Draft
Short-Lived Climate Pollutant Reduction Strategy

September 2015

California Environmental Protection Agency

Air Resources Board

Table of Contents

Appendices

EXECUTIVE SUMMARY

It is clear that the impacts of climate change are already upon us. California continues to suffer through historic temperatures, drought, and wildfires, and the State faces the prospect of an epochal El Niño season in the coming winter. Each year seems to bring a new global temperature record, and new evidence suggests sea levels are rising much faster than predicted. What was once, and remains, a generational problem of CO_2 balance in the atmosphere has now become an immediate threat to our California lifestyle.

The only practical way to rapidly reduce the impacts of climate change is to employ strategies built on the tremendous body of science. The science unequivocally underscores the need to immediately reduce emissions of Short-Lived Climate Pollutants (SLCPs), which include black carbon (soot), methane (CH_4), and fluorinated gases (F-gases, including hydrofluorocarbons, or HFCs). They are powerful climate forcers and dangerous air pollutants that remain in the atmosphere for a much shorter period of time than longer-lived climate pollutants, such as CO_2, and are estimated to be responsible for about 40 percent of current net climate forcing. While the climate impacts of CO_2 reductions take decades or more to materialize, cutting emissions of SLCPs can immediately slow global warming and reduce the impacts of climate change.

While we must continue to steadily reduce CO_2 emissions for long-term climate stability, we also need a global commitment and near-term actions to dramatically reduce SLCP emissions over the next 10–15 years. California is committed to taking further action to reduce SLCP emissions by 2030. Senate Bill 605 (Lara, Chapter 523, Statutes of 2014) requires the Air Resources Board (ARB or Board) to develop a plan in 2015 to reduce emissions of SLCPs. Additionally, Governor Brown has identified reductions of SLCP emissions as one of "five pillars" to meet an overarching goal to reduce California's GHG emissions by 40 percent below 1990 levels by 2030. This draft SLCP Reduction Strategy (Draft Strategy) was developed pursuant to SB 605 and lays out a range of options to accelerate SLCP emission reductions in California, including incentivizing early voluntary reduction actions and market-supporting activities, and regulatory action.

Using cost-effective and available technologies and strategies, worldwide anthropogenic sources of SLCP emissions can be largely controlled by 2030 and the global benefits of a collective commitment to substantially reduce SLCP emissions would be profound. Leading efforts by California, the United States, Mexico, Norway, Europe, the Arctic Council, and several countries and non-governmental entities acting through the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) are already targeting SLCPs.

Deploying existing technologies globally to reduce SLCP emissions can cut the expected rate of global warming in half and keep average warming below the dangerous 2^oC threshold at least through 2050. We can slow sea level rise significantly, reduce disruption of historic rainfall patterns, and boost agricultural productivity by reducing crop losses to air pollution. Cutting SLCP emissions

immediately will slow climate feedback mechanisms in the Arctic and elsewhere that would otherwise further accelerate global warming and make climate change far more difficult to solve and far more costly to live with, as more resources are shifted to disaster relief, conflict management, and adaptation. Most importantly, we can dramatically reduce global air pollution, saving millions of lives each year. Many of these benefits will primarily accrue in regions and populations disproportionately impacted by climate change, including the developing world.

California - Already a Leader on Reducing SLCP Emissions

California has been a global leader in cutting air pollution and fighting climate change for decades, which is serving as a catalyst for national and international action. A focused strategy for reducing emissions of SLCPs will benefit California—as well as our planet and other regions that continue to follow California's lead.

The State is already seeing the benefits of historical action on SLCP emissions. Existing policies are saving thousands of lives in the State each year, and they provide a strong foundation to support further efforts to reduce emissions of these dangerous pollutants:

- *Black Carbon*: California has cut levels of black carbon emissions from anthropogenic sources by more than 90 percent since the 1960s. From 2000 to 2020, California will have cut black carbon from mobile sources by 75 percent and from anthropogenic sources by 60 percent. These efforts prevent an estimated 5,000 premature deaths in the State each year. If the world replicated this success, it would prevent an estimated 3.5 million premature deaths each year, and slow global warming by as much as 15 percent, offsetting one to two decades of CO_2 emissions.
- *Methane*: California has the nation's strongest standards for limiting methane emissions from landfills. It has offset protocols under its Cap-and-Trade program to encourage the reduction of methane emissions, and rules under development and being implemented to create a comprehensive approach to limit methane leaks from oil and gas production, processing, and storage, and from the natural gas pipeline system. In addition, the State has historically regulated volatile organic compound emissions to meet air quality goals, which have resulted in a co-benefit of methane reductions. Altogether, these measures are keeping methane emissions from rising in California.
- *F-gases*: The State has regulations in place to reduce emissions from refrigerants, motor vehicle air-conditioning, and consumer products that together will cut emissions of F-gases by 25 percent below otherwise projected levels in 2020. The State's Cap-and-Trade offset protocol for ozone depleting substances incentivizes the capture and destruction of those gases (which are also F-gases).

An Opportunity for California

Still, more remains to be done, and California is doubling down on its efforts to control emissions of SLCPs from all sources. A dedicated commitment, as described in this Draft Strategy, to achieve near-term (2020 timeframe) as well as longer-term reductions in SLCP emissions in California would provide significant benefits throughout the State. Actions to reduce emissions of SLCPs can improve air quality and reduce related health risks, hospitalizations, and medical expenses – especially in disadvantaged communities. State and international action to cut SLCP levels would reduce damage to forests and crops, lower background ozone and particulate levels to help meet federal health-based air quality standards, and reduce disruption of historic rainfall patterns.

As California pursues additional reductions in black carbon, further climate change and public health benefits can be realized. California's efforts to reduce particulate matter emissions have been linked with improved lung function in children. Further reducing black carbon emissions also decreases exposure to toxic diesel particulate matter and associated health risks. Significant national and international climate change, air quality, and public health benefits can be achieved if the rest of the nation and the world follow California's lead on black carbon.

Reducing methane emissions and harnessing captured methane can help meet multiple objectives, from reducing SLCP emissions to reducing air pollution, improving soil health, and increasing the supply of California-produced biofuels. Doing so can also improve air quality and water quality and generate valuable, local, renewable energy and soil amendment products. While barriers remain that limit market-based solutions to put organic waste streams to beneficial use, collaborative efforts to overcome them could open valuable markets that could help to scale solutions to reduce emissions of SLCPs. Products from organic waste streams in California, and potential environmental credits from them, could represent a billion dollar market for California dairies and other project developers. Developing infrastructure to enable these markets could lead to significant investment in the State, much of it concentrated in the Central Valley. In order to fully realize these economic and environmental benefits, California must work to overcome obstacles to financing and developing projects that use organic waste streams.

National and international agreements provide the best way to reduce the supply of and emissions from the use of refrigerants with high global warming potentials (GWP). However, additional actions in California can accelerate the development and deployment of alternatives. The Montreal Protocol has already been used to significantly reduce emissions from many sources of F-gases, which has provided significant global climate benefits. Including HFCs under the Montreal Protocol to phase down the production of F-gases could reduce global greenhouse gas (GHG) emissions by 100 billion tonnes CO_2e and reduce average global warming by as much

as 0.5°C by 2100.[1] California will monitor international negotiations to determine how the State's actions can support, complement, and speed emission reductions. Even with an international agreement, additional, cost-effective reductions in HFC emissions may be available in California, to help meet the State's 2020 and 2030 GHG goals.

In the coming years, many billions of dollars in public and private investments are anticipated to support efforts to reduce SLCP and CO_2 emissions and support our agricultural sector, build sustainable freight systems, and grow healthy forests. These investments will strengthen the State as a whole and the communities where they occur. Many of the benefits will accrue in the Central Valley, rural parts of the State, or other areas disproportionately impacted by pollution, such as those along freight corridors.

Stubborn barriers remain, including connecting distributed electricity and biogas projects, which have slowed previous efforts to reduce emissions of SLCPs and capture a wide array of benefits. These barriers are not insurmountable, and now is the time to solve them. State agencies, utilities, and other stakeholders need to work immediately to identify and resolve remaining obstacles to connecting distributed electricity with the grid and injecting renewable natural gas into the pipeline. Supporting the use of the cleanest technologies with funding and strategies that maximize air, climate, and water benefits can accelerate their introduction. Building market certainty and value for the energy, soil amendment, and other products that come from compost or anaerobic digestion facilities would help to secure financing and scale project deployment.

Building on California Leadership

This Draft Strategy builds on California's ongoing leadership to address climate change and improve air quality. It has been developed with input from State and local agencies, academic experts, a working group of agricultural experts and farmers convened by the California Department of Food and Agriculture (CDFA), businesses, and other interested stakeholders in an open and public process. ARB and State agencies collaborated to identify reduction measures for specific sectors, including the dairy, wastewater, and waste sectors. In addition, ARB collaborated with the local air districts to identify SLCP emission reduction measures that could be implemented through district action. Throughout this process, ARB has sought advice from academic, and industry representatives. For example, climate change experts reviewed material in the May 2015 Concept Paper as well as in this Draft Strategy. Additionally, ARB staff is working closely with manufacturers to determine the feasibility and cost of replacement products for high-GWP refrigerants, and with the dairy industry to evaluate options for reducing emissions of methane at dairies.

While reducing GHG emissions is a key objective for the State, California remains committed to further reducing emissions of criteria (smog-forming) pollutants and toxic

[1] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) The role of HFCs in mitigating 21st century climate change , ATMOS. CHEM. PHYS. 13:6083-608

air pollutants, as well. Many of the concepts described in this Draft Strategy have already been discussed in the context of sustainable freight strategies, state implementation plans for air quality, and plans for bioenergy, waste management, water management, healthy soils, and sustainable management of the state's natural resources. The SLCP Strategy, along with those other planning efforts, will inform and be integrated into the upcoming 2016 Scoping Plan, which will incorporate input from a wide range of stakeholders to develop an integrated plan for reducing emissions of GHGs, criteria pollutants, and toxic air pollutants through 2030. The process for updating the Scoping Plan will kick off in fall 2015 and is scheduled for completion in 2016.

State agencies are committed to continuing to work together to ensure that the concepts outlined in this Draft Strategy are implemented in a coordinated and synergistic way. The sections below describe mandatory and voluntary measures, incentives, and other policies that:

- Encourage national and international deployment of California's well-established and proven measures to reduce black carbon emissions;
- Pursue additional reductions in black carbon emissions from off-road and non-mobile sources;
- Reduce methane or avoid methane emissions before they are released;
- Make the best use of methane that is generated (for example, as a transportation fuel or for clean power generation); and
- Accelerate the transition to low-GWP refrigerants.

ARB staff will receive and consider comments on this Draft Strategy and prepare a proposed Strategy to present to the Board in late 2015, with a final proposed Strategy presented to the Board for consideration in Spring 2016.

Achieving Science-Based Targets

Assessments of global potential to reduce SLCP emissions suggest that cost-effective measures can cut methane emissions by about 40 percent and black carbon by about 80 percent below 2005 levels. Additionally, a new global phase down of HFCs under the Montreal Protocol and other efforts could cut the expected production of F-gases by 70 percent in 2030. Achieving these levels of global reductions would deliver significant climate benefits. It would cut the expected rate of global warming in half by 2050, slowing global temperature rise by about 0.6^{o}C, which would reduce the risk of dangerous climate feedbacks such as accelerated Arctic melting and sea level rise.

Based on stakeholder feedback on the Concept Paper released in May 2015, as well as further analysis, ARB is proposing targets to reduce emissions of methane and F-gases by 40 percent below current (2013) levels by 2030, and anthropogenic (non-forest) black carbon emissions by 50 percent below current levels by 2030.

The goals and proposed measures included in this Draft Strategy will reduce SLCP emissions to levels in-line with these targets. The proposed targets are summarized in Table 1.

Table 1. California SLCP Emissions and Proposed Target Emission Levels ($MMTCO_2e$)[1]

		2030	
Pollutant	**2013**	**BAU[2]**	**Draft Strategy**
Black carbon (non-forest)	38	26	19
Methane	118	117	71
F-gases	40	65	24

[1] Using 20-year GWPs from the 4th Assessment report of the IPCC for methane and F-gases, and 5th Assessment report for black carbon

[2] Business As Usual forecasted inventory includes reductions from implementation of current regulations

Climate change is no longer a problem to be defined simply in terms of a legacy we leave to our grandchildren or impacts in the year 2100. It is affecting us now, and will only accelerate in our lifetime. Due to the urgency of the issue, and the need to recognize the costs and benefits of addressing it immediately, we use 20-year GWPs in this report to quantify emissions of SLCPs.

Black Carbon

Black carbon is not one of the climate pollutants originally included in international climate frameworks, and it is not included in California's AB 32 inventory. However, recent studies have shown that black carbon plays a far greater role in global warming than previously believed. California has made tremendous progress in reducing black carbon emissions as part of its efforts to reduce carcinogenic diesel particulate matter emissions and improve air quality. California has already cut anthropogenic black carbon emissions by over 90 percent since the 1960s, and existing measures are projected to cut mobile source emissions by 75 percent and total anthropogenic emissions by nearly 60 percent between 2000 and 2020. Putting measures in place to achieve similar levels of reductions worldwide is the quickest way to reduce the impacts of climate change, and would save millions of lives per year.

These reductions have come from strong efforts to reduce on-road vehicle emissions, especially diesel particulate matter. Car and truck engines used to be the largest sources of black carbon emissions in California, but California's existing air quality policies will virtually eliminate black carbon emissions from on-road diesel engines within 10 years. These policies are based on existing technologies, which could be deployed throughout the country and the world.

With the large reduction in emissions of black carbon from vehicles, other sources of black carbon emissions will become more significant contributors to the State's black carbon inventory over time. In particular, without additional actions, off-road mobile, fuel combustion in the industrial and power sectors, and residential fireplaces will account

for more than three-quarters of black carbon emissions in California in 2030. However, black carbon emissions from these sources have declined significantly, as well – by almost 30 percent since 2000. Continued progress on these sectors – transitioning to cleaner and more efficient uses of energy, reducing emissions from residential fireplaces, taking steps to meet federal health-based air quality standards by 2031, and developing a sustainable freight system – will continue to reduce black carbon emissions and should allow us to meet the targets established in this Draft Strategy. Additional measures in these areas will be identified in the State's Mobile Source State Implementation Plan Strategy, 2016 Scoping Plan Update, and Sustainable Freight Strategy, a multi-agency effort to deploy a sustainable and efficient system for goods movement.

The largest source of black carbon emissions in California, by far, is wildfire. An average wildfire season contributes two-thirds of current black carbon emissions in California. As climate change accelerates, our drought-ravaged forests will only become more vulnerable to wildfire and disease. Indeed, many of California's forests are already in a perilous condition and require accelerated management and investment to protect them. Several Federal, State, and local agencies are currently coordinating on forest planning, which will lead to the development of a comprehensive Forest Carbon Plan in 2016. As part of this and related efforts, black carbon mitigation will be considered along with forest health, carbon sequestration, habitat and watershed production, and other drivers associated with protecting our forests.

Methane

Methane is responsible for about 20 percent of current net climate forcing globally. In California, about half of methane emissions come from organic waste streams that can be put to valuable use as sources of renewable energy or fuel and soil amendments. The other half mostly comes from enteric fermentation (burps) from dairy cows and livestock and fugitive emissions (leaks) from oil production, processing, and storage, gas pipeline system, or industrial operations. California can cut methane emissions by 40 percent below current levels in 2030 by avoiding or capturing methane from manure at dairies, meeting national industry targets for reducing methane emissions from enteric fermentation, effectively eliminating disposal of organics in landfills, and reducing fugitive methane emissions by 40-45 percent from all sources.

Strong market support and broad collaboration among State agencies, industry, and other stakeholders will be necessary to reduce landfill and manure methane emissions by putting organic waste streams to beneficial use. The State will support early action to build infrastructure and reduce emissions through existing incentives, potentially new and continued Greenhouse Gas Reduction Fund investments, and accelerated efforts to overcome barriers and foster markets. Continued and potentially new working groups will work to foster market conditions to support private sector investment in infrastructure, including building markets for compost and soil amendments, overcoming barriers to pipeline injection of biomethane, and identifying optimal financing mechanisms and levels to reach the goals in this Draft Strategy at minimal cost.

Ultimately, a combination of incentives, State and private sector investment, and regulations will be necessary to capture the value in organic waste streams and ensure lasting emission reductions. For landfills, ARB will work with CalRecycle to develop a regulation by 2018 to progress towards existing State targets for landfill diversion by 2020, and to effectively eliminate organic disposal in landfills by 2025. On dairies, ARB, in consultation with CDFA will develop a regulation by 2018 to require avoiding or capturing methane from manure management at new and expanded dairies. This will limit any potential growth in methane emissions from manure management practices in the State. Additionally, the agencies will monitor progress towards targets for existing dairies to reduce methane emissions from dairy manure management by 20 percent in 2020, 50 percent in 2025, and 75 percent in 2030. Based on progress toward these voluntary targets, and considering the level of market support available and potential for emissions leakage, ARB will develop a timeline for regulating existing dairies to require avoiding or capturing methane emissions from manure management. Finally, as many of the State's wastewater treatment plants undergo renovation or reconstruction over the next 15 years, ARB will work with the State and regional Water Boards to assess the feasibility and benefits of actions to require capturing and effectively utilizing methane generated from wastewater treatment.

This Draft Strategy also establishes a goal of reducing fugitive methane emissions from oil and gas by 40 percent below current levels in 2025 and 45 percent in 2030, and from all other sources by 40 percent in 2030. This aligns with the goal of the Obama Administration to reduce methane emissions from oil and gas operations by 40–45 percent below 2012 levels by 2025.

California has a comprehensive and stringent emerging framework to reduce methane emissions from oil and gas production, processing, storage, and the natural gas pipeline system. ARB is developing a regulation to reduce fugitive methane emissions from the oil and gas production, processing and storage sector, which will be among the most stringent such regulations in the country, along with similar policies in Colorado and Wyoming. Additionally, pursuant to Senate Bill 1371 (Leno, Chapter 525, Statutes of 2014), the California Public Utilities Commission has launched a rulemaking to minimize methane leaks from natural gas transmission and distribution pipelines. Increases in energy efficiency and renewable energy, as well as more dense development patterns, will reduce oil and gas demand and fugitive emissions. ARB and the California Energy Commission (CEC) have also conducted several research projects to improve methane emission monitoring and accounting, as well as identify emission "hotspots," which are responsible for large fractions of total fugitive emissions. These efforts will continue, and are critical to accelerating leak detection and fugitive methane emission reductions from all sectors, not just oil and gas.

Finally, the dairy industry has long been proactive in reducing the environmental footprint associated with its product, and the national dairy industry has set a voluntary goal of reducing emissions from enteric fermentation by 25 percent below 2008 levels by 2020. This level of reduction from current levels by 2030 is set as a goal for the

sector. While options exist to affect enteric emissions, more research is needed to fully evaluate the viability of these strategies in California and assess their associated costs and benefits.

F-gases

Fluorinated gases, and in particular HFCs, are the fastest-growing source of GHG emissions in California and globally. More than three-quarters of HFC emissions in California come from the use of refrigerants in the commercial, industrial, residential, and transportation sectors. In many cases, alternatives with much lower GWPs are already available and the United States Environmental Protection Agency (U.S. EPA) is beginning to impose bans on the use of F-gases with the highest GWPs in certain applications and sectors. Additionally, there is strong international momentum and interest to phase down the use of HFCs under the Montreal Protocol, as has already been done for other F-gases. An agreement to do so could be potentially reached at the annual Meeting of Parties in November 2015. In the absence of a sufficiently rigorous international agreement in November, ARB will evaluate the feasibility of a phasedown for California that aligns with similar efforts and stringency levels in Australia, Canada, Europe, and Japan.

California can complement these national and potential international actions by taking additional steps to reduce F-gas emissions at low cost. Early action, ahead of some of the phase down schedules being proposed internationally, can avoid locking-in the use of high-GWP refrigerants in new or retrofitted systems in the coming years. This would lead to unnecessary emissions now and into the future, requiring the State to take additional —likely more costly—steps to meet its 2030 climate targets. The State should consider developing an incentive program to encourage the use of low-GWP refrigerants, which could lead to very low cost emission reductions and could be implemented while further regulations are considered or developed. Also, as effective alternatives become available, ARB will consider developing bans on the use high-GWP refrigerants in sectors and applications not covered by U.S. EPA regulations.

This Draft Strategy identifies measures that can reduce F-gas emissions by more than 40 percent in California by 2030 and potentially capture additional, available reductions in HFC emissions now, and into the future. ARB will monitor progress on national and international efforts to reduce F-gas emissions, and may update this set of measures if additional national or international steps are taken before the proposed Strategy is released.

A summary of all proposed SLCP emission reduction measures and estimated reductions is presented in Table 2.

Table 2: Summary of Proposed New SLCP Measures and Estimated Emission Reductions ($MMTCO_2e$)[1]

Measure Name	2030 Annual Emission Reductions	2030 Annual Emissions
Black Carbon (Non-Forest)		
2030 BAU[2]		26
Residential Fireplace and Woodstove Conversion	3	
Sustainable Freight Strategy State Implementation Plans Clean Energy Goals	~4[3]	
2030 BAU with new measures		19
Methane		
2030 BAU[2]		117
Dairy Manure	21	
Dairy and Livestock Enteric Fermentation	5	
Landfill	5	
Oil and Gas	8	
Wastewater, Industrial, and Other	7	
2030 BAU with new measures		71
F-Gases		
2030 BAU[2]		65
Financial Incentive for Low-GWP Refrigeration Early Adoption	2	
HFC Supply Phasedown	23	
Sales ban of very-high GWP refrigerants	1	
Prohibition on new equipment with high-GWP	15	
2030 BAU with new measures		24

[1] Using 20-year GWPs from the 4th Assessment report of the IPCC for methane and F-gases, and 5th Assessment report for black carbon

[2] "Business As Usual" forecasted inventory includes reductions from implementation of current regulations

[3] Additional black carbon reductions will be realized from planned measures, and are expected to help the State meet the black carbon target. However, an estimate of emission reductions is not currently available, but will be developed as part of these planning efforts.

Putting the Strategy into Action

The proposals and emission estimates presented in this report are preliminary, and will be further evaluated through a public process before a proposed Strategy is presented to the Board in late 2015. While the goals and actions identified in this Draft Strategy offer potentially significant economic, climate and health benefits, a more thorough

accounting of costs and benefits will be presented in the proposed Strategy. Several analyses consider the costs and benefits of actions like those described in this plan to cut SLCP emissions, and find that efforts to do so can deliver relatively low-cost GHG reductions. However, additional references with California-specific information would be helpful to inform our economic analysis. During the public review process, ARB welcomes this type of information, along with other comments. A macroeconomic analysis of the measures identified in the proposed strategy will be developed as part of a broader analysis in the 2016 Scoping Plan Update.

Any regulatory measures developed pursuant to the SLCP Strategy would undergo a complete, public rulemaking process including workshops, and economic and environmental evaluations. While this Draft Strategy is intended to be comprehensive, it is not exhaustive. We will continue to pursue new cost-effective programs and measures as technology and research on SLCP emission sources and potential mitigation measures advances.

Effectively implementing this Draft Strategy will require working with local, regional, federal and international partners, and diligently investing time and money to overcome market barriers that hinder progress. The extent to which we do so will drive results, which can include a wide range of significant economic and environmental benefits for California broadly, and many of the State's most disadvantaged communities, specifically.

Finally, the State will only realize the full benefits of strong action to reduce SLCP and CO_2 emissions if others take committed action, as well. Strong, near-term action to cut emissions of SLCPs, in conjunction with immediate and continuous reductions in emissions of CO_2, is the only way to stabilize global warming below 2^oC. Accordingly, California has signed a number of agreements to work together with other countries, including China and Mexico, to support actions to fight climate change and cut air pollution. Additionally, California is bringing together subnational jurisdictions under the Subnational Global Climate Leadership Memorandum of Understanding (the "Under 2 MOU"), which commits signatories to take steps to reduce SLCP and CO_2 emissions and meet the goal of keeping global average warming below the 2^oC threshold by reducing their GHG emissions to under 2 metric tons per capita, or 80–95 percent below 1990 levels, by 2050. To date, a total of 41 jurisdictions representing 19 countries and five continents have signed or endorsed the Under 2 MOU, collectively representing more than $12.3 trillion in GDP and 387 million people. If the signatories represented a single country, it would be the second largest economy in the world behind only the United States. As it implements the actions identified in this Draft Strategy and other related climate change planning efforts, California will continue to share its successes and approach with others, to expand action to address climate change and deliver local and global benefits for the State.

I. Introduction: Showing the Way to 2°C

California must achieve deep reductions in short-lived climate pollutant (SLCP) emissions by 2030 to help avoid the worst impact of climate change and meet air quality goals. Additionally, intensified, global action to reduce these emissions is the only practical way to immediately slow global warming and is necessary to keep warming below 2°C through at least 2050, which is a critical threshold to manage the damaging effects of climate change. A broad scientific consensus has emerged, based on extensive research, that a 2°C (3.6°F) increase in global average temperature above pre-industrial levels poses severe risks to natural systems and human health and well-being. This is an increase of only 1.1°C (2.0°F) above the present level. Even a slight increase in global warming would lead to significant sea level rise, and the overall impact from climate change would be substantially greater if global warming exceeds 2°C. Strong, near-term action to cut emissions of SLCPs, in conjunction with immediate and continuous reductions in emissions of carbon dioxide (CO_2), is the only way to stabilize global warming below 2°C.

