APPENDIX J – UNCERTAINTY ANALYSIS

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California 2030 Uncertainty Analysis

The 2022 Scoping Plan charts an ambitious path for California to achieve carbon neutrality and reduce anthropogenic emissions by 85% below 1990 levels no later than 2045. The plan builds on California's existing suite of climate and air quality policies that have impacted all sectors of the economy and helped the state achieve its 2020 targets years ahead of schedule. But as outlined in the PATHWAYS modelling of the 2022 Scoping Plan Reference Scenario, California will not achieve carbon neutrality in 2045 under current policy - additional actions are needed.

There is also uncertainty that the current mix of policies (regulations, incentives, and carbon pricing) will be sufficient to achieve California's 2030 target, at least 40% below 1990 greenhouse gas (GHG) emissions. Uncertainty is an inherent part of emissions forecasting and modeling – there is no model capable of predicting the future with perfect accuracy. As the on-going global COVID-19 pandemic and recovery has demonstrated, unexpected events can dramatically impact human welfare, economic activity, and GHG emissions.

In this analysis, we identify the drivers of uncertainty and analyze the potential impact of implementation delays on GHG emissions in 2030. That is, what if delayed implementation of actions as defined in the Scoping Plan Reference Scenario fail to achieve anticipated GHG reductions by 2030? This uncertainty analysis focuses on progress in achieving the 2030 target of at least 40% below 1990 levels by 2030 and does not include an assessment of the uncertainty faced in implementing the Scoping Plan scenario for achieving carbon neutrality by 2045.

We construct two scenarios that capture the largest emissions impact in 2030 from delays in implementation under the Scoping Plan Reference Scenario: delayed renewable capacity and delayed transportation electrification. We quantify the magnitude of the emissions impact under these two scenarios, highlighting the importance of these two actions in achieving the reductions outlined in the Scoping Plan Reference Scenario to hit California's 2030 climate target.

Uncertainty in California's 2022 Scoping Plan Reference Scenario

The main drivers of future GHG emissions – technology costs, energy prices, macroeconomic conditions, and policy implementation – are not known with perfect certainty. Modelers make informed assumptions about these drivers and estimate a range of GHG emissions based on historic, current, and potential future trends.

Unanticipated changes in these variables impact GHG emissions, however they are largely outside the control of policy makers. In just the past few years, we have seen global geopolitical and macroeconomic events dramatically alter energy prices, technology costs, and GHG emissions in California. The impacts of these events are still being felt and will continue to impact California's economy and emissions – but are largely outside the control of the State.

This analysis focuses on the climate policies included in the 2022 Scoping Plan Reference Scenario as modeled by Energy and Environmental Economics, Inc. (E3). We focus on the uncertainties related to implementation that can potentially be addressed and mitigated through additional policy interventions. For each Scoping Plan Reference Scenario sector assumption, we evaluated the implementation risk and potential vulnerability to achieving the policy objective. Table 1 provides an overview of our findings.

Table 1. 2022 Scoping Plan Reference Scenario assumptions and implementation risk[1]

Sector	Scoping Plan Reference Scenario Assumptions	Risk
Buildings	Align with 2019 Integrated Energy Policy Report[2] Mid-Mid (gas and electric)	none
	25% all-electric new construction starting in 2026 with 15% of sales of electric devices for existing buildings by 2030	consumer demand supply of electric devices transmission permitting renewable infrastructure
Electricity	38 MMT statewide GHG constraint by 2030, 60% RPS by 2030 and beyond	transmission and renewable generation permitting expansion of existing renewable capacity new renewable capacity

[1] The analyzed risks are not inclusive of all potential risks of achieving the emissions levels outlined in the Scoping Plan Reference Scenario. The analyzed risks are the scenario assumptions from E3's modeling of the of 2022 Scoping Plan Reference Scenario using PATHWAYS detailed in Appendix H.

