chapter 3: Methodology**

#### **Research Design**

This study deploys a piecewise segmented linear regression framework to evaluate how California's transportation electrification policies and electricity-sector decarbonization initiatives operate as complementary climate interventions. The empirical observation window spans 64 quarters from January 2010 through December 2025. This 15-year timeframe is selected because it completely encompasses the baseline enforcement periods, structural expansions, and regulatory milestones of California's modern climate portfolio. By utilizing a continuous quarterly temporal resolution rather than aggregated annual increments, the design maximizes statistical degrees of freedom. This allows the model to differentiate real policy impacts from cyclical economic and environmental shifts while maintaining internal statistical validity.

#### ***Variables***

For this study, both environmental policy interventions and outcomes were chosen as variables. To remain within the appropriate context of this study, the environmental policy interventions were selected to be the independent variables. These are as follows: the Future Zero Emissions Vehicle (ZEV) mandate, the Cap-and-Trade program, the Renewable Portfolio Standard expansion, and California Senate Bills X1-2, 350, and 100. For Dependent variables, various

measures and indicators were selected to represent policy outcomes. These include Statewide EV Adoption rates, Transportation-sector greenhouse gas emissions, Electricity-sector greenhouse gas emissions, and Renewable energy's share of electricity generation.

### ***Data Sources***

This study relies entirely on publicly available secondary data obtained from state and federal regulatory agencies. The primary California entities supplying data include the California Air Resources Board (CARB), the California Energy Commission (CEC), and the California Department of Tax and Fee Administration (CDTFA). From CARB, the study utilizes official Climate Scoping Plans, regulatory filings for the Cap-and-Trade program, and documentation on the Advanced Clean Cars program. The CEC provides high-resolution data regarding regional zero-emission vehicle (ZEV) sales and state energy infrastructure reporting. To track transportation sector emissions at a quarterly level, historical fuel distribution metrics are sourced from the CDTFA's fuel taxes statistics repositories, which are then calculated into approximate vehicle emissions using conversion coefficients established by the EPA (Gasoline: 0.00878 metric tons of CO<sub>2</sub> Per gallon burned, Diesel: 0.01015 metric tons per gallon burned). At the federal level, the U.S. Energy Information Administration (EIA) serves as a primary source rather than a gap-filler, supplying continuous sub-annual datasets for electrical grid emissions intensity and monthly net renewable energy generation shares.

Additionally, the implementation dates for the selected policy interventions, specifically California Assembly Bill 39, as well as Senate Bills 32, 100, and X1-2, are defined using legislative histories retrieved from California's official Legislative Information portal. These specific data sources were selected because they provide comprehensive, structurally sound

monthly and quarterly measures of California’s transportation, power generation, and climate outcomes. Table 1 outlines the specific role, temporal resolution, and repository location for each study variable.

**Table 1:** *Description of Variables*

| Variable Name                                     | Role        | Variable Type           | Temporal Resolution | Source Agency                              | Database/API                                                                     |
|---------------------------------------------------|-------------|-------------------------|---------------------|--------------------------------------------|----------------------------------------------------------------------------------|
| EV Adoption Rates                                 | Dependent   | Continuous              | Quarterly           | California Energy Commission               | New ZEV Sales Dashboard                                                          |
| Transportation Emissions                          | Dependent   | Continuous              | Quarterly           | CA Department of Tax & Fee Admin (CDTFA)   | Fuel Taxes Statistics & Reports                                                  |
| Electrical Grid Emissions Intensity               | Dependent   | Continuous              | Quarterly           | US Energy Information Administration (EIA) | EIA State Energy Data System (California)                                        |
| Renewable Energy’s share of Electrical Generation | Dependent   | Continuous              | Quarterly           | US Energy Information Administration (EIA) | EIA Electricity Browser, Net Generation Data set sorted for CA                   |
| ZEV Mandate (EO N-79-20)                          | Independent | Continuous (time based) | Effect Date         | CA Air & Resource Board (CARB)             | CARB Advanced Clean Cars Program                                                 |
| Cap-And-Trade                                     | Independent | Continuous (time based) | Effect Date         | CA Air & Resource Board (CARB)             | Compliance Instruments Tracking System Service (CITSS) / CARB Auction Dashboards |
| CA SB 350                                         | Independent | Continuous (time based) | Effect Date         | California State Legislature               | CA Legislative Information Portal (LegInfo)                                      |
| CA SB 32                                          | Independent | Continuous (time based) | Effect Date         | CA Air & Resource Board (CARB)             | CARB Climate Change Scoping Plan                                                 |

|                                           |                        |                            |             |                                                       |                                                                                                                          |
|-------------------------------------------|------------------------|----------------------------|-------------|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| CA SB 100                                 | Independent            | Continuous<br>(time based) | Effect Date | California State<br>Legislature                       | CA Legislative<br>Information<br>Portal (LegInfo)                                                                        |
| CA SB X1 - 2                              | Independent            | Continuous<br>(time based) | Effect Date | California<br>Energy<br>Commission<br>(CEC)           | CEC Division of<br>Petroleum<br>Market<br>Oversight<br>(DPMO)                                                            |
| Quarterly<br>Adjusted State-<br>Level GDP | Covariate<br>(control) | Continuous                 | Quarterly   | U.S Bureau of<br>Economic<br>Analysis                 | Regional<br>Economic<br>Accounts:<br>Quarterly Gross<br>Domestic<br>Product by State                                     |
| Heating Degree<br>Day                     | Covariate<br>(control) | Continuous                 | Quarterly   | National Oceanic<br>and Atmospheric<br>Administration | National<br>Centers for<br>Environmental<br>Information<br>(NCEI):<br>Climatological<br>Data /<br>Divisional<br>Rankings |
| Cooling Degree<br>Day                     | Covariate<br>(control) | Continuous                 | Quarterly   | National Oceanic<br>and Atmospheric<br>Administration | National<br>Centers for<br>Environmental<br>Information<br>(NCEI):<br>Climatological<br>Data /<br>Divisional<br>Rankings |