Short-lived climate pollutants, including methane (CH_4), black carbon (soot), and fluorinated gases (F-gases, including hydrofluorocarbons, or HFCs), are among the most harmful to both human health and global climate. They are powerful climate forcers that remain in the atmosphere for a much shorter period of time than longer-lived climate pollutants, including CO_2, which is the primary driver of climate change. Their relative climate forcing, when measured in terms of how they heat the atmosphere, can be tens, hundreds, or even thousands of times greater than that of CO_2. Short-lived climate pollutants contribute about 40 percent to current anthropogenic global radiative forcing, which is the primary forcing agent for observed climate change. [2,3,4,5,6]

California has taken significant steps to reduce SLCP emissions, especially black carbon from transportation, methane from oil and gas operations and landfill emissions,

---

[2] Calculation based on IPCC AR5 WGI Chapter 8. https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf

[3] Ramanathan V, Xu Y. The Copenhagen Accord for limiting global warming: criteria, constraints, and available avenues. Proceedings of the National Academy of Sciences of the United States of America. 2010;107 (18):8055–8062. [PMC free article]

[4] IGSD (2013) Primer on Short-Lived Climate Pollutants, Institute for Governance and Sustainable Development, February 2013. http://igsd.org/documents/PrimeronShort-LivedClimatePollutantsFeb192013.pdf

[5] Akbar, Sameer; Ebinger, Jane; Kleiman, Gary; Oguah, Samuel. 2013. *Integration of short-lived climate pollutants in World Bank activities: a report prepared at the request of the G8*. Washington DC ; World Bank. http://documents.worldbank.org/curated/en/2013/06/18119798/integration-short-lived-climate-pollutants-world-bank-activities-report-prepared-request-g8
web.stanford.edu/group/efmh/jacobson/Articles/VIII/BCClimRespJGR0710.pdf

[6] Molina M, Zaelke D, Sarma KM, Andersen SO, Ramanathan V, Kaniaru D. Reducing abrupt climate change risk using the Montreal Protocol and other regulatory actions to complement cuts in CO2 emissions. *Proceedings of the National Academy of Sciences of the United States of America*. 2009;106(49):20616-20621. doi:10.1073/pnas.0902568106.
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2791591/

and F-gas emissions from refrigerants, insulating foams, and aerosol propellants. Still, more can and must to be done to reduce emissions from these and other sources in the State, including methane from waste management and dairies, black carbon from off-road and non-mobile sources, and F-gas emissions from refrigeration and air conditioning systems. The State is committed to further reducing SLCP emissions.

The Legislature recognized the critical role that SLCPs must play in the State's climate efforts with the passage of Senate Bill 605 (Lara, Chapter 523, Statutes of 2014), which requires the Air Resources Board (ARB or Board) to develop a strategy by the end of 2015 to reduce SLCP emissions. In his 2015 Inaugural Address, Governor Brown reinforced this commitment and called on California to show the world the path to limiting global warming below 2^{o}C through 2050, while highlighting the role that action to cut SLCPs must play in this effort. In April, the Governor set a target for reducing overall GHG emissions to 40 percent below 1990 levels by 2030, which the actions identified in this report will support.

Significant reductions in SLCP emissions can be achieved globally using cost-effective technologies and strategies, some of which have already been demonstrated effectively in California. Over the past several decades, the State's efforts in controlling these harmful emissions have prevented thousands of premature deaths in California, saved the State many tens of billions of dollars in energy and health costs, and have occurred alongside strong economic growth throughout our diverse economy. Applying California's experiences to reduce SLCP emissions globally would help prevent millions of premature deaths each year; boost agricultural productivity; limit disruption of historic rainfall patterns; slow the melting of glaciers, snowpack, and sea ice; reduce sea level rise; and provide trillions of dollars in economic benefits each year.

A. Significant Benefits from Accelerated Action to Cut SLCP Emissions

While reducing CO_2 emissions limits climate change over the long term, reducing emissions of SLCPs will effectively slow the rate of climate change in the near-term. Therefore, the best path forward is to emphasize parallel strategies for reducing SLCP and CO_2 emissions.[7,8] Studies indicate that available technologies, if universally adopted, can effectively reduce global methane emissions an estimated 40 percent and black carbon an estimated 80 percent below 1990 levels by 2030.[9] Additionally, a new proposed global phase down of HFCs under the Montreal Protocol (if adopted) and

[7] Shoemaker, J K; Schrag, D P; Molina, M J; Ramanathan, V (2013) What Role for Short-Lived Climate Pollutants in Mitigation Policy? Science 342 (6164) 1323-1324

[8] Rogelj, J, Schaeffer M, Meinshausen M, Shindell D, Hare W, Klimont Z, Velders G, Amann M, Schellnhuber HJ. 2014. Disentangling the effects of CO2 and short-lived climate forcer mitigation. Proceedings of the National Academy of Sciences (PNAS). http://www.pnas.org/cgi/doi/10.1073/pnas.1415631111

[9] UNEP (2014) Time to Act (To Reduce Short-Lived Climate Pollutants), The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants, United Nations Environment Programme, Second Edition, May. http://www.unep.org/ccac/Publications/Publications/TimeToAct/tabid/133392/Default.aspx

other efforts could cut the expected production of HFCs by up to 70 percent by 2030, and up to 85 percent by 2035.[10,11]

Achieving this scale of global reductions would deliver significant climate benefits. It would cut the expected rate of global warming in half by 2050, slowing global temperature rise by about 0.6°C,[12,13] which would reduce the risk of dangerous climate feedbacks such as accelerated Arctic melting and sea level rise.[14] It would also increase the probability of staying below the 2°C threshold to more than 90 percent through 2050.[15,16]

The benefits could be even greater in the Arctic, which is especially vulnerable to black carbon emissions and is warming twice as fast as the rest of the world.[17] This could be critically important for stabilizing climate change and its impacts, as the Arctic is an important driver of sea level rise and weather patterns throughout the Northern Hemisphere.[18,19] Reducing emissions of SLCPs can slow down the rate of sea level rise by 24–50 percent this century, if efforts to reduce emissions begin now. Mitigating emissions of both CO_2 and SLCPs can reduce the projected sea level rise rate by 50–67 percent by 2100.[20]

Deploying existing, cost-effective technologies to reduce SLCP emissions can also cut global emissions of fine particulate matter (PM2.5) by an estimated 50 percent, oxides

---

[10] Velders et al (2009) The Large Contribution of Projected HFC Emissions to Future Climate Forcing, *Proceedings of the National Academies* 106 (27), 10949-10954. www.pnas.org/cgi/doi/10.1073/pnas.0902817106

[11] Velders et al (2014) "Growth of climate change commitments from HFC banks and emissions", G. J. M. Velders, S. Solomon, and J. S. Daniel. *Atmospheric Chemistry and Physics*, 14, 4563–4572, 2014. doi:10.5194/acp-14-4563-2014. www.atmos-chem-phys.net/14/4563/2014/.

[12] Ramanathan V, Xu Y. The Copenhagen Accord for limiting global warming: criteria, constraints, and available avenues. Proceedings of the National Academy of Sciences of the United States of America. 2010;107 (18):8055–8062. [PMC free article]

[13] UNEP (2014) Time to Act (To Reduce Short-Lived Climate Pollutants), The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants, United Nations Environment Programme, Second Edition, May. http://www.unep.org/ccac/Publications/Publications/TimeToAct/tabid/133392/Default.aspx

[14] UNEP and WMO (2011) Integrated Assessment of Black Carbon and Tropospheric Ozone, United Nations Environment Programme and World Meteorological Association. http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf

[15] Ramanathan, V. and Yangyang Xu (2010) The Copenhagen Accord for Limiting Global Warming: Criteria, Constraints, and Available Avenues, *Proceedings of the National Academies of Sciences* **107** (18), pp.8055-8062. http://www.pnas.org/content/107/18/8055

[16] Xu, Y., D. Zaelke, G. J. M. Velders, and V. Ramanathan (2013), The role of HFCs in mitigating 21st century climate change, *Atmos. Chem. Phys.*, 13(12), 6083–6089

[17] Quinn et al (2008) Short-lived pollutants in the Arctic: Their impact and possible mitigation strategies, *Atmospheric Chemistry and Physics* **8**, 1723-1735. http://www.atmos-chem-phys.net/8/1723/2008/acp-8-1723-2008.html

[18] Francis, J. A. and S. J. Vavrus. 2012. Evidence linking Arctic amplification to extreme weather in mid-latitudes. Geophysical Research Letters 39.

[19] Screen, J. A. and I. Simmonds. 2013. Exploring links between Arctic amplification and mid-latitude weather. Geophysical Research Letters 40(5):959-964.

[20] Hu, A., Y. Xu, C. Tebaldi, W. M. Washington, and V. Ramanathan (2013), Mitigation of short-lived climate pollutants slows sea-level rise *Nature Climate Change* 3(5), 1–5, doi:10.1038/nclimate1869

of nitrogen (NO_x) emissions by 35 percent, and carbon monoxide (CO) emissions by 60 percent.[21] If these measures were fully in place by 2030, an estimated 3.5 million premature deaths and 53 million metric tons of crop losses could be avoided globally, each year. The economic value of these climate, crop, and health benefits is estimated to be about $5.9 trillion annually.[22] Most of these benefits would accrue in the developing world and places where disproportionate climate impacts are already being felt.

Many of the benefits of cutting SLCP emissions in California will accrue in the most disadvantaged parts of the State, where pollution levels and their health impacts are often highest, and where further economic development may be most needed. For example:

- Further cutting black carbon emissions from the transportation sector and building a sustainable freight system would have health and economic benefits for communities in the East Bay, Southern California, and the Inland Empire along freight corridors and near ports and railyards where diesel particulate matter concentrations are highest.
- Investments to cut methane and black carbon emissions as part of an integrated strategy to reduce emissions from agriculture and waste can provide important benefits for the Central Valley and other agricultural communities. They can help build an increasingly resilient and competitive agricultural sector by supporting jobs and economic growth, healthy soils, and improved air quality, water quality, and public health in those communities.
- Improving management and health of forests and rural landscapes to sequester carbon and mitigate black carbon emissions from wildfires can help bring investment, economic, and climate resiliency benefits throughout the Sierra and other rural parts of California.
- Switching to low-GWP refrigerants can also improve the energy efficiency of certain appliances and systems, which can help to cut electricity bills throughout the State.

B. Building on California's Air Quality and Climate Leadership

California's ongoing efforts to improve air quality and address climate change have already led to important reductions in SLCP emissions, and they provide a strong foundation to support further efforts to reduce emissions of these dangerous pollutants.

- *Black carbon*: California has cut anthropogenic sources of black carbon emissions by more than 90 percent since the 1960s. From 2000 to 2020,

[21] UNEP and WMO (2011) Integrated Assessment of Black Carbon and Tropospheric Ozone, United Nations Environment Programme and World Meteorological Association. http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf

[22] Shindell et al. (2012) Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security, *Science* **335**, 183 (2012). http://www.sciencemag.org/content/335/6065/183

California will have cut black carbon from mobile sources by 75 percent. These efforts prevent an estimated 5,000 premature deaths in the State each year, and deliver important climate benefits. If the world replicated this success, it would slow global warming by an estimated 15 percent,[23] essentially offsetting one to two decades' worth of CO_2 emissions.[24]

- *Methane*: California has the nation's strongest standards for limiting methane emissions from landfills, has offset protocols under our Cap-and-Trade program to encourage the reduction of methane emissions, and has rules under development and being implemented to create a comprehensive approach to limit methane leaks from the oil and gas production, processing, and storage sector, and the natural gas pipeline system. These efforts are serving to keep methane emissions fairly steady in the State.
- *F-gases*: The State has regulations in place to reduce emissions from refrigerants, motor vehicle air-conditioning, and consumer products that together will cut emissions of F-gases by 25 percent below otherwise projected levels in 2020. The State's Cap-and-Trade offset protocol for ozone depleting substances incentivizes the capture and destruction of those gases (which are also F-gases).

Still, more remains to be done. California is home to some of the highest levels of air pollution in the country, and although the State has substantially reduced particulate matter and black carbon emissions from on-road transportation, vehicles still pollute the air in our communities and harm the lungs of some of our most vulnerable populations. Methane is responsible for about 20 percent of current global warming, [25] and its emissions continue to increase in California and globally. F-gases, specifically HFCs, are the fastest growing source of GHG emissions in California and globally.

C. Purpose of SLCP Reduction Strategy

The State is committed to further reducing SLCP emissions. The 2014 Update to the Climate Change Scoping Plan (2014 Scoping Plan Update) identified SLCPs as an important aspect of a comprehensive approach to addressing climate change. It committed ARB to develop an SLCP strategy in 2015 as part of a broad effort to reduce emissions of all GHGs from all sources, including CO_2 from energy-related activities, as well as emissions from natural and working lands, and nitrous oxide.

Senate Bill 605 (California Health and Safety Code Section 39730), reaffirmed and codified that commitment. The bill requires ARB to develop a comprehensive strategy

[23] Ramanathan et al (2013) Black Carbon and the Regional Climate of California, Report to the California Air Resources Board, Contract 08-323, April 15. http://www.arb.ca.gov/research/single-project.php?row_id=64841

[24] Wallack, J. and Veerabhadran Ramanathan (2009) The Other Climate Changers: Why Black Carbon and Ozone Also Matter, *Foreign Affairs*, September/October 2009, pp. 105-113. https://www.foreignaffairs.com/articles/2009-09-01/other-climate-changers

[25] Kirschke, S. *et al.* (2013) Three decades of global methane sources and sinks. *Nature Geosci.* **6**, 813–823. http://www.nature.com/ngeo/journal/v6/n10/full/ngeo1955.html?WT.ec_id=NGEO-201310

to reduce emissions of SLCPs in the State by January 1, 2016, and in developing the strategy to:

- Complete an inventory of sources and emissions of SLCPs in the State based on available data;
- Identify research needs to address any data gaps;
- Identify existing and potential new control measures to reduce emissions;
- Prioritize the development of new measures for SLCPs that offer co-benefits by improving water quality or reducing other air pollutants that impact community health and benefit disadvantaged communities, as identified pursuant to California Health and Safety Code Section 39711;
- Coordinate with other state agencies and districts to develop and implement measures identified as part of the comprehensive strategy;
- Consult with experts in academia, industry, and the community on SLCPs. The topics shall include, but not be limited to, all of the following:
    - Assessment of the current status of controls that directly or indirectly reduce emissions of SLCPs in the State.
    - Identification of opportunities and challenges for controlling emissions.
    - Recommendations to further reduce emissions; and
- Hold at least one public workshop during the development of the strategy.

ARB developed this draft SLCP Reduction Strategy report (Draft Strategy) pursuant to SB 605, in coordination with other state agencies and local air quality management and air pollution control districts. The Draft Strategy has been developed with input from interested stakeholders in an open and public process and describes a proposed strategy for California to reduce emissions of SLCPs through 2030. It describes ongoing and potential new measures to reduce SLCP emissions from all major sources in the State, and describes current and future research needs for improving the SLCP emission inventory and better understanding potential mitigation measures. California's SLCP emission inventory and current and future research needs is included in Appendix A, and research efforts to evaluate potential mitigation measures for each SLCP is included in Appendix B. Measures included in the final SLCP Reduction Strategy would be developed under future public regulatory processes with the appropriate public process, economic analyses, environmental analyses, and consideration of environmental justice.

D. Achieving Science-Based Targets

In May 2015, ARB released a Concept Paper for reducing SLCP emissions.[26] The Concept Paper included suggested targets for SLCP emission reductions through 2030 that aligned with leading scientific assessments for what levels of SLCP reductions can, and should be, achieved globally. Based on an initial review during the development of the Concept Paper, these targets were designed to be ambitious but achievable in

[26] http://www.arb.ca.gov/cc/shortlived/concept_paper.pdf

California, and also in-line with the Governor's goal to reduce economy-wide GHG emissions by 40 percent below 1990 levels by 2030.

Based on stakeholder feedback on the Concept Paper, as well as further analysis, ARB is proposing targets to reduce methane and F-gas emissions by 40 percent below current (2013) levels by 2030, and black carbon emissions by 50 percent below current levels by 2030. These proposed targets are in-line with other countries' commitments to reducing SLCP emissions. For example, Mexico recently committed to reducing black carbon emissions by 51 percent below 2013 levels in 2030, along with actions to reduce emissions of CO_2, as part of its Intended Nationally Determined Contribution as a party to the UN Framework Convention on Climate Change. The targets are translated into millions of metric tonnes of CO_2-equivalent ($MMTCO_2e$) in Table 3.

Table 3. California SLCP Emissions and Proposed Target Emission Levels ($MMTCO_2e$)[1]

Pollutant	Inventory	Forecast[2]	Targets
	2013	2030	2030
Black Carbon[3]	38	26	19
Methane	118	117	71
F-gases	40	65	24

[1] Using 20-year Global Warming Potentials and AR4 except Black Carbon, which uses AR5
[2] Includes reductions from implementation of current regulations
[3] All non-forest sources

These targets are not binding, but provide important indices against which to measure the State's progress to reduce SLCP emissions. California efforts to reduce SLCP emissions, consistent with these targets, are important to further the purposes of AB 32, whose requirements charge ARB with reaching and maintaining the statewide GHG limit, as well as taking steps to continue reductions. Several Executive Orders (EO), including Governor Brown's recent EO B-30-15, further charge ARB with continuing and maintaining emission reductions. The measures identified in this Draft Strategy and their expected emission reductions will feed into the update to the Climate Change Scoping Plan to be developed over the next year. The upcoming 2016 Scoping Plan will establish a broad framework for meeting all of California's climate-related targets and will include an evaluation of all proposed GHG reducing activities, for both short-lived and longer-lived pollutants.

Throughout this Draft Strategy, there is an emphasis on early, often voluntary, actions supported by public investments and strong policy incentives. This approach is intended to achieve earlier reductions (in the 2020 timeframe), bring projects online quickly, and help scale sector-wide solutions while potential regulatory or other measures to reduce SLCP emissions are developed. By supporting early action through investments and commitments to overcome barriers, we can maximize benefits throughout California, while minimizing the impact of future regulations on businesses in these sectors.

Together with California's previous efforts to successfully reduce black carbon and other SLCP emissions, implementing the measures identified in this Draft Strategy to meet these targets would put California on the path to meet the Governor's 2030 climate goals, while delivering significant agricultural, air quality, economic, health, water, and other climate co-benefits.

E. Coordinating Research Efforts Related to SLCPs

Many California State agencies sponsor climate-related research. State-sponsored climate research, including research related to SLCPs, has been guided by the needs identified in state laws, Executive Orders, and other policy documents, as well as the best and latest science.

Since 2008, the Climate Action Team Research Working Group (CATRWG) has provided a forum for State agencies to discuss and coordinate their proposed research activities. The CATRWG also facilitates coordination with external groups including academia, federal agencies, the international community, and private entities. Integration and coordination with non-state sponsored research programs is important to leverage State resources and to provide coherent and practical research results for California.

To support these efforts, the CATRWG has created a catalog of relevant research projects supported by the State since the early 2000s.[27] The catalog keeps State agencies and interested stakeholders informed about the range of activities and the status of individual projects. The catalog includes a number of projects related to the impacts of SLCPs on regional climate in California, research underway to enhance SLCP inventories, and evaluations of SLCP mitigation strategies.

In 2015, the CATRWG released a Climate Change Research Plan for California.[28] The Plan synthesizes the knowledge gaps, and presents research priorities for the next three to five years for policy-relevant, California-specific research. It includes research needs related to the mitigation of SLCPs and specific needs to improve SLCP inventories. The Plan outlines these research needs in order to inform the State's ongoing activities without duplicating federal research activities. This is an unprecedented effort resulting in the first comprehensive climate change research plan developed by any state. The CATRWG will update the Plan every other year, with major revisions every four years. Research related to SLCPs will continue to be a priority in these updates.

Future State-sponsored research will be guided by recommendations in the CATRWG Research Plan, as well as other documents, such as the SLCP Reduction Strategy. State agencies will continue to leverage funding and avoid duplication of effort through

[27] California's State-sponsored Research Catalog: http://cal-adapt.org/research/
[28] Climate Change Research Plan for California (2015) http://www.climatechange.ca.gov/climate_action_team/reports/CAT_research_plan_2015.pdf

coordination in CATRWG meetings. State agencies that sponsor research will also continue their individual efforts to align future research needs with input from stakeholders, academic experts and other public and private research entities.

F. Process for Developing the SLCP Reduction Strategy

This Draft Strategy was developed with input from State and local agencies, academic experts, a working group of agricultural experts and farmers convened by CDFA, and other interested stakeholders in an open and public process. ARB and State agencies collaborated to identify reduction measures for specific sectors, including the dairy, wastewater, and waste sectors. In addition, ARB collaborated with the local air districts to identify SLCP emission reduction measures that could be implemented through district action. The Draft Strategy will be further refined based on stakeholder input.

In May 2015, ARB released for public review, a Concept Paper to initiate discussion on the development of this Draft Strategy.[29] The paper described initial ideas to be explored as the Strategy was developed, and sought to elicit new ideas and refinement of current measures to reduce emissions of SLCPs throughout the State. The Concept Paper was presented at a public meeting later in May, to solicit public input. Comments received on the Concept Paper are posted at: http://www.arb.ca.gov/lispub/comm2/bccommlog.php?listname=slcpstrategy-ws. After consideration of comments received, staff developed this Draft Strategy, which was released for public comment on September 30, 2015.

ARB will hold workshops to solicit comments on this Draft Strategy, including comments related to the development of a California Environmental Quality Act (CEQA) document. After consideration of public comments received, ARB will develop a proposed strategy and an accompanying draft Environmental Analysis (EA), to be presented to the Board in late 2015. Staff will present the final proposed SLCP Reduction Strategy, the final EA, and written responses to comments received on the EA to the Board for consideration at a public hearing in Spring 2016.

[29] http://www.arb.ca.gov/cc/shortlived/concept_paper.pdf

II. California's Approach to Reducing SLCP Emissions

The 2014 Scoping Plan Update described California's approach to climate change as one reliant on science and foundational research. The Update focused on: preserving natural resources that provide for our economy and define our lifestyle in California, fostering resilient economic growth throughout the State, improving public health, and supporting economic, social and environmental justice. The State's commitment to addressing climate change and public health is born of necessity, but provides tremendous opportunity to build competitiveness and resilience into our communities, resources, and economy. We understand that steps we take to reduce emissions and strengthen our State against the impacts of climate change provide economic opportunities today, and untether our future potential from limits imposed by resource constraints and pollution.

This approach continues to guide us as we focus on reducing emissions of SLCPs to meet science-based targets in this Draft Strategy. Additionally, California's approach to reducing SLCP emissions is framed by the concepts described below.

A. Prioritize Actions with Diverse Benefits

The direct benefits of cutting SLCP emissions will be immediately tangible, and can be substantial. As part of an integrated strategy to not only reduce emissions of SLCPs, but also to develop renewable sources of energy and strengthen the competitiveness and resiliency of our agricultural, waste, and other sectors, they can deliver even greater benefits, including:

- Reduced asthma risk, hospitalization, premature death, and associated medical costs from air pollution, especially in disadvantaged communities;
- Reduced global and localized climate change impacts, including sea level rise and disrupted precipitation patterns, and associated costs;
- Reduced crop losses from air pollution;
- Healthier forests, wildlife habitats, and watersheds;
- Healthy soils that are more sustainable and resilient to climate change, sequester GHGs, require less synthetic amendments, and improve water retention;
- The creation of a new industry, mostly in rural parts of the State and the Central Valley, around utilizing organic waste streams to generate renewable energy, fuels, and compost—bringing billions in investment; and
- Stronger agricultural and freight sectors that are well positioned to continue competing globally and growing as a source of jobs and economic development in California.

Clearly, there are a number of drivers and benefits to reducing SLCP emissions that extend beyond mitigating the impacts of climate change. The measures identified in this Draft Strategy are intended to provide a wide array of climate, health, and economic

benefits throughout the State. As they are further developed and implemented, a key focus will be to provide and maximize multiple benefits.

B. Put Organic Waste to Beneficial Use

California's organic waste streams are responsible for half of the State's methane emissions and represent a valuable energy and nutrient resource. Effectively implementing the measures described in this Draft Strategy will not only reduce methane emissions but provide many other benefits as well, including cutting emissions of CO_2 and boosting economic growth in agricultural and rural communities.

Building infrastructure to better manage organic waste streams could lead to billions of dollars of investment and thousands of jobs in the State.[30,31] This infrastructure could provide valuable new sources of renewable electricity or biogas, clean transportation fuels, compost, and other beneficial soil amendments. Collectively, products from organic waste streams in California, and potential environmental credits from them, could represent a billion dollar market for California dairies and other project developers.[32]

Utilizing clean technologies to put organic waste streams to a beneficial use can also serve to improve regional air and water quality and support economic growth in agricultural and other communities throughout the State. For example, most dairies in California currently store manure in uncovered lagoons and use lagoon water to fertilize on-site forage crops. This approach to managing manure has helped to improve the efficiency of dairy farms and milk production over the years. However, these lagoons also create one of the largest sources of methane emissions in the State and—when combined with imprecise or improper land application of nutrients, water, and salts via flood irrigation of lagoon effluent—can create adverse groundwater and nutrient management issues on farms. Alternatively, manure can be managed in a way to reduce or avoid methane emissions and open up opportunities for improving farm nutrient management activities.

In order to capture the entire potential value from California's waste resources, significant amounts of infrastructure remain to be built and markets must be fully

[30] Kaffka et al (2011) Economic, Social, and Environmental Effects of Current and Near-term Biomass Use in California, California Biomass Collaborative, University of California, Davis. http://biomass.ucdavis.edu/publications/

[31] Due to its large dairy industry, California likely represents more than its share of the estimated 11,000 potential new biogas systems that could be built in the U.S. and the associated $33 billion in capital deployment, 275,000 short-term construction jobs, and 18,000 permanent jobs.
USDA, USEPA, USDOE (2014) Biogas Opportunities Roadmap: Voluntary Actions to Reduce Methane Emissions and Increase Energy Independence.
http://www.usda.gov/oce/reports/energy/Biogas_Opportunities_Roadmap_8-1-14.pdf

[32] Informa Economics (2013) National Market Value of Anaerobic Digester Products, Prepared for the Innovation Center for U.S. Dairy, February.
http://www.usdairy.com/~/media/usd/public/nationalmarketvalueofanaerobicdigesterproducts.pdf.pdf

enabled. Barriers remain to achieving these wide-ranging economic and environmental benefits, and must be addressed.

