April 10, 2017

Air Resources Board
1001 I Street
Sacramento, CA 95814

Re: Managing uncertainty and risk in the proposed Scoping Plan Update

Dear ARB Board Members and staff,

Thank you for the opportunity to comment on the Air Resource Board's (ARB) proposed Scoping Plan Update.[1] Our comments today build on those two of us have previously submitted in response to the November 2016 Workshop[2] and the December 2016 Discussion Draft.[3] We incorporate these comments by reference.

Our new comments in this letter focus on managing three sources of uncertainty and risk in the Scoping Plan Update, with the goal of increasing the resilience of California's overall climate strategy:

1. Preemption risks affecting vehicle efficiency standards;

2. Preemption and political risks affecting planned hydrofluorocarbon (HFC) emission reductions; and,

3. Uncertainty in projecting business-as-usual emissions through 2030.

First, we analyze two important sources of uncertainty related to the Trump Administration's hostile views on climate policy. We note that the Scoping Plan Update

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1 ARB, The 2017 Climate Change Scoping Plan Update: The Proposed Strategy for Achieving California's 2030 Greenhouse Gas Target (Jan. 20, 2017) ("Proposed Scoping Plan Update"), *available at* https://www.arb.ca.gov/cc/scopingplan/2030sp_pp_final.pdf.

2 Michael Wara and Danny Cullenward, Comment letter to ARB re: Public Workshop on the 2030 Target Scoping Plan (Nov. 21, 2016), *available at* http://www.ghgpolicy.org/law-policy/.

3 Michael Wara and Danny Cullenward, Comment letter to ARB re: Discussion Draft: 2030 Target Scoping Plan Update (December 2, 2016), *available at* http://www.ghgpolicy.org/law-policy/.

process began in a context where California could expect ongoing support from the federal government. However, since the November election—and in particular, in the wake of President Trump's recent Executive Order[4]—it has become clear that several of the regulatory authorities that California has relied on in the past may now be in legal and/or political jeopardy. While we hope that California will ultimately retain these authorities, we argue here the final Scoping Plan Update should more explicitly account for the potential impact of federal preemption and other federal policy changes.

Specifically, we analyze potential impacts from changes in:

- **Light-duty vehicle efficiency standards.** We assess risks to planned transportation sector emission reductions from the possible reversal of the mid-term review of the federal Corporate Average Fuel Economy (CAFE) standards for light-duty vehicles (LDVs)[5] and possible revocation of the Clean Air Act waiver[6] for California's Advanced Clean Car (ACC) program.[7] ARB's PATHWAYS modeling indicates that emission reductions from policies that target LDVs are expected to cumulatively contribute 39 $MMtCO_2e$ over 2021 to 2030; however, we project using ARB's PATHWAYS and VISION models that if the mid-term CAFE standards are reversed and California loses its ACC waiver, emissions could be 52 $MMtCO_2e$ higher than the proposed Scoping Plan Scenario over the same period.

- **Short-lived climate pollutants.** We assess risks to planned reductions of hydrofluorocarbon (HFC) emissions under the Short-Lived Climate Pollutant Reduction Strategy (SLCP Strategy),[8] which assumes compliance with the Kigali

4 President Donald J. Trump, Executive Order on Promoting Energy Independence and Economic Growth (Mar. 28, 2017) (hereinafter "Executive Order on Energy"), *available at* https://www.whitehouse.gov/the-press-office/2017/03/28/presidential-executive-order-promoting-energy-independence-and-economi-1.

5 EPA, Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas (GHG) Emissions Standards for Model Years 2022-2025, https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-greenhouse-gas-ghg.

6 EPA, California State Motor Vehicle Pollution Control Standards; Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's Advanced Clean Car Program and a Within the Scope Confirmation for California's Zero Emission Vehicle Amendments for 2017 and Earlier Model Years, 78 Fed. Reg. 2,112 (Jan. 9, 2013).

7 ARB, Advanced Clean Cars Program, https://www.arb.ca.gov/msprog/acc/acc.htm.

8 ARB, Short-Lived Climate Pollutant Reduction Strategy (Mar. 2017) (SLCP Strategy), https://www.arb.ca.gov/cc/shortlived/shortlived.htm.

Amendment to the Montreal Protocol[9] and a stable set of regulatory authorities from the Environmental Protection Agency's Significant New Alternatives Program (EPA SNAP).[10] ARB's PATHWAYS modeling indicates that the proposed Scoping Plan Update includes about 111 $MMtCO_2e$ in cumulative HFC reductions over 2021-2030; however, based on the SLCP Strategy, we calculate that about 51 $MMtCO_2e$ of those planned reductions are contingent on federal implementation of the Kigali Amendment, which has not been ratified by the U.S. Senate and is not likely to be ratified in the near term. Additional risks could develop if EPA makes deleterious modifications to its SNAP regulations.

In both instances, federal policymakers could make decisions that are hostile to climate policy and would therefore frustrate some of the planned reductions included in the proposed Scoping Plan Update Scenario. Collectively, these risks could lead to cumulative emissions that are 103 $MMtCO_2e$ higher than the proposed Scoping Plan Update scenario, a gap that is equivalent to 15% of the 680 $MMtCO_2e$ cumulative reductions ARB projects are needed to reach the SB 32 2030 target.

We recommend that ARB analyze these risks and include quantitative estimates of their possible impacts in the final Scoping Plan Update. This assessment should also identify what other policy measures would be pursued to make up for any lost ground. To assist ARB staff in this effort, we provide calculations and methodologies based on ARB's own modeling work for these two important policy areas.

Finally, as two of us have expressed in prior comments, we also emphasize the importance of considering a broader range of plausible business-as-usual scenarios related to future economic and technological changes in California.[11] In contrast, the proposed Scoping Plan Update projects a single reference scenario representing business-as-usual emissions through 2030, despite the fact that no economy-wide forecast is reliable over this timeframe. We believe ARB should analyze multiple reference scenarios that represent a range of realistic possible futures in the final 2030 Scoping Plan, consistent

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9 UNEP Ozone Secretariat, http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/41453.

10 EPA, Significant New Alternatives Program, https://www.epa.gov/snap.

11 We have repeatedly emphasized this fundamental point in our earlier comments throughout the scoping plan development process. *See* Wara & Cullenward, *supra* note 2 at 7-8; *see also* Wara & Cullenward, *supra* note 3 at 7.

with best practices adopted in other prominent efforts to assess long-term energy futures[12] and the impact of proposed policies over long timeframes.[13]

1. Light-duty vehicle efficiency standards

One of the largest contributions to the proposed Scoping Plan Update comes from Mobile Sources CFT and Freight, a set of measures that focuses on deployment of zero-emission vehicles in California.[14] ARB projects that reductions in emissions from mobile sources will contribute 67 $MMtCO_2e$ (or 9.9%) of the total cumulative reductions between 2021 and 2030.[15] Projections from ARB's PATHWAYS model indicate that 39 $MMtCO_2e$ in cumulative reductions are expected from improvements in the LDV fleet—including improvements in internal combustion engines, plug-in hybrid electric vehicles, and zero emission vehicles (ZEVs), such as battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (HFCVs).[16]

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[12] For example, the Energy Information Administration incorporates uncertainty in its Annual Energy Outlook series by evaluating a reference case along with numerous side cases that incorporate lower or higher than expected economic growth, fuel costs, technological change, and other key factors. U.S. Energy Information Administration, Annual Energy Outlook 2017 (Jan. 2017) at 5-6, *available at* https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf .

[13] In evaluating the Clean Power Plan, for example, EIA evaluated the Clean Power Plan under higher than expected economic growth, a high oil and gas resources case, and various alternative technology scenarios. U.S. Energy Information Administration, Analysis of the Impacts of the Clean Power Plan, 12 (May, 2015), *available at* https://www.eia.gov/analysis/requests/powerplants/cleanplan/.

[14] Proposed Scoping Plan Update at 41. Note that the Mobile Sources measure focuses on zero-emissions vehicles and is distinct from reducing the carbon intensity of liquid transportation fuels, such as through the Low Carbon Fuel Standard.

[15] *Id.*

[16] *See* Appendix A. We note that greenhouse gas savings from LDV improvements are potentially attributable to multiple sectors; there is some ambiguity as to how the proposed Scoping Plan Update Scenario allocates total reductions. Reduced emissions from internal combustion engines (ICEs) are generally accounted for in the transportation sector. Switching from ICEs to ZEVs creates emission reductions, but those reductions can be accounted for in different ways. A switch from ICEs to BEVs, for example, reduces gross emissions in the transportation sector but increases gross emissions in the electricity sector. We cannot say with precision how the figures in the proposed Scoping Plan Update allocate the gross reductions by sector. (The Scoping Plan Update also attributes 25 MMtCO2e in emissions cuts to the Low Carbon Fuel Standard (LCFS) and 88 MMtCO2e to the 50% Renewable Portfolio Standard (RPS)—two efforts that affect transportation sector emissions.) However, this issue does not impact the analysis presented here. The 39 $MMtCO_2e$ in cumulative LDV

Here, we assess critical legal uncertainties associated with ARB's ability to regulate greenhouse gas standards for light-duty vehicles LDVs and potential relaxation of federal Corporate Average Fuel Economy (CAFE) standards. The key legal issue is whether or not California will retain its Clean Air Act waiver authority that allows ARB to (1) pursue greenhouse gas tailpipe emissions standards that are more stringent than federal CAFE standards and (2) require a growing share of plug-in hybrid, battery electric, and hydrogen fuel cell vehicles in future model year sales.

Our assessment is supported by quantitative modeling using results from the VISION and PATHWAYS models, along with a comparison of the two models' results. These calculations can be found in Appendix A to this comment letter.

1.1. California's authority to regulate mobile source greenhouse gas emissions depends on federal policy

Legal authority to regulate greenhouse gas emissions from mobile sources is shared between the U.S. EPA and ARB. Under the Clean Air Act, states are generally preempted from regulating these emissions.[17] The one exception is California, which may request a waiver from the EPA Administrator that allows the state to exceed federal standards.[18] Other states can choose to follow the federal standard or the stricter California standard, if one exists.[19]

For decades, California has used its waiver authority to reduce mobile source emissions, encouraging the development and deployment of pollution controls and other advanced vehicle technologies. Initially, California waivers focused on reducing local air pollution; in the context of climate policy, California set aggressive tailpipe greenhouse gas emissions standards for LDVs in 2004, expressed on a gCO_2e/mile basis. When President Obama took office, his administration coordinated federal CAFE standards (administered by NHTSA) and mobile source pollution regulations under the Clean Air Act

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reductions projected by PATHWAYS is a net calculation; similarly, the results we report are net calculations. Additional analysis would be needed to ascertain the changes by sector, but this ambiguity does not affect the bottom line impact on cumulative emission reductions needed to achieve the SB 32 target for 2030.

17 42 U.S.C. § 7543(a).

18 *Id*. at § 7543(b).

19 *Id*. at § 7507.

(administered by EPA), setting new federal standards on a gCO_2e/mile that matched California's standards through model year (MY) 2016.[20]

In 2012, EPA and NHTSA issued new LDV CAFE standards for MY 2017-25.[21] As part of that process, the agencies agreed to defer a "Mid-Term Evaluation" to finalize standards for MY 2022-25, to be conducted in collaboration with ARB in order to maintain a consistent national standard over this time period.[22]

In 2013, EPA granted ARB an omnibus waiver covering ARB's Advanced Clean Car (ACC) program, integrating separately authorized programs into a single waiver.[23] The ACC waiver included permission for California to maintain its greenhouse gas emission standards, Low Emissions Vehicle (LEV) program, and Zero Emissions Vehicle (ZEV) program. The ACC waiver thus provides the necessary legal authority for California to pursue additional emission reductions from mobile sources—especially to support the deployment of electric and hydrogen fuel cell vehicles.

Although the ZEV authority was anticipated to be the most important part of ARB's ACC waiver, the ability to maintain existing greenhouse gas tailpipe standards through MY 2025 and to strengthen them in future model years is also an important part of ARB's overall strategy for reducing emissions from mobile sources. ARB's tailpipe standards would become all the more important if federal standards were relaxed relative to the previously harmonized state and federal program.

That very scenario is now playing out at the federal level. On January 12, 2017, outgoing EPA Administrator McCarthy issued her Mid-Term Evaluation determination that the MY 2022-25 LDV standards met all applicable requirements and should be maintained.[24] A few days later, ARB released its own independent mid-term review of the broader ACC

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20 EPA and DOT NHTSA, Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule, 75 Fed. Reg. 25,324 (May 7, 2010).

21 Department of Transportation (DOT), 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule, 77 Fed. Reg. 62,624 (Oct. 15, 2012).

22 *Id*. at 62,628.

23 78 Fed. Reg. 2,112.

24 EPA, Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, EPA-420-R-17-001 (Jan. 12, 2017).

program, reaching similar conclusions.[25] But the Trump Administration appears set on reversing course. In March 2017, EPA Administrator Pruitt and Department of Transportation Secretary Chao announced their intention to review former Administrator McCarthy's decision.[26] A final determination is due by April 1, 2018.[27] If EPA and DOT reverse these findings, federal LDV CAFE standards would remain at MY 2021 levels through 2025, rather than increasing in stringency through 2025.

If EPA and DOT reverse EPA's mid-term review and hold LDV CAFE standards at their MY 2021 levels, California could continue to require in-state LDV sales to meet higher standards under its ACC waiver authority. But if EPA reinterprets its waiver review authority and as a consequence withdraws the ACC waiver, California's plans could be hit simultaneously by relaxed federal standards for internal combustion engines and the prospect of being unable to encourage electric and hydrogen fuel cell vehicles under its ZEV program. Unfortunately, EPA Administrator Pruitt indicated in his confirmation hearing that he planned to "review" rather than "uphold" ARB's vehicle waiver.[28]

We expect that any such action would be vigorously opposed by ARB and hope that the agency would ultimately prevail in court. Nevertheless, we believe that this uncertainty illustrates the need to quantify the potential impact of a waiver loss for the proposed Scoping Plan Update Scenario. Based on the Trump Administration's decision to review the MY 2022-25 LDV standards determination, our expectation is that the most likely scenario in case of a waiver loss is one in which federal standards are held constant at their MY 2021 values in future MYs.