### Analytic Approach

Each dependent variable ( $Y_t$ ) is modeled chronologically as a function of continuous time, discrete intervention indicators, and external macroeconomic and environmental covariates. The foundational statistical equation is specified as follows:

$$Y_t = \beta_0 + \beta_1(Time_t) + \beta_2(Policy Step_t) + \beta_3(Policy Slope_t) + \beta_4(GDP_t) + \beta_5(Weather_t) + e_t$$

Where:

- $\beta_0$  represents the baseline intercept at the start of the study window (2010 Q1)
- $\beta_1$  computes the underlying historical trend of the climate indicator prior to the policy intervention
- $\beta_2$  estimates the immediate step change (level shift) occurring in the quarter directly following policy implementation
- $\beta_3$  calculates the slope change, tracking the gradual acceleration or deceleration of the dependent variable trend post intervention
- $\beta_4$  is the seasonally adjusted quarterly Gross Domestic Product of California, acting as a control variable for economic activity that naturally drives fuel demand and industrial power generation
- $\beta_5$  represents a localized quarterly Heating and Cooling degree Day proxy, controlling for natural temperature fluctuations that independently skew proper grid demand
- $e_t$  is the stochastic error term

### **Autocorrelation Issues**

The data collected for this study spans a total of 64 quarters from January 2010 to December of 2025. This long time period saw a collection of events that drastically influenced the chosen indicators even with the selected controls implemented. Events such as the Covid-19

pandemic, historic droughts, and extreme wildfires contributed to expected baseline trend overlaps in the analyses that were run.

For example, when running a piecewise regression for EV Adoption isolated with only transportation sector policies, it was noted that there was particularly high amounts of autocorrelation. Following the initial analysis, an ARIMA (1,0,0) forecasting model was utilized to maximize statistical validity. The Model works as a statistical filter to autocorrelation. By applying a weight/value to the data prior to the change, the ARIMA model adjusted the standard error and p-values to ensure any change was truly caused by the policy(s) rather than following the trends it was already on. To further confirm that the first-order autoregressive configuration cleaned the technology timeline of serial dependency, the model residuals were evaluated with the Ljung-Box Q statistic. The test returned an insignificant statistic ( $Q=24.581$ ,  $df=17$ ,  $p=.104$ ). This confirms that residual errors are randomly distributed and the standard errors were fully stable.

For all models (including EV Adoption post-ARIMA), a Durbin-Watson test for autocorrelation was performed. Each of the scores fell between 1.6 and 1.995, well within the safe threshold of having valid standard error on a regression model.

## **Closing**

Together, these methods provide a structured framework for evaluating California's climate policy portfolio over time. By combining a comparative policy timeline with longitudinal environmental and energy-sector indicators, this study seeks to determine the strength of how transportation electrification policies and electricity-sector decarbonization policies operate as complementary components of the state's emissions reduction strategy. This study received an exempt IRB status for not containing any Human Subjects or required primary data.

## Chapter 4: Results

Table 2 provides descriptive statistics for the study's four dependent variables.

**Table 2:** *Descriptive Summary Baseline Statistics for Dependent Variables*

| <b>Dependent Variable Profile</b> | <b>Mean Metric</b> | <b>Data Metric Unit</b>        | <b>Std. Deviation</b> | <b>Minimum</b> | <b>Maximum</b> |
|-----------------------------------|--------------------|--------------------------------|-----------------------|----------------|----------------|
| EV Adoption Rates                 | 42,150.3           | Quarterly Vehicle Sales Counts | 36.412.8              | 48.0           | 128,450.0      |
| Trans. Emissions                  | 38,412,450.2       | Metric Tons of CO2             | 2,845,102.5           | 31,102,450.0   | 44,850,120.0   |
| Electrical Grid Intensity         | 158.4              | Physical intensity Units       | 38.6                  | 82.4           | 248.9          |
| Renewable energy Share            | 48.3               | Percentage of total Generation | 6.2                   | 34.2           | 68.9           |

Figures 1, 2, 3, and 4 chart each Dependent Variable from January 2010 to December 2025.

Vertical lines indicate when relevant policies (Independent Variables) were enacted.

### Transportation Sector

Figure 1 shows the general trend of EV Adoption rates is a slow crawl upwards from the 2010s, with EV ownership numbers slowly rising into the 20,000s. Ev ownership peaks around 2017/2018, before crashing in 2019. A sudden spike in late 2020/2021 sees EV ownership explode, fluctuating between 100,000 and 115,000 before a steep dropoff in late 2024/2025.