C. Identify Practical Solutions to Overcome Barriers

Maximizing the diverse benefits of putting organic waste streams to beneficial uses will require overcoming barriers that have hindered such efforts in the past. Barriers affect many parts of the supply and marketing chain, including feedstock, technology, market/economics, permitting, technical feasibility, infrastructure, logistics, and user behavior.

For example, inexpensive and abundant landfill capacity makes organic material diversion and use economically difficult. Developing projects to generate renewable energy from this waste stream will require additional investments in clean technology and management practices, aligning economic incentives that currently favor landfilling with the State's objectives to put organic resources to better use, and streamlining various governmental and utility permitting processes.

Technology or market barriers also remain in some sectors. Interconnecting distributed sources of renewable energy onto the electricity grid, or biogas into pipelines, remains an unnecessarily long and costly process in many cases. Utilizing biogas in a conventional combustion engine to create electricity can exacerbate air quality problems in many parts of the State, including the Central Valley and Southern California. Clean engine and fuel options, or low-GWP refrigerants, are not available for all applications. Markets for compost and soil amendments need to be built out and strengthened, which would provide an important value stream for financing anaerobic digestion and compost facilities. Additional support and time may be needed to strengthen existing and emerging markets for renewable natural gas and fuels, soil amendments, and their associated environmental attributes.

But these barriers are not insurmountable. As California develops this Draft Strategy to reduce SLCP emissions and plans to meet its climate and air quality goals for 2030, now is the time to solve them. This Draft Strategy identifies strategies and funding mechanisms to encourage the use of the cleanest technologies to advance the State's air quality, water quality, climate change, and other environmental objectives. Solutions that address several environmental concerns—air quality, climate, and water quality—and can be easily financed, are clear winners.

Several existing programs already provide incentives to convert waste streams to various forms of energy, which can be leveraged along with new efforts to increase the share of renewable biogas used in California buildings, industry, and transportation. One example is the Low Carbon Fuel Standard, which provides a strong economic incentive to utilize organic waste resources for production of transportation fuels. At current LCFS credit prices, the potential value for anaerobic digesters at dairies could

be about $400 million per year.[33,34] In order to enable this market, however, barriers to pipeline injection of biogas, among others, must be addressed. State agencies are already collaborating to overcome barriers to pipeline injection of biogas, pursuant to the Governor's call to make heating fuels cleaner,[35] but they will redouble their efforts. This includes monitoring market progress pursuant to Assembly Bill 1900 (Gatto, Chapter 602, Statutes of 2012) and considering appropriate adjustments, as needed. Also, supplemental policy options to accelerate biogas projects and access to the pipeline will be considered, including steps that utilities can take, options to accommodate varying heat rates of pipeline gas in certain instances, and potential new policies like a feed-in-tariff for renewable biogas.

Building market certainty and value for compost and other soil amendment products will also help to secure financing for projects to use organic waste and cut emissions of SLCPs. Soil amendments from anaerobic digesters at California dairies represent a potential $200-400 million market in California, exceeding the likely value of energy products from the resource.[36] Efforts to increase composting and anaerobic digestion—and capture the diverse benefits from doing so—can be supported by efforts to promote and account for the benefits of using compost, manure, and other soil amendments that come from these processes. ARB is coordinating with CDFA and other agencies working on the Healthy Soils Initiative to identify additional research needs to inform the science and accounting methods necessary to quantify the benefits of using compost and other soil amendments and address any potential problems such as buildup of salts or heavy metals in soil. Collaboration among state agencies, water districts, and local governments will help quantify the benefits of using compost for urban storm water management, soil remediation, water conservation, and other beneficial uses.

D. Invest in SLCP Emission Reductions and Communities

Achieving significant reductions in SLCPs will require substantial investments to provide incentives and direct funding for priority sectors, sources, and technologies. Public investments should be smart and strategic, to leverage private investment and accelerate market transitions to cleaner technologies that foster significant system-wide solutions to cut emissions of SLCPs, maximize resource recovery from organic waste streams, and provide economic and health benefits in agricultural, disadvantaged, and rural parts of the State. Examples may include targeted support to reduce emissions of SLCPs and CO_2 through integrated strategies at dairies, landfills and in organic waste management; throughout the freight system; in commercial refrigeration applications;

[33] Assumes California dairies produce 34 percent of national biogas potential at U.S. dairies, with a carbon intensity of -100 and average August 2015 credit trading prices of $57.
[34] Informa Economics (2013) National Market Value of Anaerobic Digester Products, Prepared for the Innovation Center for U.S. Dairy, February. http://www.usdairy.com/~/media/usd/public/nationalmarketvalueofanaerobicdigesterproducts.pdf.pdf
[35] https://www.gov.ca.gov/news.php?id=18828
[36] Informa Economics (2013) National Market Value of Anaerobic Digester Products, Prepared for the Innovation Center for U.S. Dairy, February.

and from the management of woody waste materials in the agricultural and forestry sectors.

Many of the sources and sectors responsible for SLCP emissions are concentrated in communities with high levels of pollution or unemployment, which could especially benefit from targeted investments to improve public health and boost economic growth. These include SLCP emissions from sources of organic waste and dairies in the Central Valley; ports and freight corridors in the East Bay, Los Angeles area and Inland Empire; and oil production, landfills and other sources of SLCP emissions throughout the State. Many communities in these areas, along with forested and rural communities in the northern part of the State and the Sierra, have some of the worst pollution burdens in the State, and high rates of poverty and unemployment. They are also where many billions of dollars in public and private investment will accrue in the coming years to reduce SLCP and CO_2 emissions and strengthen our agricultural sector, build sustainable freight systems, and grow healthy forests.

Initial estimates regarding infrastructure build out to meet the goals identified in this Draft Strategy is similar for both the waste sector and dairy sector. CalRecycle and CDFA both estimate that investments or incentives on the order of $100 million per year for five years would be needed in each sector to build the necessary initial infrastructure. There could be some opportunity to optimize investments and co-locate infrastructure or utilize existing infrastructure, especially excess digestion capacity that exists at many wastewater treatment plants, which could potentially reduce the level of incentive funding needed to reach the targets outlined in this Draft Strategy. Additional research and working group efforts will focus on opportunities to optimize infrastructure rollout and maximize benefit from any State investment.

The State will need to continue coordinating and utilizing funding sources, such as the Greenhouse Gas Reduction Fund (Cap-and-Trade auction proceeds),[37] the Alternative and Renewable Fuel and Vehicle Technology Program (AB 118), Electric Program Investment Charge (EPIC) Program, Carl Moyer program, Air Quality Improvement Program, and the Proposition 39: Clean Energy Job Creation Fund to expand clean energy investments in California and further reduce emissions of SLCPs and other GHGs. Additionally, programs including the Bioenergy Feed-In Tariff, created by Senate Bill 1122 (Rubio, Chapter 612, Statutes of 2012), Low Carbon Fuel Standard, Cap-and-Trade, Self-Generation Incentive Program, and others provide important market signals and potential revenue streams to support projects to reduce SLCP emissions. These programs are described in more detail in Chapter VII.

Potential new funding mechanisms and incentive structures must also be considered. These could include adjusting the waste disposal tipping fee structure to account for the true cost of managing organic materials and landfills, state procurement contracts for renewable natural gas and other fuels in buildings or vehicles, or labeling programs to

[37] AB 1532 (Pérez, Chapter 807), SB 535 (De León, Chapter 830), and SB 1018 (Senate Budget Committee, Chapter 39) established the GHG Reduction Fund to receive Cap-and-Trade auction proceeds.

recognize leading companies in the market place, including those producing milk with low levels of dairy methane emissions or freight haulers using clean technologies.

E. Advance the Science of SLCP Sources and Emissions

Data related to SLCPs and their sources is often less available or of lower quality than it is for CO_2. One reason is that energy-related emissions of CO_2 are often easier to quantify than emissions of other GHGs, which may form through complex biological or other processes where existing reporting guidelines and procedures may not apply. There has also been less of a focus on collecting additional data that could help to quantify GHG emissions from some non-CO_2 sources.

This Draft Strategy, including Appendices A and B, describes several coordinated research efforts under way and potential new ones. Others not identified here may be considered in the future, to provide a better understanding of methane emissions from the natural gas system and natural gas and oil supplied to California, dairy operations, landfills, as well as various sources of F-gas and black carbon emissions.

For example, methane emissions are emitted from a wide range of biological processes and fugitive and area sources that make estimating emissions difficult. California's methane emission estimates are derived from a variety of surveys, government data sources, growth assumptions and modeling methodologies. ARB staff is continuously assessing ways to improve the methane inventory by incorporating the latest scientific understanding of methane sources, through coordinated research with other agencies, and by using the best available activity data. Additional research and improved data sources will be needed to continue to refine the methane inventory and provide California-specific activity data.

While improving data access and quality is not a prerequisite for many actions to reduce emissions of SLCPs, it is nonetheless important for informing ongoing efforts to reduce SLCP emissions and meet broader climate targets. Improved data and reliable GHG measurements from landfills, dairies, and other more difficult-to-measure sources would also be necessary before these sources could be potentially included in California's Cap-and-Trade Program. State agencies will continue to monitor technology development and support continued research to improve the accuracy and reliability of emissions accounting from these sources.

F. Need for Focused SLCP Programs

This Draft Strategy outlines specific emission reduction measures that could reduce California's emissions of SLCPs. This reliance on direct regulations, in concert with the existing greenhouse gas Cap-and-Trade Program, is consistent with California's approach on addressing climate change. California has already adopted several direct measures that ensure GHG emission reductions are achieved in specific sectors, including for SLCPs (for example, the Refrigerant Management Program that regulates F-gas emissions). These types of requirements motivate focused change – such as

increased deployment of renewable energy (Renewable Portfolio Standard) or transformation of transportation fuels (Low Carbon Fuel Standard) – which may be more readily realized through direct measures than sole reliance on the Cap-and-Trade Program.

The Cap-and-Trade Program covers combustion and process operations. These emissions can be measured according to the accuracy requirements of the Mandatory Greenhouse Gas Emissions Reporting Regulation, which includes accurate quantification methodologies that allow for consistent carbon costs,[38] and the sources accord with those covered by federal reporting programs.[39] In contrast, most fugitive emissions[40] (a category into which SLCP emissions generally fall) do not meet these criteria.[41] They are frequently difficult to measure, measurements have high uncertainties,[42] measurement methods are often difficult and less precise,[43] and carbon costs are hard to assign with the same reliability as for combustion sources of CO_2.[44]

Because of these difficulties, and the importance of seeking SLCP-specific emission reductions, which the Cap-and-Trade Program is not designed to produce, this Draft Strategy does not recommend expanding Cap-and-Trade Program coverage. Instead, the Draft Strategy focuses on specific measures for SLCP-emitting sectors, consistent with the approach ARB adopted while developing the AB 32 Scoping Plan and Cap-and-Trade Program.

ARB notes that stakeholders have expressed divergent views on this basic approach as it relates to animal agriculture. On one hand, the Animal Legal Defense Fund has

---

[38] *California Air Resources Board (2011) California's Cap-and-Trade Program Final Statement of Reasons*, Response to Comment E-31, at pg. 425. available at http://www.arb.ca.gov/regact/2010/capandtrade10/fsor.pdf.

[39] *Id.*, Response to Comment E-69, at pg. 448. available at http://www.arb.ca.gov/regact/2010/capandtrade10/fsor.pdf.

[40] Fugitives from certain oil and gas sources are an exception because, unlike other fugitive emissions, they are possible to quantify with rigor.

[41] ARB's responses to comments in the 2011 Final Statement of Reasons for the Regulation and Western Climate Initiative design documentation provide detailed rationale for the treatment of fugitive emissions in specific sectors. For example, the quantification methods that are often used to quantify fugitive emissions, including calibrated bagging, high volume sampling, and a default emissions factor, only provide a snapshot of emissions rather than actual measurements of emissions from the source. *See also* Western Climate Initiative, Inc. (2010) WCI Comments on the Proposed Mandatory Reporting of GHG Emissions from Proposed Reporting for Oil and Gas Operations (Subpart W), at pg. 44. available at http://www.westernclimateinitiative.org/document-archives/func-download/258/chk,ab6041717dc1be9cd3430f4f7585cb8e/no_html,1/.

[42] Western Climate Initiative, Inc. (2010) WCI Comments on the Proposed Mandatory Reporting of GHG Emissions from Proposed Reporting for Oil and Gas Operations (Subpart W) at pg. 39. available at http://www.westernclimateinitiative.org/document-archives/func-download/258/chk,ab6041717dc1be9cd3430f4f7585cb8e/no_html,1/.

[43] California Air Resources Board (2011) California's Cap-and-Trade Program Final Statement of Reasons, Response to Comment E-69, pg. 430 and 448. available at http://www.arb.ca.gov/regact/2010/capandtrade10/fsor.pdf.

[44] *Id.*, Response to Comment E-31, at pg. 425. available at http://www.arb.ca.gov/regact/2010/capandtrade10/fsor.pdf.

petitioned ARB to include emissions from that sector in the Cap-and-Trade Program. On the other hand, representatives of many environmental justice and environmental groups have argued that direct, sector-specific measures are preferable, as have representatives of the dairy industry. This Draft Strategy focuses on direct measures, consistent with the necessity of reducing SLCP emissions from this sector specifically, and in-line with the design principles that underlie the Cap-and-Trade Regulation.[45]

[45] The Livestock Project Compliance Offset Protocol is one such more focused measure now in operation. It contrasts with the wholesale coverage of the sector by the Cap-and-Trade Program that some stakeholders suggest. This protocol, focused on encouraging sector-specific reductions, would not operate if facilities in the sector had compliance obligations in the Program. The protocol balances the need for clear quantification methodologies and regulatory program requirements and ensures any credited voluntary GHG emission reductions meet the AB 32 criteria. The quantification methods included in this protocol use conservative factors to ensure that only real emission reductions are eligible for issuance of compliance offset credit.

III. Latest Understanding of Science on SLCPs

Climate change is already beginning to transform life on Earth**.** Around the globe, seasons are shifting, temperatures are climbing and sea levels are rising. Continued emissions of GHGs will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of GHG emissions.

There is growing recognition within the scientific and policy communities that efforts to address climate change should focus not only on reducing CO_2 emissions, but also on reducing emissions of SLCPs. While reducing CO_2 emissions will limit total warming over the long-term, reducing emissions of SLCPs will effectively slow the near-term rate of climate change. Therefore, the best path forward is to emphasize a coordinated strategy for simultaneous emission reductions for both SLCPs and CO_2,[46,47] which is needed to keep average warming below 2°C this century.

Short-lived climate pollutants have atmospheric lifetimes on the order of a few days to a few decades, and their relative climate forcing impacts, when measured in terms of how they heat the atmosphere, can be tens, hundreds, or even thousands of times greater than that of CO_2. Short-lived climate pollutants contribute about 40 percent to the current anthropogenic global radiative forcing, which is the primary forcing agent for observed climate change.[48,49,50,51,52]

---

[46] Shoemaker, J K; Schrag, D P; Molina, M J; Ramanathan, V (2013) What Role for Short-Lived Climate Pollutants in Mitigation Policy? Science 342 (6164) 1323-1324

[47] Rogelj, J, Schaeffer M, Meinshausen M, Shindell D, Hare W, Klimont Z, Velders G, Amann M, Schellnhuber HJ. 2014. Disentangling the effects of CO2 and short-lived climate forcer mitigation. Proceedings of the National Academy of Sciences (PNAS). http://www.pnas.org/cgi/doi/10.1073/pnas.1415631111

[48] Calculation based on IPCC AR5 WGI Chapter 8. https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf

[49] Molina M, Zaelke D, Sarma KM, Andersen SO, Ramanathan V, Kaniaru D. (2009) Reducing abrupt climate change risk using the Montreal Protocol and other regulatory actions to complement cuts in CO_2 emissions. *Proceedings of the National Academy of Sciences of the United States of America*. 2009;106(49):20616-20621. doi:10.1073/pnas.0902568106. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2791591/

[50] Ramanathan V, Xu Y. (2010) The Copenhagen Accord for limiting global warming: criteria, constraints, and available avenues. Proceedings of the National Academy of Sciences of the United States of America. 2010;107 (18):8055–8062. [PMC free article]

[51] IGSD (2013) Primer on Short-Lived Climate Pollutants, Institute for Governance and Sustainable Development, February 2013. http://igsd.org/documents/PrimeronShort-LivedClimatePollutantsFeb192013.pdf.

[52] Akbar, Sameer; Ebinger, Jane; Kleiman, Gary; Oguah, Samuel. (2013) *Integration of short-lived climate pollutants in World Bank activities: a report prepared at the request of the G8*. Washington DC; World Bank. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/08/19/000333037_20130819113818/Rendered/PDF/804810WP0G80Re00Box0379805B00OUO090.pdf

Studies indicate that available technologies, if universally adopted, can effectively reduce global methane emissions an estimated 40 percent and black carbon an estimated 80 percent below 2005 levels by 2030.[53] Additionally, a global phase down of HFCs currently being negotiated under the Montreal Protocol and other efforts could cut the expected production of HFCs by up to 70 percent by 2030, and up to 85 percent by 2035.[54,55] Achieving these levels of global reductions would deliver significant climate benefits. It would cut the expected rate of global warming in half by 2050, slowing global temperature rise by about 0.6 ^{o}C,[56,57] which would reduce the risk of dangerous climate impacts, such as accelerated Arctic melting and sea level rise.[58]

Co-Benefits of Reducing SLCPs

In addition to limiting climate change impacts already underway, SLCP emission reductions would reduce local air pollution and produce other co-benefits. The benefits could be even greater in the Arctic, which is especially vulnerable to black carbon emissions and is warming twice as fast as the rest of the world.[59] This would be critically important for stabilizing climate change and its impacts, as the Arctic is an important driver of sea level rise and weather patterns throughout the Northern Hemisphere. Climate change in the Arctic potentially impacts drought in California and extreme snow and cold in the upper Midwest and New England, although such links have not been definitively proven.[60,61] Accelerated warming in the Arctic could also lead

[53] UNEP (2014) Time to Act (To Reduce Short-Lived Climate Pollutants), The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants, United Nations Environment Programme, Second Edition, May. http://www.unep.org/ccac/Publications/Publications/TimeToAct/tabid/133392/Default.aspx
[54] Velders et al (2009) The Large Contribution of Projected HFC Emissions to Future Climate Forcing, *Proceedings of the National Academies* **106** (27), 10949-10954. www.pnas.org/cgi/doi/10.1073/pnas.0902817106
[55] Velders et al (2014) "Growth of climate change commitments from HFC banks and emissions", G. J. M. Velders, S. Solomon, and J. S. Daniel. *Atmospheric Chemistry and Physics*, 14, 4563–4572, 2014. doi:10.5194/acp-14-4563-2014. www.atmos-chem-phys.net/14/4563/2014/.
[56] Ramanathan V, Xu Y. (2010) The Copenhagen Accord for limiting global warming: criteria, constraints, and available avenues. Proceedings of the National Academy of Sciences of the United States of America. 2010;107 (18):8055–8062. [PMC free article]
[57] UNEP (2014) Time to Act (To Reduce Short-Lived Climate Pollutants), The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants, United Nations Environment Programme, Second Edition, May. http://www.unep.org/ccac/Publications/Publications/TimeToAct/tabid/133392/Default.aspx
[58] UNEP and WMO (2011) Integrated Assessment of Black Carbon and Tropospheric Ozone, United Nations Environment Programme and World Meteorological Association. http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf
[59] Quinn et al (2008) Short-lived pollutants in the Arctic: Their impact and possible mitigation strategies, *Atmospheric Chemistry and Physics* **8**, 1723-1735. http://www.atmos-chem-phys.net/8/1723/2008/acp-8-1723-2008.html
[60] Francis, J. A. and S. J. Vavrus. 2012. Evidence linking Arctic amplification to extreme weather in mid-latitudes. Geophysical Research Letters 39.
[61] Screen, J. A. and I. Simmonds (2013) Exploring links between Arctic amplification and mid-latitude weather. Geophysical Research Letters 40(5):959-964.

to irreversible climate "tipping points," such as the release of vast quantities of CO_2 and methane from melting permafrost.[62]

In California, State and international action to reduce emissions of SLCPs can improve air quality and reduce related health risks. Other benefits to California include reducing damage to forests and crops, reducing background ozone and particulate levels to help meet federal air quality standards, and reducing disruption of historic rainfall patterns. California is working with a set of national and subnational partners throughout the world to fight air pollution and climate change, which will help deliver these benefits to our State while providing significant benefits where emission reductions occur.

Climate Impact

Global mean sea level will continue to rise during the twenty-first century, and the rate of sea level rise will exceed that observed during 1971 to 2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets.[63] A recent study raises the possibility of a more rapid rate of sea level rise in this century than forecast by the U.N.'s Intergovernmental Panel on Climate Change (IPCC).[64] The authors conclude that 2^{o} C global warming above the preindustrial level would spur ice shelf melt sufficient to cause a sea level rise of several meters. Sea level rise is an important impact of climate change on California due to the long coastline and large population that lives near coastal waters. Mitigating SLCP emissions can have significant benefits for slowing sea level rise, reducing the rate by 24-50 percent by 2100, if it begins now. Mitigating emissions of both CO_2 and SLCPs can reduce the projected rate of sea level rise by 50–67 percent by 2100.[65]

Climate warming has intensified the recent drought in the southwestern U.S. as part of a trend toward enhanced drought that is projected to intensify through this century.[66] California droughts may be increasingly intensified due to declining availability of

---

[62] Ramanathan V, Xu Y. The Copenhagen Accord for limiting global warming: criteria, constraints, and available avenues. Proceedings of the National Academy of Sciences of the United States of America. 2010;107 (18):8055–8062. [PMC free article].

[63] IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf.

[64] Hansen, J., Sato, M., Hearty, P., Ruedy, R., Kelley, M., Masson-Delmotte, V., Russell, G., Tselioudis, G., Cao, J., Rignot, E., Velicogna, I., Kandiano, E., von Schuckmann, K., Kharecha, P., Legrande, A. N., Bauer, M., and Lo, K.-W.(2015) Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming is highly dangerous, Atmos. Chem. Phys. Discuss., 15, 20059-20179, doi:10.5194/acpd-15-20059-2015, 2015. http://www.atmos-chem-phys-discuss.net/15/20059/2015/acpd-15-20059-2015.html

[65] Hu, A., Y. Xu, C. Tebaldi, W. M. Washington, and V. Ramanathan (2013), Mitigation of short-lived climate pollutants slows sea-level rise *Nature Climate Change* 3(5), 1–5, doi:10.1038/nclimate1869

[66] Cook, B. I., T. R. Ault, and J. E. Smerdon (2015), Unprecedented 21st century drought risk in the American Southwest and Central Plains, *Science Advances*, *1*(1), e1400082, doi:10.1126/sciadv.1400082.

groundwater reserves. In the Central Valley, the current drought has cost California agriculture about $2.7 billion and more than 20,000 jobs in 2015, and agriculture is expected to face more frequent drought.[67] The current California drought highlights the critical need for developing drought resilience, even if wet conditions mitigate the current drought.[68,69]

Global Warming Potential

The IPCC developed the concept of global warming potential (GWP) as an index to evaluate the climate impacts of different GHGs, including SLCPs. This metric provides a comparison of the ability of each GHG to trap heat in the atmosphere relative to CO_2 over a specified time horizon. Global warming potentials account for the lifetime of different GHGs in the atmosphere, and the amount of energy they absorb on a per-kilogram basis, relative to CO_2, to represent the relative climate forcing of a kilogram of emissions when averaged over a time period of interest (for example, 20 years or 10 years). Current practice in most of the world for developing GHG emission inventories, including California's inventory, is to use GWP values from the 4th Assessment Report of the IPCC (AR4), which was released in 2007. For the first time, GWP estimates for black carbon are reported in the 5th Assessment Report of the IPCC (AR5), which includes the independent scientific assessment of black carbon radiative forcing published by Bond et al.[70] This Draft Strategy uses AR4 values for methane and F-gases, but AR5 for black carbon.

Considering ways of comparing the contributions of different climate pollutants to climate change has been raised in the IPCC AR5. The report focuses the discussion on the more well-known GWP and Global Temperature change Potential (GTP), though other concepts are also briefly discussed. The GTP is defined as the change in global mean surface temperature at a chosen point in time in response to an emission pulse, relative to that of CO_2. The Norwegian Environment Agency has recently performed an integrated assessment of climate, health and environmental effects of Norwegian emissions of SLCPs, and proposed measures for reducing such effects by 2030.[71] Specifically, they used the "GTP10, Norway", a global temperature change potential calculated ten years after the emission occurred in Norway, which they identify as the

[67] Economic Analysis of the 2015 Drought for California Agriculture. https://watershed.ucdavis.edu/droughtimpacts

[68] Noah S. Diffenbaugh, N.S., D.L. Swain, and D. Touma (2015) Anthropogenic warming has increased drought risk in California *PNAS 2015 112 (13) 3931-3936; published ahead of print March 2, 2015, doi:10.1073/pnas.1422385112. http://www.pnas.org/content/112/13/3931.abstract*

[69] A.P. Williams et al. (2015) Contribution of anthropogenic warming to California drought during 2012–2014**.** *Geophysical Research Letters*, 2015 DOI: 10.1002/2015GL064924

[70] Bond, T. C., S. J. Doherty, D. W. Fahey, et al. (2013) "Bounding the role of black carbon in the climate system: A scientific assessment." Journal of Geophysical Research: Atmospheres doi:10.1002/jgrd .50171. http://onlinelibrary.wiley.com/doi/10.1002/jgrd.50171/pdf

[71] Norwegian Environment Agency, *Summary of proposed action plan for Norwegian emissions of short lived climate forcers*, report M135/2014; http://www.miljodirektoratet.no/Documents/publikasjoner/M135/M135.pdf

most practically appropriate metric for analyzing measures for Norwegian emissions of SLCPs in the short term. Overall, there is not one, single metric that describes the comparative climate effects of various short-lived and long-lived climate pollutants perfectly. The use of GWPs with a time horizon of 20 years better captures the importance of the SLCPs and gives a better perspective on the speed at which SLCP emission controls will impact the atmosphere relative to CO_2 emission controls. Thus, the emission estimates presented later in this report are calculated using 20-year GWP. Table 4 illustrates the lifetime and 20-year GWP for each SLCP.