1.2. Impact on the proposed Scoping Plan Update Scenario

We calculate that the loss of both California's ACC waiver and a relaxation of MY 2022-25 LDV CAFE standards are projected to result in cumulative emissions that are 52 $MMtCO_2e$ higher than the proposed Scoping Plan Update Scenario.

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[25] ARB, California's Advanced Clean Cars Midterm Review: Summary Report for the Technical Analysis of the Light Duty Vehicle Standards (Jan. 18, 2017).

[26] DOT and EPA, Notice of Intention To Reconsider the Final Determination of the Mid-Term Evaluation of Greenhouse Gas Emissions Standards for Model Year 2022–2025 Light-duty Vehicles, 82 Fed. Reg. 14,671 (Mar. 22, 2017).

[27] *Id*. at 14,672.

[28] Evan Halper, Trump's EPA pick casts doubt on California's power to regulate auto emissions, Los Angeles Times (Jan. 18, 2017).

As described in Appendix A, we modeled a vehicle waiver loss and mid-term LDV CAFE reversal scenario using two core assumptions. First, we assumed that the emissions from new internal combustion engine vehicles (ICEs) would follow the federal CAFE standards, which in turn would stay constant from MY 2021 through MY 2030. This results in higher emissions from ICEs relative to the proposed Scoping Plan Update Scenario, which assumes that ICEs remain subject to unified state and federal greenhouse gas standards through 2025 and then follow an increasingly stringent state standard thereafter. Second, we assume that as a result of loss of authority for the ZEV program, sales of battery electric, hydrogen fuel cell, and plug-in hybrid vehicles in California remain constant at their 2018 levels through 2030, instead of accelerating as planned in the proposed Scoping Plan Update Scenario. This scenario is intended as a conservative case to bound uncertainty in the Scoping Plan Update process.

We note that our calculations indicate a greater impact than the 39 $MMtCO_2e$ cumulative emission reductions expected from LDV improvements in 2021-2030 in the proposed Scoping Plan Update Scenario, relative to the reference case. The reason is that the reference case assumes existing MY 2022-25 LDV CAFE standards stay in place, whereas our analysis assumes that LDV CAFE standards will freeze at MY 2021 levels through 2030. As a result, the cumulative impacts from maximally deleterious federal policy changes are larger than initial contribution calculated by ARB for LDVs in the proposed Scoping Plan Update Scenario because our scenario is based on applicable policy becoming more lax than in the original proposed Scoping Plan Update reference scenario.

We plot the results for our scenario in Figure 2. There, the blue line shows the reference case emissions and the green line shows the proposed Scoping Plan Update Scenario. The red line shows the impacts on the proposed Scoping Plan Update Scenario from a loss of California's waiver authority and a relaxation of federal CAFE standards after a reversal of the mid-term evaluation.

Figure 2 shows the contribution of specific changes to the cumulative emission reduction impacts we report, expressed relative to the proposed Scoping Plan Update Scenario. In case of a waiver loss and relaxed CAFE standards, California ICE emissions increase. Because we assume that ZEV sales stay constant from 2018 forward, fewer ZEVs are deployed and are replaced instead with ICE vehicles. An interaction effect between ICE and ZEV emissions reflects the fact that not only are ZEVs replaced with ICEs, but that the emissions of ICEs also increase relative to the expected emissions from ICEs had they been subject instead to California's state-level greenhouse gas emissions standards.

Figure 1: LDV CO_2 emissions ($MMtCO_2e$ per year)

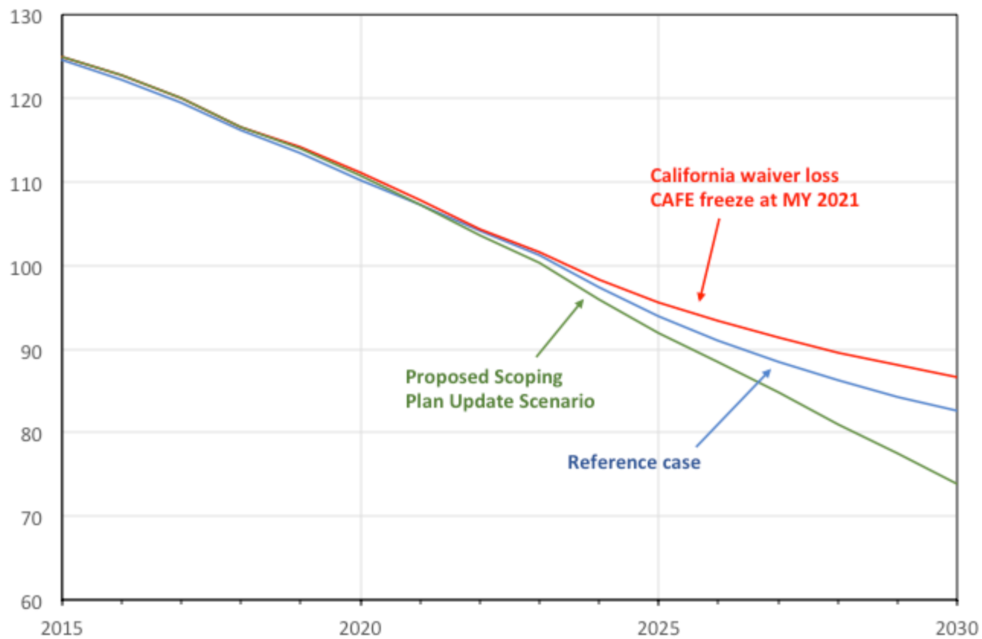
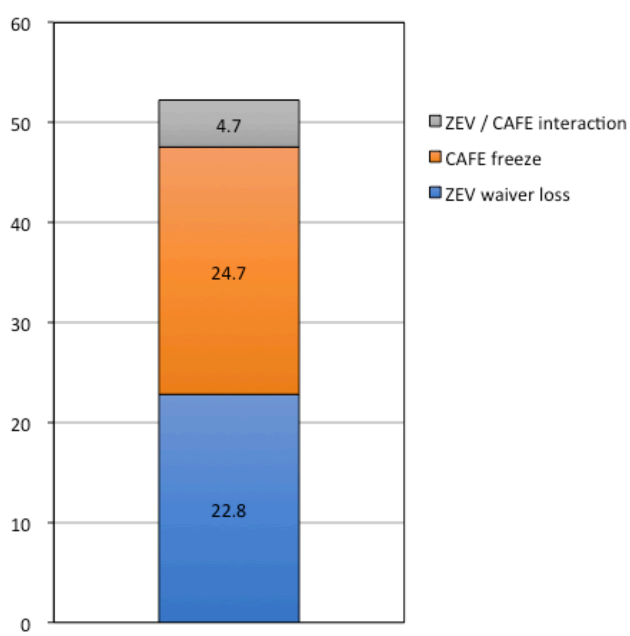


Figure 2: Contribution of policy changes to LDV CO_2 emissions (cumulative $MMtCO_2e$ through 2030)



2. Short-lived climate pollutants

The single largest contribution to the proposed Scoping Plan Update Scenario is ARB's SLCP Reduction Strategy, which establishes a plan to reduce emissions of methane (CH_4), hydrofluorocarbons (HFCs), and black carbon (BC). ARB projects that reductions in statewide emissions due to the SLCP Strategy will contribute 217 $MMtCO_2e$ (or 31.9%) of the total cumulative reductions needed between 2021 and 2030 to meet the SB 32 target for 2030.[29]

Here, we assess critical legal and political uncertainties associated with the HFC emission reductions ARB includes in the proposed Scoping Plan Update Scenario. We estimate that about 111 $MMtCO_2e$ of cumulative SLCP reductions identified in the proposed Scoping Plan Update Scenario are attributable to HFC reductions.[30] Of this total, we estimate that about 51 $MMtCO_2e$ are likely to be at risk due to the recent shift in federal climate policy and its impact on the prospects for ratification of the Kigali Amendment to the Montreal Protocol; additional risks may emerge if the U.S. EPA changes its domestic regulatory policies affecting HFCs.

Our assessment is supported by a quantitative examination and comparison of the SLCP Strategy and its implementation in PATHWAYS modeling for the proposed Scoping Plan Update in Appendix B to this comment letter.

2.1. California's authority to regulate HFCs depends on federal policy

Legal authority to regulate HFC emissions is shared between the U.S. EPA and ARB. EPA is required under the Significant New Alternatives Program (SNAP) to specify allowed uses for chemical substitutes, including HFCs, that replace Ozone Depleting Substances (ODSs).[31] Under its SNAP authority, EPA specifies allowed uses of HFCs and other compounds in applications that were previously met with chlorofluorocarbons (CFCs) and other ODSs.

States have authority to further limit acceptable uses of ODS substitutes to a subset of those approved under the EPA SNAP program (*e.g.*, low Global Warming Potential

29 Proposed Scoping Plan Update at 41.

30 This total originates from PATHWAYS emission categories described as "fugitive refrigerants (CFCs, HCFCs, and HFCs)." We assumed these numbers could be used as a proxy for HFC emission reductions. *See* Appendix B.

31 42 U.S.C. § 7671(k).

(GWP) compounds). However, states cannot mandate the use of compounds that are not listed as acceptable substitutes under SNAP.

The SNAP list has been amended twice in recent years to limit the use of high-GWP HFCs in certain applications and to add new alternatives to HFCs to lists of acceptable ODS substitutes.[32] These amendments were made as technological innovation has brought low-GWP alternatives to market that can substitute for HFCs, which pose no risk to stratospheric ozone but are potent GHGs. EPA's recent amendments enable California to limit additional uses of high-GWP HFCs by banning their use and instead mandating the use of other, SNAP-listed, alternatives. Similarly, the SNAP list now enables substitution of certain lower-GWP alternatives for HFCs in existing air conditioning and refrigeration systems; California can likewise mandate substitutions where allowed by federal regulations.

EPA also regulates the production and consumption of specific ODSs and their substitutes, including HFCs, across the United States.[33] This authority implements the United States' international obligations under the Montreal Protocol on Substances that Deplete the Ozone Layer.[34] In 2016, parties to the Montreal Protocol agreed to the Kigali Amendment,[35] which contemplates a global phasedown in the production and consumption of HFC-containing products. The Kigali Amendment is a key element of ARB's final SLCP Reduction Strategy. However, the Obama Administration did not submit the Kigali Amendment to the Senate for ratification[36] and the Trump Administration has given no indication that it will do so in the future.

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32 EPA, Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes Under the Significant New Alternatives Program, 80 Fed. Reg. 42,870 (July 20, 2015); EPA, Protection of Stratospheric Ozone: New Listings of Substitutes; Changes of Listing Status; and Reinterpretation of Unacceptability for Close Cell Foam Products Under the Significant New Alternatives Policy Program; and Revision of Clean Air Act Section 608 Prohibition for Propane, 81 Fed. Reg. 86,778 (Dec. 1, 2016).

33 42 U.S.C. 7671(a)-(e).

34 United Nations Environment Program, Montreal Protocol on Substances that Deplete the Ozone Layer, Article 2a – 2j; 42 U.S.C. §7671(a)-7671(d).

35 United Nations Environment Program, Decisions of the Meetings of the Parties to the Montreal Protocol, 28th Meeting of the Parties (Kigali, 10-15 October, 2016), Annex I: Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer.

36 All four prior amendments to the Montreal Protocol have been submitted for ratification to the U.S. Senate.

Given that President Trump recently revoked[37] the Obama Administration's Climate Action Plan—which highlighted efforts to phase out HFCs by amendment to the Montreal Protocol[38]—we believe the near-term prospects for Senate ratification of the Kigali Amendments and associated EPA implementation are dim.

2.2. Impact on the proposed Scoping Plan Update Scenario

Successful implementation of California's SLCP Reduction Strategy—and the associated reductions in the proposed Scoping Plan Update Scenario—depends in part on implementation of new state regulations to limit the use of HFCs. Absent modifications to the current SNAP regulations, California appears to have legal authority to proceed with these elements of the SLCP Strategy. All that California need do is specify which of the accepted substitutes for new and existing applications currently available on the SNAP list are permitted in California and which are not.

The SLCP Reduction Strategy projects that limitations on uses of high-GWP HFCs will reduce annual statewide HFC emissions by 20 $MMtCO_2e$ in 2030, using 20-year GWPs.[39] Based on this projection, we estimate that these policies are likely to achieve 54 $MMtCO_2e$ of cumulative reductions over 2021-2030, using 100-year GWPs.[40] This amounts to 25% of the total contribution of the SLCP Reduction Strategy to the proposed Scoping Plan Update Scenario. In our view, ARB is on solid legal ground in assuming that it has authority to mandate these reductions, absent currently unforeseen changes to the federal SNAP regulations.

Achieving the reductions projected in both the SLCP Reduction Strategy and the proposed Scoping Plan Update Scenario will also depend on an accelerated HFC phasedown driven by U.S. ratification and implementation of the Kigali Amendment. As explained above, we believe this outcome is unlikely at the present time. In the SLCP Reduction Strategy, the HFC supply phasedown is projected to reduce annual emissions

37 Executive Order on Energy § 3(b)(i).

38 Executive Office of the President, The President's Climate Action Plan at 10, 21 (June 2013), *available at* https://obamawhitehouse.archives.gov/sites/default/files/image/president27sclimateactionplan.pdf

39 SLCP Strategy at 12.

40 *See* Appendix B, Table 2-3

by 19 $MMtCO_2e$ in 2030, using 20-year GWPs.[41] Based on this projection, we estimate that these policies are likely to achieve about 51 $MMtCO_2e$ in cumulative reductions over 2021-2030 using 100-year GWPs.[42] This amounts to 24% of the total contribution of the SLCP Strategy to the overall reductions in the proposed Scoping Plan Update Scenario.