**Figure 1:** *EV Adoption Rates, 2010-2025*

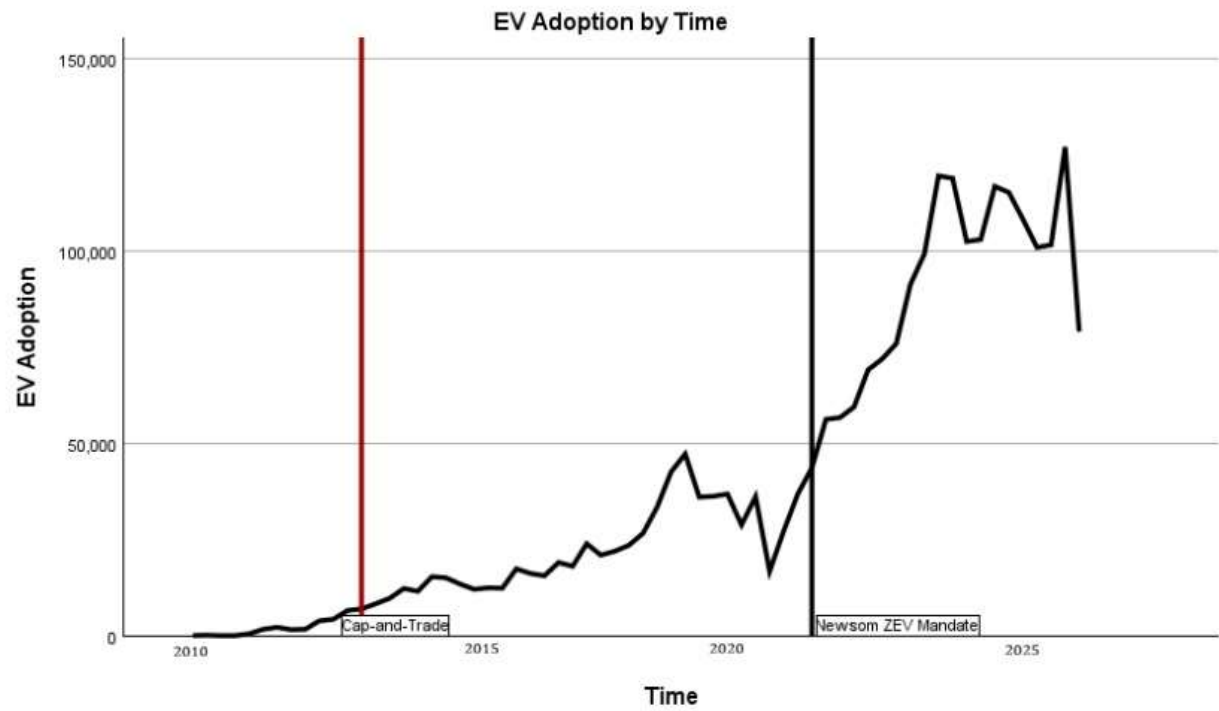
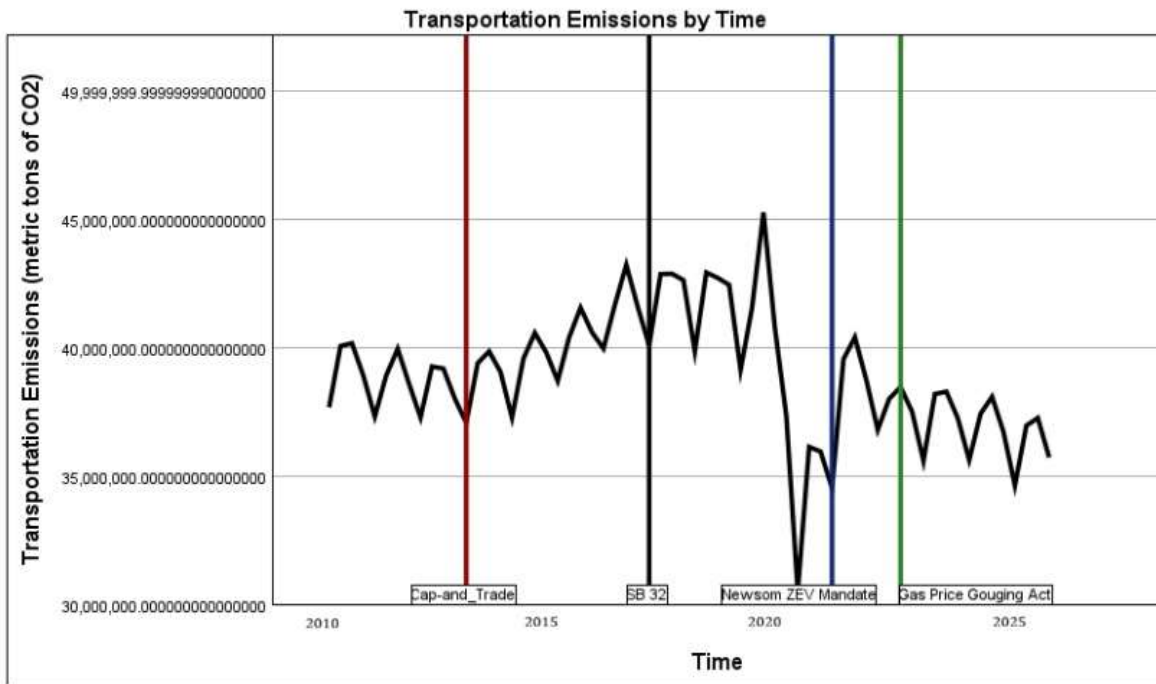


Figure 2 shows that CO<sub>2</sub> emissions in California change rather drastically quarter by quarter, but when viewed from a year-to-year perspective, shows a repetitive pattern of peaks and valleys consistently across the 64 quarter time frame. By 2015, the overall trend of transportation sector emissions began to steadily climb, peaking well over 45,000,000 metric tons of CO<sub>2</sub>, only for a massive drop to occur in 2020 due to the lockdowns. In Early 2021, we see a return to the

rhythmic peaks and valleys observed in the past, but the overall trend is moving slowly downwards towards 35,000,000 metric tons by 2025.

**Figure 2:** *Transportation Emissions, 2010-2025*



## Energy Sector

Figure 3 shows that California's Electrical Grid intensity follows a similar pattern to the Transportation sector's vehicle emissions, with repetitive peaks and valleys depending on quarter, but a clearer, observable trend year to year. The grid emissions took a drastic upwards step in 2013, and remained here until around 2015/2016, where they dropped back down to 2010/2011 adjacent levels. The downward level shift of -49.92 metric tons of CO<sub>2</sub> produced by California's electrical grid ( $p=.003$ ), while the renewable share of generated energy increased by 8.87 percent ( $p=.004$ ).