Table 4: Global Warming Potential for SLCPs

Pollutant	Lifetime (years)	20-year GWP*
Carbon dioxide	~100**	1
Methane	12	72
F-Gases (Hydrofluorocarbons)	1.4 – 52	437 – 6350
Black carbon	Days to weeks	3,200

* All AR4 except black carbon which uses AR5.
**CO_2 has a variable atmospheric lifetime and cannot be readily approximated as a single number.

The following sections describe the major SLCPs. An inventory of sources and emissions, and a discussion of current and proposed new control measures are included in other portions of this report.

A. Black Carbon

Airborne particulate matter (PM) varies in its composition and plays a significant role in human health and the climate system. Particulate matter is emitted from a variety of natural processes and human activities, and tends to remain in the air for only a few days to about a week, resulting in extreme spatial and temporal variability. Among different types of particles, carbonaceous particles (those that contain organic and black carbon) are particularly important because of their abundance in the atmosphere. With respect to climate impact, black carbon is the principal absorber of visible solar radiation in the atmosphere while organic carbon is often described as light-reflecting compounds.

Black carbon is emitted from burning fuels such as coal, diesel, and biomass. Black carbon contributes to climate change both directly by absorbing sunlight and indirectly by depositing on snow and by interacting with clouds and affecting cloud formation. In addition to its climate and health impacts, black carbon disrupts cloud formation, precipitation patterns, water storage in snowpack and glaciers, and agricultural productivity.

Scientists have known for some time that sources that emit black carbon also emit other short-lived particles that may either cool or warm the atmosphere. Lighter colored particles, for example, tend to reflect rather than absorb solar radiation and so have a cooling rather than warming impact. Until recently, it had been thought that the impact of lighter colored and reflecting organic carbon from combustion sources largely offset

the warming impact of black carbon from this source. However, new studies have suggested that certain fractions of organic carbon known as "brown carbon" could be a stronger absorber of solar radiation than previously understood.[72,73] The warming effect of brown carbon may offset the cooling impact of other organic carbon particles; hence, quantification of that absorption is necessary so that climate models can evaluate the net climate effect of organic carbon.

To help characterize and differentiate sources of brown carbon from black carbon and understand their climate impact in California, a current ARB-funded research project is applying advanced measurement methodology along with regional and global climate modeling simulations to characterize the extent to which brown carbon contributes to climate forcing in California. This project will improve our understanding of the fundamental processes that dominate brown carbon formation, and help to determine the potential climate benefit of mitigating sources of brown carbon emissions in California.

B. Methane

Methane is the principal component of natural gas and is also produced biologically under anaerobic conditions in ruminants (animals with a four-part stomach, including cattle and sheep), landfills, and waste handling. Atmospheric methane concentrations have been increasing as a result of human activities related to agriculture, fossil fuel extraction and distribution, and waste generation and processing. The atmospheric lifetime of methane is about 12 years. It is well-mixed within the atmosphere, and like other GHGs, warms the atmosphere by blocking infrared radiation (heat) that is re-emitted from the earth's surface from reaching space. Almost all of methane's impact occurs within the first two decades after it is emitted.

Methane is responsible for about 20 percent of current global warming,[74] and methane emissions continue to increase globally. There is particular concern among scientists that continued climate warming may cause massive releases of methane from thawing artic permafrost, and dissolve frozen methane clathrate deposits trapped within shallow ocean sea floors.

A recent study, which examines the interaction of methane with other atmospheric gases, indicates methane emissions may have even greater climate change impacts

[72] Jacobson, M. Z. (2014), Effects of biomass burning on climate, accounting for heat and moisture fluxes, black and brown carbon, and cloud absorption effects, J. Geophys. Res. Atmos., 119, 8980–9002, doi:10.1002/2014JD021861 http://onlinelibrary.wiley.com/doi/10.1002/2014JD021861/pdf

[73] Kodros, J. K., Scott, C. E., Farina, S. C., Lee, Y. H., L'Orange, C., Volckens, J., and Pierce, J. R.: Uncertainties in global aerosols and climate effects due to biofuel emissions, Atmos. Chem. Phys., 15, 8577-8596, doi:10.5194/acp-15-8577-2015, 2015. http://www.atmos-chem-phys.net/15/8577/2015/acp-15-8577-2015.pdf

[74] Kirschke, S. *et al.* (2013) Three decades of global methane sources and sinks. *Nature Geosci.* **6**, 813–823. http://www.nature.com/ngeo/journal/v6/n10/full/ngeo1955.html?WT.ec_id=NGEO-201310

than previously understood.[75] In the AR5 report, when all the feedbacks are included, the GWP for methane was increased, from 25 to 28 over a 100-year timespan and from 72 to 84 over a 20-year timespan. However, for consistency with reporting requirements under the United Nations Framework Convention on Climate Change, ARB is using GWP values from the AR4.

Methane also contributes to global background levels of ozone in the lower atmosphere (troposphere). Photo-oxidation of both methane and carbon monoxide lead to net production of global background levels of ozone. Ozone itself is a powerful SLCP as well as a regional ground level air pollutant. Tropospheric ozone is not emitted directly into the atmosphere, but rather formed by photochemical reactions. Its average atmospheric lifetime of a few weeks produces a global distribution highly variable by season, altitude, and location. The radiative forcing of tropospheric ozone is primarily attributed to emissions of methane, but also to carbon monoxide, volatile organics, and nitrogen oxides that eventually form ozone.

Ozone negatively impacts human health, and can lead to asthma attacks, hospitalizations, and even premature death. It impairs the ability of plants to absorb CO_2, thereby suppressing crop yields and harming ecosystems. Ozone also affects evaporation rates, cloud formation, and precipitation levels. In addition to the direct climate benefits of cutting methane emissions, it can also reduce global background levels of ozone pollution and provide additional climate, health, and other benefits.[76,77,78]

Regional ozone concentrations reflect contributions from both ozone formed from criteria pollutant emissions (NO_X and volatile organic compounds [VOCs]) on a regional scale, and ozone transported on hemispheric scales (global background levels of ozone). Due to its low reactivity, methane emissions do not affect regional scale ozone production that occurs over hours to days. However, regional methane emissions which are fairly well-mixed in the atmosphere contribute to the global abundance of methane, which in turn contributes to global background levels of ozone. About two-thirds of the rise in global levels of tropospheric background ozone can be attributed to methane

[75] Holmes, C. D., M. J. Prather, O. A. Sovde, and G. Myhre. 2013. "Future methane, hydroxyl, and their uncertainties: Key climate and emission parameters for future predictions." Atmospheric Chemistry and Physics 13: 285–302. http://www.atmos-chem-phys.net/13/285/2013/acp-13-285-2013.pd

[76] Fiore, A. M., J. J. West, L. W. Horowitz, V. Naik, and M. D. Schwarzkopf (2008) Characterizing the tropospheric ozone response to methane emission controls and the benefits to climate and air quality, J. Geophys. Res., 113, D08307, doi:10.1029/2007JD009162.

[77] West, J. J., A. M. Fiore, L. W. Horowitz, and D. L. Mauzerall (2006), Global health benefits of mitigating ozone pollution with methane emission controls, Proc. Natl. Acad. Sci. U.S.A., 103, 3988–3993.

[78] Fiore, A. M., F. J. Dentener, O. Wild, C. Cuvelier, M. G. Schultz, P. Hess, C. Textor, M. Schulz, R. M. Doherty, L. W. Horowitz, I. A. MacKenzie, M. G. Sanderson, D. Shindell, D. S. Stevenson, S. Szopa, R. Van Dingenen, G. Zeng, C. Atherton, D. J. Bergmann, I. Bey, G. Carmichael, W. J. Collins, B. Duncan, G. Faluvegi, G. Folberth, M. Gauss, S. Gong, D. Hauglustaine, T. Holloway, I. S. A. Isaksen, D. Jacob, J. E. Jonson, J. W. Kaminski, T. J. Keating, A. Lupu, E. Marmer, V. Montanaro, R. J. Park, G. Pitari, K. J. Pringle, J. A. Pyle, S. Schroeder, M. G. Vivanco, P. Wind, G. Wojcik, S. Wu, and A. Zuber (2009), Multimodel estimates of intercontinental source-receptor relationships for ozone pollution, J. Geophys. Res., 114, D04301, doi:10.1029/2008JD010816.

emissions. Studies have also shown that the global background ozone concentrations can approach 40 parts per billion and have been increasing in recent years. Increases in background ozone make it harder to attain the health-based ambient air quality standards set by U.S. EPA and California.

C. Fluorinated Gases (Hydrofluorocarbons)

Hydrofluorocarbons (HFCs) are synthetic gases used in refrigeration, air conditioning, insulating foams, solvents, aerosol products, and fire protection. They are primarily produced for use as substitutes for ozone-depleting substances, including chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), which are being phased out under the Montreal Protocol. Currently, HFCs are a small fraction of the total climate forcing, but they are the fastest growing source of GHG emissions in California and globally, primarily driven by the increased demand for refrigeration and air conditioning.

HFCs vary significantly in their ability to influence climate. Their differing ability is mostly due to differences in their atmospheric lifetimes, which determine how much they accumulate in the atmosphere. The mix of HFCs in current use, weighted by usage (tonnage), has an average atmospheric lifetime of 15 years. HFCs are also potent GHGs, with a warming effect hundreds to thousands of times more powerful than CO_2. The average GWP of the current mix of HFCs being used is about 1600. The major concern with respect to HFCs is that their contribution to climate forcing is expected to increase rapidly in the future as they continue to replace ozone depleting substances (ODS), such that they will become very significant contributors. Studies indicate that a lack of action to prevent the growth of HFCs would greatly undermine efforts to address climate change. A recent study concluded that replacing high-GWP HFCs with low-GWP alternatives could avoid 0.1°C of warming by 2050 and warming of up to 0.5°C by 2100,[79] offering one of the most cost-effective climate mitigation strategies available.

The successful phase-out of CFCs and the ongoing phase-out of HCFCs have made the Montreal Protocol the world's most effective climate treaty.[80,81] Between 1990 and 2010 the Montreal Protocol reduced CO_2e emissions nearly twenty times more than the initial commitment period of the Kyoto Protocol.[82] Although HFCs have contributed a miniscule amount of historical climate forcing, they are projected to increase significantly in the absence of control policies. Hence, a global phase down of HFCs is

[79] Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) The role of HFCs in mitigating 21st century climate change , ATMOS. CHEM. PHYS. 13:6083-608.
[80] Velders G. J. M. *et al.* (2007) *The importance of the Montreal Protocol in protecting climate*, Proc. Nat'l. Acad. Sci. USA 104:4814.
[81] Wu, Y., L.M. Polvani and R. Seager, (2013): The Importance of the Montreal Protocol in Protecting the Earth's Hydroclimate. *J. Climate*, 26, DOI: 10.1175/JCLI-D-12-00675.1, http://www.ldeo.columbia.edu/res/div/ocp/glodech/PDFS/Wu_etal_O3_2013.pdf
[82] UNEP (2012) The Montreal Protocol and the Green Economy: Assessing the contributions and co-benefits of a Multilateral Environmental Agreement.

necessary to slow their effect on climate change. International, national, and state efforts to reduce emissions of HFCs are discussed in more detail in Chapter VI.

IV. Reducing Black Carbon Emissions

Black carbon is the light-absorbing component of fine particulate matter (PM) produced during incomplete combustion of fuels. Diesel engines and biomass burning, including wildfires, are significant sources of black carbon in California. The lifetime of black carbon is very short, from days to weeks, compared to other SLCPs, which may remain in the atmosphere for a few decades.

California has done more than any other jurisdiction in the world to reduce PM and black carbon emissions. As a result, ambient levels of black carbon in California are now 90 percent lower than in the early 1960s, despite the use of diesel fuel more than tripling over the same time period.[83] If the rest of the world achieved similar reductions, it could substantially improve health and slow global warming. California's actions can serve as a blue print for other jurisdictions to reduce SLCP emissions and improve public health. California is continuing to explore additional ways to reduce black carbon emissions. Complying with federal air quality standards and reducing localized risk will require substantial reductions in smog-forming and PM emissions from mobile sources and other source categories.

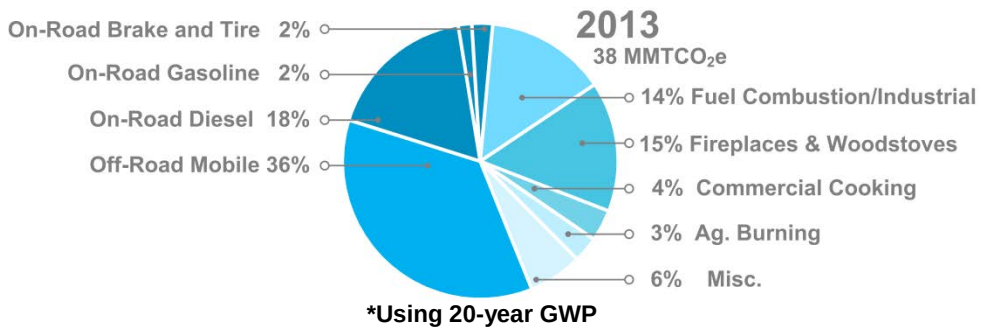
For purposes of this report, black carbon emissions are discussed in two categories, anthropogenic (non-forest) sources and forest-related sources. Anthropogenic sources include on- and off-road transportation, residential wood burning, fuel combustion, and industrial processes. Forest-related sources include prescribed fire and wildfire and are separated to account for the unique challenges associated with inventorying and mitigating these sources. In a typical year, wildfires account for over half of California's black carbon emissions, but this varies from year to year. Prescribed fires also emit black carbon, but are an important tool for forest managers to help restore and maintain forest health, which in turn can reduce wildfire severity and the associated black carbon emissions from catastrophic wildfires.

A. Anthropogenic (Non-Forest) Sources of Black Carbon Emissions

California's major anthropogenic sources of black carbon include off-road transportation, on-road transportation, residential wood burning, fuel combustion, and industrial processes (Figure 1). The fuel combustion and industrial source categories include a variety of stationary and portable equipment such as boilers, turbines, and steam generators, as well as process emissions from industrial operations, such as cement and asphalt production and pulp and paper mills. Sources in the miscellaneous category include dust, waste disposal, unplanned structure and car fires, residential natural gas combustion, and non-agricultural open burning (mostly residential green waste burning).

[83] V. Ramanathan et al. 2013. Black Carbon and the Regional Climate of California. Report to the California Air Resources Board No. 08-323. http://www.arb.ca.gov/research/apr/past/08-323.pdf

Figure 1: California 2013 Anthropogenic Black Carbon Emission Sources*

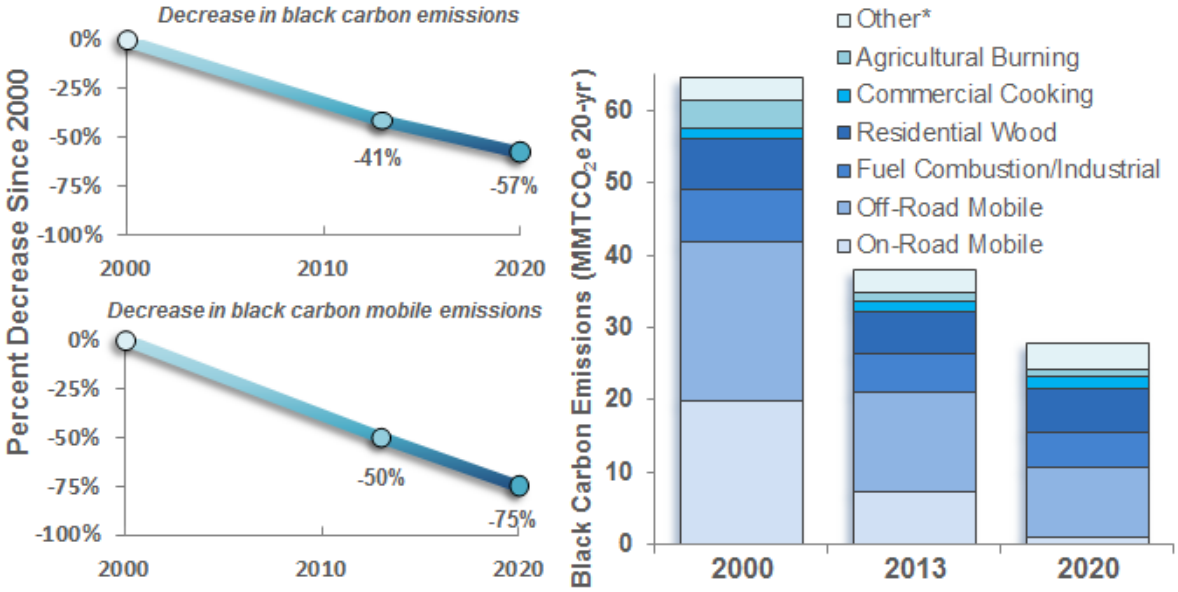


***Using 20-year GWP**

1. Progress to Date

California's program to reduce emissions from transportation sources of black carbon can serve as a blueprint for other jurisdictions seeking to address both the climate change and public health impacts of mobile sources, particularly diesel engines. Over the last few decades, ARB has employed a variety of strategies that has drastically reduced black carbon emissions from mobile sources, including lower emission standards, clean fuel requirements, in-use rules, incentives, and investments in research and new technology. Diesel particulate filters have been instrumental in reducing black carbon in on-road and major portions of the off-road sector. Today's DPF-equipped trucks are more than 99 percent cleaner than those manufactured in 1990. Measures have also been implemented on the State and local level to reduce PM, and thus black carbon, emissions from non-mobile sources, including residential burning, commercial cooking, and agricultural burning. Existing measures are projected to cut mobile emissions by 75 percent and total anthropogenic emissions by nearly 60 percent between 2000 and 2020 (Figure 2).

Figure 2: California's Black Carbon Emissions between 2000 and 2020 with Existing Measures



California has highlighted our accomplishments in discussions with other jurisdictions, including a SLCP-focused side event, jointly hosted with Mexico, at the Conference of Parties in Lima in 2014. We will continue to work closely with our partners in other states, in the federal government, and internationally to highlight the successful actions California has taken, and will continue to take, to reduce black carbon from mobile sources.

Mobile Sources

In 2000, ARB approved a Diesel Risk Reduction Plan, calling for an 85 percent reduction in diesel PM emissions by 2020.[84] Diesel engines often operate for decades after they are purchased, so while lower emission standards provide major emission reductions, those reductions can take time to materialize as older engines are replaced with new ones meeting the standard. To reduce risk and speed emission reductions, ARB implemented in-use rules for on-road and off-road fleets to meet performance standards through the use of alternative fuels, after-treatment retrofits, or replacement of older vehicles with newer vehicles manufactured to current emission standards. In-use on-road rules are expected to reduce black carbon emissions from on-road sources by 80 percent between 2000 and 2020. ARB's off-road rules apply to approximately 150,000 off-road vehicles and are expected to reduce diesel PM emissions by 20 percent between 2009 and 2023.

These regulations provide significant reduction in diesel PM exposure in communities located near California's major ports and intermodal railyards and contribute to a larger coordinated effort to reduce black carbon and PM emissions from all sources at ports

[84] Final Diesel Risk Reduction Plan available at: http://www.arb.ca.gov/diesel/documents/rrpapp.htm

and railyards.[85] Overall, since 2005, California has reduced diesel particulate emissions, along with the associated health risks, by 70 percent at the largest ports and 50–70 percent at the highest-risk railyards.

Incentive programs, including the Carl Moyer Memorial Program, AB 923, AB 118 Air Quality Improvement Program (AQIP), Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), and Proposition 1B, have provided the means to transform California's mobile fleet into one of the cleanest in the world. These programs have provided more than $1.6 billion over the past 15 years to clean up diesel engines and simultaneously reduce black carbon.

Cleaner fuels have been a cornerstone of ARB efforts to reduce mobile emissions, enabling cleaner vehicle technologies that have reduced smog-forming emissions by 15 percent and reduced cancer risks from vehicle pollution by 40 percent. The Low Carbon Fuel Standard provides a strong financial incentive to develop clean fuel alternatives, which may also reduce black carbon. For example, renewable diesel and biodiesel may reduce both PM and black carbon emissions compared to conventional diesel, especially in engines where diesel particulate filter technology is not available.

California has also paved the way for increased penetration of zero-emission vehicles (ZEV) through incentive programs and investment in new technology. The ZEV regulation was first adopted in 1990, as part of the Low Emission Vehicle Program. Today California is the world's single largest market for light-duty passenger ZEVs, accounting for 20 percent of all ZEVs on the road.[86] ARB will continue to lead in this area with the Governor's ZEV action plans to accelerate use of ZEVs and deploy 1.5 million passenger ZEVs in California by 2025. Providing financial and technological pathways to accelerating growth in ZEVs and other advanced engine technologies within California will push market development for clean and zero-emission vehicles throughout the world, providing additional black carbon emission reductions outside of California.

As emissions from mobile sources decrease, non-mobile sources will become an increasingly important fraction of the black carbon inventory. The main non-mobile emission sources include residential wood combustion, fuel combustion from stationary and small portable equipment, and industrial sources. Commercial cooking and agricultural burning make up a smaller portion of emissions.

Residential Wood Combustion

A number of local air districts have residential wood combustion rules, and are working to make further progress in this category to meet air quality standards and protect

[85] Dallmann et al. 2011. Effects of Diesel Particle Filter Retrofits and Accelerated Fleet Turnover on Drayage Truck Emissions at the Port of Oakland, Environmental Science & Technology, 45, 10773-10779.
[86] Draft 2015 ZEV Action Plan available at: http://gov.ca.gov/docs/DRAFT_2015_ZEV_Action_Plan_042415.pdf

public health.[87] Strategies in place to reduce emissions from residential wood combustion include winter burning curtailment, opacity emission limits, incentives to replace old wood burning devices with more efficient models, and banning or limiting wood burning devices in new and existing housing. Additionally the U.S. EPA has recently introduced a new source performance standard requiring manufacturers of residential wood stoves, pellet stoves, forced air furnaces, and hydronic heaters to meet national emission standards. Statewide black carbon emissions from residential wood combustion have declined by nearly 20 percent between 2000 and 2013 in response to existing district rules.

Commercial Cooking

Commercial cooking emissions are primarily from charbroiling. The two types of charbroilers include chain-driven, where food moves mechanically through a semi-enclosed broiler, and under-fired, where food is cooked on a grill similar to a home barbeque. A number of local air districts require air pollution control technologies for chain-driven broilers, reducing particulate emissions from these charbroilers by over 80 percent. Under-fired charbroilers are a larger source of PM, but no cost-effective air pollution control technology has been identified to date. Air districts are working to develop air pollution control devices for under-fired charbroilers. Demonstration projects for emerging control technologies are in progress and it is anticipated that large districts will develop rules for these emissions going forward.

Agriculture

Agricultural burning was historically used as a cost-effective way to remove agricultural residue left behind on fields, help control weeds and pests, and prevent the spread of plant disease, but emissions impacted local air quality and prompted concern for public health. Various programs are currently administered by the local air districts in coordination with ARB to reasonably regulate agricultural burning as required by state law. The Sacramento Valley Rice Straw Burning Phasedown Program, local district Smoke Management Programs, and San Joaquin Valley agricultural burning phase down efforts have resulted in an approximately 70 percent reduction in black carbon emissions from agricultural burning between 2000 and 2013.

Agriculture irrigation pumps are a small source of black carbon on a statewide level, but may be an important local source. Multiple federal, state, and local governments have provided incentives to convert agricultural diesel irrigation engines to either newer cleaner diesel engines or to electric motors. This has led to black carbon emissions from irrigation pumps declining by half between 2000 and 2013, with additional reductions expected going forward in response to existing measures.

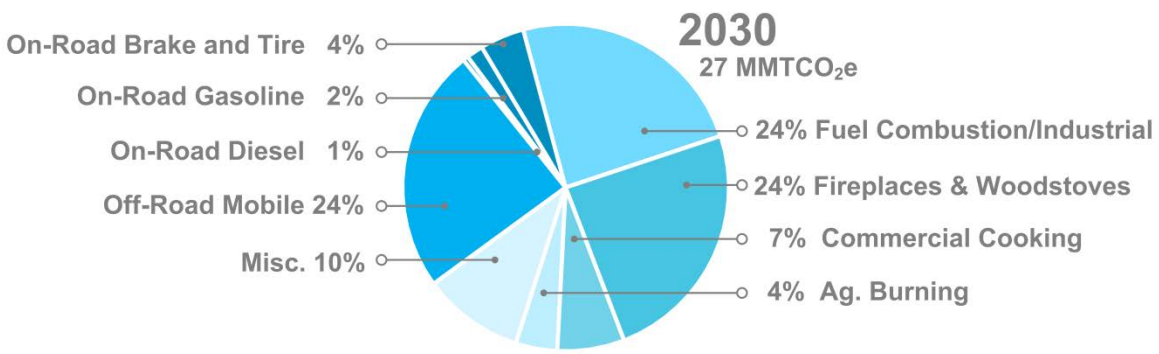
[87] Yap and Garcia 2015. Effectiveness of residential wood-burning regulation on decreasing particulate matter levels and hospitalizations in the San Joaquin Valley Air Basin, Am J Public Health, 105(4), 772-778.