Given the current position of the Trump Administration regarding climate policy generally and the former administration's U.S. Climate Action Plan in particular, we judge domestic adoption of the Kigali Amendment to be an unlikely outcome at this time. As a result, we recommend that ARB explicitly incorporate a quantitative analysis of this possibility in the final Scoping Plan Update.

3. Addressing uncertainty in the proposed Scoping Plan Update reference scenario

In addition to discussing the risk that federal policy decisions interfere with California's ability to pursue certain state climate policy strategies, we also highlight the need to better address uncertainty in the proposed Scoping Plan Update's reference scenario.

Forecasting exercises are rarely accurate more than a few years forward, as acknowledged by ARB in the proposed Scoping Plan Update.[43] Yet despite this acknowledgement, the emissions reductions calculated for the proposed Scoping Plan Update are based on one reference case (without additional California policy intervention) projected with precision all the way to 2030. Based on this deterministic scenario, ARB calculates that 680 $MMtCO_2e$ in cumulative emission reductions over 2021 to 2030 are required to meet the SB 32 target for 2030.[44]

We recommend that ARB supplement this work by analyzing multiple reference scenarios that account for the significant economic and technological uncertainty that are necessarily involved in projections over this extended timeframe. A scenario-based evaluation is essential to identify key strengths and weaknesses in a proposed policy strategy precisely because the performance of individual policies—especially regulatory policies, on which the proposed Scoping Plan Update principally relies—depends on the business-as-usual trends in individual economic sectors.

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[41] SLCP Strategy at 12.

[42] *See* Appendix B, Table 2-3.

[43] Proposed Scoping Plan Update at 44-45.

[44] *Id*. at 37.

We note that we are not the only commenters to raise these issues in ARB's 2030 planning process. UC Davis economist and ARB scoping plan advisor Professor James Bushnell expressed a similar view, producing modeling results that appear to be based on important work that he and other economists recently published.[45] At a November 2016 workshop for the 2030 Scoping Plan process, Professor Bushnell showed a figure that illustrated uncertainty in projecting a subset of statewide emissions through 2030.[46] We include his figure here as Figure 3.

As Figure 3 indicates, Professor Bushnell's modeling work suggests a wide range of business-as-usual emission outcomes is plausible, with projected 2030 annual emissions ranging from approximately 250 to 500 MMtCO_2e. For comparison, the proposed Scoping Plan Update scenario projects that 2030 emissions will be 392.4 MMtCO_2e.[47]

One key implication of Professor Bushnell's analysis is that the difference between the reference scenario and the proposed Scoping Plan Update Scenario—in other words, the annual reductions required in 2030 to meet the SB 32 target—might range anywhere from 0 to 250 MMtCO_2e in 2030. In contrast, ARB assumes that the annual effort required in 2030 will be precisely 133.8 MMtCO_2e.[48]

Similarly, the implications for the cumulative emission reductions required to reach the SB 32 target are equally significant: cumulative emission reductions are calculated as the difference between business-as-usual emissions and a preferred mitigation trajectory, and are therefore dependent on assumptions about how the business-as-usual reference scenario would evolve in the absence of additional policy measures.

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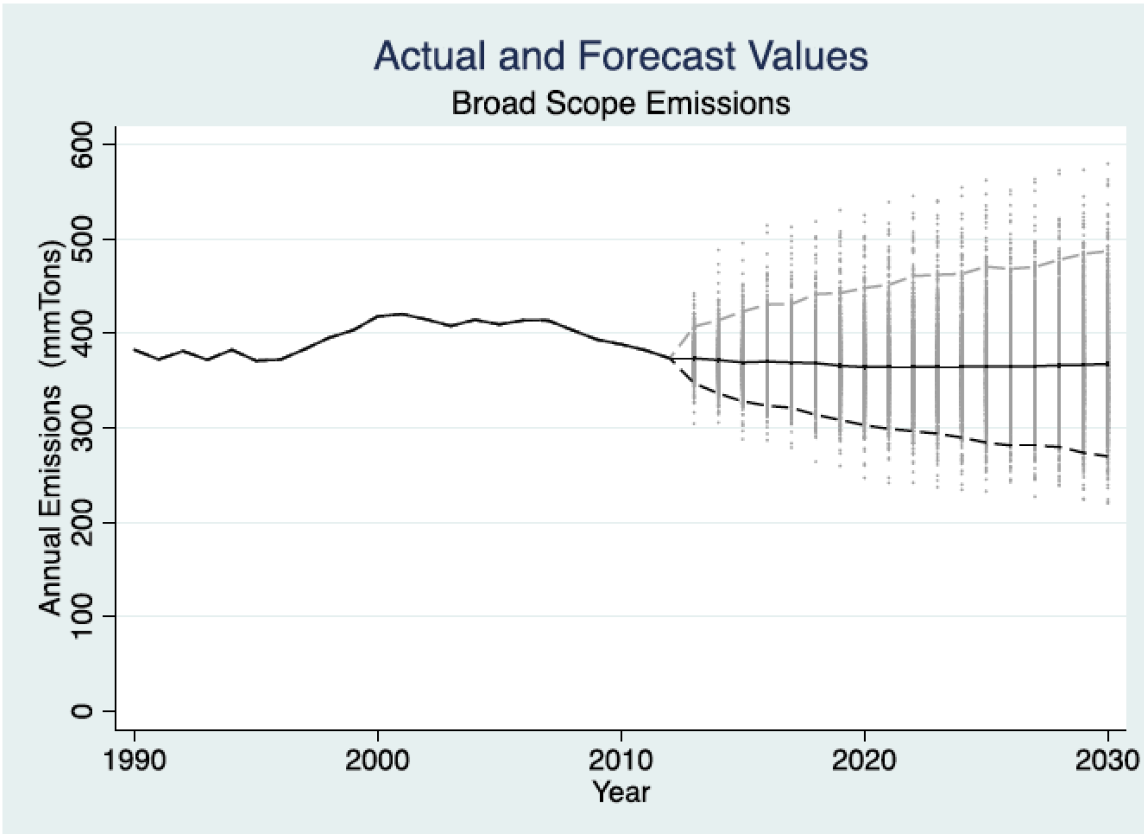
[45] Severin Borenstein et al., Expecting the Unexpected: Emissions Uncertainty and Environmental Market Design. Energy Institute @ Haas Working Paper #274 (Aug. 2016), *available at* https://ei.haas.berkeley.edu/research/papers/WP274.pdf.

[46] James Bushnell, Economic Modeling and Environmental Policy Choice, presentation at Public ARB Workshop on the 2030 Scoping Plan (Nov. 7, 2016), *available at* https://www.arb.ca.gov/cc/scopingplan/meetings/110716/bushnellpresentation.pdf.

[47] Proposed Scoping Plan Update at 37 (Table II-2).

[48] *Id*. (the difference between the projected 2030 reference emissions [392.4 MMtCO_2e] and the SB 32 Target for 2030 [258.6 MMtCO_2e]).

Figure 3: Uncertainty in reference case emissions



Professor Bushnell and his colleagues have previously suggested that the primary driver of uncertainty in reference scenario emissions is economic growth.[49] Yet ARB's proposed Scoping Plan Scenario reference case assumes a single rate of economic growth.[50] A better approach would be to perform an uncertainty analysis.

Uncertainty analysis is particularly important for ensuring the resilience of regulatory strategies. The potential contribution of specific regulatory programs to a cumulative mitigation target depends on the economic drivers of emissions in the sectors that are being regulated. For example, a regulatory program that reduces the greenhouse gas emissions from vehicles has expected net impacts that vary depending on the total vehicle

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49 Borenstein et al. note the challenge faced by ARB because of the variability in overall state economic activity, the even greater variability in sector specific economic activity, and the greenhouse gas emissions that result. They recommend specifically against the use of point estimates of business-as-usual. Borenstein et al., *supra* note 45 at 11-12.

50 Proposed Scoping Plan Update at 44-45.

miles traveled in the state, which in turn depends on expected population trends, land use choices, and economic growth projections. We note that variability in economic drivers and emissions within individual sectors has historically been far greater than variations in statewide economic growth and emissions.[51]

Without exploring the uncertainty in key variables like economic growth, fuel prices, and their impacts on emissions drivers like vehicle miles traveled, the proposed Scoping Plan Update is vulnerable to the risk that the future unfolds in ways that a static regulatory plan developed years in advance cannot not properly mitigate.

ARB suggests that the requirement to revise Scoping Plans every five years will mitigate these risks,[52] but that suggestion is misplaced: by not analyzing these important risks prospectively, the proposed Scoping Plan Update could create consequences that cannot be remedied when a problem is identified five years from now. We also note that ARB has never public analyzed any of these issues as they apply to past Scoping Plans.

We recommend instead that ARB supplement its current approach to evaluating the performance of the proposed Scoping Plan Update Scenario and its alternatives by explicit assessment of uncertainty in the reference case.

4. Conclusions and recommendations

In this comment letter we have quantified risks from changes in federal climate policy to the transportation and SLCP components of ARB's proposed Scoping Plan Update. Based on our calculations using ARB data and models, we find that cumulative emissions over 2021 to 2030 could be 103 $MMtCO_2e$ higher than the proposed Scoping Plan Update Scenario.

These changes are projected as a result of a potential loss of California's vehicle waiver authority and freeze in federal LDF CAFE standards (52 $MMtCO_2e$), as well as a potential loss of the contribution of Kigali Amendment-driven HFC reductions to the Short-Lived Climate Pollutant Strategy (51 $MMtCO_2e$). A cumulative emissions increase of 103 $MMtCO_2e$ over 2021 to 2030 is equivalent to 15% of the planned reductions ARB calculates are necessary to achieve the 2030 target (680 $MMtCO2_e$).

51 Borenstein et al., *supra* 45 at 11-12.

52 Proposed Scoping Plan Update at 45.

- **Recommendation #1.** We recommend that ARB analyze the impact on the proposed Scoping Plan Update Scenario of a loss of California's vehicle waiver authorities under the Clean Air Act, including the expectation that federal CAFE standards are held constant at their MY 2021 levels, not increased through MY 2025.

- **Recommendation #2.** We recommend that ARB analyze the impact on the SLCP Strategy and the proposed Scoping Plan Update Scenario of a failure by the United States to ratify the Kigali Amendment to the Montreal Protocol.

If either of these risks comes to pass, it will be necessary to explore how other policy measures can make up the difference. One option would be to allocate the necessary reductions to the cap-and-trade program. Under this scenario, the expected contribution of cap-and-trade to ARB's cumulative emissions target would increase from 191 $MMtCO_2$ to 294 $MMtCO_2e$, an increase of 54%. ARB could also strengthen existing regulatory programs or identify and develop new measures.

We note that if the cap-and-trade program is expected to generate 294 $MMtCO_2e$ in cumulative reductions, the resulting impact on the proposed Scoping Plan Update Scenario would closely resemble the alternative Uncertainty Scenario.[53]

- **Recommendation #3.** We recommend that ARB specify the policy measures that would be used to mitigate the consequences of emission increases from changes to the proposed Scoping Plan Update Scenario, as calculated above.

In addition, we highlight the continuing need to analyze uncertainty in the reference scenario. The calculations above are made with respect to ARB's deterministic reference scenario and would change if baseline emissions are higher or lower than ARB currently forecasts.

- **Recommendation #4.** We recommend that ARB explicitly analyze uncertainty in the baseline scenario through 2030. No single point estimate of future emissions more than a few years into the future constitutes a reliable basis for strategic planning. In particular, a robust Scoping Plan Update would incorporate a quantitative estimate of how high or low economic growth and high or low fuel prices would impact the necessary reductions to reach the SB 32 target for 2030.

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[53] Proposed Scoping Plan Update at 41 (Figure II-2) (showing that cap-and-trade in the "Uncertainty Scenario" contributes 342 $MMtCO_2e$).

Thank you again for the opportunity to comment on the proposed Scoping Plan Update. We appreciate the hard work that ARB staff and Board Members are doing to prepare a strategy to achieve California's ambitious climate targets and hope our work will support a successful outcome. Please be in touch if we can be helpful.

Sincerely,

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Managing Uncertainty and Risk in the Proposed Scoping Plan Update

Appendix A: Technical Report on Light-Duty Vehicle Emissions

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1. Introduction

If California loses the legal authority for its Advanced Clean Car (ACC) program and/or for setting Corporate Average Fuel Economy (CAFE) standards that are more stringent than federal standards, this could affect the state's ability to meet mandated targets for cutting greenhouse gas emissions through 2030.

This technical report describes modeling by Near Zero to estimate the impact on the state's greenhouse gas emissions that could result from the loss of such legal authority and from a freeze in federal CAFE standards.

The projections shown are not intended to be forecasts of what will happen. Rather, they show possible outcomes if other features of the energy and transportation system remain as specified in VISION and PATHWAYS scenarios, such as improvements in the efficiency of electric vehicles and reductions in the carbon dioxide (CO_2) intensity of electricity generation (CO_2 emissions per kWh of electricity), and with plausible outcomes for the effect of the changes in legal authority described above.

Based on our analysis, we have the following technical recommendation:

ARB should report detailed PATHWAYS results, including vehicle miles traveled (VMT), energy consumption, and greenhouse gas emissions for each vehicle model year and each combination of vehicle type (i.e., light duty automobiles) and technology type (i.e., battery-electric vehicle). This data appears to be generated during a PATHWAYS model run, however it does not appear to be accessible through any of the standard model outputs in the latest configuration of the model (version 2.4.0).

2. Modeling Assumptions for Loss of Waiver Authority

To simulate loss of authority for the ACC program in a particular year, we assumed that additions of new battery electric vehicles (BEV), hydrogen fuel cell vehicles (HFCV), and plug-in hybrid electric vehicles (PHEV) in future years would each remain at the same rate as in the year of the loss of authority. For example, if that authority were lost in 2018, the number of new BEV added annually is simulated to be constant from 2018 through 2030.