[2] https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report

Sector	Scoping Plan Reference Scenario Assumptions	Risk
Industry	Petroleum refining energy demand ramped down in line with in-state petroleum demand Oil & Gas extraction ramped down to 30% below 2019 levels by 2030 and 40% by 2045, aligned with California Institute for Transportation Studies business as usual scenario[3]	demand for petroleum remains high demand for petroleum remains high
Transportation	VMT per capita reduced 4% below 2019 levels by 2045, aligned with MSS BAU scenario	VMT remains static or increases through 2030
	40% LDV ZEV sales by 2030, minimal MHDV decarbonization aligned with CA ITS BAU scenario	vehicle availability public charging permitting and installation low consumer adoption across certain regions and populations electricity transmission permitting
	No aviation, ocean-going vessel, cargo-handling equipment, or rail decarbonization beyond implementation of regulations as of 2020	none
	LDV fuel economy standards aligned with EMFAC 2017	none
	Truck fuel economy reflect Phase 2 GHG Standards	none
	Align with LCFS through 2030 and beyond	low feedstock availability
Carbon Dioxide Removal	No CDR	None
Methane and HFCs	SB 1383 organic waste reduction goal is achieved by 2025	organic waste diversion infrastructure permitting low participation in organic diversion
	Organic waste diverted: 11 MMT from compost, 1.8 from anaerobic digestion, 0.2 from co-digestion	Permitting and construction of organic waste infrastructure

[3] https://escholarship.org/uc/item/3np3p2t0

Sector	Scoping Plan Reference Scenario Assumptions	Risk
	SB 1383 40% reduction from dairy and livestock below 2013 by 2030 AMMP and Dairy Digesters reduce emissions by 4.6 MMT through 2030	dairy digester permitting dairy digester adoption dairy digester adoption
	No additional MMP implemented beyond 2020	None
	SB 1383 40% HFCs below 2013 by 2030	supply side disruptions

We also quantified the magnitude of the potential impact on GHG emissions of failing to achieve the sector assumptions. We then constructed two sensitivity scenarios that encapsulate the largest potential GHG impact in 2030 – delays in renewable energy capacity buildout and delays in transportation electrification.

Implementation risk

This analysis focuses on the implementation risk of achieving the Scoping Plan Reference Scenario assumptions in the power and transportation sectors. We also focus on risks and uncertainties that can be addressed through policy intervention in California.

Delayed renewable capacity scenario

In the Scoping Plan Reference Scenario, California has a 38 MMT GHG constraint in the power sector and achieves a 60% Renewable Portfolio Standard (RPS) by 2030 as required in SB 100.[4] Under the delayed renewable capacity scenario, we construct an emissions trajectory from 2022 to 2030 under a 5-year delay in renewable capacity including infrastructure for existing renewable facilities as well as delays in permitting and construction for new renewable generation and transmission.

In 2020, 34.5% of California's retail electricity sales were RPS eligible coming from solar, wind, geothermal, or small hydroelectric sources.[5] This leaves a sizable gap to achieving the power sector emissions outlined in the Scoping Plan Reference Scenario. California agencies estimate that achieving the goals of SB 100 will require 6 GW of new solar,

[4] https://www.energy.ca.gov/sb100

[5] https://www.energy.ca.gov/news/2022-02/new-data-indicates-california-remains-ahead-clean-electricity-goals#:~:text=SACRAMENTO%20%2D%2D%20Data%20from%20the,zero%2Dcarbon%20sources%20in%202020.

wind, and battery resources annually for the next 25 years.[6] This requires nearly tripling existing solar and wind build rates and an eight-fold acceleration in battery storage to achieve the 2030 and 2045 targets in SB 100. Any delays in zoning, permitting, and siting of renewable generation and transmission expansion jeopardize the goals of SB 100 and SB 32 and put California off track in achieving its 2030 target and carbon neutrality by 2045. Environmental review, jurisdictional overlap, and land use considerations can lengthen permitting timelines, causing delays in construction and renewable generation that can provide energy to California's electric grid.