2. Additional Reductions by 2030

California has achieved tremendous reductions in black carbon emissions, especially in the mobile sector, and even more reductions are expected as current measures are fully implemented. In 2000, on-road mobile sources contributed a third of anthropogenic black carbon emissions, but are projected to account for only a small fraction of total emissions by 2030. Off-road mobile emissions, including aircraft, watercraft, trains, small equipment, forklifts and farm equipment, have declined by over a third since 2000, and are projected to decrease by another half by 2030.

However, meeting the 2030 black carbon emission target identified in this Draft Strategy (for anthropogenic sources only) requires additional emission reductions across multiple sectors. Off-road mobile sources, along with stationary fuel combustion and residential wood burning, will make up the majority of emissions by 2030 (Figure3). Additional 2030 reductions will be realized through implementation of measures identified in plans currently being developed, including the Sustainable Freight Strategy and the State Implementation Plans (SIPs). Additional reductions are also expected through a district-lead commercial cooking regulation, but the magnitude of emission reductions is currently unknown.

Figure 3: California's 2030 Anthropogenic Black Carbon Emission Sources with Existing Measures*



***Using 20-year GWP**

Mobile Sources

ARB is developing an integrated mobile source strategy to meet California's air quality and climate mandates, reduce petroleum use, and develop a more sustainable freight system. Accomplishing this will require a transformation to near-zero and zero emission technologies, cleaner renewable fuels, greater system and operational efficiencies, and new approaches to passenger and freight mobility. These strategies will be reflected in the Sustainable Freight Strategy[88] (released in early 2015) and the upcoming SIP for the South Coast. Black carbon reductions associated with these strategies will be quantified as part of these plans.

[88] ARB Sustainable Freight Transport Initiative: http://www.arb.ca.gov/gmp/sfti/sfti.htm

The Sustainable Freight Strategy will accelerate emission reductions and implementation of ZEV technology in California's freight transport system while supporting improved efficiency and a competitive logistics system. In July 2015, the Governor signed EO B-32-15 calling for California State Transportation Agency, Cal/EPA, Natural Resources Agency, ARB, California Department of Transportation, CEC, and the Governor's Office of Business and Economic Development, to coordinate in the development of a multi-agency sustainable freight strategy that will meet the State's environmental and economic goals. The agencies must develop an action plan by July 2016 that establishes targets, identifies actions to achieve the targets, and initiates work on pilot projects. The SIP, which is due to U.S. EPA in 2016, will outline measures to meet federal clean air standards for ozone and PM over the next 20 years and develop additional strategies that may reduce black carbon emissions from both the on-road and off-road mobile sectors. In Fall 2015, ARB will release the proposed Mobile Source Strategy for the SIP, which will outline additional measures to reduce particulate matter emissions, including black carbon, from mobile sources (including off-road). These coordinated efforts will provide California a clear path forward to reduce the State's impacts on climate change.

Stationary Fuel Combustion and Industrial Sources

Emissions from stationary fuel combustion will be addressed by a number of State and federal planning efforts, including the SIP, Cap-and-Trade Program, increased building energy efficiency and renewable energy goals, and the federal Clean Power Plan (promulgated under Clean Air Act Section 111(d)). California's Cap and Trade regulation and the LCFS create market signals to incentivize efficiency improvements as well as the use of biomass-derived liquid fuels that would emit lower levels of PM and black carbon than traditional fossil fuels. The federal Clean Power Plan, which accelerates the transition from coal towards lower carbon intensive fuels for electricity production, will reduce black carbon emissions, and emissions of other GHGs, across the nation. Further emission reduction opportunities from stationary fuel combustion and industrial processes may also be identified as part of the SIP process.

3. Recommended Actions

This section describes proposed new measures (summarized in Table 5 below) to assist the State in meeting the proposed 2030 black carbon emission target.

Table 5: Proposed New Black Carbon Emission Reduction Measures and Estimated Emission Reductions ($MMTCO_2e$)[1]

Measure	2030 Annual Emission Reductions	2030 Annual Emissions
2030 BAU[2]		26
Residential Fireplace and Woodstove Conversion	3	
Sustainable Freight Strategy State Implementation Plans Clean Energy Goals	~4[3]	
2030 BAU with new measures		19

[1] Using 20-year GWPs from the 5th Assessment report of the IPCC

[2] "Business As Usual' forecasted inventory includes reductions from implementation of current regulations

[3] Additional black carbon reductions will be realized from planned measures, and are expected to help the State meet the black carbon target. However, an estimate of emission reductions is not currently available, but will be developed as part of these planning efforts.

Residential Fireplace and Woodstove Conversion Measure

Residential wood combustion is forecast to be the largest individual anthropogenic source of black carbon in 2030 if no new programs are implemented, accounting for a quarter of anthropogenic black carbon emissions. Reducing 2030 residential wood combustion black carbon emissions by half (3 $MMTCO_2e$) would set California on a path toward meeting the 2030 target proposed in this Draft Strategy.

Removal of old fireplaces and woodstoves and replacement with EPA-Certified devices, gas fireplaces, or electric heating can provide long lasting reductions in emissions of black carbon, criterial pollutants, and air toxics in residential neighborhoods. Removed wood burning devices should be destroyed or recycled to ensure permanent emission reductions. Monetary incentives to stimulate removal of old wood burning devices are popular and can achieve significant emission reductions. Multiple air districts have invested in incentive programs, but additional funding is necessary to continue to realize emission reductions in this category. In addition, programs should be expanded to include all regions of California. Incentive funding to support further district efforts could come from a variety of national, State, and local resources.

ARB is proposing to work with the air districts to determine the most effective approach to avoid new residential wood combustion emissions in California. This could include encouraging the installation of gas fireplaces or non-wood burning centralized heating in new construction. In areas where these are not an option, the cleanest available burning technology could be required.

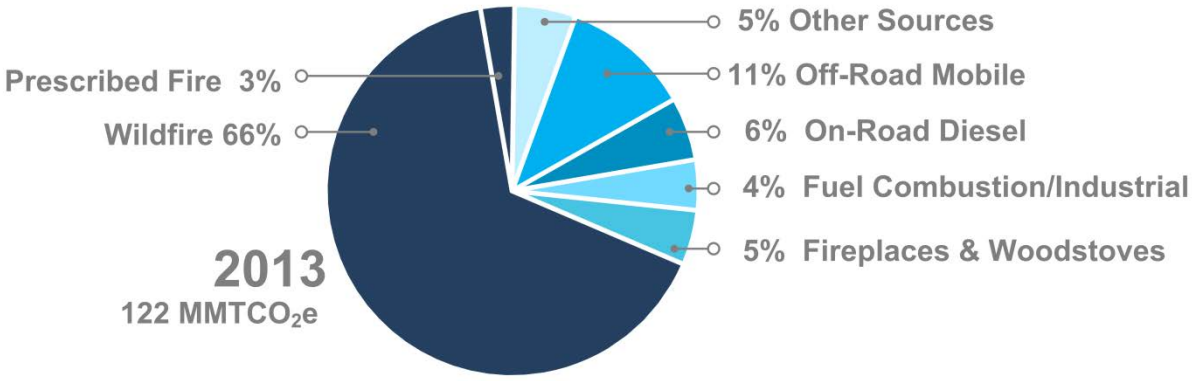
Education and outreach are important tools to reduce emissions from residential wood combustion. A broader public understanding of the health and environmental impacts

of wood smoke may cause voluntary changes in behavior to use other heating sources and may cause individuals to avoid unnecessary burning both indoors and outdoors. Education on proper burn practices may reduce emissions when wood is used, and is essential to achieve full emission reductions from EPA-Certified wood burning devices. Some districts have already implemented education programs, which should be expanded to all parts of the State as part of this measure.

B. Forest-Related Sources of Black Carbon Emissions

Forests provide the largest global reservoir for carbon storage after oceans. Wildfire events release part of this stored carbon as carbon dioxide or black carbon.[89] Wildfire is the single largest source of black carbon emissions in California (Figure 4), and models show that frequency of large fire events and the associated emissions will likely increase by the end of the 21st century as the climate changes and as fuels supporting more severe fires accumulate due to a century of fire suppression.[90,91] The wildfire emission estimate contains especially large uncertainty, and emissions are more difficult to mitigate than for anthropogenic sources. Additionally, wildfires exhibit large year-to-year variations in emissions. For these reasons, forest-related black carbon emissions are treated separately in this section, and are not included in the previous target discussion.

Figure 4: California 2013 Black Carbon Emissions (Including Wildfire and Prescribed Fire)*



*** Using 20-year GWP**

1. Progress to Date

Prior to European settlement, most forest types in California exhibited low to moderate intensity burning with decadal fire return intervals. A century of aggressive wildfire suppression, coupled with a changing climate, has contributed to heavy accumulations

[89] Hurteau, and North 2009. Fuel treatment effects on tree-based forest carbon storage and emissions under modeled wildfire scenarios. Frontiers in Ecology and the Environment. 7: 409–414.
[90] Westerling et al. 2006. Warming and earlier spring increase western US forest wildfire activity. Science, 313(5789), 940-943.
[91] Hurteau et al. 2014. Projected effects of climate and development on California wildfire emissions through 2100. Environmental Science & Technology, 48(4), 2298-2304.

of live and dead vegetation fuels on public forest lands.[92] These fuels result in increasing fire size and severity, with long-term negative impacts to ecosystems and increased black carbon emissions. In wildfire-prone forests, tree-based carbon stocks are best protected by fuel reduction treatments that produce low-density stands dominated by large, fire-resistant trees to reduce the expected increase in wildfire frequency, severity, and associated emissions.[93]

State and Federal agencies are working in coordination on action plans to reduce catastrophic wildfire and associated black carbon emissions. Since 2000, the National Fire Plan, the Federal Wildland Fire Management Policy, and companion State wildland fire and resource management plans have stimulated activities to restore the ecological role of fire and reduce excess fuel on forested lands. CAL FIRE is currently identifying forested areas of greatest risk of wildfire with the largest buildup of dead and dying trees to prioritize for fuels reduction and other forest management activities.

As part of the Scoping Plan Update development, California state agencies will evaluate ways to meet the Governor's objective of ensuring that natural and working lands are net carbon sinks. In addition, ARB and other State and federal agencies, and the California Natural Resources Agency are developing a Forest Carbon Plan which will identify strategies for achieving net carbon storage and minimizing GHG emissions from forest lands, while ensuring forest resilience, health, and continued ecosystem services. This plan will provide holistic forest management recommendations to reduce catastrophic wildfire, open biomass burning, and black carbon emissions.

2. Additional Reductions by 2030

Forest programs should be crafted in coordination with state and local agencies as well as the Forest Carbon Plan and the Bioenergy Action Plan, to reduce catastrophic wildfire, accelerate fuels reduction, and incentivize productive use of forest biomass residues while ensuring the sustainability of forest ecosystems. The current rate of fuel reduction activity is insufficient to improve forest health and avoid catastrophic wildfire and produce resilient forests.[94] The rate and effectiveness of forest risk reduction practices will need to increase from their present levels in order to keep pace with management needs, particularly in the face of climate change and persistent drought.

Fuel reduction techniques include prescribed fire, mechanical thinning, grazing and other methods. Prescribed fire is an important management tool employed by land managers to promote ecosystem health and reduce fuel load, particularly in areas that are not suitable for mechanical fuel reduction treatments. While prescribed fire emits

[92] Kilgore, B. 1981. Fire in ecosystem distribution and structure: western forests and scrublands. In: Proceedings of the Conference: Fire Regimes and Ecosystem Properties. USDA Forest Service, 58-89. General Technical Report WO-GTR-26.
[93] Hurteau et al. 2014. Projected effects of climate and development on California wildfire emissions through 2100. Environmental Science & Technology, 48(4), 2298-2304.
[94] North, M.P. et al. 2012. Using Fire to Increase the Scale, Benefits, and Future Maintenance of Fuels Treatments. Journal of Forestry 100, 7, 392-401.

black carbon, the resulting forest stands will be at lower risk for catastrophic wildfires, thus reducing overall black carbon emissions. Unlike wildfire, prescribed fire can be timed to minimize air quality impacts. Evidence exists that the use of prescribed fire can also reduce the air quality impacts associated with wildfires, thereby reducing single dose exposure.[95,96] Mechanical thinning produces woody biomass that must be disposed of in some manner. The primary disposal of this residue is to burn it in piles, or have it chipped and scattered in the forest. However, it can also be used as a value-added product (e.g., landscaping materials), or used for bioenergy production. Open pile burning emits black carbon similar to wildfires, thus, other alternatives are needed to reduce black carbon emissions and provide a more productive use of this woody biomass. Finding a productive use for this forestry residue, such as in bioenergy or liquid fuels production, can help California reduce its forest-derived black carbon footprint while meeting renewable energy and low carbon fuel goals, providing jobs, fostering rural economic development, and enhancing energy security.

Though electricity generation from forest residue has recognized benefits, the number of operating bioenergy plants and the generation capacity is decreasing due to fixed price contracts expiring and the uncertainty of future power pricing policies. Bioenergy production costs more than other energy sources due to the large distribution of the biomass and the costs to process and transport it to the facilities. Establishing a robust biomass use market with diverse wood product manufacturing and distributed bioenergy production is essential to provide value to biomass and thereby make it cost-effective to transport from the forest to end users. Management to improve forest health should continue to drive the amount and type of biomass removed from the forest to ensure only sustainable forest management practices are promoted. Existing regulations and approved land management practices should be applied to ensure there are no adverse effects on soil, water, or biodiversity.

Developing technologies show great potential to utilize woody biomass and provide additional benefits. Wood-derived biofuels are moving into the early demonstration stages and offer potential to offset vehicle petroleum use, among other uses. Pyrolysis generates electricity and biochar, an inert carbon-rich byproduct which may improve soil fertility.[97] Current research suggests biochar could contribute to significant carbon storage globally, but the benefits of large-scale projects have not been demonstrated or quantified, and several research gaps remain. Several entities have developed or are developing biochar projects which will provide an opportunity to evaluate biochar further.[98, 99]

---

[95] Schweizer and Cisernos 2014. Wildland fire management and air quality in the southern Sierra Nevada: Using the Lion Fire as a case study with a multi-year perspective on PM2.5 impacts and fire policy. Journal of Environmental Management 144, 265-278.
[96] Cisneros et al. 2014. Spatial and seasonal patterns of particulate matter less than 2.5 microns in the Sierra Nevada Mountains, California. Atmospheric Pollution Research 5, 581-590.
[97] Koper, T., et al. 2010. 2010 Methodology for Biochar Projects V1.0. American Carbon Registry.
[98] CAPCOA GHG Exchange (2014). Biochar Production for Project Reporting Protocol: GHG Emission Reduction Accounting. Version 3.0.: http://www.placer.ca.gov
[99] Koper, T., et al. 2010. 2010 Methodology for Biochar Projects V1.0. American Carbon Registry.

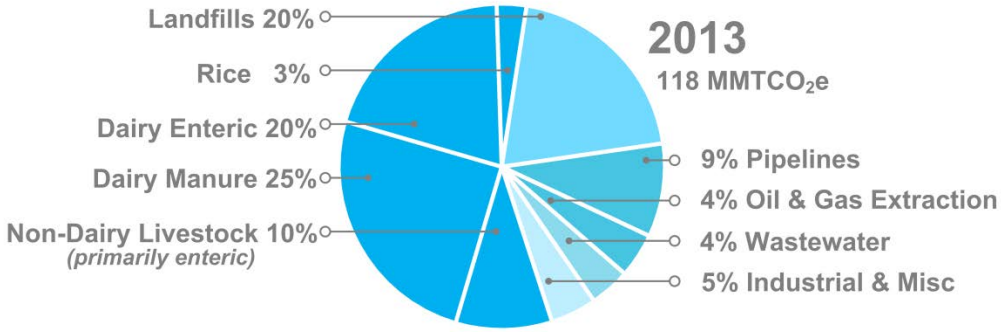
A plan that provides for strong and focused coordination affords the best opportunity to balance the many ecological, policy, financial, health and emission tradeoffs of any given forest or land management strategy. Long term interagency coordination is necessary to create a competitive bioenergy market by researching ways to increase the environmental and economic sustainability of bioenergy production, and fully quantify the benefits of bioenergy production in California. Putting woody biomass to its most beneficial use requires lifecycle and economic analysis of the many waste diversion options to fully quantify the benefit and identify possible unintended consequences of each biomass use option by region. Over the long term, all pathways should be explored to provide a diverse set of options to maximize use of woody biomass and achieve black carbon, GHG, and criteria air pollutant emission reductions. However, given the current imbalance of biomass supply to viable outlets, exploring near-term waste utilization techniques must be a priority to avoid open pile burning to the extent possible.

V. Reducing Methane Emissions

Methane is emitted from a wide range of fugitive sources and biological processes, and is the second largest source of GHG emissions globally. Methane emissions are growing globally as a result of human activities related to agriculture, waste handling and treatment, and oil and gas production. Agriculture represents the largest methane source in California, accounting for nearly 60 percent of methane emissions (Figure 5). Landfills are the next largest source of methane, accounting for a fifth of statewide methane emissions. Pipeline leaks, oil and gas extraction, wastewater, and other industrial and miscellaneous sources make up the remainder of emissions. As California continues to rely on natural gas for a large fraction of its energy supply, it is critical to increase supplies of renewable natural gas and minimize fugitive emissions of methane from natural gas infrastructure.

In California, where natural gas may increasingly fuel trucks and heavy-duty vehicles, we must ensure that the use of natural gas provides a climate benefit compared to the diesel fuel it displaces. As we increase the number of facilities producing and using renewable supplies of natural gas, hydrogen, or other fuels in a cleaner energy economy, we must also take steps to minimize potential methane leaks from those facilities. ARB and other agencies are funding research to identify high-methane "hot spot" emitters in the oil and natural gas sector and other sectors throughout California.

Figure 5: California 2013 Methane Emission Sources*



*** Using 20-yr GWP**

California can cut methane emissions by 40 percent below current levels in 2030 by avoiding or capturing methane from manure at large dairies, meeting industry targets for reducing methane emissions from enteric fermentation, effectively eliminating disposal of organics in landfills, and reducing fugitive methane emissions by 40-45 percent from all sources.

A. Progress to Date

The State has taken important steps to reduce methane emissions from all its major sources, but more needs to be done to control methane emissions, especially from

organic waste streams going to landfills and at dairies. In addition to reducing methane emissions from these sources, capturing methane can provide fuel for power plants, buildings, vehicles and industrial operations to displace fossil-based natural gas use.

Technologies to recover methane are already widely available and used in key sectors. For example, some methane emissions from landfills, wastewater treatment facilities or from manure at dairies are already captured and used as a renewable source of natural gas to fuel vehicles or generate electricity. Some organic materials, such as food waste and yard trimmings, are being redirected from landfill disposal to anaerobic digestion and composting facilities to produce renewable energy, fuel and soil amendments. Steps are also being taken to reduce natural gas leaks from oil and gas wells, pipelines, valves, and pumps to improve safety, avoid energy losses, and reduce methane emissions associated with natural gas use.

In addition to ongoing efforts and practices to reduce and use captured methane for beneficial purposes, several recent legislative and regulatory actions will further support the reduction or capture of methane within these sectors. These actions prioritize diverting organic material from landfills and include incentivizing the use of biogas for transportation fuel, pipeline injection, or electricity generation.

- Senate Bill 1122 (Rubio, Chapter 612, Statutes 2012), directed the California Public Utility Commission (CPUC) to require the State's investor owned utilities to develop and offer 10 to 20 year market-price contracts to procure an additional 250 megawatts of cumulative electricity generation from biogas facilities that commence operating on or after June of 2013. Eligible projects and sources include biogas-generated electricity from wastewater treatment, municipal organic waste, food processing, dairy manure and agricultural organic material, and sustainable forest materials.

- The Low Carbon Fuel Standard (LCFS) requires transportation fuel providers to procure clean fuels to reduce the carbon intensity of California's fuel mix. The LCFS provides a market signal to incentivize using captured methane as a transportation fuel, among other clean fuel options. Transportation fuel derived from biogas may also qualify for Renewable Identification Number (RIN) credits as part of the U.S. EPA Renewable Fuel Standard 2. ARB has developed a LCFS pathway for the production of biomethane from high solids anaerobic digestion of organic (food and green) wastes that has the lowest carbon intensity of any pathway developed to date. ARB is evaluating a new LCFS pathway for dairy-derived biogas, which would include the GHG benefits of methane destruction and provide a significant financial incentive for using dairy-derived biogas as a vehicle fuel.

- Assembly Bill 1900 (Gatto, Chapter 602, Statutes of 2012) directed the CPUC to adopt natural gas constituent standards (in consultation with ARB and the Office of Environmental Health and Hazard Assessment). The legislation is also designed to streamline and standardize customer pipeline access rules, and

encourage the development of statewide policies and programs to promote all sources of biomethane production and distribution. It also directs the CEC to identify constraints to the use and interconnection of biomethane and offer solutions in its Integrated Energy Policy Report. The CPUC has adopted natural gas constituent standards and created a $40 million program to offset up to $1.5 million in interconnection costs for biomethane projects.

- Assembly Bill 1257 (Bocanegra, Chapter 749, Statutes of 2013) directs the CEC to assemble a report by November 2015 (and every four years after), in consultation with other State agencies, to identify strategies for maximizing the benefits obtained from natural gas as an energy source. The report will examine strategies and recommendations regarding natural gas, including low emission resources such as biogas and biomethane; the use of natural gas as a transportation fuel; centralized and distributed electricity generation; cooking, cooling, and space heating; engine and appliance applications; its role in the development of zero net energy buildings; and GHG emissions associated with the natural gas system. The report will also examine infrastructure and storage needs and pipeline and system reliability concerns.

- Compliance Offset Protocols under the State's Cap-and-Trade Program include a livestock protocol, rice cultivation protocol, and mine methane capture protocol. The protocols provide methods to quantify, report, and credit GHG emission reductions from sectors not covered by the Cap-and-Trade Program. The livestock protocol credits operators who voluntarily install manure biogas capture and destruction technologies. The rice protocol allows compliance offset credits to be issued for emission reductions achieved by switching to rice cultivation practices that reduce methane emissions. The mine methane capture protocol incentivizes capturing methane that would otherwise be vented into the atmosphere from active and abandoned mines.

- Methane emissions from landfills are being controlled under ARB's Landfill Methane Control Measure, which was approved in 2009. The regulation requires owners and operators of certain uncontrolled municipal solid waste landfills to install gas collection and control systems, and requires existing and newly installed gas and control systems to operate in an optimal manner. The regulation allows local air districts to voluntarily enter into agreements with ARB to implement and enforce the regulation and to assess fees to cover costs. Some local air districts have also adopted rules to implement federal standards for the installation of gas collection and control systems.

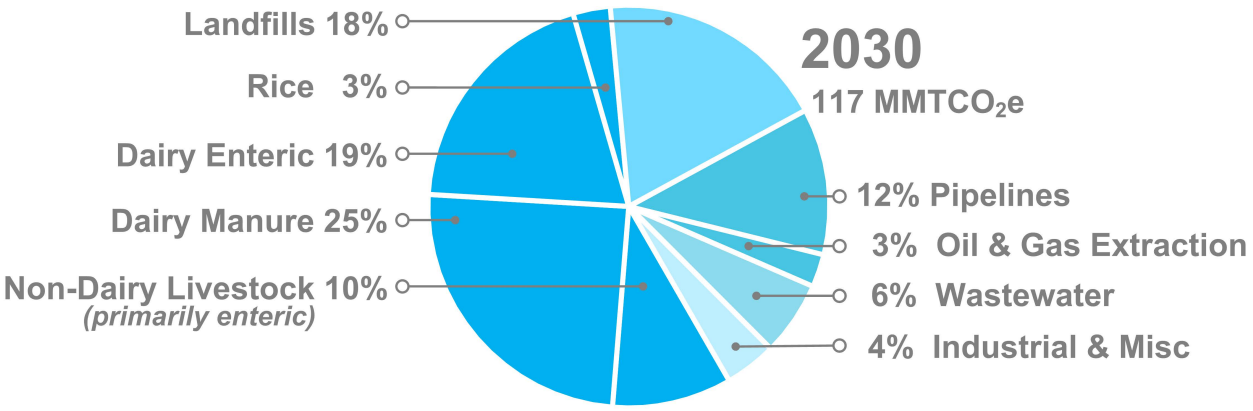
- California has established clear goals to reduce waste disposal, and divert organic material from landfills for beneficial purposes. AB 341 (Chesbro, Chapter 476, Statutes of 2011), for example, established a State target to reduce by 75 percent the amount of solid waste sent to landfills by 2020 through recycling, composting, and source reduction practices. The 2014 Scoping Plan

Update calls for eliminating the disposal of organic materials at landfills, which would potentially eliminate future methane emissions from landfills.

- The Legislature has also taken recent steps to further increase the diversion of organic materials from landfills. AB 1826 (Chesbro, Chapter 727, Statutes of 2014) requires businesses generating specified amounts of organic wastes to begin arranging for the recycling and diversion of those wastes from landfill disposal beginning in 2016. AB 1594 (Williams, Chapter 719, Statutes of 2014) re-classifies the use of green waste for landfill "alternative daily cover" as disposal, beginning in 2020.

Collectively, these measures will help to keep methane emissions in California fairly steady through 2030. However, the science-based pathway to 2°C—including meeting the Governor's goal to reduce GHG emissions by 40 percent below 1990 levels by 2030—requires further reducing methane emissions in California. Significant opportunity remains to further reduce methane emissions from the major sources in the State (Figure 6). Doing so will require overcoming various economic and institutional barriers, but will provide a wide range of economic and environmental benefits throughout the State—especially where they are most needed.