**Figure 3:** *Electrical Grid Emissions Intensity, 2010-2025*

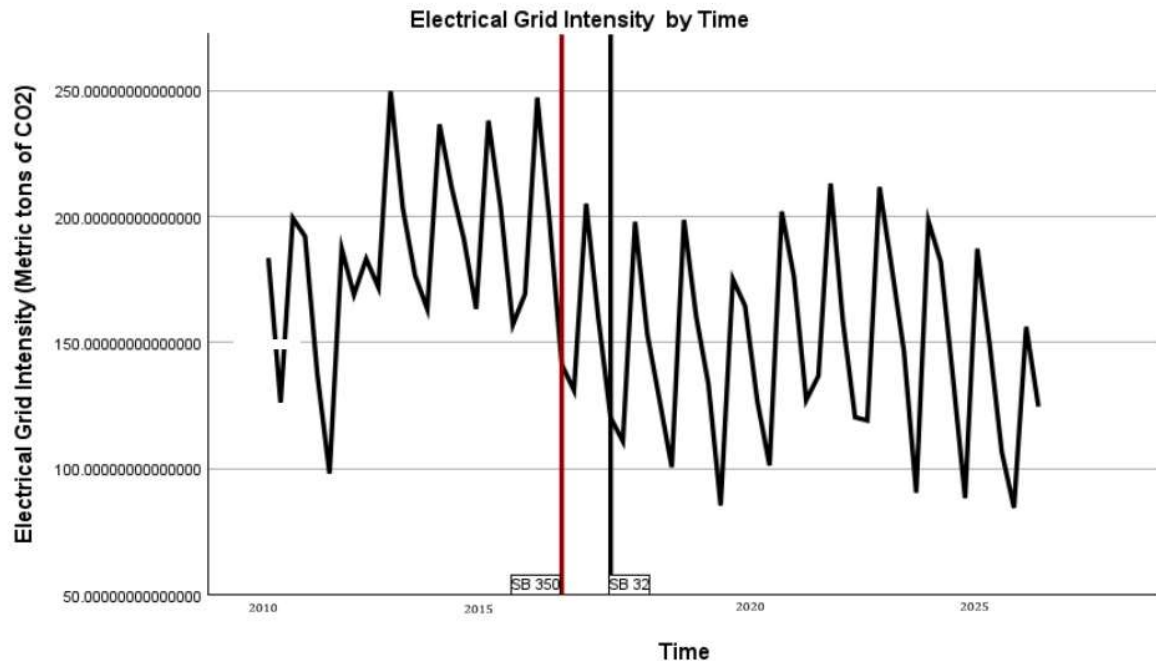
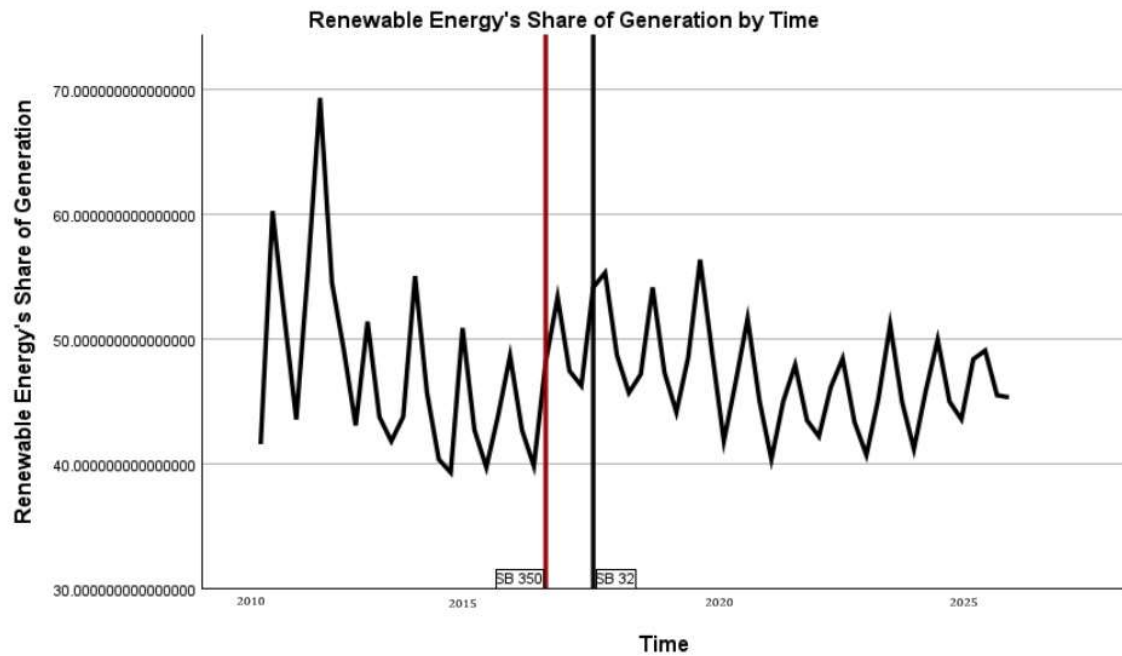


Figure 4 follows a similar pattern to figure 3, as the share of energy fluctuates heavily depending on quarter. While the highest peak of renewable energy's share came around 2011/2012, the variance between different quarters (i.e. quarters where renewable energy takes up more vs less of the share) tightens up over time.