To simulate the loss of CAFE standard authority, and a freeze of federal CAFE standards with a particular model year, we assumed that all gasoline and diesel light-duty vehicles sold from this year onward would maintain the same efficiency as the fleet of vehicles in the model year that CAFE standards were frozen. For example, with CAFE standards frozen in 2021 and a loss of the ACC program, then after 2021 more light-duty automobiles (both gasoline and diesel) would be sold in years 2022-2030, and these were assumed to have the same efficiency as the average of all light-duty automobiles sold in 2021.

These basic assumptions could be modified, depending on one's view of the likely effect of these policy changes. We chose these particular assumptions to provide a somewhat pessimistic bounding case, to illustrate the maximum effect these policy changes could have on California's emissions.

We note that sales of battery-electric vehicles and plug-in hybrid vehicles have been increasing rapidly in recent years, and future sales are generally expected to be supported by the ACC.[1] To more realistically model the effect that loss of ACC might have on sales of these vehicles, more detailed economic analysis would be required to compare the relative economics of various types of vehicles, factoring in (among other things) the expected costs of petroleum fuels, electricity, and hydrogen, as well as prices on carbon emissions and tax-related incentives for purchasing particular types of vehicles.

3. Modeling Approach Follows ARB's in the Proposed Scoping Plan Update

To realistically model the impact of these regulatory changes, it is necessary to specify properties of particular vehicle model years, including the sales of new vehicles of each technology type (i.e., gasoline internal combustion, battery electric vehicles, hydrogen fuel cell vehicles, etc.), as well as the efficiency of those vehicles.

The California Air Resources Board (ARB) uses the California PATHWAYS model (hereafter PATHWAYS) as its main tool for simulating scenarios for the Scoping Plan Update. The standard outputs from PATHWAYS version 2.4.0 (used for the Scoping Plan Update) don't provide detail

[1] U.S. EIA, "California program encourages adoption of zero-emissions vehicles," October 3, 2016, at: https://www.eia.gov/todayinenergy/detail.php?id=28192

on particular model years of vehicles, so they can't be used as the basis for a robust analysis of the effects of policy changes such as loss of the ACC and/or CAFE waivers.

PATHWAYS draws on a variety of other ARB sub-models, using their results and integrating them for creating projections of emissions for all sectors. For the transportation sector, PATHWAYS draws on results from the VISION and EMFAC2014 models, and has interactions with the Biofuel Supply Module (BFSM).[2]So Near Zero has instead used outputs from the VISION 2.1 model (hereafter VISION). Both VISION and PATHWAYS both draw on vehicle stock projections from EMFAC2014, as described in the Scoping Plan Update Appendix D (PATHWAYS model documentation).[3]

In each scenario, Near Zero's modeling used VISION's VMT and energy consumption, separated by vehicle type, technology type, and model year (i.e., light-duty automobiles, battery electric, model year 2025). We used those detailed results and modified particular model years, changing the VMT from each set of vehicles. If there were also adjustments to the efficiency (energy consumed/VMT) necessary in a scenario, these were adjusted for each affected set of vehicles, and the resulting energy consumption was calculated based on this modified efficiency.

To calculate resulting CO_2 emissions, Near Zero's modeling used CO_2 emissions rates from PATHWAYS for each energy source (gasoline, electricity, and hydrogen). These emissions rates were calculated from outputs posted on ARB's website—specifically, the transportation sector emissions for each energy source (i.e., gasoline) divided by the transportation sector consumption of that same energy source.[4]

Near Zero's modeling is written in Python, employing the NumPy and Pandas libraries for handling large arrays of data.[5] (Full outputs from the VISION passenger module contain over 700,000 lines of data for each scenario.) We will provide the underlying code on request, and in

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[2] PATHWAYS and BFSM are available at: https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm. VISION is available at: https://www.arb.ca.gov/planning/vision/vision.htm. EMFAC is available at: https://www.arb.ca.gov/msei/categories.htm

[3] https://www.arb.ca.gov/cc/scopingplan/app_d_pathways.pdf

[4] See the file named "pathways_main_outputs_final_17jan2017.xlsm" at https://www.arb.ca.gov/cc/scopingplan/pathways_main_outputs_final_17jan2017.xlsm. In this file, data for energy consumption by sector and by energy source are in a hidden sheet named "Final_Energy1" and similarly greenhouse gas emissions by sector and energy source are in a hidden sheet named "Energy_GHGs_by_Sect1".

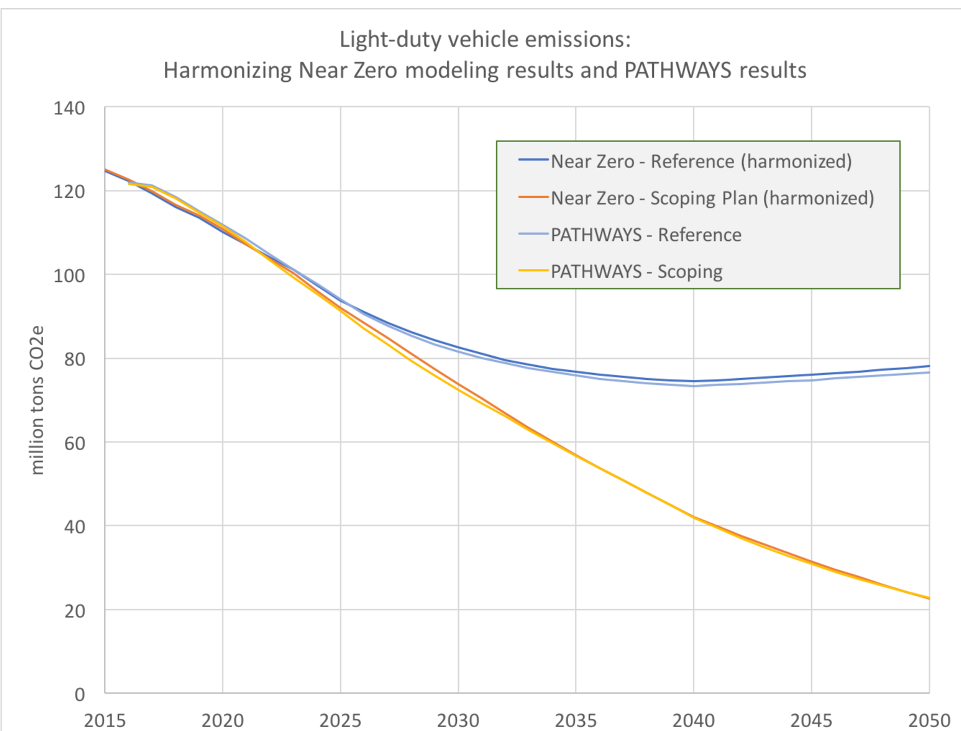
[5] More information on NumPy at http://www.numpy.org, and on Pandas at: http://pandas.pydata.org

the future we plan to make the code accessible through Near Zero's website (http://nearzero.org).

To check the correspondence between Near Zero's model and PATHWAYS results, we ran Near Zero's model with no modifications to legal authorities or to CAFE standards, to attempt to replicate the Reference case and proposed Scoping Plan Update scenario. (VISION's "Current Control Program scenario" corresponds to the PATHWAYS Reference case, and VISION's "Clean Technology and Fuels Scenario corresponds to the PATHWAYS Scoping Plan case.)

Light-duty vehicle emissions from Near Zero's modeling, for both the Reference case and Scoping Plan scenario, were consistently ~7% higher than PATHWAYS results. This was due to light-duty vehicles having consistently higher VMT in VISION (~4% higher) and consistently lower mileage, measured in VMT/gge (~3% lower). These differences were relatively consistent across years. The standard PATHWAYS outputs do not provide more detail on light-duty vehicle VMT or energy consumption, so it was not possible to attribute these differences to particular vehicle technology types (i.e., gasoline or BEV). To harmonize results between Near Zero's modeling and PATHWAYS results, Near Zero's modeled emissions were reduced by 7% (see Figure 3-1). In this report and the corresponding comment letter, all emissions quantities are from the harmonized results.

Figure 3-1. Harmonizing Light-Duty Vehicle Emissions



4. Comparison of VISION and PATHWAYS vehicle stocks

To model the effects of possible changes in California's vehicle emissions due to shifts in federal regulations, Near Zero used outputs from ARB's VISION 2.1 model, which include vehicle stocks (known as "daily population"), vehicle miles traveled (VMT), and energy consumption, separated by model year, vehicle type (such as light-duty automobiles), and technology type (such as gasoline internal combustion vehicles or battery-electric vehicles).

For this analysis, Near Zero focused on light-duty vehicles. The definition of light-duty vehicles differs between VISION and PATHWAYS. This analysis follows the PATHWAYS definition of light-duty vehicles, which corresponds to VISION categories:

- vehicle type 1 (light-duty automobiles)
- vehicle type 2 (light-duty trucks 1)
- vehicle type 3 (light-duty trucks 2)
- vehicle type 4 (referred to in VISION as medium-duty vehicles)

Table S1 (at the end of this report) shows a full correspondence between vehicle categories in VISION and PATHWAYS, as well as in ARB's EMFAC model, which both VISION and PATHWAYS drew upon.

Table 4-1 lists the various vehicle technology types as defined in VISION's passenger module, and corresponding vehicle types in PATHWAYS. Light-duty vehicles of technology type 2 (diesel) typically make up 1% or less of the total vehicle stock. So for this analysis of light-duty vehicles, vehicle miles traveled and energy consumption from gasoline and diesel vehicles were lumped together, and emissions rates for gasoline were applied to calculate these vehicles' CO_2 emissions. Also in both the Reference case and Scoping Plan scenario, there were no LDV vehicles of type 4 (ethanol), type 5 (CNG), or type 6 (LNG).

Table 4-1: Vehicle Technology Types in VISION and PATHWAYS

VISION passenger vehicle technology number	VISION passenger vehicle technology name	PATHWAYS vehicle technology name
1	gasoline	Gasoline LDV
2	diesel	n/a
3	electric	BEV
4	ethanol	n/a
5	compressed natural gas (CNG)	n/a
6	liquefied natural gas (LNG)	n/a
7	hydrogen fuel cell	Hydrogen Fuel Cell
8	plug-in hybrid electric	PHEV25

For light-duty vehicles, vehicle stocks for each class (light-duty auto or light-duty truck) and technology type are a close match between VISION and PATHWAYS, particularly through 2030 (see Figure S1, at the end of this document). The close correspondence between these outputs from VISION and PATHWAYS suggest that the detailed outputs from VISION for each model year, vehicle type, and technology type can be used as a proxy for vehicle stocks in PATHWAYS.

5. Scenarios Modeled

To simulate the effect of several possible combinations of regulatory outcomes, Near Zero also made modifications to VISION outputs as follows (with results for each scenario shown in Figure 2):

- **Scoping Plan Update Scenario**: CA retains legal authority to implement the ACC Waiver and CAFE standards are maintained through 2025, and with continued improvments in efficiency beyond 2025.
- **Loss of CA efficiency waiver & EPA midterm review reversal:** CA is limited to federal CAFE standards, which are fixed at the 2021 model year emissions rates, for all models from 2021 onward.
- **Loss of ACC in 2018**: To simulate loss of authority for the ACC and a severe impact from that change, we assumed that annual sales of battery electric, hydrogen fuel cell, and plug-in hybrid electric vehicles would remain at the same rate as in the year when the waiver(s) were revoked. To supply the same amount of VMT for consumers, additional gasoline and

diesel vehicles were added, using a stock turnover approach, with vehicle efficiency for each model year meeting the average efficiency of vehicles at that time in the scenario being modeled (VISION's Current Controls Program scenario or Cleaner Technology and Fuels (CTF) scenario).

- **Loss of all waivers and CAFE standards fixed at 2021 model year:** As above, with CAFE standards fixed from model year 2021 onward, and ZEV sales fixed at the 2018 rate for all subsequent years.

Figure 2: Variations on the Proposed Scoping Plan Update Scenario
"Loss ACC 2018": Sales of battery electric, hydrogen fuel cell, and plug-in hybrid vehicles remain at 2018 rate. "CAFE 2021": CAFE standards freeze at the 2021 model year standard. All other aspects of the scenario (i.e., total VMT traveled and emissions intensity of energy sources) remain the same.