Figure 6. California's 2030 Methane Emission Sources with Existing Measures*



*Using 20-year GWP

B. Recommended Actions to Further Reduce Methane Emissions

California can reduce methane emissions by 40 percent below current levels through a collaborative and mixed approach that combines incentives, public and private investment, and regulation. By investing early and committing to immediately resolve issues that hinder progress, California can make significant progress in the near-term, and capture associated benefits.

In the landfill and dairy sectors, significant composting and anaerobic digestion infrastructure capacity remains to be built before the State can fully put its organic waste streams to beneficial use. In those sectors, California will work with industry and

other stakeholders to support and accelerate project development. By effectively eliminating the disposal of organics in landfills and putting organic waste streams to beneficial use, emissions from landfills and dairies can be significantly reduced.

There are a host of activities underway at the State and Federal level and by gas utilities to reduce methane emissions from the natural gas system.[100] In particular, regulations are being developed to reduce fugitive methane emissions from the oil and gas production, processing and storage sector, and from the natural gas transmission and distribution system. By effectively implementing these policies, and supporting them with continued and improved emissions monitoring, California can match the goals of the Obama Administration to reduce methane emissions from the oil and gas sector by 40-45 percent by 2025. The State will aim to extend successful approaches to reduce emissions from the oil and gas sector to other sectors, to reduce fugitive methane emissions from all sources by similar levels by 2030.

Table 6, below, describes emission reductions by sector to reduce methane emissions by 40 percent below current levels by 2030.

Table 6: Proposed New Methane Emission Reduction Measures and Estimated Emission Reductions ($MMTCO_2e$)[1]

Measure Name	2030 Annual Emission Reductions	2030 Annual Emissions
2030 BAU[2]		117
Dairy Manure	21	
Dairy and Livestock Enteric Fermentation	5	
Landfill	5	
Oil and Gas	8	
Wastewater, Industrial, Other	7	
2030 BAU with new measures		71

[1] Using 20-year GWPs from the 4th Assessment report of the IPCC
[2] "Business As Usual" forecasted inventory includes reductions from implementation of current regulations

Dairy Manure

California's dairy and livestock industries account for roughly half of the State's total methane emissions or about five percent of the State's overall GHG emissions. About half of the emissions from the State's 5.5 million total beef and dairy cows come from enteric fermentation (mostly belching), and the other half from manure management practices, primarily lagoon storage of flushed manure from milking cows.

[100] *AB 1257 Natural Gas Act Report: Strategies to Maximize the Benefits Obtained from Natural Gas as an Energy Source*, California Energy Commission, September 2015. https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=15-IEPR-04

California has the most dairy cows in the country and the highest aggregated dairy methane emissions. The State also has higher per-milking head methane emissions than most of the rest of the United States, due to the widespread use of flush water lagoon systems for collecting and storing manure. Milk production feed efficiency at California dairies, however, is among the best in the world; California dairy cows produce low enteric fermentation emissions per gallon of milk. So if dairy farms in California were to manage manure in a way to further reduce methane emissions, a gallon of California milk might be the least GHG intensive in the world.

Dairy methane emissions may be significantly reduced by switching from flush water lagoon systems without methane capture to dry or slurry manure management practices. Anaerobic digesters can also be installed to capture and utilize manure methane, and can be used with flush water lagoon systems, dry, or slurry manure collection practices. The use of dry manure systems, such as vacuum or scrape, may allow for easier transport and storage of manure to off-site or centralized digester systems, which can improve economies of scale, biogas production efficiencies, and nutrient management on the dairy. Dairies with flush water lagoon systems typically use flood irrigation over dairy feed crops, such as corn silage and alfalfa, to dilute and disperse nutrients from manure in the lagoon. If done improperly, this practice can lead to soil and groundwater contamination, and is subject to regulation by regional water quality control boards, including the Dairy General Order in the Central Valley. Dry manure management may lead to air quality challenges, however, which need to be fully considered. Ultimately, the optimal mix of technologies and manure management practices to reduce methane emissions, protect air and water quality, and support dairy economics will depend on dairy-specific factors and vary across the State.

In some instances, pasture-based dairy management may be an option, as well, but there are tradeoffs that limit its applicability. In a pasture system, manure is left in the field and decomposes aerobically (versus anaerobically in a lagoon), which avoids methane emissions. Many organic milk producers rely on pasture systems for much of their operations, and it is a fairly common practice in other states and at smaller dairies in coastal and northern parts of California. However, for larger dairies and those in the Central Valley, pasture would require using significantly more, irrigated, land and may also pose feed production and animal welfare concerns. Pasture dairy operations may still face potential nutrient management and groundwater issues, and still must maintain liquid storage to comply with regulations for milking parlor operations and stormwater management. Milk production and feed efficiencies are lower in pasture-based systems, requiring more cows and higher enteric fermentation emissions per unit of milk, and pasture-based systems limit the ability to manage manure as a valuable organic waste resource. As for other alternatives to reduce methane from manure management, pasture-based systems may be a viable option in some instances, but likely not all.

Captured biogas can be used to power farm trucks and equipment, injected into natural gas pipelines, used as a transportation fuel, or used to generate on-site renewable

electricity and heat. On-site electricity generation can displace emissions from centralized fossil-based systems or exported to neighbors or the electricity grid when feasible. Technologies that reduce or eliminate criteria pollutant and toxic emissions should be encouraged in both incentive and regulatory programs, particularly in areas with severe or extreme air pollution. This will help to overcome air quality permitting issues that can hinder project development, especially in the Central Valley and Southern California. Dairy manure can also be mixed with other organic materials diverted from landfills or wastewater treatment plants to improve digester performance and economics, with centralized digesters playing a key role in helping California meet its organic diversion and bioenergy goals. While barriers remain to building out necessary infrastructure in the State, if the market were fully enabled, anaerobic digestion at California dairies could lead to billions of dollars of investment and thousands of new jobs, concentrated in the Central Valley, and represent a billion dollar annual market.[101]

Accordingly, dairy manure offers a tremendous opportunity to reduce emissions in California. About half of the expected methane emission reductions by 2030 identified in this Draft Strategy come from changing typical manure management practices at California dairies. Working together, State agencies, dairy farmers, and other stakeholders can achieve this level of reduction through a combination of financial incentives, infrastructure deployment, market development and regulatory actions:

- **Regulate new dairies.**[102] In order to minimize the potential for emission increases from dairies moving forward, ARB, in consultation with CDFA, will develop a regulation by 2018 that would establish requirements for manure management best practices for new dairies and expansions at existing dairies that occur on or after the effective date of the proposed regulation.
- **Monitor progress toward strong, voluntary targets.** In order to scale infrastructure and progress toward necessary emission reductions by 2030, early and continual progress is needed. With appropriate market and institutional support, methane emissions from dairies can be reduced by 20 percent in 2020, 50 percent in 2025, and 75 percent in 2030. ARB, with the support of CDFA, will monitor progress toward meeting these targets through data submitted by dairies and ongoing “hot spots” and ambient methane measurements. If sufficient progress is not made, additional market support may be warranted, or the agencies may consider accelerating potential regulatory timelines to achieve further reductions from this sector.
- **Align financial incentives with improved manure management practices.** Achieving the 2020 and 2025 targets will require reductions about equivalent to

[101] See Chapter 2, Section B.

[102] Requiring emission reductions from the sector would mean that offsets under the Cap-and-Trade program would no longer be issued for new projects once the regulation takes effect. Existing projects are allowed to receive credits for ten years, and would still be able to finish out their crediting period. Any new projects developed after a regulation is in effect would still be eligible for incentives under other programs, including the bioenergy feed-in-tariff (pursuant to Senate Bill 1122) and the Low Carbon Fuel Standard.

putting digesters on more than 100 dairies in the State. (California has over 1,500 dairies and about 1,000 dairies with more than 500 milking head that might be suitable for digesters.) Continued and likely increased State funding or incentives is important to support initial infrastructure, to prove technologies and market opportunities that are necessary to scale potential solutions. CDFA estimates that at least $100 million per year for five years will be needed to support the development of necessary manure management infrastructure, in the form of grants or loans or other incentive payments. The State will support research to identify coordinated infrastructure build out opportunities that minimize costs and maximize value, and may form a coordinated working group to identify optimal financing and incentive structures for composting, anaerobic digestion, and other organics and manure management infrastructure in the State.

- **Collaborate to overcome barriers.** To help dairies meet these targets, ARB and CDFA will establish a working group with other relevant agencies and stakeholders to focus specifically on solutions to barriers to dairy manure projects, including permit coordination, feed-in tariffs, simplified interconnection procedures and contracts, credits under the Low Carbon Fuel Standard, increasing the market value of manure products, and uniform biogas pipeline standards. In addition, State agencies will coordinate activities with federal agencies, including the U.S. Department of Agriculture and U.S. Department of Energy, to align common efforts and attract federal investment to California. Further, ARB will work with State and Regional water quality agencies to ensure opportunities for conservation and water quality efforts are developed jointly.
- **Foster markets.** In many cases, installing anaerobic digesters at dairies may not yet be cost-effective, if the only marketable product is energy. However, if soil amendment products and environmental credits can be monetized from these projects, as well, they may offer attractive rates of return for farmers and investors.[103] Markets for these other products need further support, however, before they can offer reliable returns to help finance projects, and infrastructure to support these markets needs to be fully developed. CalRecycle, CDFA, and other agencies are working together to support healthy soils through composting and building markets for soil amendment products in the State. Enabling pipeline injection of biomethane and minimizing associated costs will help get dairy biogas into the transportation sector and allow for the generation of Low Carbon Fuel Standard Credits (LCFS), which could provide an especially valuable revenue stream. ARB will immediately begin to work with manure-to-methane-to-transportation fuel pathway applicants to enhance LCFS credits from such projects, by including manure methane destruction in the carbon intensity calculations. Initial estimates suggest that this would reduce the carbon intensity of a dairy digester pathway from about 30 gCO_2e/MJ currently to at least -100 gCO_2e/MJ. At current credit prices, this change would increase the value of LCFS credits from these projects by about $1 per diesel gallon equivalent.

[103] Informa Economics (2013) National Market Value of Anaerobic Digester Products, Prepared for the Innovation Center for U.S. Dairy, February.

- **Ensure reductions from existing dairies.** ARB will work with CDFA to monitor progress towards voluntary targets and identify an appropriate timeline for developing a regulation to ensure progress on emission reductions is maintained. If voluntary targets are not met through sufficient market support and financial incentives, an accelerated timeline for regulatory action may be appropriate. In developing potential regulations, ARB will take into consideration existing and past levels of market support and the potential for emissions leakage. ARB staff will periodically report to the Board on progress and any recommendations for accelerating emission reductions from dairies, including potential regulations.

Dairy and Livestock Enteric Fermentation

Methane that is produced by the microorganisms involved in the digestive processes in the stomachs of ruminants, such as sheep, goats, buffalo and cattle, is referred to as enteric fermentation. Since these emissions account for 29 percent of California's methane inventory, it is essential to develop strategies to reduce emissions from these sources to meet State GHG emission reduction targets.

Strategies that have been investigated to reduce enteric fermentation include increasing rumen efficiency and reducing the amount of methane produced for a given amount of feed intake, breeding animals for lower methane production, gut microbial interventions, and changes to nutrition and animal management. Further research is needed to fully evaluate the viability of these strategies to California; and to assess their associated costs and co-benefits, potential impacts on animal productivity, on animal and human health, other environmental impacts, and GHG and air toxic emissions associated with feed lifecycles. Regionally-specific lifecycle emission assessments of enteric emission reduction strategies should be as expansive as possible to account for any unintended emission increases in other sectors. For example, strategies to produce more easily digestible feed that lowers enteric fermentation might increase emissions associated with GHG-intensive feed production and transport.

The dairy industry in California and the U.S. has been proactive in trying to reduce GHG emissions associated with their operations and product. Indeed, the environmental footprint of dairy products has declined significantly over the past 60 years.[104] Continuing these efforts, a broad coalition of the national dairy industry has set sustainability targets for 2020, compared to 2008 levels. These include reducing the GHG intensity of fluid milk by 25 percent,[105] as well as enteric fermentation emissions by 25 percent.[106] In California's GHG inventory, enteric

[104] Capper, J.L, Caddy, R.A. and D.E. Bauman (2009) The environmental impact of dairy production: 1944 compared with 2007, *Journal of Animal Science,* 87**(6)** pp. 2160-2167. doi:10.2527/jas.2009-1781

[105] http://www.usda.gov/wps/portal/usda/usdamediafb?contentid=2013/04/0076.xml&printable=true&contentidonly=true

[106] Innovation Center for U.S. Dairy (2008) U.S. Dairy Sustainability Initiative: A Roadmap to Reduce Greenhouse Gas Emissions and Increase Business Value, December. http://www.usdairy.com/~/media/usd/public/roadmaptoreduceghgemissions.pdf.pdf

fermentation emissions have been fairly constant since 2008. If a 25 percent reduction in enteric fermentation emissions from dairy cows were achieved by 2030, it would reduce methane emissions by 5 $MMTCO_2e$ (based on a 20-year GWP) compared to current levels.

This Draft Strategy sets those levels as a goal for reducing methane emissions from enteric fermentation in California. By continuing historic annual improvements in milk production efficiency and progressing toward their established voluntary targets, the industry may meet this goal independently. However, State agencies will support research and continue to monitor progress to develop strategies that can help to reduce enteric fermentation emissions from dairy cows and livestock in the California context. Once mitigation strategies have been successfully evaluated, long-term emission reduction potential and goals can be established on a broader scale.

Landfills

Landfilling of organic materials leads to the anaerobic breakdown of these materials into methane, which can work its way out of the landfill as a fugitive emission. Organic waste constitutes more than one-third of California's waste stream, and as with dairy manure, a holistic approach is needed to effectively divert and manage it. This means not only keeping organics out of landfills, either by source reduction or diversion, but also improving the infrastructure for recycling organics, including composting, anaerobic digestion and other novel processes for energy recovery. California must have enough in-state composting and in-vessel digestion or other organics processing and recycling capacity to maximize the benefits from this waste stream and effectively minimize the spreading of unprocessed organic waste on open lands, which can have adverse environmental impacts. It also means having markets for this material that are robust and resilient whether as soil amendments, transportation fuels, energy, or other uses. The State can accelerate progress by providing more consistent financial and institutional support for these efforts, and taking steps to align tipping fees and financial incentives in the sector with its organics diversion goals.

Diverting organic wastes can provide a variety of environmental and economic benefits. Composting returns nutrients to the soil, builds soil organic matter, improves water holding capacity, and increases carbon sequestration in the landscape. The anaerobic digestion of organic waste can also support the State's efforts to obtain at least 50 percent of its electricity from renewable resources, aid in reducing the carbon intensity of transportation fuels, and displace fossil natural gas consumption. As described in Chapter 2, eliminating the disposal of organics in landfills as part of a broad effort to put California's organic waste streams to beneficial use can generate thousands of jobs and provide billions of dollars in value, much of it concentrated in the Central Valley and other rural areas.

Eliminating the disposal of organics in landfills would align California with a growing range of efforts to do so in other states and countries. In 1999, the European Commission required all member states to reduce the amount of organic waste headed

for landfills to 35 percent of 1995 levels by 2016. Since then, a number of countries have instituted some form of ban on organic materials in landfills, for example Sweden banned the landfilling of any organic waste by 2005. Here in the U.S., 29 states currently have some form of ban or mandate regarding organic waste in landfills. Vermont, Massachusetts, Connecticut and Rhode Island all have some form of food waste ban, along with New York City, Seattle, and Vancouver. In California, San Francisco and Alameda County require that food waste be separated and kept out of the landfill, and both Los Angeles and San Francisco, along with other cities, have plans in place to become zero-waste.

The State has already established its intent to phase out the disposal of organics from landfills. Existing law sets a goal of diverting 75 percent of solid waste from landfills by 2020 and provides other measures and requirements to support diverting organics from landfills. California will build on that intent and progress, with market and institutional support, and effectively eliminate the disposal of organics in landfills by 2025, by diverting at least 75 percent of organic materials from landfills by 2020, and 90 percent by 2025 (an 80 percent reduction over current disposal levels). Due to the multi-year timeframe required to breakdown landfilled organic material, emission reductions from organics diversion accumulate over time. These actions would reduce landfill emissions by 5 $MMTCO_2e$ in 2030,[107] increasing to 21 $MMTCO_2e$ by 2050 (using a 20-year GWP).

Still, waste-in-place will continue to emit methane for decades to come. California has a Landfill Regulation in place that requires owners and operators of certain uncontrolled municipal solid waste landfills to install gas collection and control systems. This effort has improved management of landfills in California and reduced methane emissions. There may be additional opportunities to employ best practices and further reduce methane emissions from landfills over time.

However, quantifying emissions from landfills is difficult, due to their area-wide nature and several landfill-specific factors (size, age, materials deposited, local atmospheric conditions, soils, landfill cover, and gas collection system). In the GHG inventory, and its climate programs, ARB assumes a methane capture efficiency of 75 percent at landfills. This conforms with common practice nationally. In its Landfill Regulation, ARB estimated that the landfill regulation may increase the collection efficiency at regulated landfills to 80-85 percent.

Estimates of methane collection efficiency at landfills, both with and without gas collection systems, vary widely. In the U.S. EPA landfill database, the weighted average of collection efficiencies at California landfills is 78 percent.[108] But this data is

[107] Methane emission reductions from landfills (Table 6) are calculated assuming regulated landfills achieve methane capture efficiencies of 80 percent by 2030 and 85 percent by 2050, and that the State effectively eliminates organic disposal at landfills by 2025 by meeting the organics diversion targets identified in this Draft Strategy.

[108] The average collection efficiency at California landfills in 2013, according to EPA's database is 76 percent. When weighted by methane generation, the average is 78 percent. http://www3.epa.gov/airtoxics/landfill/landflpg.html

self-reported and the reporting process does not easily incorporate investments made pursuant to California's regulation. Additionally, various studies suggest that California's methane inventory is underestimating methane emissions in the State. The source(s) of potential incremental methane emissions has not been identified, which suggests that additional evaluation of landfill emissions is necessary, along with and other major sources of methane in the State.

The State will support research to improve understanding of emissions from landfills and engage stakeholders in potential opportunities to further control them. Once more is understood about emissions from California's diverse set of landfills, ARB may update the assumptions regarding collection efficiency used in its inventory and various programs and consider whether additional actions, including a "phase 2" of the landfill regulation, would deliver further cost-effective GHG emission reductions.

Uncertainty around landfill emissions does not suggest that the existing Landfill Regulation is not reducing emissions or that steps to divert organics from landfills should be delayed. To the contrary, what is certain is that best management practices at landfills reduce methane emissions, diverting organics from landfills can provide a wide range of economic and environmental benefits in California, and that doing so is the only reliable way to avoid methane emissions from landfills on a lasting basis.

Accordingly, the State will take the following actions to reduce methane emissions from landfills in California:

- **Monitor progress through annual reporting.** CalRecycle will provide an annual public update on the disposal, diversion, and recycling of organics, beginning in 2016.
- **Require organics diversion from landfills.** ARB, in conjunction with CalRecycle, will consider the development of a regulation by 2018 to require waste management agencies to effectively eliminate the disposal of organics in landfills by 2025. Under this proposed regulation, material would be diverted to organics recycling facilities to make useful products, including compost, fuel or energy. These facilities may be developed at existing landfill and other waste management sites, or at new stand-alone sites. Organic wastes could also be diverted to regional waste water treatment plants or dairies for co-digestion with wastewater sludge, biosolids, or manure.
- **Align financial incentives with organics diversion.** Achieving the 2020 target of 75 percent diversion will likely require approximately 100 new or expanded facilities statewide to process and reuse diverted organic waste from landfills — through composting, anaerobic digestion, or other methods. Achieving 90 percent diversion by 2025 will require even more infrastructure build out. Continued, increased State funding is critical to building this necessary infrastructure. At the same time, an increase in California's Integrated Waste Management Fee is also needed to discourage the landfilling of organic waste and other recyclables, and provide funding to support organics recycling infrastructure. CalRecycle estimates that State support on the order of

$100 million per year for five years – in the form of grants, loans, or incentive payments – will be needed to leverage private sector financing and local rate structure changes to support the development of necessary organic infrastructure and help to foster markets.

- **Collaborate to overcome barriers.** State agencies will collaborate to resolve existing constraints in the permitting process that provides clear standards and compliance pathways for all public health and environmental goals. The beneficial use of methane produced at organic waste processing facilities faces many of the same obstacles described for dairy manure or wastewater treatment, and a common workshop or work group effort to address barriers to beneficial use of organic waste streams may be useful. Also, appropriate standards should be developed guiding the direct application of raw organic materials on land, to ensure this activity does not pose a threat to human or environmental health.
- **Foster markets**. CalRecycle will work collaboratively with other agencies and departments to identify, develop, and expand markets for the use of compost and mulch. Specifically, CalRecycle and CDFA will continue their efforts to incentivize the use of compost on agricultural lands in support of Healthy Soils Initiative, including developing best management practices for agricultural use. They will also work with the State Water Resources Control Board to evaluate potential mechanisms to account for the use of compost and its impacts on nitrogen budgets in the Irrigated Lands Program. CalRecycle will continue to work towards strengthening State procurement requirements relative to compost and mulch. Finally, building on the existing use of compost as a water conservation practice that is essential for climate adaptation with respect to drought, State agencies will support research to quantify water conservation benefits and consider developing mechanisms to account for and value them.
- **Improve understanding of landfill emissions.** ARB and CalRecycle will support research to improve understanding of emissions from California landfills and identify opportunities to further reduce emissions from existing waste-in-place. By 2020, ARB will consider the latest science and whether adjustments to emissions accounting in the inventory or other programs is warranted. Based on this information, ARB, in collaboration with CalRecycle, may consider additional actions to further reduce and capture methane emissions from landfills in the future.

Oil and Gas

California has a large oil and gas industry with more than 50,000 oil and 1,500 gas wells, including off-shore platforms. The majority of the oil wells are located in Southern California with most of the gas fields located in Northern California. An extensive network of oil and gas pipelines within the State transport California's crude oil from import terminals and on- and off-shore oil fields to refineries, and distributes finished fuels to more than 70 product terminals throughout the State.

California also has about 215,000 miles of natural gas transmission and distribution pipelines; 25 compressor stations; and 25,000 metering and regulating stations (M&R) stations. Natural gas is currently California's largest source of electrical generation fuel, and supplies most of the energy used for industrial operations. Natural gas is also a primary source of energy used for residential and commercial space heating and cooking, and represents the primary source of GHG emissions from such structures.

Much of the equipment in the oil and gas industry has been regulated for decades by the local air districts. The U.S. EPA also recently proposed additional federal measures that could address methane primarily at new sources, with coverage at some existing sources. The districts have rules and regulations to limit VOC and NO_x emissions because they are precursors of ground-level ozone. Many of the VOC controls also reduce methane as a co-benefit. Additional actions to reduce methane from the oil and gas sector should also reduce VOC and toxic air contaminant emissions, although those co-benefits have not yet been estimated.

California has an emerging, comprehensive framework in place to reduce methane emissions from the oil and gas sector. Effectively implementing this framework can reduce methane emissions from oil and gas systems by 40-45 percent in 2025, matching federal commitments. (For the purposes of calculating emission reductions in 2030, Table 6 assumes a 45 percent reduction below current levels by 2030.) The State's framework on oil and gas methane emissions includes the following elements:

- **Adopt and implement regulation on oil and gas production, processing, and storage.** ARB is currently working with local air districts and other stakeholders to develop a regulation for adoption by mid-2016. The proposed regulation, still being developed, will likely require:
    - Vapor collection on uncontrolled oil and water separators and storage tanks with emissions above a set methane standard;
    - Vapor collection on all uncontrolled well stimulation circulation tanks;
    - Leak Detection and Repair (LDAR) on components, such as valves, flanges, and connectors, currently not covered by local air district rules;
    - Vapor collection of large reciprocating compressors' vent gas, or require repair of the compressor when it is leaking above a set emission flow rate;
    - Vapor collection of centrifugal compressor vent gas, or replacement of higher emitting "wet seals" with lower emitting "dry seals"; and
    - "No bleed" pneumatic devices and pumps.

  This regulation would uniformly expand some local regulations to all air districts and include additional infrastructure components (such as valves, flanges, and seals) that are not currently covered by local district programs. ARB staff is investigating ways, including offset requirements, to ensure that there will be no net increase in NO_x emissions in cases where methane and VOC emissions cannot be sent into existing sales lines, fuel lines, reinjection wells, or combustion devices; and are instead captured by installing new vapor collection and combustion devices on existing storage tanks.

- **Effectively implement SB 1371.** Senate Bill 1371 (Leno, Chapter 525, Statutes of 2014) directs the CPUC, in consultation with ARB, to adopt rules and procedures to minimize natural gas leaks from CPUC-regulated intrastate transmission and distribution gas pipelines and facilities. Among other requirements, SB 1371 directs the CPUC to adopt rules and procedures that provide for the maximum technologically feasible and cost-effective avoidance, reduction, and repair of leaks and leaking components. In January 2015, the CPUC launched a rulemaking proceeding (R.15-01-008) to carry out the intent of SB 1371.

  Under this proceeding, CPUC published a report that identifies new gas leak detection technologies that can be used to optimize methane reductions from transmission, distribution and storage processes. CPUC also required utility companies and gas suppliers to report natural gas emission data and best leak management practices by May 15, 2015. In June, CPUC conducted a prehearing conference to discuss the draft scoping memo of relevant topics to be deliberated during the 24-month timeframe of the proceeding.