**Figure 4:** Renewable Energy's Share of Generation, 2010-2025



### Contextual Analysis of Graphical Fluctuations and Exogenous Shocks

When viewing the above figures, various cyclical wave patterns and anomalies correspond directly with real world macro-shocks and grid operational constraints. In both Figure 1 and Figure 2 (Transportation Emissions and EV Adoption), a large drop in emissions and EV Adoption is present between quarters 40 and 44. This traces directly back to the 2020 COVID-19 pandemic lockdowns. As documented by the California Legislative Analyst's Office (2021), this period generated an unprecedented drop in commercial and non-commercial miles traveled that was independent of active regulatory policies.

In contrast, Figures 3 and 4 (Electrical Grid Intensity and renewable share) displays severe, repeating seasonal spikes that occur during the third quarter of every calendar year. These fluctuations capture the physical development of fossil-heavy natural gas peaker plants required to maintain grid stability during extreme heat waves in the summer. Despite ambient temperatures and extreme heat events trending upwards in California over the observed 15-year window, the height of these emissions has been decreasing while the range of renewable share has stabilized.

### **Multivariate Analysis: Multi-Sector Interactions & Spillover**

Below are isolated tables with statistical outcomes for each variable. With each of these models, multicollinearity arose when attempting to lump all the chosen independent variables for the study. To remedy this, variables were removed from each model systematically until a model with an acceptable autocorrelation test statistic was returned.

EV Adoption rates had the most difficult time with multicollinearity. The only version of the model that was able to be verified using the ARIMA (1,0,0) was this version which omitted all but EO N-79-20 and SB 100. Table 3 presents the regression results with only these two independent variables, both of which are statistically significant. EO N-79-20, which mandated only electric vehicles by 2035 was associated with an increase in electric vehicle sales, while SB 100, which mandates renewable energy, was associated with a similar decrease in electric vehicle sales.

**Table 3:** *Regression Matrix of Isolated Baselines and Cross-Sector Interactions for Model 1 (EV Adoption)*

| <b>Independent Policy Predictor</b> | <b>B value</b>    | <b>t-stat</b> | <b>Significance (p)</b> | <b>Auto Correlation***</b> |
|-------------------------------------|-------------------|---------------|-------------------------|----------------------------|
| <b>EO N-79-20</b>                   | <b>+7,271.411</b> | <b>2.472</b>  | <b>.017</b>             | Ljung-Box = .104           |
| <b>SB 100</b>                       | <b>-7,381.515</b> | <b>-2.086</b> | <b>.042</b>             | Ljung-Box = .104           |

*Note: Bolded numbers indicates statistically significant value*

Table 4 presents the regression results for Transportation Emissions. Similarly to above, each of the policies not listed here (EO N-79-20, Cap-and-Trade, and SB 350) had high VIF stats, which signified collinearity. They were individually removed, yielding this model with only SB 32, SB X1-2 and SB 100 as the most stable. Only SB X1-2 and SB 100 were statistically significant and both predictably were associated with a decrease in transportation emissions.

**Table 4:** *Regression Matrix of Isolated Baselines and Cross-Sector Interactions for Model 2 (Trans. Emissions)*

| <b>Independent Policy Predictor</b> | <b>B value</b>      | <b>t-stat</b> | <b>Significance (p)</b> | <b>Auto Correlation***</b> |
|-------------------------------------|---------------------|---------------|-------------------------|----------------------------|
| SB 32                               | -476,849.000        | -1.717        | .093                    | Durbin-Watson=2.262        |
| <b>SB X1-2</b>                      | <b>-621,587.000</b> | -5.972        | <b>&lt;.001</b>         | Durbin-Watson=2.262        |
| <b>SB 100</b>                       | <b>-609,981.101</b> | -2.429        | <b>.019</b>             | Durbin-Watson=2.262        |

*Note: Bolded numbers indicates statistically significant value*

Table 5 presents the regression results for Grid Intensity. From this model, SB 100, Cap-and-Trade, and SB X1-2 were all omitted. What most likely occurred was due to the implementation periods of these policies being so close to one another, that the model could not properly determine which policy had the strongest association with the observed grid intensity shifts. EO N-79-20, despite its insignificant p value, was included in the model due to its unpredicted result. Both SB 350 and SB 32, which encouraged renewable energy and discouraged fossil fuels respectively, were both statistically significant and associated with a decrease in electrical grid intensity.

**Table 5:** *Regression Matrix of Isolated Baselines and Cross-Sector Interactions for Model 3 (Grid Intensity)*

| <b>Independent Policy Predictor</b> | <b>B value</b> | <b>t-stat</b> | <b>Significance (p)</b> | <b>Auto Correlation</b> |
|-------------------------------------|----------------|---------------|-------------------------|-------------------------|
| <b>SB 350</b>                       | <b>-49.925</b> | -3.101        | <b>.003</b>             | Durbin-Watson=1.622     |
| <b>SB 32</b>                        | <b>-66.264</b> | -2.839        | <b>.006</b>             | Durbin-Watson=1.622     |
| EO N-79-20                          | -1.496         | -.758         | .452                    | Durbin-Watson=1.622     |

*Note: Bolded numbers indicates statistically significant value*

Finally, Table 6 presents the regression results for Renewable Energy Share. Cap-and-Trade, SB 100, and SB X1-2 were all excluded from this model due to multicollinearity issues most likely caused by proximity to one another. Each of these variables had VIFs well above the threshold of 10 for an acceptable level of correlation. SB 350 and SB 32 were statistically significant, both with a positive effect on renewable energy share. Similarly to above, EO N-79-20 was included despite its insignificant p value for its implications.