According to the California Public Utility Commission (CPUC), transmission projects can take 13 years to complete – from planning through construction.[7] Up to three years can be spent in the planning phase while construction is estimated to take one to five years. The stated timeline for permitting projects is three to four years, however recent efforts have tried to shorten this timeline. In 2022, AB 205 passed which requires the California Energy Commission to approve certain classes of renewable projects within 270 days.[8]

The unprecedented growth in renewable capacity and lengthy permitting process puts the power sector at risk of failing to achieve the 60% RPS in 2030 as assumed in the Scoping Plan Reference Scenario. However, policy interventions like AB 205 could reduce the risk of delayed renewable capacity.

Delayed transportation electrification

In the transportation sector, there are two assumptions driving emissions in 2030 in the Scoping Plan Reference Scenario- per-capita vehicle miles travelled (VMT) are reduced 4% below 2019 levels by 2045 and 40% of light-duty vehicle (LDV) sales are zero emission vehicles (ZEV) by 2030 (with minimal medium-duty and heavy-duty vehicle decarbonization) aligned with California Institute for Transportation Studies (ITS) BAU scenario. In California, per-capita VMT increased from 2017 to 2019.[9] Therefore, the assumption that VMT decreases, even marginally, without additional action is a risk to achieving the 2030 emissions under the Scoping Plan Reference Scenario. However, the overall emissions impact in 2030 of failing to achieve the 4% per capita VMT reduction

[6] https://www.energy.ca.gov/news/2021-03/california-releases-report-charting-path-100-percent-clean-electricity

[7] https://www.cpuc.ca.gov/-/media/cpuc-website/files/legacyfiles/g/5065-general-information-on-permitting-electric-transmission.pdf

[8] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220AB205

[9] https://dot.ca.gov/programs/sustainability/sb-743/california-vmt-data

is relatively small under the Scoping Plan Reference Scenario as compared to the emissions impact of near-term transportation electrification.

Delaying electrification transportation has the second largest GHG emissions impact related to implementation uncertainty, compared to the GHG impact of delayed renewables deployment. In the Scoping Plan Reference Scenario, 40% of LDV sales are ZEV in 2030. In 2021, 13% of LDV sales were ZEVs. Increasing sales to 40% over the next decade requires an available supply of ZEVs, sufficient infrastructure to support in-home and public charging, and consumer demand for ZEVs. There is uncertainty and risk related to global ZEV supply and penetration, as global demand for ZEVs is increasing[10] there are growing concerns about ZEV availability due to global supply chain issues and potential shortages in raw materials that can impact battery and vehicle production.

At the state level, a suite of regulations and incentives have been driving ZEV adoption including the Clean Fuel Reward Program, Clean Vehicle Rebate Program (CVRP), Advanced Clean Cars, the Low Carbon Fuel Standard (LCFS), Clean Cars 4 All, and Advanced Clean Trucks. In addition, California has an array of incentive programs to support public and private LDV, MDV, and HDV vehicle charging infrastructure.[11]

However, there are risks that these existing programs may not be adequate. As of 2021, there were nearly 200,000 electric vehicle chargers installed or planned in California. However, to support California zero emissions fleets, an estimated 1.2 million chargers will be needed by 2030.[12] Despite California's aggressive ZEV funding, there are concerns about ZEV penetration and adoption especially in low income and disadvantaged communities.[13]

Delays in vehicle electrification will also impact emissions in the industrial sector. If California does not reach 40% LDV ZEV sales and does not achieve any decarbonization in the medium- and heavy-duty sectors, there will be an increase in gasoline and diesel combustion relative to the Scoping Plan Reference Scenario in 2030. This could impact the Scoping Plan Reference Scenario assumption[14] that oil and gas extraction ramps down in line with demand and is reduced to 30% below 2019 levels by 2030. Under

[10] https://www.iea.org/commentaries/how-global-electric-car-sales-defied-covid-19-in-2020

[11] https://ww2.arb.ca.gov/zero-emission-vehicle-zev-infrastructure-topics

[12] https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127

[13] While this analysis focuses on the uncertainty of electric vehicle penetration, there are other zero emission vehicle technologies including hydrogen for fuel cell vehicles across all vehicle classes.