  ARB continues to actively participate in the proceeding and will lead efforts to analyze collected utility emission data, develop quantification protocols, and identify potential mitigation strategies. In particular, ARB will focus on the potential emission reduction potential of the proceeding in keeping with the objectives of AB 32 as they pertain to:
  - Comparing the data collected under SB 1371 with the Mandatory Reporting Regulation;
  - Analyzing emission data to determine potential mitigation strategies. For example, the proceeding may require the replacement of older pipelines or pipelines constructed of a certain material;
  - Identify any remaining data gaps;
  - Establishing procedures for the development and use of metrics to quantify emissions; and
  - Reviewing and evaluating the effectiveness of existing practices for the operation, maintenance, repair, and replacement of natural gas pipeline facilities to determine the potential to reduce methane leaks and where alternative practices may be required.

  The final decision on potential rules and procedures by the CPUC, including ratemaking and financial incentives to minimize gas leaks, is anticipated in the Fall of 2017. Upon evaluation of the industry's compliance with the decision, ARB will determine whether additional regulatory actions or incentives are required to further reduce methane emissions from this source.
- **Improve leak detection.** Several efforts are underway at the CEC and ARB to improve emissions monitoring to help identify sources of fugitive methane emissions and reduce them, including from oil and gas operations. For example, the CEC provided research funding for operation of a mobile leak detection platform. In 2015, ARB will release a Request for Proposal (RFP) to collect emissions data from oil production wastewater ponds. Results from this contract are expected in 2018, and if they indicate that these ponds are significant sources of methane, ARB may initiate a regulatory process to reduce

those methane emissions. Additionally, ARB and NASA's Jet Propulsion Laboratory are collaborating to identify large "hot spot" methane sources through a systematic survey of high methane emitters throughout California. This project will use aerial and ground measurement to survey oil and gas fields and infrastructures, dairies, feedlots, digesters, landfills, rice fields, and waste water treatment facilities to provide a greater understanding of methane sources. Finally, ARB is actively participating in the Megacities Carbon Project being conducted in the South Coast Air Basin, which is developing and testing methods for monitoring various GHG emissions to link monitored concentrations to emission activity.

Wastewater Treatment, Industrial, and Other Sources

Wastewater treatment, industrial operations, rice cultivation, and other sources of organic waste account for about 9 percent of the State's methane inventory. California's 250 wastewater treatment plants are designed to remove contaminants from wastewater, primarily from household sewage. Treatment of wastewater typically relies on physical, chemical, and biological processes to remove contaminants and produce environmentally-safe, treated wastewater (or treated effluent).

A typical by-product of sewage treatment is a semi-solid slurry or sludge that undergoes further treatment before being suitable for disposal or land application. Most municipal wastewater sources contain organic constituents which are treated anaerobically. This treatment process produces methane.

Methane emissions can be avoided by either treating the wastewater and the associated sludge under aerobic conditions or by capturing methane released under anaerobic conditions. Technologies are available to capture and use the methane generated by these facilities as a source of renewable power or transportation fuel to benefit California's climate and energy goals.[109] Approximately 150 of the State's wastewater treatment plants, which treat over 90 percent of total wastewater flow, currently use anaerobic digestion in their treatment process. About 110 of these plants use some or all of the captured methane to generate electricity.

Many wastewater treatment plants have large amounts of spare capacity to potentially take in additional sources of organic waste for anaerobic digestion. Most treatment plants are located close to population centers and could utilize significant amounts of food and other organic waste streams from adjacent cities and towns. As such, wastewater facilities provide an opportunity to help divert organic wastes from landfills and use them to produce renewable electricity, fuels, and soil amendments. These

[109] The Environmental Protection Agency's Combined Heat and Power Partnership Report (2011) estimates that existing California wastewater treatment infrastructure could potentially generate between 600,000 to 900,000 megawatt hours of annual electricity. Realizing this potential would not only reduce methane emissions, but achieve GHG emission reductions by displacing fossil-based electricity generation currently needed to power these facilities.

facilities can be designed to co-digest materials such as fats, oils and grease from food and other organic wastes.

Diverting these organic materials into wastewater digestion systems can support the capture and reduction of methane emissions from regional organic sources, further boost the beneficial use of methane gas at wastewater treatment plants, and reduce flaring or non-contained releases of methane to the atmosphere. These facilities can also be designed to produce agricultural "biosolids", which when composted can be used to help sequester soil carbon and reduce the use of fossil-fuel based fertilizers.

As many of the State's wastewater treatment plants undergo renovation or reconstruction over the next 15 years, ARB will work with the State Water Resources Control Board, Regional Water Quality Control Boards, and others to assess the feasibility and benefits of actions to require capturing and effectively utilizing methane generated from wastewater treatment. A program that relies on financial incentives and/or regulatory actions could be implemented to ensure that new and existing wastewater treatment plants in California fully implement methane capture systems (potentially to produce on-site renewable electricity, transportation fuel, or pipeline biogas), and maximize digestion of regional organic materials. The potential actions could be tailored to each wastewater treatment plant based on size or capacity, and other factors such as potential for co-digestion expansion or stand-alone digesters located at wastewater treatment plants, proximity of co-digestion waste streams, and regional air quality standards and rules. The Water Boards could develop permit terms and other regulatory tools to support the program while achieving water supply, water quality, and related co-benefits. Cal Recycle could require or incentivize landfill operators to divert organics to wastewater treatment plants.

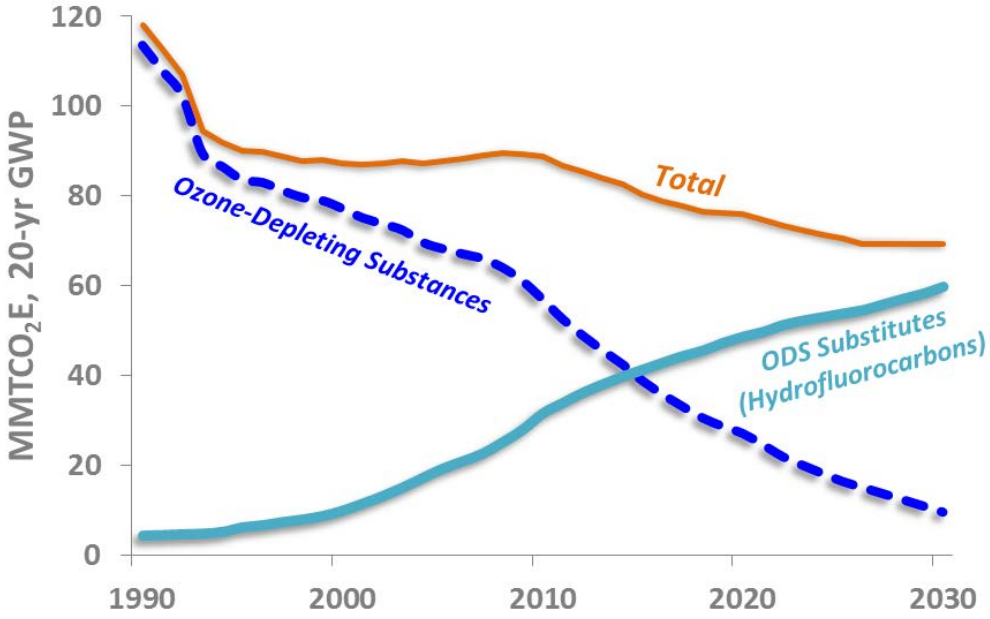
Many wastewater treatment plants are permitted to burn digester biogas through flaring and are classified as industrial facilities. Capturing the biogas to produce electricity, such as through a combined heat and power (CHP) system may result in re-classifying the facility's purpose as "electricity generation" and subject the plant to more onerous emission compliance and abatement equipment rules, even though the change in criteria pollutant emissions are minimal. In addition, the beneficial use of methane generated at wastewater treatment facilities faces many of the same hurdles faced by dairy digesters and waste treatment facilities. State agencies will work collaboratively to address these barriers, as they are for those hindering other productive uses of California's waste streams, in the dairy and landfill sectors, as well.

Coupled with improved monitoring to detect and fix leaks and fugitive emissions, as described for the oil and gas sector, California aims to reduce fugitive methane emissions from wastewater, industrial, and other sources by 40 percent below current levels by 2030.

VI. Reducing F-Gas Emissions

Fluorinated gases (F-gases) are the fastest-growing source of GHG emissions both globally and in California. They include ozone-depleting substances (ODS) that are being phased out under the Montreal Protocol, and their primary substitute, hydrofluorocarbons (HFCs). F-gases currently comprise four percent of all GHG emissions in California, although annual HFC emissions are expected to increase 60 percent under business-as-usual by 2030 as HFCs continue to replace ODS (Figure 7).

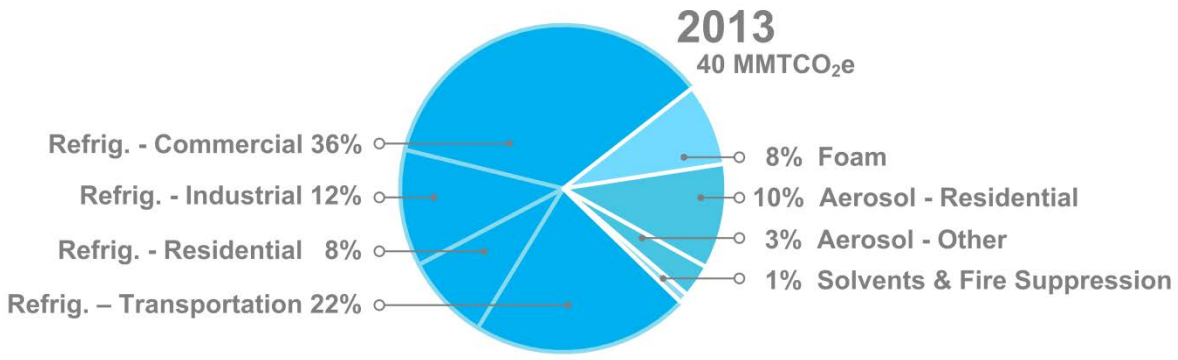
Figure 7. Emission Trends of ODS and ODS substitutes (hydrofluorocarbons)



The majority of F-gas emissions come from fugitive emissions of refrigerants used in refrigeration and air-conditioning (AC) systems. The largest uses of F-gases are in commercial refrigeration and air-conditioning, which comprise more than 36 percent of F-gas emissions. More than half of refrigeration and air-conditioning equipment currently uses HCFC-22, a high-GWP ODS which is scheduled for a complete phase-out of new production and import in the U.S. beginning January 2020. The HCFC-22 refrigerant is being replaced with HFCs that have higher GWPs, thus increasing the GHG impact of refrigerants. We expect that in anticipation of the HCFC-22 phase-out beginning in 2020, most owners of equipment using HCFC-22 will either replace the equipment by 2020, or at a minimum replace the HCFC-22 refrigerant in the same equipment (retrofit) with a high-GWP HFC refrigerant. A window of opportunity exists in the next five years to accelerate the transition of refrigeration and air-conditioning equipment to lower-GWP refrigerants, before another generation of equipment is locked into using higher-GWP refrigerants over their average lifetimes of 15 to 20 years.

F-gas emissions from transportation are largely from mobile vehicle air-conditioning (MVAC), and as California and the U.S. EPA implement the MVAC credits programs under their light-duty vehicle GHG emission standards, and the MVAC leakage standards under their heavy-duty vehicle GHG emission standards, the share of F-gas emissions from the transportation sector will decline. Aerosol propellants (consumer and medical dose inhalers) comprise 13 percent of F-gas emissions, and insulating foam expansion agents contribute another eight percent of F-gas emissions. Solvents and fire suppressant F-gas emissions contribute one percent of all F-gas emissions. Figure 8 shows the emissions sectors that contribute to California's overall HFC emissions. (ODS emissions are not shown because they are being completely phased out under the Montreal Protocol and are not included in the AB 32 GHG emission reduction targets.)

Figure 8: California 2013 F-gas (Hydrofluorocarbons) Emission Sources*



***Using 20-year GWP**

Sulfuryl fluoride (SO_2F_2) is a fluorinated gas with a lifetime of several decades. It was believed to have a negligible GWP until 2009, when it was assigned a 20-year GWP of 6840. Because sulfuryl fluoride was not identified as a high-GWP gas at the time, it was not included as an AB 32 gas and is not annually inventoried as a part of ARB's statewide GHG inventory. Sulfuryl fluoride is used as a pesticide fumigant and is one of the most common replacements for methyl bromide. According to the California Department of Pesticide Regulation (DPR), 3 million pounds of sulfuryl fluoride were used in 2013. If sulfuryl fluoride were added to ARB's GHG inventory, it would increase the short-lived F-gas emission inventory by a quarter. Although both DPR and U.S. EPA have investigated lower-GWP alternatives to sulfuryl fluoride, no effective substitutes have yet been identified. ARB will continue to monitor the use of this fumigant as well as potential substitutes.

This Draft Strategy identifies measures that can reduce F-gas emissions by 40 percent in California by 2030. They represent a reasonable path forward for California, but the State's approach on F-gases could be affected by a potential international agreement that may be reached in November 2015 to phase down the use of HFCs globally. ARB will monitor progress on national and international efforts to reduce F-gas emissions,

and may update this set of measures if additional national or international steps are taken before the proposed Strategy is released.

A. Progress to Date

California is among the world's leaders in reducing F-gas emissions. Measures adopted under AB 32 have reduced emissions from a variety of sources. The biggest reductions of high-GWP F-gases are coming from ARB's Refrigerant Management Program, which requires facilities with refrigeration systems to inspect and repair leaks, maintain service records, and in some cases, report refrigerant use. The Refrigerant Management Program has helped change industry practices to become more proactive in preventing refrigerant leaks, which has helped businesses save money by avoiding system repairs and downtime as well as the cost of replacement refrigerant. Other measures already in place include low-GWP requirements for consumer product aerosol propellants and a self-sealing valve requirement for small cans of automotive refrigerants purchased by "do-it-yourself" mechanics.

California's efforts to reduce emissions of F-gases are part of a broader set of national and international commitments. World leaders have agreed to work together and through the Montreal Protocol to phase down the production of HFCs. The U.S. EPA can impose federal bans on F-gases under the Significant New Alternatives Policy (SNAP) Program. In July 2015, the U.S. EPA adopted bans on specific HFCs with very high GWPs used in new commercial refrigeration systems, the manufacture of polyurethane foam, and new light-duty motor vehicle air-conditioning systems.[110] In many cases, these national bans copied programs that were first demonstrated in California.

The U.S. national bans are expected to decrease HFC emissions in California by ten percent annually below business as usual by 2025. The European Union (EU) has adopted the world's leading F-gas regulation that will phase down the production and import of HFCs by almost 80 percent from 2015 levels by 2030.[111,112]

Additionally, in response to President Obama's Climate Action Plan, the White House announced private sector commitments and executive actions to reduce emissions of

[110] Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes Under the Significant New Alternatives Policy Program; Final Rule. Federal Register. Volume 80, Number 138, Monday, July 20, 2015. Part II. Environmental Protection Agency. 40 CFR Part 82. http://www.epa.gov/ozone/snap/regulations.html

[111] Velders et al (2014) "Growth of climate change commitments from HFC banks and emissions", G. J. M. Velders, S. Solomon, and J. S. Daniel. *Atmospheric Chemistry and Physics*, 14, 4563–4572, 2014. doi:10.5194/acp-14-4563-2014. www.atmos-chem-phys.net/14/4563/2014/.

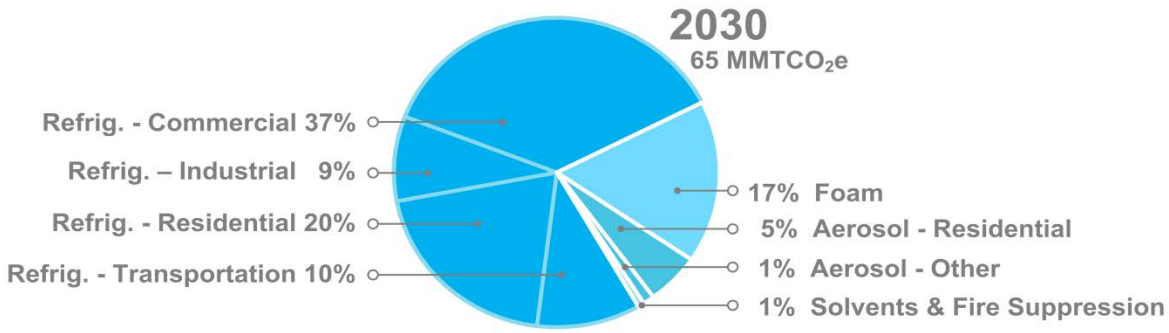
[112] EC (2014) European Commission (EC), April 16, 2006 "Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006". http://ec.europa.eu/clima/policies/f-gas/legislation/documentation_en.htm

hydrofluorocarbons (HFCs).[113] U.S. industry is leading the way by investing hundreds of millions of dollars to develop and deploy the next generation of HFC alternatives that are safer for the environment. These investments span the entire HFC supply chain—from where the chemicals are produced, to where they are used in manufacturing, to where consumers see them in stores.

Substantial progress has also been made to safely use natural refrigerants (such as CO_2, ammonia (NH_3), and hydrocarbons (HCs), with GWPs ≤ 3) all over the world, especially in Europe and Asia. The refrigeration and air-conditioning industry is looking closely at which applications suit which natural refrigerants. Reports summarizing the progress made in North America show nearly 300,000 pieces of light commercial equipment using CO_2 or hydrocarbons, more than 300 stores using CO_2 systems, and over 250 "next-generation" small-charge ammonia systems in industrial installations. Large companies investing in natural refrigerants include end users, and a wide range of equipment manufacturers.

These State and national efforts will lead to significant reductions in F-gas emissions in California through 2030, compared to where they would be otherwise. Still, F-gas (HFC) emissions in California are expected to grow by more than 60 percent without additional action (Figure 9).

Figure 9: California's 2030 F-Gas Emission Sources with Existing Measures*



***Using 20-year GWP**

B. Recommended Actions to Further Reduce F-Gas Emissions

The State supports strong, national, and international actions to reduce F-gas emissions. The U.S. EPA has already taken a number of steps to prohibit the use of new high-GWP F-gases in consumer product aerosol propellants, polyurethane insulating foam, and light-duty mobile vehicle air-conditioning. An international

[113] Fact Sheet: Obama Administration Partners with Private Sector on New Commitments to Slash Emissions of Potent Greenhouse Gases and Catalyze Global HFC Phase Down: http://www.igsd.org/documents/20140916HFCFactSheet.pdf

agreement could be reached in November to phase down the production and use of HFCs under the Montreal Protocol. The proposed Montreal Protocol HFC phase down amendments, if adopted, will reduce HFC emissions significantly by 2050.

However, if additional measures can be applied in California to achieve further GHG emission reductions in the near-term and at low cost, California will consider taking them to support the State's 2020 and 2030 GHG targets. Specifically, as effective alternatives become available, ARB will consider developing bans on the use of high-GWP refrigerants in sectors and applications where lower-GWP alternates are feasible and readily available. All refrigerants and substitutes to high-GWP F-gases must first be approved by the U.S. EPA's SNAP Program to ensure the alternatives meet health and safety criteria. The approval process is designed to minimize the risk of using newer alternatives to F-gases by identifying substitutes that offer lower overall risks to human health and the environment.

Also, in the absence of a sufficiently rigorous international agreement in November, ARB will evaluate the feasibility of a phasedown for California that aligns with similar efforts and stringency levels in Australia, Canada, the EU, and Japan.

Even with a strong international agreement to phase down the use of HFCs, additional opportunities may remain to reduce F-gas emissions in California in the near-term and through 2030 at low cost. Early action, ahead of some of the phase down schedules being proposed internationally, can avoid locking-in the use of high-GWP refrigerants in new or retrofitted systems in the coming years. This would lead to unnecessary emissions now and into the future, requiring the State to take additional—likely more costly—steps to meet its 2030 climate targets.

For example, the State should consider developing an incentive program to encourage the use of low-GWP refrigerants, which could lead to very low-cost emission reductions and could be implemented while further regulations are considered or developed. This would provide long-term avoided emissions by countering the current trend of replacing HCFC-22, the most common refrigerant for both refrigeration and air-conditioning, with higher-GWP HFCs. This trend is accelerating in the U.S. in response to the 2020 phase-out of HCFC-22 under the Montreal Protocol.

In light of ongoing international discussions, this Draft Strategy describes a set of potential measures that can reduce F-gas emissions by 40 percent in California by 2030 (see Table 7). This set of measures has been designed to minimize regulatory requirements and achieve fast and assured emission reductions. ARB will monitor progress on national and international efforts to reduce F-gas emissions, and may update this set of measures if additional national or international steps are taken before the proposed Strategy is released.

Table 7: Proposed New F-Gas 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	23	
Sales ban of very-high GWP refrigerants	1	
Prohibition on new equipment with high-GWP	15	
2030 BAU with new measures[3]		24

[1] Using 20-year GWPs from the 4th Assessment report of the IPCC
[2] "Business as Usual" forecasted inventory includes reductions from implementation of current ARB and U.S. EPA regulations
[3] Additional reductions from potential energy efficiency improvements as a result of using low-GWP alternates are not included in the above estimates

Incentive Programs

A financial incentive program would defray the potential added cost of installing low-GWP refrigeration equipment in new commercial facilities or converting existing high-GWP systems to lower-GWP options (retrofit program) and would provide immediate emission reductions. A loan or grant program would support qualifying facilities that take action to reduce emissions prior to any national or state requirements to do so.

Data reported under the existing Refrigerant Management Program indicates that more than 2,400 facilities in California currently use HCFC-22 refrigerant, which has not been allowed in new equipment since January 2010, and for which all new production and import will cease by January 1, 2020. Therefore, these facilities must either buy increasingly scarce recycled HCFC-22 to maintain their systems, or replace or retrofit their existing systems with another refrigerant within five years.

Although lower-GWP options are currently available and cost effective, in many cases with improved energy efficiency, there are two main barriers to more widespread adoption of low-GWP commercial refrigeration: 1) potentially higher up-front costs, and 2) lack of familiarity with low-GWP refrigeration. The incentive program could remove the added initial cost barrier and build familiarity with low-GWP refrigeration systems to help them scale throughout the sector.

One of the advantages of an incentive program is that it could fund early adoption of low-GWP technologies, with substantial long-term effects on avoided emissions. The

incentive program would “lock in” early and permanent GHG reductions prior to any mandatory measures.

ARB could implement the program partnering with third-party entities such as local air districts and non-profit organizations. CPUC also has an existing program to incentivize energy efficiency that could potentially be used to administer funding distribution to qualified businesses.

Phasedown in Supply of HFCs

An HFC phasedown allows industry the flexibility to make market-based decisions on when and where to continue using high-GWP HFCs before transitioning to lower-GWP options. The EU has recently adopted a supply phasedown, at the top level of supply for both production and import (first arrival of virgin refrigerant). The EU model identified the existing market based on past production and import and aims to reduce it 79 percent by 2030.

In the international arena, countries will meet in Dubai in November 2015, to discuss an HFC phasedown amendment to the Montreal Protocol. Broad-based national or international agreements are the most effective phasedown approaches, minimizing the possibility of simply displacing emissions to other locations.

Depending upon the outcome of the November 2015 Montreal Protocol meeting and stringency of the phasedown, if adopted, ARB may pursue a California HFC phasedown schedule that will meet the State GHG emission reduction goals. California would seek a partnership with the EU, Canada, Japan, and Australia, who are all currently pursuing their own separate HFC phasedown programs.

Phasedown programs offer several advantages over other regulatory approaches, such as fees or fixed limits on the maximum GWP of F-gases allowed. A broad-based phasedown program significantly reduces the number of regulated entities compared to downstream regulation or application-specific bans or limits, causes minimum disruption to industry, and guarantees emission reductions. Industry stakeholders generally favor a phasedown approach as a technically feasible and cost-effective means of reducing HFC emissions, while allowing them flexibility in transitioning to low-GWP alternates.

Prohibition on the Sale of New Refrigerant with Very-High GWPs

This measure would prohibit the sale or distribution of refrigerants with very-high GWP values, with an exemption for refrigerants that are certified reclaimed or recycled. The maximum GWP values would be developed after additional research and stakeholder meetings, and would reflect the availability of U.S. EPA SNAP-approved alternatives that could be used as near drop-in replacements that work in both new equipment and existing equipment.

In July 2015, the U.S. EPA adopted a ban on using refrigerants with a very-high 100-year GWP of 2500 or greater in new and retrofitted refrigeration systems at retail food facilities beginning in the second half of 2016. Several refrigerants are currently available with a 100-year GWP of less than 1500 that can be used in existing equipment designed for higher-GWP refrigerants.

A sales ban on very high-GWP refrigerants is enforceable and provides immediate reductions. Such a ban facilitates a much faster transition away from very high-GWP refrigerants to lower-GWP alternatives in existing equipment (thus avoiding the ongoing high-GWP emissions from equipment that typically lasts for 15 years or longer).

High-GWP Refrigerant Prohibitions in New Stationary Systems

This measure would prohibit the use of high-GWP refrigerants in new commercial, industrial, and residential stationary refrigeration and air-conditioning equipment. Certain exceptions could be made to any maximum GWP limit if a low-GWP refrigerant is not technically feasible in a specific application.

Low-GWP commercial refrigeration using ammonia is already extensively used in food processing and cold storage. Additionally, more than 100 retail food stores in the U.S. have begun using CO_2 as the primary or secondary refrigerant. In Europe, CO_2 refrigeration is used in more than 4,000 retail food stores, and generally is cost neutral compared to HFC refrigeration systems. In the hotter climate zones of California, using 100 percent CO_2 refrigeration may not be as energy-efficient as HFC refrigerants. For these hotter climates, manufacturers are currently developing blends of HFC refrigerants combined with a new class of very-low GWP synthetic refrigerants known as hydrofluoro-olefins (HFOs). The HFO-HFC blends have 100-year GWPs between 400 and 1300, and their use would reduce GHGs in these systems by more than 75 percent compared to business as usual.[114] Hybrid refrigeration such as secondary loop and cascade systems, using a small HFC central charge and a larger CO_2 charge, experience no energy penalty, even in hotter climates.