**Table 6:** *Regression Matrix of Isolated Baselines and Cross-Sector Interactions for Model 4 (Renewable Share)*

| <b>Independent Policy Predictor</b> | <b>B value</b> | <b>t-stat</b> | <b>Significance (p)</b> | <b>Auto Correlation</b> |
|-------------------------------------|----------------|---------------|-------------------------|-------------------------|
| <b>SB 350</b>                       | <b>+8.870</b>  | 3.013         | <b>.004</b>             | Durbin-Watson=1.589     |
| <b>SB 32</b>                        | <b>+12.304</b> | 2.922         | <b>.005</b>             | Durbin-Watson=1.589     |
| EO N-79-20                          | +.418          | 1.161         | .251                    | Durbin-Watson=1.589     |

*Note: Bolded numbers indicates statistically significant value*

## Discussion

### *Baseline Findings*

The statistically significant results for the baseline analyses on the transportation sector shows that each of these policies achieve their primary, native functions within their own sectors. Gavin Newsom's Executive Order calling for 100% of all automaker's vehicles sold in 2035 to be ZEVs drastically increased sales of Electric Vehicles. Executive Order N-79-20 resulted in a sales velocity jump of 7,271 vehicles per quarter ( $B = 7271.411$ ,  $p=.017$ ). It is worth noting that the slope at the time was already steep, as electric vehicles were gaining traction. However, a steep

increase of this size is a noticeable shift in the transportation sector, offsetting thousands of metric tons of CO<sub>2</sub> emissions from fossil fuels into the electrical generation sector.

Senate Bill 32 and X1-2 both successfully reduced carbon emissions. CO<sub>2</sub> emissions in the transportation sector were cut aggressively by California Senate Bill 32, which saw a substantial decrease in the trend of emissions by over 450 thousand metric tons ( $b=-476,849$ ,  $p<.001$ ). The Recent Gas Price Gouging Act (SB X1-2) accelerated this reduction, decreasing the observed emissions trend by 621,587 metric tons every quarter ( $p<.001$ ). Even following the pandemic, which reduced vehicle emissions by approximately 10%, the proactive policy implementation at this time prevented emissions from rising back up to lockdown levels.

Similarly, the energy sector made strides towards their goals, with the data trending towards proposed levels discussed by legislators. Senate Bill 32 succeeded in influencing energy sector policies such that grid carbon intensity was reduced. From 2016 onwards, grid intensity fell by 66.26 metric tons of CO<sub>2</sub> ( $p=.006$ ). SB 32 also pushed the renewable share of generated energy upwards by 12.3 percent in the immediate quarter following implementation ( $p=.005$ ). SB 350 compounded the impact, decreasing grid intensity by an additional 49 metric tons of CO<sub>2</sub> per year ( $p=.003$ ). These two Senate Bills, while achieving similar results, operate on relatively different methodologies. CA SB 350 focused on increasing renewable energy goals while promoting clean energy in disparaged communities. CA SB 32 focused on setting hard limits on greenhouse gas emissions throughout the state in all sectors, with energy generation specifically targeted in this bill. Regardless, both bills contributed to reductions in Grid Emissions intensity and an increase in renewable share.

### *Multi-Sector Analyses*

As hypothesized, SB 100's energy-sector policies requiring renewable energy directly influenced the effects of the transportation policies relating to carbon emissions, as seen from the impact on the slope of the emissions trajectory ( $B=-609,981.101$ ,  $p=.019$ ). This is also consistent with the integrated systems theories proposed by Gillingham, Ovaere, and Weber (2021). However, the relationship between the transportation and energy sectors is not an entirely direct relationship of positive or negative outcomes.

The findings reject one of the most prominent anti-EV narratives frequently cited by policy opponents: the claim that accelerating vehicle electrification simply shifts the carbon burden onto the electrical grid and that the energy grid cannot handle this burden transfer. EO N-79-20's insignificant impact against both grid emissions intensity and renewable share ( $p=.452$ ,  $p=.251$  respectively) demonstrates that the electrical grid was able to absorb thousands of new vehicles without worsening its baseline emissions. Based on these findings, it becomes evident that there is a direct line of influence from energy sector policies to transportation sector outcomes, but transportation sector policies seldom have any significant impact on the energy sector's environmental outcomes.

An unexpected finding of this study was the EV market cooling effect that began in 2019. The EV Adoption model associates this with Senate Bill 100, which was focused on promoting renewable energy. Gillingham et al (2021) claim that energy sector policies and transportation policies coexist as compliments, so this is a surprising result. It is important to note that this is an association and more likely a correlation that is not causal in nature. There is no logical mechanism for SB 100 to directly influence EV sales, as SB 100 solely regulates the electricity market. Instead, other factors likely played an important role in the slowing EV adoption rate in 2019. The

adoption of SB 100 was followed by the COVID-19 lockdowns, which was a more likely causal factor for a reduction in sales that contributed to this statistical outcome.

## **Chapter 5: Conclusion**

The data found from this study reinforces the understanding of multi-sector spillover and effects of policy implementations. Regarding the overarching hypothesis of the study, desired outcomes in the transportation sector received a boost when coupled with green policies tied to the energy sector. In short, environmental reforms in the transportation sector benefited from both its own policies and policies from the energy sector, while the energy sector benefitted from energy policies, but gained little from environmentally friendly transportation policies.

### **Policy Implications for Washington State**

The interactions observed between California's Transportation and energy sectors offer vital lessons for the State of Washington. As Washington moves forward with its landmark 2026 agreement to officially link its cap-and-invest carbon market with California and Quebec, understanding the cross-sector interactions will be key to ensuring the state executes an optimized strategy to achieve its goals.