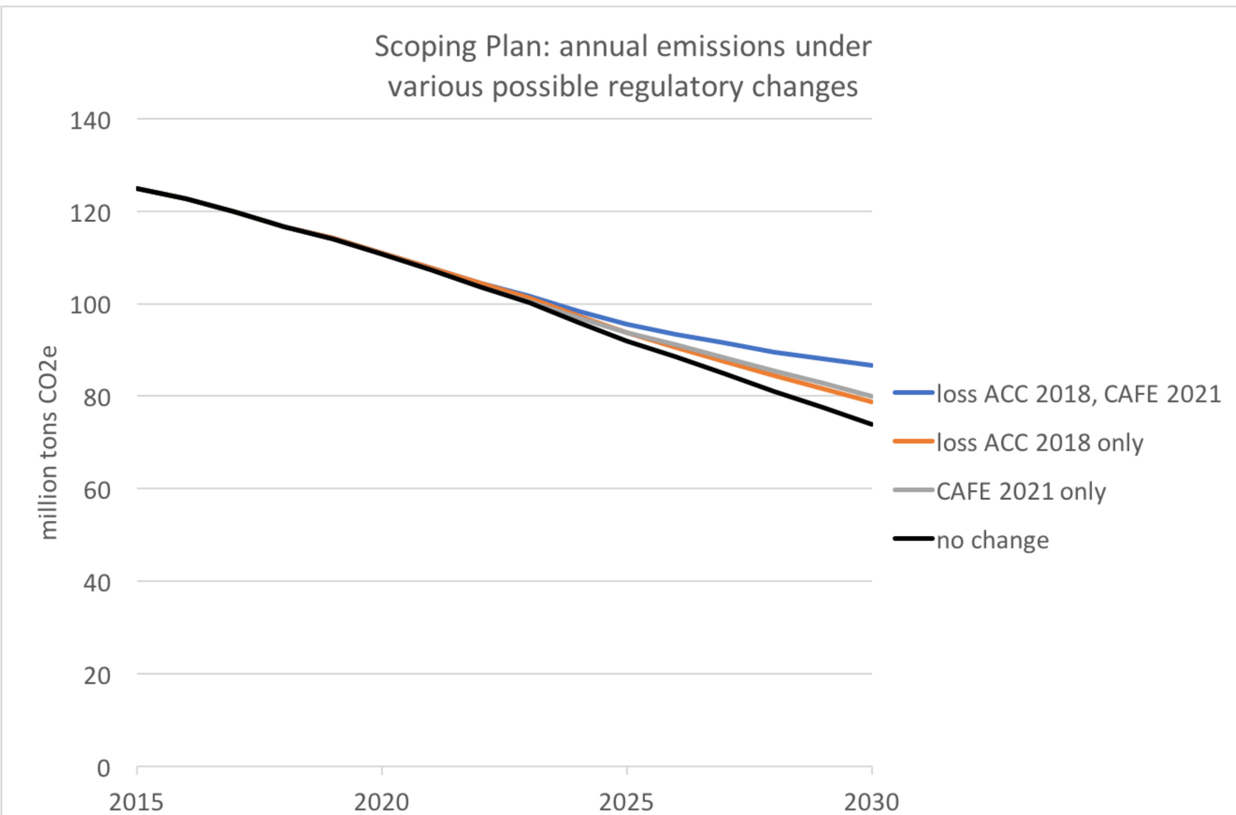


Table S1: Classification of road vehicles in EMFAC 2014, PATHWAYS, and VISION[6]

Light-duty vehicles by the definition in PATHWAYS—which are the focus of this report—are shown in green.

PATHWAYS vehicle class	EMFAC2014 vehicle class	VISION module	VISION vehicle description
LDA	LDA	PVM	Light-Duty Automobiles (i.e. Passenger Cars)
LDT	LDT1	PVM	Light-Duty Trucks (0-3,750 lbs GVWR)
LDT	LDT2	PVM	Light-Duty Trucks (3,751-5,750 lbs GVWR)
LDT	MDV	PVM	Medium-Duty Trucks (5,751-8,500 lbs GVWR)
MDV	LHD1	HDV	Light-Heavy-Duty Trucks (GVWR 8501-10000 lbs)
MDV	LHD2	HDV	Light-Heavy-Duty Trucks (GVWR 10001-14000 lbs)
MCY	MCY	n/a	n/a
MDV	T6 Ag	HDV	Medium-Heavy Duty Diesel Agriculture Truck
MDV	T6 CAIRP heavy	HDV	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>26000 lbs
MDV	T6 CAIRP small	HDV	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR<=26000 lbs
MDV	T6 instate construction heavy	HDV	Medium-Heavy Duty Diesel instate construction Truck with GVWR>26000 lbs
MDV	T6 instate construction small	HDV	Medium-Heavy Duty Diesel instate construction Truck with GVWR<=26000 lbs

[6] For VISION, PVM is the Passenger Vehicle Module, and HDV is the Heavy Duty Vehicle Module. Sources: California PATHWAYS Model Framework and Methods, Model version: 2.4 (January 2017), Table 12, available at: https://www.arb.ca.gov/cc/scopingplan/california_pathways_model_framework_jan2017.pdf; and Vision 2.1 Scenario Modeling System Limited Scope Release, Table 2, available at: https://www.arb.ca.gov/planning/vision/docs/vision2.1_model_documentation_20170202.pdf.

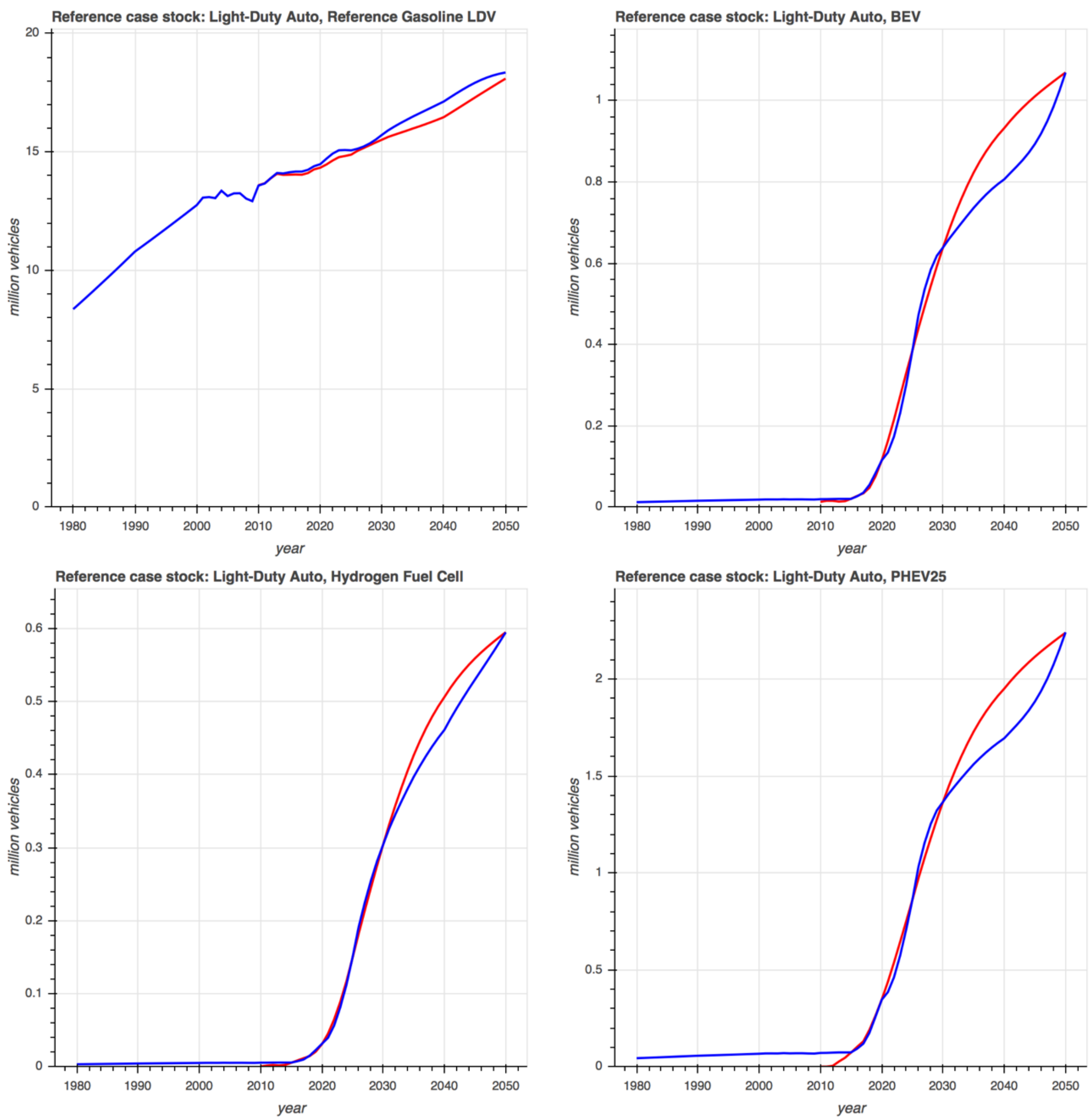
MDV	T6 instate heavy	HDV	Medium-Heavy Duty Diesel instate Truck with GVWR>26000 lbs
MDV	T6 instate small	HDV	Medium-Heavy Duty Diesel instate Truck with GVWR<=26000 lbs
MDV	T6 OOS heavy	HDV	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR>26000 lbs
MDV	T6 OOS small	HDV	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR<=26000 lbs
MDV	T6 Public	HDV	Medium-Heavy Duty Diesel Public Fleet Truck
MDV	T6 utility	HDV	Medium-Heavy Duty Diesel Utility Fleet Truck
MDV	T6TS	HDV	Medium-Heavy Duty Gasoline Truck
HDV	T7 Ag	HDV	Heavy-Heavy Duty Diesel Agriculture Truck
HDV	T7 CAIRP	HDV	Heavy-Heavy Duty Diesel CA International Registration Plan Truck
HDV	T7 CAIRP construction	HDV	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck
HDV	T7 NNOOS	HDV	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-state Truck
HDV	T7 NOOS	HDV	Heavy-Heavy Duty Diesel Neighboring Out-of-state Truck
HDV	T7 other port	HDV	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities
HDV	T7 POAK	HDV	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area
HDV	T7 POLA	HDV	Heavy-Heavy Duty Diesel Drayage Truck near South Coast
HDV	T7 Public	HDV	Heavy-Heavy Duty Diesel Public Fleet Truck
HDV	T7 Single	HDV	Heavy-Heavy Duty Diesel Single Unit Truck

HDV	T7 single construction	HDV	Heavy-Heavy Duty Diesel Single Unit Construction Truck
HDV	T7 SWCV	HDV	Heavy-Heavy Duty Solid Waste Collection Truck
HDV	T7 tractor	HDV	Heavy-Heavy Duty Diesel Tractor Truck
HDV	T7 tractor construction	HDV	Heavy-Heavy Duty Diesel Tractor Construction Truck
HDV	T7 utility	HDV	Heavy-Heavy Duty Diesel Utility Fleet Truck
HDV	T7IS	HDV	Heavy-Heavy Duty Gasoline Truck
HDV	PTO	HDV	Power Take Off
BUS	SBUS	PVM	School Buses
BUS	UBUS	PVM	Urban Buses
BUS	Motor Coach	n/a	n/a
BUS	OBUS - GAS	PVM	Other Buses
BUS	All Other Buses - DSL	n/a	n/a

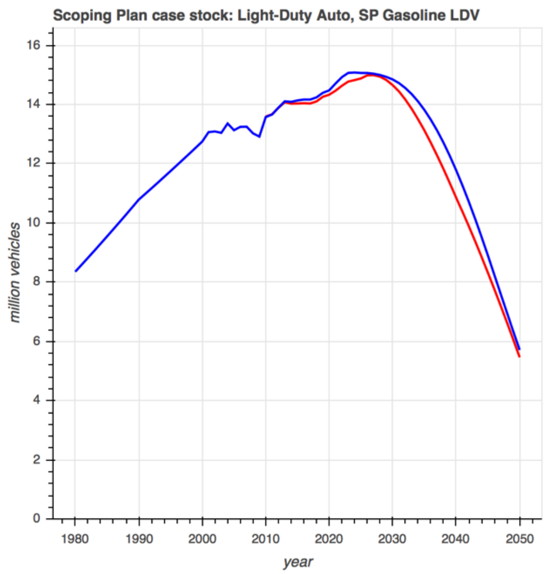
Figure S1. Vehicle Stocks by Class and Technology Type