[14] This assumption is included in E3's PATHWAYS Scoping Plan Reference Scenario which is detailed in Appendix H.

delayed electrification, California's demand for petroleum will increase relative to the levels assumed in the Scoping Plan Reference Scenario.

Similar to the delay in renewable capacity, policy interventions can potentially prevent the delay in transportation electrification (e.g. streamlining permitting of ZEV infrastructure and consumer adoption).

The Rhodium reference scenario

We analyze the 2030 GHG emissions impact of the two uncertainty scenarios - delayed renewable capacity and delayed transportation electrification – relative to a reference scenario of California's projected GHG emissions in 2030. For this uncertainty analysis, we use California's 2030 emissions from Taking Stock 2022 as the reference scenario (Rhodium reference scenario).

Each year, Rhodium Group completes an independent analysis of future US GHG emissions based on a range of economic and technology trends. Taking Stock 2022 was completed in July 2022 and represents our most recent assessment of GHG emissions through 2030.[15] To model future GHG emissions, we use RHG-NEMS, a modified version of the detailed National Energy Modeling System (NEMS)[16] used by the Energy Information Administration (EIA) to produce the Annual Energy Outlook (AEO) 2022.[17] RHG-NEMS includes all US economic sectors and includes projections for the six gases targeted for reduction under the Kyoto Protocol.

US emissions projections are then downscaled for all 50 states. RHG-NEMS forecasts fuel consumption by sector at varying levels of geographic aggregation which are then downscaled to the state-level using state-level activity data. For the power sector, RHG-NEMS reports individual plant-level emissions, however projections of fuel consumption across other sectors are downscaled to the state-level from census-level GHG emissions using state shares of historic fuel consumption. Additional detail on RHG-NEMS and downscaling can be found in Taking Stock 2022.[18]

The Rhodium reference scenario is the California downscaled emissions projection from Taking Stock 2022's central emissions scenario. The Rhodium reference scenario

[15] https://rhg.com/research/taking-stock-2022/

[16] https://www.eia.gov/outlooks/aeo/nems/documentation/

[17] https://www.eia.gov/outlooks/aeo/

[18] https://rhg.com/wp-content/uploads/2022/07/Taking-Stock-2022_US-Emissions-Outlook.pdf

includes 6 gas GHG emissions projections under central energy market and clean technology costs and baseline economic growth through 2030.

While the uncertainty scenarios explore the impact of implementation uncertainty, Taking Stock 2022 included sensitivities to understand the trends driving emissions and their potential impact in 2030. The four main drivers of emissions in Taking Stock 2022 are macroeconomic assumptions, state and federal policy, oil and natural gas prices, and clean technology costs.

Emission drivers

Based on assumptions across these four drivers we constructed three emissions scenarios in Taking Stock 2022: low, central, and high. The Taking Stock 2022 low emissions scenario includes low clean technology costs, high oil and gas prices, and central macroeconomic conditions. The central emissions scenario includes central energy market prices and technology costs and baseline economic growth. The high emissions scenario includes high clean technology costs, low oil and natural gas prices and high economic growth. This analysis is based on Taking Stock 2022's central emissions scenario.