California's policy strategy proves that regulatory instruments clearly do not operate independently. The fact that Energy sector policies effectively amplified positive transportation sector outcomes, and that the shifting of the carbon burden caused by EO N-79-20 had no significant impact on energy sector emissions outcomes demonstrates the positive relationship between these two policy sectors. So long as Washington's Electrical grid continues to grow at a pace strong enough to support fast paced electrification, the state should see a similar interaction to what California experienced during the observation period. To achieve this, as Washington plans to roll out EV and electrification mandates similar to California, it must bundle these policies along with ones that bolster the electrical grid and stifle its emissions. Regional grid assessments

per the ICF claim that a 4-7 GigaWatt increase in electrical distribution system capacity in the state of WA in order to accommodate for a complete shift from ICE to EVs (ICF, 2025). Without these changes, Washington State's carbon emissions burden would be entirely shifted to the electrical sector rather than being absorbed as it was in California.

### **Limitations & Constraints**

While this study is meticulous in its attempts to control for different outside impacts to each of the climate indicators, there are two main limitations that this study faces.

The usage of statewide aggregated data points, while informative, means that the study is entirely unable to track intra-state geographic disparities. Considering California is a geographically large and diverse state, the study unfortunately treats every single area as one specific region. In its current form, it is unable to differentiate how these policies behave in wealthy coastal cities like San Francisco or Los Angeles from inland or rural cities like Sacramento or Barstow. Due to the differences in population density and priorities, it is likely that the populous coastal cities are being overrepresented while the inland cities are being underrepresented. Nevertheless, this study provides a good starting point that can be built upon in the future.

Despite controlling for weather, time trends, and GDP, the current models are unable to account for federal policy shifts or global supply chain stocks. This study attempts to treat the state of California and its policies as if it exists in a vacuum. Unfortunately, since these National and Global variables have measurable effects in the selected policy sectors, directly analyzing the state in an isolated manner produces insightful findings, but ultimately must be further analyzed and contextualized using controls on these outside variables.

A critical constraint of this time-series analysis is the structural misalignment between a policy's effective date and its operational market effect time. In piecewise segmented analyses, impacts are typically isolated via abrupt level step-changes or post intervention slope adjustments that happen immediately after a policy is implemented. In real world applications however, institutional factors introduce significant implementation lags that delay observed impacts. Because of these lags, evaluating a policy strictly based on immediate trend breaks can lead the model to underestimate its early cumulative impact.

### **Future Studies & Follow-up Research**

Considering the current findings and limitations, what will most likely yield the most insightful information would be tackling the intra-state differences in these policies between different regions of the State of California. The simplest method of doing so would be to downscale this study into specific counties, cities, or census tracts to not only find out how they differ from this study but how each selected region differs from one another. A comprehensive study detailing the specific differences between all the regions of California would yield Legislators and Policymakers with further insight on how to optimize their strategy to hit their aggressive targets in the allotted time.

## **Conclusion**

The empirical findings yield two definitive conclusions regarding multi-sector policy complementarity. First, the analysis established conclusive proof of positive policy spillovers, demonstrating that utility-sector clean energy rules (Senate Bill 100) actively accelerated emissions reductions inside the transportation sector. By forcing the power grid to decarbonize, the grid mandate amplified the carbon-cutting capacity of every electric vehicle deployed under the state's vehicle regulations. Second, the study uncovered proof of a vital "no-penalty" phenomenon regarding grid stability. Despite a substantial acceleration in electric vehicle sales driven by Executive Order N-79-20, the rapid deployment of clean cars did not overload the sub-national energy grid or cause a corresponding spike in power-sector emissions intensity. Taken together, these metrics prove that California's grid expanded its clean generation capacity rapidly enough to absorb the new vehicle charging load, successfully maintaining a safe, cross-sector environmental equilibrium.

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|                     |                      | Model Statistics     |                 |    |      |                    |
|---------------------|----------------------|----------------------|-----------------|----|------|--------------------|
| Model               | Number of Predictors | Model Fit statistics | Ljung-Box Q(18) |    |      | Number of Outliers |
|                     |                      | Stationary R-squared | Statistics      | DF | Sig. |                    |
| Ev_Adoption-Model_1 | 6                    | .953                 | 23.161          | 17 | .144 | <.001              |

[illegible]

*Model 2 (Transportation Emissions) Outputs*

**Model Summary<sup>b</sup>**

| Model | R                 | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|-------|-------------------|----------|-------------------|----------------------------|---------------|
| 1     | .967 <sup>a</sup> | .935     | .911              | 748229.57043               | 2.262         |

a. Predictors: (Constant), Policy5\_slope, Heating Degree days, Policy1\_step, Policy 3\_step, Policy7\_Slope, Cooling Degree Days, Policy5\_step, Policy2\_step, Policy7\_step, Policy4\_step, Policy6\_step, GDP, Time, Policy6\_slope, Policy4\_slope, Policy2\_slope, Policy3\_slope