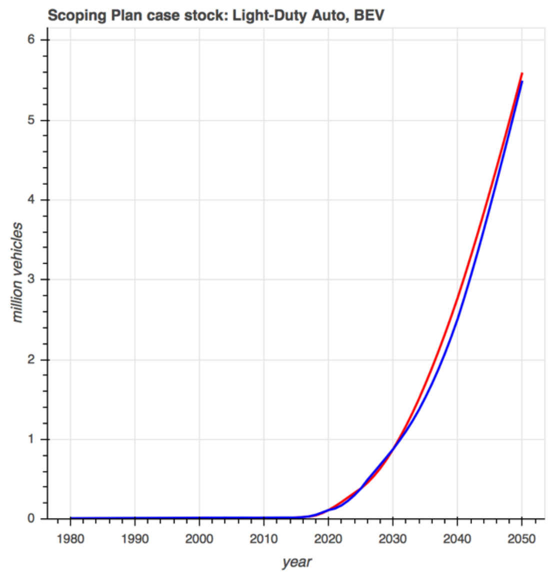
VISION in red, PATHWAYS in blue

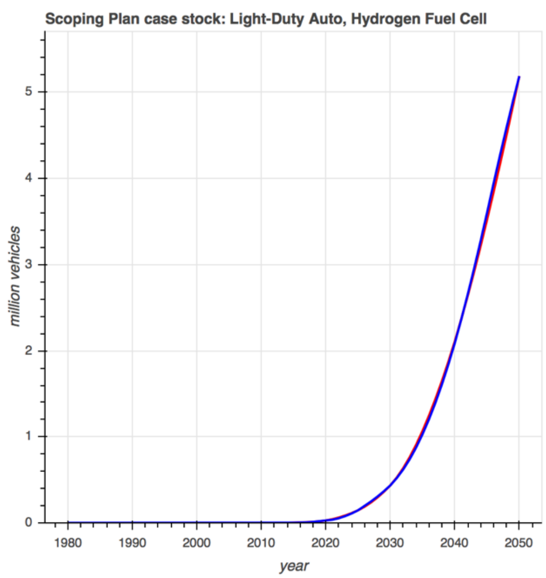
a) Light-Duty Autos, Reference Case

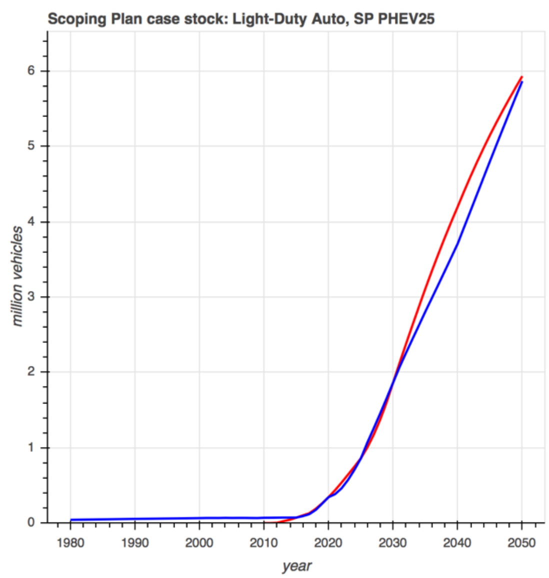


b) Light-Duty Autos, Scoping Plan Update Proposed Scenario

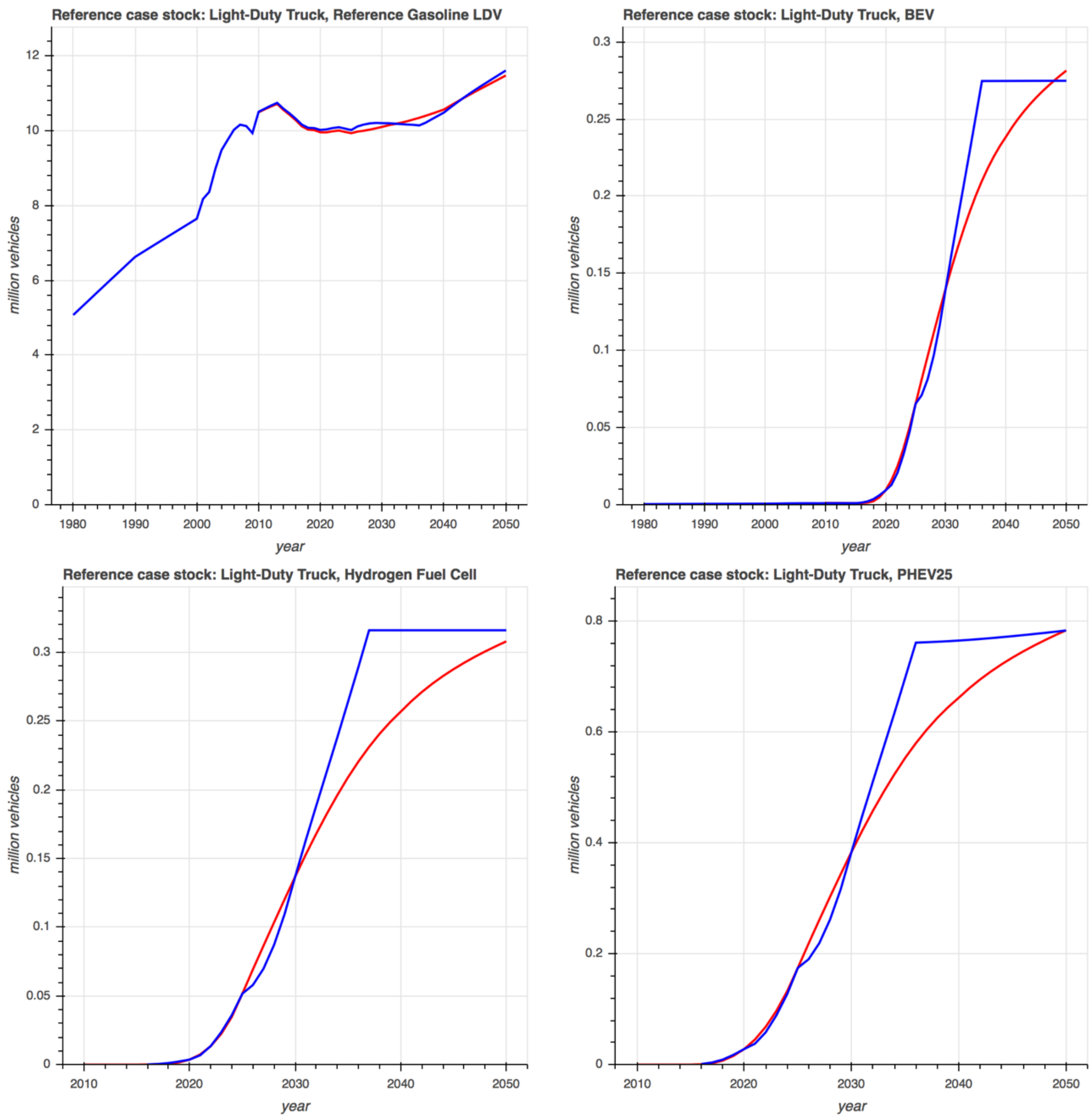




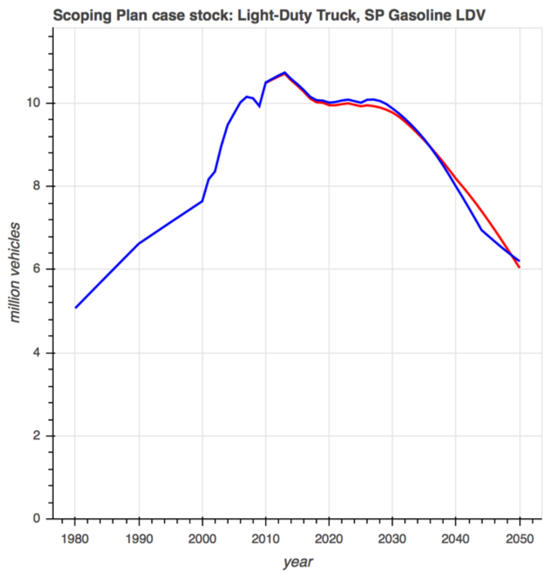


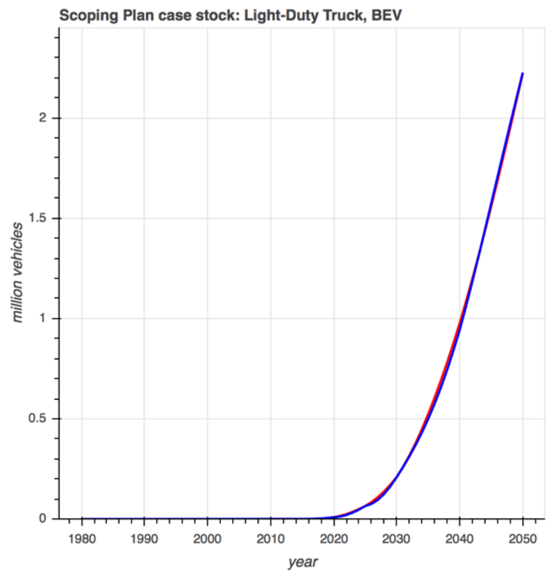


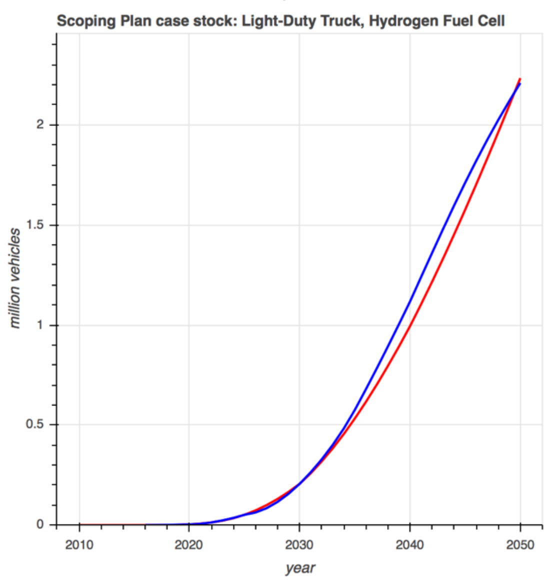
c) Light-Duty Trucks, Reference case

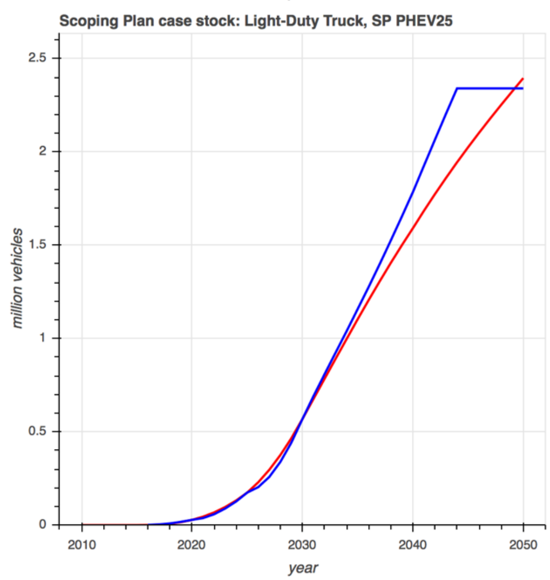


d) Light-Duty Trucks, Scoping Plan Update Proposed Scenario









Managing Uncertainty and Risk in the Proposed Scoping Plan Update

Appendix B: Technical Report on Emissions of Hydrofluorocarbons

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1. Introduction

The purpose of this technical report is to evaluate the treatment of emissions of hydrofluorocarbons (HFCs) in modeling conducted in support of the California Air Resources Board (ARB) 2017 Climate Change Scoping Plan Update: The Proposed Strategy for Achieving California's 2030 Greenhouse Gas Target[1] ("proposed Scoping Plan Update"). We examine the HFC emission reductions assumed in the proposed Scoping Plan Update and their relationship to existing and proposed policy measures laid out in the ARB Short-Lived Climate Pollutant (SLCP) Reduction Strategy[2].

ARB has undertaken sophisticated modeling to generate "business as usual" (BAU) projections and reduction scenarios for HFC emissions in support of the SLCP Reduction Strategy. We applaud this work, as it provides a rigorous basis for exploring a range of possible future BAU and policy scenarios that reflect the uncertainties inherent in future projections. But the modeling in support of the proposed Scoping Plan Update (using the PATHWAYS model) only draws on this work at the scale of total HFC emissions and reductions, without directly considering the contribution of specific policy measures reducing HFC emissions to overall emission reductions in the proposed Scoping Plan Update.

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[1] California Air Resources Board (hereinafter "ARB"), The 2017 Climate Change Scoping Plan Update: The Proposed Strategy for Achieving California's 2030 Greenhouse Gas Target (January 2017) (hereinafter "proposed Scoping Plan Update"), available at: https://www.arb.ca.gov/cc/scopingplan/2030sp_pp_final.pdf

[2] ARB, Final Proposed Short-Lived Climate Pollutant Reduction Strategy (March 2017), available at: https://www.arb.ca.gov/cc/shortlived/meetings/03142017/final_slcp_report.pdf

Based on our analysis, we have the following technical recommendations:

- **Technical Recommendation #1:** ARB should provide further details about the assumptions and uncertainties underlying the proposed Scoping Plan Update Reference scenario for HFC emissions (based on PATHWAYS modeling), and explain the approach taken to harmonize potential inconsistencies among the data sources from which it draws.

- **Technical Recommendation #2:** ARB should provide further details regarding how specific policy measures for reducing HFC emissions laid out in the proposed Scoping Plan Update and SLCP Reduction Strategy are assumed to contribute to cumulative 2021-2030 emission reductions in the Proposed Scoping Plan scenario and Uncertainty scenario (presented in Figure II-2 of the proposed Scoping Plan Update).

- **Technical Recommendation #3:** ARB should clarify the effects of the recent revisions to historical HFC emissions in the GHG Emissions Inventory on the ARB projection for 2030 "business as usual" HFC emissions and on the 2030 target for HFC emission reductions of 40% below 2013 emissions.

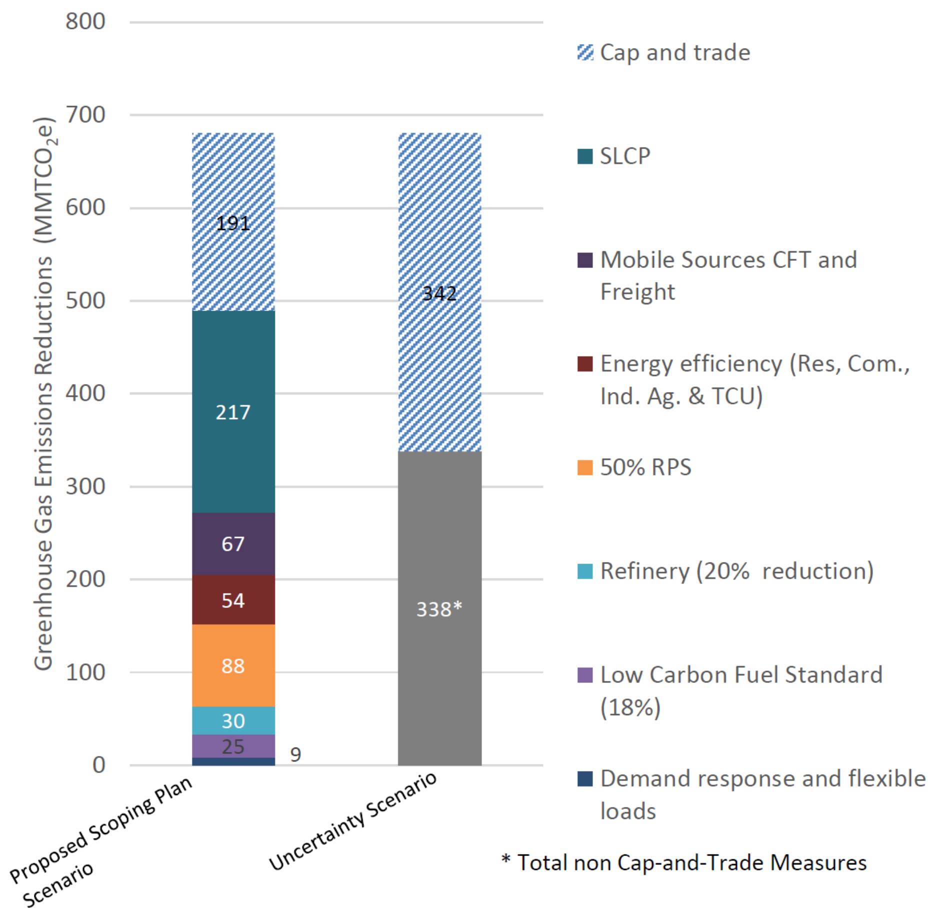
2. Contribution of HFCs to Scoping Plan Emission Reductions

The proposed Scoping Plan Update uses the California PATHWAYS 2.4 model[3] to calculate "business as usual" ("Reference scenario") greenhouse gas (GHG) emissions and GHG reductions required to meet California's target of a 40% reduction in greenhouse gases by 2030 compared to 1990 levels. The annual 2030 statewide target emissions level for California is 260 million metric tons of CO2-equivalent (MMTCO$_2$e).[4] Figure II-2 from the proposed Scoping Plan Update presents estimated 2021-2030 cumulative GHG reductions under the Proposed Scoping Plan scenario.