Under the central emissions scenario, we project that annual economic growth averages 2.3% through 2025 and slows to 1.8% average growth from 2026 through 2030. This is in line with the AEO 2022 low economic growth rates and current federal macroeconomic forecasts. Oil and natural gas prices are calibrated to EIA's June 2022 Short-Term Energy Outlook (STEO)[19] through 2023, after which we generally aligned with the reference case and high and low oil and gas resource cases from AEO 2022. Under the central emissions scenario, renewable generation and utility-scale energy storage technology costs are based on the moderate cases from the National Renewable Energy Laboratory's (NREL) Annual Technology Cost Baseline 2022.[20] We use electric vehicle battery costs from Bloomberg New Energy Finance (BNEF)[21] and NREL's Electrification Futures Study.[22]

Taking Stock 2022's central emissions scenario also includes all actionable state and federal policies on the books as of June 2022. This does not include proposed regulations (like the EPA oil and gas methane rule) or California's Advanced Clean Cars II regulation that was passed in August 2022. All other substantiative California policies

[19] https://www.eia.gov/outlooks/steo/

[20] https://atb.nrel.gov/electricity/2022/index

[21] https://about.bnef.com/new-energy-outlook/

[22] https://www.nrel.gov/analysis/electrification-futures.html

included in the Scoping Plan Reference Scenario are included in the Rhodium reference scenario.

In addition, the California Cap-and-Trade Program is included in the Taking Stock 2022 central emissions scenario which reflects state and federal policies included in NEMS.[23] California's Cap-and-Trade Program is represented through increased energy prices that flow across economic sectors.[24] However, some of the emissions covered by the California Cap-and-Trade Program are not energy and fuel related emissions, and given that RHG-NEMS is an energy systems model, RHG-NEMS does not explicitly model the entire Cap-and-Trade program effects.

The Rhodium reference case also includes the emissions impact of the Inflation Reduction Act (IRA) that was signed on August 16, 2022.[25] The IRA is a climate change and clean energy investment package that represents the largest action ever taken by the US government on climate change. We find that the IRA will drive clean energy investment and lower household energy costs and reduce US GHG emissions 32 to 42% below 2005 levels by 2030, relative to 24 to 35% under Taking Stock 2022.[26]

The package will drive emission reductions across sectors with tax incentives and credits targeting domestic manufacturing of clean technology to accelerate deployment of emerging clean technologies. The IRA will have a profound impact on US emissions, and in turn, will affect the emissions trajectory of states. This analysis represents the first time that a state-level GHG forecast has included the impacts of the IRA.

Rhodium reference scenario emissions

Under the Rhodium reference scenario, California emits 324 million metric tons (MMT) of carbon dioxide equivalent (CO2e) in 2030. The Rhodium reference scenario reflects the sector assumptions in the Scoping Plan Reference Scenario – including 40% LDV ZEV sales and 60% RPS in 2030.

The Rhodium reference scenario used in this analysis varies from the Scoping Plan Reference Scenario as they rely on different technology and energy costs, deployment rates, economic assumptions - including recovery from the COVID-19 pandemic, and the state and federal policies included in the forecast. For instance, the Scoping Plan Reference Scenario is based on EIA's technology cost projections from the Annual