b. Dependent Variable: Trans\_Emissions

**Coefficients<sup>a</sup>**

| Model |                     | Unstandardized Coefficients |             | Standardized Coefficients | t      | Sig.  | Collinearity Statistics |          |
|-------|---------------------|-----------------------------|-------------|---------------------------|--------|-------|-------------------------|----------|
|       |                     | B                           | Std. Error  | Beta                      |        |       | Tolerance               | VIF      |
| 1     | (Constant)          | -17267089.286               | 5787368.113 |                           | -2.984 | .005  |                         |          |
|       | Time                | -401085.446                 | 88083.025   | -.2970                    | -4.553 | <.001 | .003                    | 302.669  |
|       | GDP                 | 27.677                      | 2.702       | .4469                     | 10.243 | <.001 | .007                    | 135.460  |
|       | Heating Degree days | -2573.267                   | 418.804     | -.511                     | -6.144 | <.001 | .203                    | 4.917    |
|       | Cooling Degree Days | -806.947                    | 682.862     | -.097                     | -1.182 | .243  | .206                    | 4.843    |
|       | Policy1_step        | -870503.607                 | 768919.991  | -.127                     | -1.132 | .263  | .112                    | 8.911    |
|       | Policy2_step        | 56731.730                   | 707612.522  | .009                      | .080   | .936  | .115                    | 8.720    |
|       | Policy2_slope       | -112347.882                 | 110398.173  | -.767                     | -1.018 | .314  | .002                    | 404.046  |
|       | Policy4_step        | -805634.068                 | 858879.976  | -.160                     | -.938  | .353  | .048                    | 20.753   |
|       | Policy4_slope       | -609300.623                 | 354954.516  | -2.940                    | -1.717 | .093  | .000                    | 2087.421 |
|       | Policy6_step        | -2423840.088                | 838023.320  | -.461                     | -2.892 | .006  | .055                    | 18.111   |
|       | Policy6_slope       | 1152888.381                 | 216322.234  | 3.054                     | 5.329  | <.001 | .004                    | 233.611  |
|       | Policy7_step        | -356785.864                 | 654252.051  | -.054                     | -.545  | .588  | .144                    | 6.965    |
|       | Policy7_Slope       | -621587.523                 | 104083.614  | -.652                     | -5.972 | <.001 | .118                    | 8.474    |
|       | Policy3_slope       | 393502.595                  | 341052.820  | .2126                     | 1.154  | .255  | .000                    | 2417.093 |
|       | Policy 3_step       | 140670.746                  | 1005402.685 | .027                      | .140   | .889  | .037                    | 27.083   |
|       | Policy5_step        | 746326.170                  | 903684.521  | .148                      | .826   | .413  | .044                    | 22.974   |
|       | Policy5_slope       | -609981.101                 | 251102.246  | -2.191                    | -2.429 | .019  | .002                    | 578.712  |

a. Dependent Variable: Trans\_Emissions

*Model 3 (Grid Intensity) Outputs*

**Model Summary<sup>b</sup>**

| Model | R                 | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|-------|-------------------|----------|-------------------|----------------------------|---------------|
| 1     | .825 <sup>a</sup> | .680     | .633              | 25.147847642               | 1.794         |

a. Predictors: (Constant), Policy3\_slope, Heating Degree days, Policy2\_step, Policy 3\_step, Cooling Degree Days, GDP, Time, Policy2\_slope

b. Dependent Variable: Grid\_intensity

**Coefficients<sup>a</sup>**

| Model |                     | Unstandardized Coefficients |            | Standardized Coefficients | t      | Sig.  | Collinearity Statistics |         |
|-------|---------------------|-----------------------------|------------|---------------------------|--------|-------|-------------------------|---------|
|       |                     | B                           | Std. Error | Beta                      |        |       | Tolerance               | VIF     |
| 1     | (Constant)          | -103.344                    | 150.900    |                           | -.685  | .496  |                         |         |
|       | Time                | 2.375                       | 2.302      | 1.065                     | 1.032  | .307  | .005                    | 183.034 |
|       | GDP                 | 8.611E-5                    | .000       | .842                      | 1.210  | .231  | .012                    | 83.126  |
|       | Heating Degree days | .055                        | .013       | .657                      | 4.063  | <.001 | .222                    | 4.500   |
|       | Cooling Degree Days | .155                        | .022       | 1.135                     | 7.024  | <.001 | .223                    | 4.487   |
|       | Policy2_step        | -2.156                      | 20.672     | -.020                     | -.104  | .917  | .152                    | 6.588   |
|       | Policy2_slope       | -4.207                      | 3.112      | -1.739                    | -1.352 | .182  | .004                    | 284.292 |
|       | Policy 3_step       | -49.925                     | 16.100     | -.587                     | -3.101 | .003  | .163                    | 6.148   |
|       | Policy3_slope       | -.272                       | 2.170      | -.089                     | -.125  | .901  | .012                    | 86.661  |

a. Dependent Variable: Grid\_intensity

*Model 4 (Renewable Share) Outputs*

**Model Summary<sup>b</sup>**

| Model | R                 | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|-------|-------------------|----------|-------------------|----------------------------|---------------|
| 1     | .571 <sup>a</sup> | .326     | .227              | 4.8359100702               | 1.589         |

a. Predictors: (Constant), Policy6\_slope, Heating Degree days, Policy4\_step, Policy6\_step, Cooling Degree Days, Time, Policy4\_slope, GDP

b. Dependent Variable: Renewable Share

**Coefficients<sup>a</sup>**

| Model |                     | Unstandardized Coefficients |            | Standardized Coefficients | t      | Sig. | Collinearity Statistics |        |
|-------|---------------------|-----------------------------|------------|---------------------------|--------|------|-------------------------|--------|
|       |                     | B                           | Std. Error | Beta                      |        |      | Tolerance               | VIF    |
| 1     | (Constant)          | 78.730                      | 28.407     |                           | 2.771  | .008 |                         |        |
|       | Time                | -.157                       | .303       | -.532                     | -.519  | .606 | .012                    | 85.634 |
|       | GDP                 | -8.406E-6                   | .000       | -.620                     | -.614  | .542 | .012                    | 83.308 |
|       | Heating Degree days | -.009                       | .003       | -.806                     | -3.393 | .001 | .217                    | 4.604  |
|       | Cooling Degree Days | -.013                       | .004       | -.691                     | -2.904 | .005 | .217                    | 4.619  |
|       | Policy4_step        | 9.702                       | 3.437      | .882                      | 2.823  | .007 | .126                    | 7.955  |
|       | Policy4_slope       | -.048                       | .342       | -.105                     | -.139  | .890 | .022                    | 46.389 |
|       | Policy6_step        | -1.733                      | 3.334      | -.151                     | -.520  | .605 | .146                    | 6.861  |
|       | Policy6_slope       | .418                        | .360       | .506                      | 1.161  | .251 | .065                    | 15.464 |

a. Dependent Variable: Renewable Share