[3] Energy and Environmental Economics, Inc. (hereinafter "E3"), California PATHWAYS version 2.4, available at: https://www.arb.ca.gov/cc/scopingplan/pathways_2.4.0_19jan2017.zip

[4] ARB, *supra* note 1 at 16.

Figure II-2. Proposed Scoping Plan Scenario – Estimated Cumulative GHG Reductions by Measure (2021–2030)



Roughly a third (32%) of total cumulative 2021-2030 GHG reductions in Figure II-2, 217 $MMTCO_2e$ using 100-year Global Warming Potentials (GWP-100; see section 2.1), are attributed to implementation of the SLCP Reduction Strategy. According to the PATHWAYS results provided in support of the proposed Scoping Plan Update,[5] roughly one half of these cumulative 2021-2030 SLCP reductions are assumed to come from reductions in emissions of fluorinated gases (F-gases), predominantly HFCs (111 $MMTCO_2e$ GWP-100, 51% of SLCP reductions and 16% of total proposed Scoping Plan Update reductions).

PATHWAYS links its assumed reductions in F-gas emissions under the Proposed Scoping Plan scenario to the HFC emission reduction target from the SLCP Reduction Strategy (returning HFC emissions to 40% below 2013 levels by 2030; see section 2.3). Table 11 from the SLCP Reduction Strategy summarizes potential measures to achieve this goal, in $MMTCO_2e$ using 20-

[5] E3, PATHWAYS Output Tool, available at: https://www.arb.ca.gov/cc/scopingplan/pathways_main_outputs_final_17jan2017.xlsm

year GWPs (GWP-20; see section 2.1).[6] Potential measures are collectively expected to reduce annual HFC emissions in 2030 by 63% below a "business as usual" (BAU) projection (to which the PATHWAYS F-gas Reference scenario is calibrated; see section 2.2.2).[7]

This BAU projection is based on an F-gas model developed by ARB that makes detailed estimates of product and equipment inventories (e.g., refrigeration and air conditioning equipment) and their evolution over time to calculate HFC emissions for the historical period and project emissions out to 2030.[8] Historical and projected emissions are updated annually, and as stated above we applaud this modeling effort, which provides a rigorous basis for exploring a range of possible future BAU and policy scenarios reflecting the uncertainties inherent in future projections.

Table 11: Proposed New HFC Emission Reduction Measures and Estimated Emission Reductions ($MMTCO_2e$)[1]

Measure Name	2030 Annual Emission Reductions	2030 Annual Emissions
2030 BAU[2]		**65**
Financial Incentive for Low-GWP Refrigeration Early Adoption	2	
HFC Supply Phasedown (to be achieved through the global HFC phasedown)[3]	19	
Prohibition on sales of very-high GWP refrigerants	5	
Prohibition on new equipment with high-GWP Refrigerants	15	
2030 BAU with new measures		**24**

[1]Using 20-year GWPs from the 4th Assessment report of the IPCC
[2]"Business as Usual" (BAU) forecasted inventory includes reductions from implementation of current ARB and U.S. EPA regulations
[3] A global HFC production and consumption phasedown was agreed to on October 15, 2016, in Kigali, Rwanda. ARB is currently evaluating the impact upon HFC emission reductions in California and plans to utilize the results from the assessment to inform future updates to BAU projections for HFC emissions.

2.1. GWP Differences in Proposed Scoping Plan Update and SLCP Reduction Strategy

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6 ARB, *supra* note 2 at 91.

7 *Id.*

8 ARB, California's High Global Warming Potential Gases Emission Inventory: Emission Inventory Methodology and Technical Support Document (April 2016), available at: https://www.arb.ca.gov/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf; Gallagher, Glenn et al. 2013. "High Global Warming Potential F‐gas Emissions in California: Comparison of Ambient-Based versus Inventory-Based Emission Estimates, and Implications of Refined Estimates." Environmental Science & Technology 48, 1084-1093. dx.doi.org/10.1021/es403447v

The SLCP Reduction Strategy expresses annual HFC emission reductions in $MMTCO_2e$ using 20-year GWPs (GWP-20) from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).[9] In contrast, the proposed Scoping Plan Update (as well as the ARB GHG Inventory) use 100-year GWPs from the same source.[10] In addition, while the SLCP Reduction Strategy uses the 20-year GWP for black carbon from the IPCC Fifth Assessment Report (AR5)[11] (the first IPCC report to report a GWP value for black carbon), the revised AR5 GWPs for other gases have not yet been incorporated in ARB calculations.

There is no one "correct" metric that captures all aspects of the differential climate effects of different emitted substances,[12] but the choice of GWP time horizon and vintage has implications for calculating CO_2-equivalent emissions and reductions from a basket of multiple GHGs. Importantly, individual GHGs will contribute differently to overall emissions (and emission reduction) totals, depending on the GWPs used. For example, the SLCP Reduction Strategy notes that the average 100-year GWP (AR4) of the current mix of HFCs in use is about 1700, while the average 20-year GWP (AR4) of the same mix is about 3800.[13] Table 2-1 lists 20- and 100-year GWP values from the IPCC AR4 and AR5 for the 9 HFCs included in the SLCP Reduction Strategy targets (see section 2.2.1).

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9 ARB, *supra* note 2 at 39-40.

10 ARB, *supra* note 1; ARB, 2016 Edition of the GHG Emissions Inventory (June 2016), available at: https://www.arb.ca.gov/cc/inventory/data/data.htm

11 ARB, *supra* note 2 at 39-40.

12 Allen, Myles R. et al. 2016. "New Use of Global Warming Potentials to Compare Cumulative and Short-Lived Climate Pollutants." Nature Climate Change 6, 773-776; Pierrehumbert, R.T. 2014. "Short-Lived Climate Pollution." Annual Review of Earth And Planetary Sciences 42, 341-379.

13 CARB, *supra* note 2 at 44.

Table 2-1: Global Warming Potentials (GWPs)

	AR4 GWP-20[a]	AR4 GWP-100[b]	AR5 GWP-20	AR5 GWP-100
HFC-125	6350	3500	6090	3170
HFC-134a	3830	1430	3710	1300
HFC-143a	5890	4470	6940	4800
HFC-152a	437	124	506	138
HFC-227ea	5310	3220	5360	3350
HFC-245fa	3380	1030	2920	858
HFC-32	2330	675	2430	677
HFC-365mfc	2520	794	2660	804
HFC-43-10mee	4140	1640	4310	1650

[a] Used in SLCP Reduction Strategy
[b] Used in proposed Scoping Plan Update, PATHWAYS, and ARB GHG Inventory

2.2. PATHWAYS Reference Scenario Assumptions

The PATHWAYS Reference scenario for F-gas emissions (and its sectoral breakdown) originates from the CALGAPS model,[14] based on modeling results from ARB's 2013 "Methodology to Estimate GHG Emissions from ODS Substitutes."[15] Total annual emissions are scaled to match more recent information on historical emissions from the ARB GHG Emissions Inventory, as well as the 2030 BAU projection from the SLCP Reduction Strategy. But recent revisions to historical HFC emissions in the ARB GHG Emissions Inventory are not yet reflected in the projection PATHWAYS uses for 2030 Reference scenario emissions, and PATHWAYS considers somewhat different baskets of F-gases for historical and projected emissions.

2.2.1. Historical Emissions

PATHWAYS stores data for its Reference scenario for F-gas emissions starting in 2010.[16] Historical emissions from 2010-2013 are benchmarked to the 2015 Edition of the ARB GHG Emissions Inventory (covering emissions from 2000-2013).[17] Details about which gases are

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14 E3, California PATHWAYS Model Framework and Methods (January 2017) (see section 4), available at: https://www.arb.ca.gov/cc/scopingplan/california_pathways_model_framework_jan2017.pdf; for description of CALGAPS, see Greenblatt, Jeffery B. 2015. "Modeling California Policy Impacts on Greenhouse Gas Emissions." Energy Policy 78 (March): 158–72. doi:10.1016/j.enpol.2014.12.024.

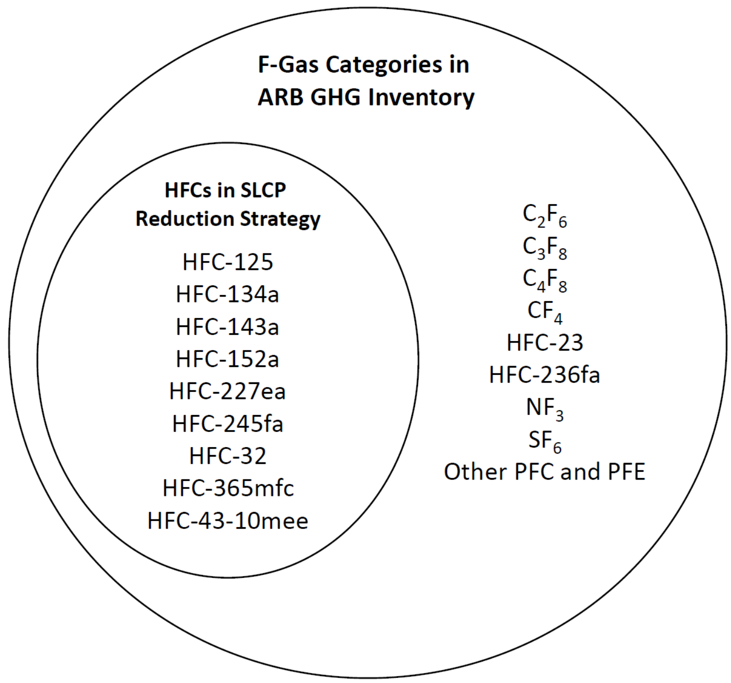
15 E3, *supra* note 3, see Non-Energy/Non-CO_2 Module.

16 *Id.*

17 ARB, 2015 Edition of the GHG Emissions Inventory (June 2015), available at: https://www.arb.ca.gov/cc/inventory/pubs/pubs.htm; ARB, Proposed Scoping Plan Update Appendix D: PATHWAYS Modeling (January 2017), available at: https://www.arb.ca.gov/cc/scopingplan/app_d_pathways.pdf

included in the benchmarking are not explicitly reported, but total emissions (in $MMTCO_2e$ using AR4 GWP-100) correspond to a basket of 18 F-gas categories (see Figure 2-1). In contrast, the SLCP Reduction Strategy relies on a basket of 9 HFCs, which represent 95-97% of total F-gas emissions in the GHG Emissions Inventory for the years 2010-2014 (using AR4 GWP-100).

Figure 2-1: F-Gas Categories in ARB GHG Inventory and SLCP Reduction Strategy



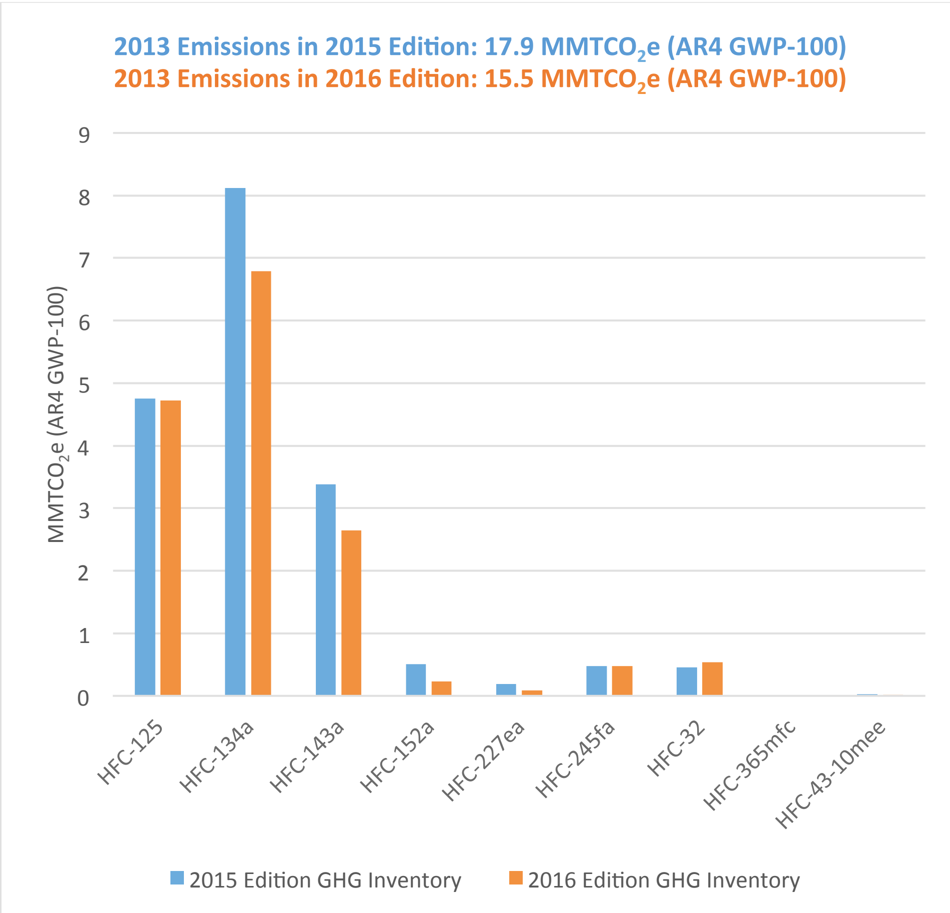
In addition, historical HFC emissions were retroactively revised in the most recent 2016 Edition of the ARB GHG Emissions Inventory (covering emissions from 2000-2014)[18] to reflect the most current California-specific information regarding the type and usage of commercial refrigerants as well as reduced actual usage of residential refrigerator-freezers, consumer aerosol propellants, and medical dose inhaler propellants.[19] These changes resulted in significant reductions of ~2-3 $MMTCO_2e$ using AR4 GWP-100 (~10-30%) in annual emissions totals compared with the 2015 Edition, depending on the year (2000-2013). For illustration, Figure 2-2 shows changes in per-gas contributions to overall 2013 HFC emissions from the 2015 Edition to

[18] ARB, 2016 Edition of the GHG Emissions Inventory (June 2016), available at: https://www.arb.ca.gov/cc/inventory/data/data.htm

[19] ARB, Inventory Updates Since the 2015 Edition of the Inventory: Supplement to the Technical Support Document (June 2016), available at: https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2014/ghg_inventory_00-14_method_update_document_20160617.pdf

the 2016 Edition of the ARB GHG Inventory (for the 9 HFCs included in the SLCP Reduction Strategy).