[23] https://www.eia.gov/outlooks/aeo/assumptions/pdf/summary.pdf

[24] https://www.eia.gov/outlooks/aeo/assumptions/pdf/electricity.pdf

[25] https://www.congress.gov/bill/117th-congress/house-bill/5376/text

[26] https://rhg.com/research/climate-clean-energy-inflation-reduction-act/

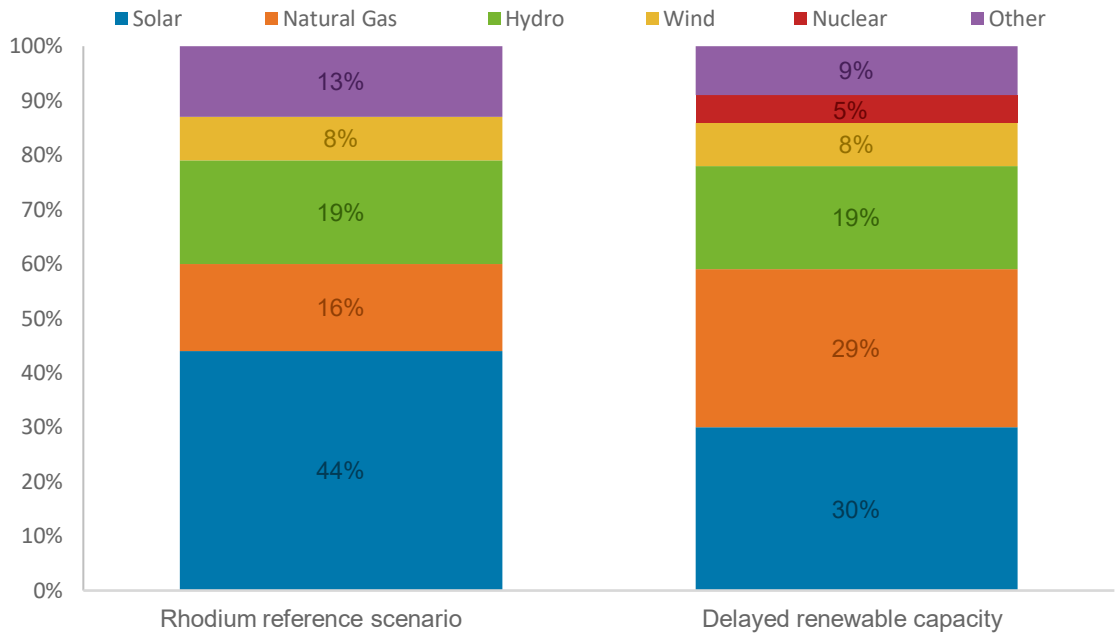
Energy Outlook (AEO) from 2021. The Rhodium reference scenario uses cost projections from AEO 2022 as well as EIA's June 2022 STEO. The Rhodium reference scenario also includes adjustments to oil and gas prices through 2023 to reflect the near-term impact of the war in Ukraine on global prices. These modifications are not included in the Scoping Plan Reference Scenario.

The Rhodium reference scenario also includes the impacts of the IRA as well as all the federal and state polices on the books as of June 2022. This represents a different set of polices than those included in the Scoping Plan Reference Scenario.

Delayed renewable capacity scenario

In the delayed renewable capacity scenario, there is widespread delay of permitting and construction of renewable capacity – both expansion of existing capacity and new generation and transmission. Constraints will impact the share of renewable electricity available to satisfy California demand, increasing emissions in the power sector. In this scenario, we model the impact of a 5-year delay in renewable capacity which increases California's power sector emissions and changes the generation mix. Figure J-1 outlines the change in California's power generation under the Rhodium reference scenario and the delayed renewable capacity scenario.

Figure J-1. California generation mix in 2030 under the Rhodium reference scenario and the delayed renewable capacity scenario



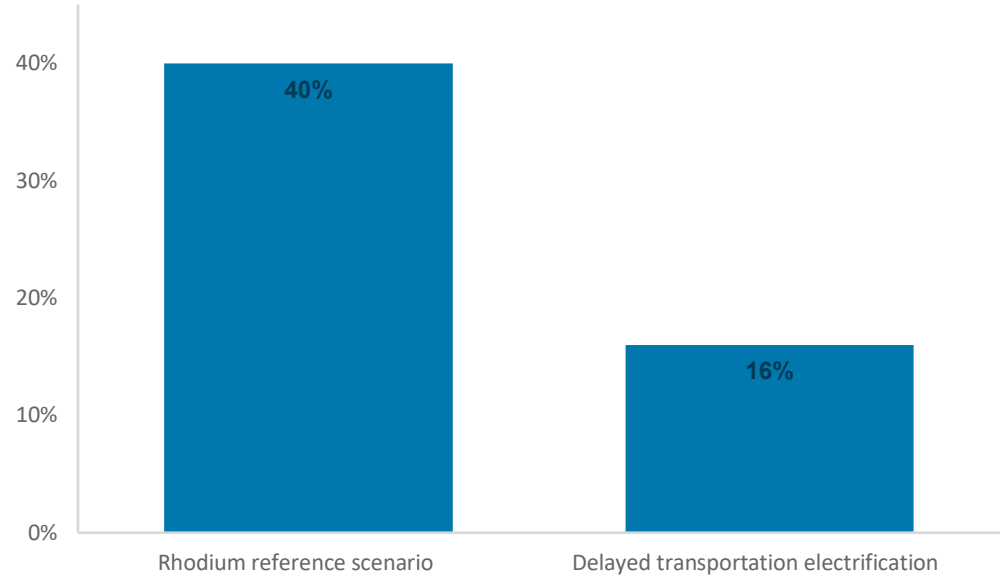
Delaying renewable generation and transmission reduces the anticipated GHG emission reductions from the California power sector in 2030. Delays in permitting and construction constraints on renewable generation and transmission across the WECC will alter California's power mix, increasing emissions. Under the delayed renewable capacity scenario, California emissions reach 349 MMT in 2030, an 8% increase in California GHG emissions in 2030 relative to the Rhodium reference scenario.