Figure 2-2: Revisions to HFC Emissions in ARB GHG Inventory (2015 and 2016)



Although this is not noted in the documentation provided with the proposed Scoping Plan Update,[20] the PATHWAYS Reference scenario appears to reflect the 2016 Edition revision in its lower total for 2014 emissions (17.1 MMTCO$_2$e in 2014 compared to 18.5 MMTCO$_2$e in 2013, using AR4 GWP-100), matching total emissions for the same basket of 18 F-gas categories from the 2016 Inventory.

Figure 2-3 summarizes the different historical trajectories described here. Note that the 2010-2013 PATHWAYS Reference scenario and the 2010-2013 18-gas emissions from the 2015 GHG Inventory are identical.

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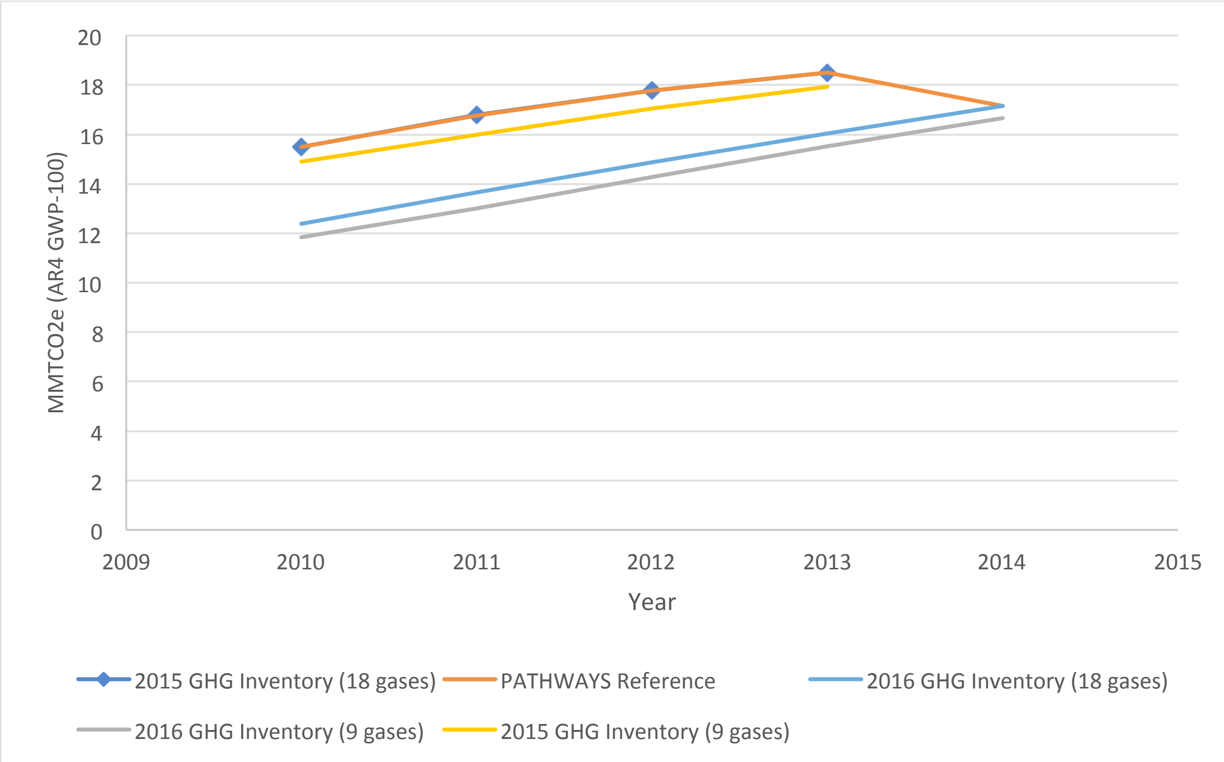
[20] ARB, Proposed Scoping Plan Update Appendix D: PATHWAYS Modeling (January 2017), available at: https://www.arb.ca.gov/cc/scopingplan/app_d_pathways.pdf

Figure 2-3: PATHWAYS Reference Scenario and ARB GHG Inventory (2015 and 2016)



2.2.2. Projected Emissions

Total annual F-gas emissions in 2030 in the Reference scenario are scaled to match the BAU projection from the SLCP Reduction Strategy, a total of 28.1 $MMTCO_2e$ (AR4 GWP-100) for a basket of 9 HFCs (see Figure 2-1). While these 9 HFCs represent 95-97% of total F-gas emissions in the GHG Emissions Inventory for the years 2010-2014 (as noted in section 2.1.2), the difference in the basket of gases used in the historical and projected calibrations is an inconsistency in the PATHWAYS Reference scenario unless emissions of gases beyond those 9 HFCs are assumed to be zero by 2030.

Perhaps most importantly, historical emissions reported in the SLCP Reduction Strategy correspond to the higher emissions of HFCs from the 2015 Edition of the GHG Emissions Inventory, not to the lower emissions in the 2016 Edition of the GHG Emissions Inventory (see section 2.2.1 and Table 2-1 in section 2.1). Thus, while the 2014 total for F-gas emissions in the PATHWAYS Reference scenario reflects the downward revision in the 2016 Edition of the GHG Emissions Inventory, the projection for 2030 does not.

How these lower historical emissions might affect the BAU projection from the SLCP Reduction Strategy is not completely clear without further information, but it is plausible that these changes would translate into a lower BAU projection for 2030 if the 2016 Edition data were incorporated. The next iteration of the ARB BAU projection for F-gas emissions may address this question.

2.2.3. Sectoral Breakdown Comparison

PATHWAYS documentation provided with the proposed Scoping Plan Update states that its sectoral breakdown for F-gas emissions (CO_2e totals for 7 categories) is based on proportions from the CALGAPS model.[21] PATHWAYS includes residential, commercial, industrial, and transportation categories described as including emissions from fugitive refrigerants (CFCs, HCFCs, and HFCs).[22] PATHWAYS also includes an electricity category described as including primarily fugitive SF_6 emissions from electrical equipment.

The 2030 BAU projection from the SLCP Reduction Strategy is based on an ARB-developed model with further sectoral disaggregation by gas and subsector (per-gas totals for 10 broad categories with 29 sub-categories).[23] While PATHWAYS calibrates total emissions to the SLCP Reduction Strategy projection, it retains the sectoral breakdown from CALGAPS.

Table 2-2 displays the high-level sectoral breakdown in 2030 for F-gas emissions from PATHWAYS and HFC emissions from the SLCP Reduction Strategy projection. Sectoral totals differ, with residential and industrial emissions lower and commercial and transportation emissions higher in PATHWAYS. The reasons for these sectoral differences are not clear, but confirm that calibration between the original CALGAPS-derived Reference scenario and the ARB modeling underlying the SLCP Reduction Strategy was done at the level of overall emissions, rather than sectoral emissions.

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[21] E3, *supra* note 14.

[22] E3, *supra* note 14 at 151.

[23] ARB, *supra* note 7 at 6-7.

Table 2-2: Sectoral Comparison of PATHWAYS and SLCP Reduction Strategy

	($MMTCO_2e$ GWP-100)	
Sector	**SLCP Reduction Strategy BAU**	**PATHWAYS Reference**
Residential	8	7.2
Commercial	11.9	13.6
Industrial	5.4	3.7
Transportation	2.8	3.4
Electricity	--	0.1
Total	**28.1**	**28.0**

2.3. PATHWAYS Implementation of F-Gas Emission Reductions

The PATHWAYS Proposed Scoping Plan scenario implements a 64% reduction in annual F-gas emissions by 2030 below the Reference scenario, from 28 $MMTCO_2e$ in the Reference scenario to 10.1 $MMTCO_2e$ in the Proposed Scoping Plan scenario.[24] Reductions are assumed to begin in 2017, and are applied in equal proportion across F-gas sectors in PATHWAYS (see section 2.2.3 for discussion of sectoral breakdown). Annual percentage reductions below the Reference scenario become more stringent by 4.5% per year from 2017 through 2029 (emissions are 4.5% below baseline in 2017, 9% below baseline in 2018, and so on) with a slightly larger increase from 2029 to 2030 of 5.3%. Specific policy measures and their effects on emissions are not explicitly modeled in PATHWAYS.

Cumulative 2021-2030 F-gas emission reductions under these assumptions are 111.3 $MMTCO_2e$ (AR4 GWP-100). Reductions are assumed to include F-gases beyond HFCs, which is not completely consistent with the scope of HFC-specific reductions laid out in the SLCP Reduction Strategy (see sections 2.2.2, 2.2.3 and Figure 2-1).[25] Subtracting F-gas emissions associated with the electricity sector, which are described as primarily fugitive SF_6 emissions,[26] yields a total of 110.8 $MMTCO_2e$ (AR4 GWP-100). Given the discussion in section 2.2 above, we use this total to quantify cumulative HFC emission reductions in the next section.

2.3.1. Mapping Cumulative Emission Reductions to Policy Measures

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[24] E3, *supra* note 5.

[25] CARB, *supra* note 2. Note that Proposed Scoping Plan Update Appendix D: PATHWAYS Modeling (*supra* note 20) states that the SLCP Reduction Strategy describes measures including a 63% reduction in F-gases, rather than HFCs.

[26] E3, *supra* note 14.

Table 11 from the SLCP Reduction Strategy (reproduced in section 2) provides CO_2-equivalent (AR4 GWP-20) estimates of the contribution of proposed HFC emission reduction measures to overall reductions in 2030 annual emissions. Per the discussion in section 2.3, PATHWAYS does not explicitly model these proposed measures.

Further information is required to understand what these reductions in 2030 annual emissions mean for reductions in earlier years, and thus how specific policy measures might translate into cumulative 2021-2030 emission reductions as expressed in the proposed Scoping Plan Update (see Figure II-2 reproduced in section 2). Further information is also required to understand how modeled reductions map to the specific legal authorities assumed to be needed to achieve those reductions. Appendix F of the SLCP Reduction Strategy[27] provides qualitative descriptions of assumptions underlying the HFC emission reductions summarized in Table 11 for 2030. These descriptions outline annual changes in equipment inventories and use of HFC refrigerants due to each policy measure category. These descriptions imply that further details about HFC emission reductions in the period through 2030 (and beyond) have been developed by ARB, potentially using the same detailed inventory estimation model underlying the SLCP Reduction Strategy BAU scenario (see section 2). But only the estimates for 2030 annual emissions presented in Table 11 have been made publicly available, to our knowledge.

Based on available information, to estimate the contribution of each proposed measure to cumulative 2021-2030 emission reductions we assume that the proportional contribution of each proposed measure to overall 2030 annual emission reductions can be applied to annual emission reductions in each year prior to 2030. We apply these proportions to emission reductions across PATHWAYS F-gas sectors, leaving out the electricity sector per section 2.3. Table 2-3 summarizes the results.

[27] ARB, SLCP Reduction Strategy Appendix F: Supporting Documentation for the Economic Assessment of Measures in the SLCP Strategy (March 2017), page 62.

Table 2-3: Mapping Cumulative Emission Reductions to Policy Measures in SLCP Reduction Strategy

	Cumulative 2021-2030 Emission Reductions ($MMTCO_2e$ AR4 GWP-100)	**Proportion of 2030 Annual Emission Reductions**
Total SLCP	216.6	--
Total residential, commercial, industrial, transportation F-gas	110.8	--
Financial incentive for low-GWP refrigeration early adoption	5.4	5%
HFC supply phasedown (Kigali)	51.3	46%
Prohibition on sales of very-high GWP refrigerants	13.5	12%
Prohibition on new equipment with high-GWP refrigerants	40.5	37%

2.3.2. Implications of HFC Emissions Inventory Updates for 2030 Reductions Target

As described in section 2.2.1, HFC emissions were revised in the 2016 Edition of the ARB GHG Inventory, leading to lower total HFC emissions for the period 2000-2013 compared with the 2015 Edition. One further implication of this update is that it implies a change in the 2030 HFC emission reductions target of 40% below 2013 emissions levels.[28] Table 2-4 summarizes the implied changes, in terms of AR4 GWP-20 as in the SLCP Reduction Strategy, and in terms of AR4 GWP-100 as in the proposed Scoping Plan Update. Totals are for emissions of the same 9 HFCs included in the SLCP Reduction Strategy targets (see Figure 2-1). The 2030 target is reduced by roughly 16% using either GWP metric. This change has not yet been incorporated into the SLCP Reduction Strategy and the proposed Scoping Plan Update.

Table 2-4: Implied changes in 2013 HFC Emissions and 2030 HFC Reduction Target

2015 Edition of the ARB GHG Inventory ($MMTCO_2e$)		
	AR4 GWP-20	AR4 GWP-100
2013 HFC Emissions	40.1	17.9
2030 Target (40% below 2013 levels)	24.1	10.8
2016 Edition of the ARB GHG Inventory ($MMTCO_2e$)		
	AR4 GWP-20	AR4 GWP-100
2013 HFC Emissions	34.7	15.5
2030 Target (40% below 2013 levels)	20.8	9.3

[28] ARB, *supra* note 2.