Delayed transportation electrification scenario

In this scenario, California does not adopt electric vehicles and charging infrastructure at the rates anticipated in the Rhodium reference scenario.[27] In this scenario, LDV ZEV sales are 16% of sales in 2030 compared to 40% assumed in the Rhodium reference scenario, as shown in Figure J-2.

[27] While this analysis focuses on the uncertainty of electric vehicle penetration, there are other zero emission vehicle technologies including hydrogen for fuel cell vehicles across all vehicle classes.

Figure J-2. California ZEV sales in 2030 under the Rhodium reference scenario and the delayed transportation electrification scenario



The delayed transportation electrification scenario represents a lower amount of ZEV sales from levels in the Rhodium reference scenario, which could be caused by a lack of vehicle availability, lack of charging stations, or low consumer demand.

The lower LDV ZEV penetration causes a change in the amount of gasoline combusted in California as well as the amount of oil extracted and refined in the state. We assume that the fraction of petroleum combusted in California sourced in California remains constant through 2030 and find that industrial emissions related to oil and gas extraction and refining will increase slightly in 2030 due to lower ZEV adoption.

We also model a lower penetration of medium- and heavy-duty vehicle (MDV and HDV) adoption and infrastructure but at a more modest level than LDVs based on the low levels of MDV and HDV electrification in the Scoping Plan Reference Scenario, 2% and nearly zero, respectively in 2030. But even modest reductions in MDV and HDV ZEV sales increase emissions from diesel combustion and industrial emissions from increased oil and gas production in California in 2030.

Under the delayed transportation electrification scenario, California emissions are 343 MMT in 2030, an increase of 6% relative to the Rhodium reference scenario.

Conclusions and extensions

California's path to carbon neutrality by 2045 is predicated on achieving the emission reductions outlined in the Scoping Plan Reference Scenario. We find that delaying renewable capacity by 5 years will increase California emissions by 8% in 2030 while delaying vehicle electrification will increase emissions by 6% in 2030. While the magnitude of these values may seem small, the risks are high. 2030 is just over seven years away and the gap to achieving the sector targets in the Scoping Plan Reference Scenario are large.

These emission reductions outlined in the Scoping Plan Reference Scenario are not guaranteed and while some of the risk and uncertainty is global and largely exogenous, there are risks associated with implementation. These risks can potentially be reduced or eliminated with targeted policy interventions. While in this analysis we have highlighted the impact of delayed renewable capacity and transportation electrification, there are uncertainties in each implementation assumption across California's economic sectors. The magnitude of the emissions impact will vary as will any potential policy or regulatory intervention.

This analysis has focused on the risks associated with California achieving the GHG emissions outlined in the Scoping Plan Reference Scenario. Any increase in emissions on the pathway to 2030 will impact California's ability to achieve carbon neutrality by 2045. In addition, the technologies and fuels needed to achieve carbon neutrality will also face significant uncertainties in the future. While outside the scope of this analysis, the same implementation risks discussed in relation to renewable capacity may be relevant to emerging technologies like carbon dioxide removal or carbon capture and renewable hydrogen production.