With respect to air-conditioning, in September 2014, the Air-Conditioning Heating & Refrigeration Institute (AHRI), an industry association representing 90 percent of U.S. air-conditioning manufacturing and 70 percent of the global industry, made a commitment through the White House Council on Environmental Quality to spend $5 billion over the next ten years to develop low-GWP options for refrigeration and air-conditioning. Many commercially available lower-GWP air-conditioning options are expected by 2020. In order to comply with the EU F-gas regulation that went into effect January 1, 2015, manufacturers are already developing air-conditioning systems that use refrigerants with a 100-year GWP of less than 750. Large chillers used primarily for office building air-conditioning are already commercially available that use an HFO refrigerant with a GWP of one.

[114] HFOs are hydrofluoro-olefins, an emerging class of F-gas with very low GWPs of 1-4, but which are classified as slightly flammable (A2L).

Current fire and appliance codes do not allow the use of slightly flammable refrigerants such as hydrocarbon refrigerants and the new HFO-HFC blends (unless the system is below a small charge size threshold of 157 grams for commercial-retail uses, and 57 grams for residential uses). Experience in Europe and other jurisdictions demonstrates that these codes can be designed to allow for the use of these refrigerants while ensuring safety. More work is required to update the safety codes in the U.S. before slightly flammable refrigerants can be used in more applications while maintaining safety.

A prohibition, or ban on the use of high-GWP HFCs in new equipment would result in certainty of reductions in applications where alternatives are readily available. By requiring equipment manufacturers to sell only ARB-compliant equipment in California, the enforcement focus is on the manufacturers and is not placed on the end-user. It should be noted that most manufacturers operate in a global environment, and have already made plans to produce and sell low-GWP equipment in Europe in order to comply with the EU F-gas regulations that went into effect January 1, 2015. Therefore, the ARB-proposed restrictions would not add undue burden for those companies already complying with EU regulations.

Additional measures that may be more effectively addressed at the Federal level include prohibitions on high-GWP F-gases in the following sectors: consumer product aerosol propellants, insulation spray foam, heavy-duty motor vehicle air-conditioning, transport refrigeration units (TRUs), and refrigerated shipping containers. ARB will continue to work with the U.S. EPA on reducing F-gas emissions from these sectors, and may pursue state-level measures if progress is not made on the Federal level.

VII. Achieving Success

Successfully implementing a strategy to reduce SLCP emissions will require integrated planning to achieve multiple objectives, coordination and collaboration among agencies at all levels of government, and focused investments and market support.

A. Integrate and Coordinate Planning

The SLCP Reduction Strategy fits within a wide range of ongoing planning efforts throughout the State to advance economic and environmental priorities. Integrated planning to achieve multiple objectives requires coordination among planning agencies and across sectors, systems, and government jurisdictions. Development of a strategy to reduce emissions of SLCPs is being closely coordinated with other relevant planning efforts. For example, this Draft Strategy acknowledges that further reductions in black carbon from California's freight system will be realized through strategies identified in the Sustainable Freight Strategy. That plan is currently being developed by ARB and other state agencies, and will accelerate emission reductions and implementation of zero and near-zero technology in California's freight transport system. Also, ARB staff and local air districts will develop additional strategies through the upcoming SIPs process, which is expected to reduce black carbon emissions from both mobile and non-mobile sources.

State Plans that will Assist the State in Meeting the SLCP Emission Reduction Goals	
✓ Sustainable Freight Strategy ✓ 2014 Scoping Plan Update ✓ Additional Scoping Plan Updates ✓ 2016 State Implementation Plan ✓ Three Year Auction Proceeds Investment Plan ✓ Caltrans Strategic Management Plan for 2015-2020 ✓ Funding Plan for the Air Quality Improvement Program (AQIP) and Low Carbon Transportation Greenhouse Gas Reduction Fund Investments	✓ ARB's Annual Research Plan ✓ CAT Climate Change Research Plan for California ✓ Water Action Plan ✓ CEC EPIC ✓ Alternative and Renewable Fuels and Vehicle Technology Program (ARFVTP) Annual Investment Plan ✓ DWR's Climate Action Plan ✓ Bioenergy Action Plan ✓ Forest Carbon Plan ✓ Healthy Soils

The 2014 Scoping Plan Update identified the important role of SLCPs to reduce climate change impacts and provided suggested recommended actions for further emission reductions. Those recommendations were evaluated and expanded upon in this Draft Strategy.

The ARB is embarking on the next update to the Scoping Plan to describe how the State can meet the Governor's goal of reducing total GHG emissions by 40 percent by 2030. This SLCP strategy is a forerunner to the Scoping Plan, providing justification for accelerated action on SLCP. The next Scoping Plan will augment the strategies

presented in this document with measures focused on CO2, providing a balanced portfolio of near-term and long-term measures.

Other concurrent planning efforts in the State could also identify additional activities that may serve to reduce SLCP emissions. For example, CEC's Integrated Energy Policy Report, the Healthy Soils Initiative, and the Forest Carbon Plan are all ongoing efforts that intersect with many of the concepts described in this Draft Report. ARB will collaborate with other agencies developing those plans to identify and prioritize activities to reduce SLCP emissions that would also support other State priorities and integrated planning efforts. Climate action planning efforts by city, county, and other local government entities will also play a key role in reducing SLCP emissions.

B. Enable Local and Regional Leadership

State policy is most effective with the support, engagement, and complementary actions of regional and local efforts. As the State shifts its climate-protection focus to the long-term and increases its efforts to reduce SLCP emissions, regional and local governments and agencies will play an increasingly important role in achieving California's GHG goals. The efforts of regional agencies, such as air districts, water districts, and municipal solid waste authorities, to incorporate GHG emission reduction strategies into their respective jurisdictions increases the State's leverage to further reduce SLCP emissions from various sources.

Local air districts have a key role to play in reducing regional and local sources of SLCP emissions, because air pollution reduction strategies employed by air districts often also reduce GHG emissions. City and county governments also play a pivotal role in reducing SLCPs. Many GHG reduction strategies identified by cities and counties in their local Sustainability or Climate Action Plans directly correlate to strategies necessary for SLCP emission reductions, such as improved waste management (increased recycling and composting), use of alternative and renewable fuels, and simply reducing vehicle miles traveled. These local government Climate Action Plans encourage, and sometimes mandate at the local level, actions taken by households and businesses within a community. Often times, these actions involve behavior change by individuals, which leads to increased conservation and sustainability, ultimately driving both community-scale GHG and SLCP emission reductions.

Below are examples of local and regional government efforts that are helping the State reduce SLCP emissions.

Methane

In California, agriculture and landfills are the primary sources of methane emissions. Aside from air district rules to reduce methane emissions at landfills, upstream efforts by cities, counties, and regional agencies to both reduce and divert food waste and other organic materials from the waste stream have the potential to greatly reduce

landfill-related methane emissions. Additionally, local municipalities and solid waste agencies are working collaboratively with air districts to foster renewable fuel opportunities, such as waste-to-energy and waste-to-fuel projects. For example, through its leadership role with Clean Cities, the Sacramento Metropolitan Air Quality Management District is working closely with numerous partners to build awareness and increase separation and diversion of organic waste to a local anaerobic digester.

Local agencies also play a role in methane reduction at wastewater treatment plants. Many local water districts own and operate wastewater treatment facilities and are implementing strategies to reduce methane emissions from wastewater treatment operations, such as capturing methane for use in fuel cells for on-site energy production. Local strategies to improve management and utilization of organic waste throughout the State may also have the ability to help reduce methane emissions throughout the agricultural and wastewater treatment sectors. Wastewater treatment offers a tremendous opportunity to divert organics from landfills and utilize them for producing energy and soil amendments. Many treatment plants are located near population centers and could potentially utilize significant amounts of food and other organic waste streams that come from cities and towns. Collaboration amongst local and regional agencies, such as solid waste management and water agencies, is the key to success.

Black Carbon

Local air districts have worked with ARB to develop programs to comply with federal air quality standards for PM (that will also reduce black carbon), such as mandatory and voluntary rules to restrict residential wood-burning in fireplaces and wood stoves, along with incentive programs to switch to cleaner burning devices. In fact, the Bay Area Air Quality Management District is considering a new rule to ban all wood burning devices in new construction and restrict the sale of buildings with old fireplaces, stoves or other wood-burning devices that fail to meet U.S. EPA emission standards. Districts have also enacted rules regulating commercial cooking and smoke management programs addressing agricultural, forest and rangeland burning operations, which have reduced black carbon and PM emissions.

In addition to air district efforts, metropolitan planning organizations, in coordination with city and county governments, can be credited with efforts to reduce vehicle emissions, and ultimately on-road related emissions, particularly through their Sustainable Community Strategy planning and implementation efforts. Local governments have stepped up by beginning with their own fleets. For example, in Sonoma County, the Board directed County staff to reduce emissions from the County's on-road fleet by 20 percent by 2010.

Local efforts to reduce diesel particulate matter, such as farm and construction equipment rules and incentive programs by air districts, play a significant role in the reduction of black carbon emissions such as the San Joaquin Valley air district's program to replace diesel agricultural irrigation pump engines with electric motors. In

addition, efforts by local port authorities, such as the San Pedro Bay Standards, have resulted in the establishment of more aggressive targets to reduce black carbon emissions, health risks, and further improve air quality, particularly for those in nearby disadvantaged communities.

F-Gases

Local air districts can play an instrumental role in aiding the reduction of F-gases, including developing regulations to require low-GWP replacements. For example, the South Coast Air Quality Management District has three regulations to reduce refrigerant emissions from stationary air conditioning and refrigeration systems and motor vehicle servicing, as well as restrictions on CFCs and halons from sterilization, fumigation and fire extinguishing equipment. In addition, many local governments are also tracking emissions of refrigerants, and some have adopted policies to reduce refrigerant emissions from city-owned air conditioning units, vehicles, and refrigerators.

C. Investments

Investments in financial incentives and direct funding are critical components for successful implementation of SLCP emission reduction strategies. Many existing State funding programs work in tandem to reduce emissions from GHGs (including SLCPs), criteria pollutants, and toxic air contaminants, and are helping foster the transition to a clean energy economy. In particular, State law (Senate Bill 535, De León, Chapter 830, Statutes of 2012) requires focused investment in communities disproportionately impacted by pollution. Many of these communities, especially in the Central Valley, along freight corridors, and in rural parts of the State, stand to benefit from dedicated action and investment to reduce emissions of SLCPs.

Although California has a number of existing incentive programs, the pool of funds is limited and it is critical to target public investments in ways that encourage system-wide solutions to produce deep and lasting public benefits. Significant investments of private capital, supported by targeted, priority investments of public funding, are necessary to scale deployment and to maximize benefits. Public investments can help incentivize early action to accelerate market transition to cleaner technologies, which can then be supported by regulatory measures. The State must coordinate funding sources such as the California Climate Investments, supported by the Greenhouse Gas Reduction Fund (GGRF), Alternative and Renewable Fuel and Vehicle Technology Program (AB 118), Electric Program Investment Charge (EPIC) Program, Carl Moyer Program, Air Quality Improvement Program, and Proposition 39: Clean Energy Job Creation Fund, to expand investments in California's clean economy and further reductions in SLCPs and other GHG emissions. Current activities and funding allocations for a few of these programs are described herein.

The GGRF is an important part of California's overall climate investment efforts to advance the goals of AB 32 (Nunez, Chapter 488, Statutes of 2006) and target investment in disadvantaged communities. The Department of Finance, in consultation

with ARB and other State agencies, is developing the Cap-and-Trade Auction Proceeds Second Investment Plan (Fiscal Years 2016-17 through 2018-19) (Second Investment Plan). A Draft Concept Paper for the Second Investment Plan presenting high-level ideas was released for public input in July 2015.

The strategy surrounding the Second Investment Plan recognizes that although carbon dioxide is the dominant GHG, other SLCPs may be responsible for as much as 40 percent of global warming experienced to-date. As a result, the Draft Second Investment Plan Concept Paper includes a new emphasis across categories in efforts to reduce SLCP emissions.

The Draft Second Investment Plan Concept Paper includes investment priorities for three main categories. In the Transportation and Sustainable Communities category, projects that increase system efficiencies, support sustainable community strategies, accelerate adoption of advanced vehicle technology, and support alternative fuels and infrastructure would be considered. These projects would help reduce fossil fuel demand and incentivize in-State production of low-carbon intensity renewable fuels, which will result in methane and black carbon reductions.

In the Clean Energy and Energy Efficiency category, recommended investments include projects that reduce black carbon, methane, and F-gas emissions through: reduced fossil fuel production and consumption; phase-out of high-GWP products; and incentives to replace woodstoves/fireplaces and utilize green waste.

In the Natural Resources and Waste Diversion category, recommended investments focus on projects that reduce methane release from organic waste and protect natural and working lands as carbon sinks. This category would also include anaerobic digesters to reduce methane emission from organic waste streams and manure and a forest health program that seeks to minimize black carbon emissions by reducing wildfire risk, among other activities.

A critical piece of the State's investment strategy, which is overseen by ARB and focused on clean transportation incentives, is the Low Carbon Transportation Investments and the Air Quality Improvement Program (AQIP). Consistent with the First Investment Plan, these programs have identified zero-emission passenger transportation and low-carbon freight transport as investment priorities, which reduce criteria pollutant and toxic emissions with concurrent reductions in GHG emissions, including black carbon. ARB has focused AQIP investments on technology advancing projects that support long-term air quality and climate change goals in addition to providing immediate emission benefits. In recent years, funding has included rebates for zero and near-zero emission passenger vehicles through the Clean Vehicle Rebate Project (CVRP), vouchers for hybrid and zero-emission trucks and buses through the Hybrid and Zero-Emission truck and Bus Voucher Incentive Program (HVIP), and the Truck Loan Assistance Program for small business truck owners in need of truck replacements or retrofits.

The CEC administers an additional key GHG reduction investment program for the transportation sector – the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). Funds that are collected from vehicle and vessel registration fees, vehicle identification plates, and vehicle smog fees provide up to $100 million per year for projects that will transform California's fuel and vehicles to help attain the State's climate change policies. Investments in alternative fuel production and infrastructure, and vehicle projects can contribute to SLCP emission reductions through reduced diesel consumption, capture and use of biogas from waste management activities as a transportation fuel, demonstration and early commercialization of advanced technology trucks that utilize biogas, and avoided fugitive methane emissions from fossil fuel production and distribution operations.

Another CEC-administered program, the Electric Program Investment Charge (EPIC) Program, supports investments in clean technologies and strategies to improve the State's electricity systems. The program provides opportunities to support SLCP emission reductions from reduced or avoided fugitive methane emissions stemming from fossil fuel production and distribution via investments such as improved energy efficiency technologies in building, industrial, agricultural and water sectors; demand response; distributed renewable generation; electric vehicle infrastructure; demonstration of biomass-to-energy conversion systems; advanced energy storage interconnection systems; and vehicle-to-grid power transfer for electric vehicles.

CDFA administers the Dairy Digester Research and Development Program. This incentive-based program supports digester development in California and can provide grants for research and demonstration projects that improve scientific and technical understanding of technologies and practices that reduce methane and other greenhouse gases emissions on dairies.

These programs represent just a portion of opportunities that exist at the federal, State, and local levels to incentivize SLCP and GHG emission reductions. The availability of dedicated and long-lasting funding sources is critical to help meet AB 32 objectives and help provide certainty and additional partnership opportunities at the national, State, regional, and local levels for further investing in projects that have the potential to reduce emissions of SLCPs.

D. Coordinate with Subnational, Federal, and International Partners

California is working with a set of national and subnational partners throughout the world to fight air pollution and climate change. This includes signatories to the Under 2 MOU, as well as others in Mexico, China, India, the U.S., Canada, and elsewhere. Many of the efforts underway through these collaborations will help reduce emissions of black carbon from the transportation sector and emissions of other SLCPs.

Last September at the United Nations (UN) Climate Summit, ARB became the first state-level entity to sign onto action statements of the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants. At the 2014 UN Conference of Parties in

Lima, California co-sponsored an event with Mexico on SLCPs and their role in an international framework to contribute to national commitments to reduce emissions. The State continues to be committed to acting both bilaterally and multilaterally to cooperate with other jurisdictions to cut SLCP emissions, and will explore additional opportunities to further reduce air pollution, greenhouse gas, and SLCP emissions through partnerships.

Building on leadership around SLCPs can provide an important example for action in other countries and jurisdictions, and is one of the most significant opportunities to accelerate international progress to fight climate change. California is in a unique position to serve as a model for action for other countries and jurisdictions to accelerate their progress to reduce emissions of both SLCPs and CO_2, based on the State's demonstrated leadership on air quality and climate change, commitments to set stringent, science-based targets to reduce emissions of both CO_2 and SLCPs, and integrated planning efforts, like this one, to develop a comprehensive policy framework to achieve those goals.

As we have done for decades already, California's actions on SLCPs can demonstrate win-win opportunities for both the most developed countries, where reducing SLCP emissions is an important element of broad efforts to cut GHG emissions, as well as for the least developed countries, where SLCP emission reductions have tremendous benefits for air quality and human health.

Ultimately, each state, region, or country has its own mix of SLCP sources, needs, and opportunities to reduce emissions. Coordinated planning to meet scientific-based emission targets, like this Draft Strategy does, is important to successfully reducing emissions and maximizing local and global benefits.

California will share this planning effort with others, and encourage them to adopt specific SLCP emission reduction targets and plans to achieve them. A few already have; President Obama has set specific targets to cut methane emissions from the oil and gas sector, Mexico has included targets to cut black carbon emissions in its Intended Nationally Determined Contribution to the United Nations Framework Convention on Climate Change, Europe and other countries have taken steps to phase down the use of HFCs, Australia and Brazil are working to reduce methane from agriculture, and Norway has developed an SLCP action plan of its own.[115] These types of commitments and planning efforts need to be adopted more broadly. By developing a comprehensive plan to achieve necessary SLCP emission reductions in an effective and beneficial way, California can foster broader action beyond its borders and demonstrate effective processes and strategies to address climate change.

[115] NEA (2014) Summary of Proposed Action Plan for Norwegian Emissions of Shortlived Climate Forcers, Norwegian Environment Agency, March. http://www.miljodirektoratet.no/en/Publications/2014/March-2014/Summary-of-proposed-action-plan-for-Norwegian-emissions-of-shortlived-climate-forcers/

VIII. Evaluations

This chapter discusses the economic, public health, and environmental justice evaluations of the proposed new measures in this Draft Strategy. It also discusses the environmental analysis that will be prepared of the SLCP Emission Strategy. It should be noted that to the extent that any of the proposals in this Plan result in regulatory action, each proposed regulation will be subject to its own public process with workshops, opportunities for stakeholder discussion, consideration of environmental justice, and legally required analyses of the economic and environmental impacts.

A. Economic Analysis

Dramatically reducing SLCP emissions will continue California's long and successful legacy of implementing innovative and effective environmental and health policies while fostering the growth of a vibrant and sustainable economy. The proposed actions can create health, environmental, and economic benefits that will positively impact Californian businesses and individuals. These benefits can be realized through near-term financial commitments and investments in SLCP emission reduction projects.

While there are potentially significant market opportunities associated with some of these measures, including putting organics to beneficial use, there are also substantial costs and funding needs associated with the proposed SLCP measures. These include costs to increase market penetration of existing technologies and research and development of innovative advanced technology. Initial analysis and various literature sources suggest that SLCP emissions from several sources, including those identified in this Draft Strategy, can be reduced at low, and sometimes negative, costs.

However, there is also a wide range in potential costs, and remaining uncertainty in some cases for how costs from literature sources may apply in the California context. In conjunction with State agencies, ARB is working closely with stakeholders and manufacturers to determine the feasibility and costs of existing and developing technologies. An assessment of the costs of the proposed measures, as well as a description of potential benefits, will be included in the proposed strategy and will be made available for evaluation during the public process prior to the presentation to the Board.

It is important to note that undertaking action on the proposed SLCP measures will also build on and support existing California efforts related to climate change and air quality. These include the update to the Scoping Plan, the 2031 State Implementation Plans, and the Sustainable Freight Strategy. The costs of these actions in total include the infrastructure, research, development, and deployment of advanced technologies that will achieve California's near- and long-term climate and air quality goals. Therefore, attribution of costs associated with the proposed SLCP measures must reflect the comprehensive benefits accruing throughout California.

The measures outlined in this report will be building blocks for California's strategy to meet climate related targets in the next update to the Scoping Plan. Expected to be finalized in 2016, the Scoping Plan will include a detailed economic assessment of ARB's complete climate change strategy, including those contained in the final SLCP Strategy. In the 2016 update to the Scoping Plan, ARB will evaluate the economic impact of California's strategy to achieve the 2030 GHG emissions target on individuals, businesses, and the California economy. Thus, while the SLCP Strategy will describe the costs and benefits of proposed measures, a detailed economic analysis of SLCP measures will be conducted in the context of ARB's complete climate change strategy that will be outlined in the 2016 update to the Scoping Plan. This allows for a comprehensive assessment of the impact of California's climate strategy on Californians and the economy.

In addition to the economic analysis of measures in the update to the Scoping Plan, regulatory measures will be subject to the economic requirements of the Administrative Procedures Act (APA) rulemaking process. Prior to finalization, regulatory measures will be analyzed in a public process including an Economic Impact Statement, Economic Impact Assessment, and a Standardized Regulatory Impact Assessment for major regulations.

B. Public Health Assessment

Particulate matter less than 2.5 µm in diameter (PM2.5, or fine particles) is responsible for the largest share of air pollution-related health effects. Black carbon is a sub-fraction of PM2.5. Consequently, measures to reduce black carbon emissions would provide a public health co-benefit, primarily by reducing fine particles. A large number of studies, particularly epidemiological studies, have linked exposure to fine particles to a wide range of adverse health effects, including premature death, hospital admissions for exacerbation of chronic cardiovascular and lung diseases, and emergency room visits for asthma.[116,117,118] As part of its periodic reviews of the national ambient air quality standards, U.S. EPA draws conclusions as to the strength of the relationship between exposure to air pollution and broad categories of adverse health effects. The U.S. EPA concluded that PM2.5 plays a "causal" role in premature

[116] Krewski D., Jerrett M., Burnett R.T., Ma R., Hughes E., Shi Y., Turner M.C., Pope C.A. III, Thurston G., Calle E.E., Thun M.J.. 2009. Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality. HEI Research Report 140. Health Effects Institute, Boston, MA. http://www.healtheffects.org/Pubs/RR140-Krewski.pdf

[117] Bell M.L., Ebisu K., Peng R.D., Walker J., Samet J.M., Zeger S.L., Dominici F. 2008. Seasonal and regional short-term effects of fine particles on hospital admissions in 202 U.S. counties, 1999–2005. Am J Epidemiol 168:1301–1310.

[118] Ito, K., G. D. Thurston and R. A. Silverman. 2007. Characterization of PM2.5, gaseous pollutants, and meteorological interactions in the context of time - series health effects models. J Expo Sci Environ Epidemiol. Vol. 17 Suppl 2: S45 - 60.

death and cardiovascular effects, and a “likely causal” role for respiratory effects in its most recent integrated science assessment for the particulate matter standards.[119]

Black carbon is a product of combustion. Combustion can produce particulate matter in two ways. It can produce particles directly in the form of soot, which includes black carbon. It can also produce particles indirectly by producing NO_X that reacts with ammonia in the atmosphere to form ammonium nitrate particles. These two types of emissions are termed primary and secondary emissions, respectively. Concentrations of primary PM2.5 are highest near their source, while secondary ammonium nitrate particles tend to spread out downwind of the source resulting in higher concentrations over a broad area. In the San Francisco Bay Area and Central Valley, ammonium nitrate particle concentrations display strong seasonal variation, peaking in winter when ample moisture and atmospheric stability allow high concentrations to accumulate.[120]

Residential wood burning produces mostly primary PM2.5, and relatively little NO_X. Since emissions of PM2.5 from wood burning are projected to increase from 2012 to 2030, the adverse impacts of wood burning are expected to increase over that time period.

On-road and off-road diesel engines impact health primarily through NO_X emissions that are converted in the atmosphere to ammonium nitrate, and to a lesser extent from primary PM2.5 emissions, including black carbon. California has already adopted standards that require on-road and off-road diesel engines to meet strict emission standards for NO_X and PM through engine design, diesel particulate filters, and fuel formulation. As these standards take effect between 2012 and 2020, primary PM2.5 emissions from diesel equipment are projected to decrease sharply. NO_X emissions are also projected to decrease. Overall the emissions and health-related impacts associated with diesel engines are expected to decrease from 2010 to 2030.

Reductions in ambient methane levels will lead to reductions in the growth of global background ozone that is the baseline for local and regional exceedances of health-based ozone standards. Ozone exposure has been linked to increases in asthma attacks, hospitalizations, and premature death. Methane controls for certain sectors such as oil and gas production, and landfills, can also lead to reductions in associated emissions of toxic VOCs.

C. Environmental Justice and Disadvantaged Communities

The State of California defines environmental justice in statute as, "the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption,

[119] U.S. EPA. 2009. Integrated Science Assessment for PM. U.S. Environmental Protection Agency, Washington, DC Publication EPA/600/R-08/139F. http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_2007_isa.html

[120] ARB. 2005. Characterization of Ambient PM10 and PM2.5 in California, Technical Report http://www.arb.ca.gov/pm/pmmeasures/pmch05/stateover05.pdf

implementation, and enforcement of environmental laws, regulations and policies." (Government Code Section 65040.12).

For over a decade, ARB has integrated environmental justice into all of its programs, policies, and regulations. Specifically, every major program, policy, plan or strategy, and rulemaking explicitly discusses environmental justice and ensures the fair treatment of people from all races, cultures, geographic areas, and income levels, especially in disadvantaged communities. ARB also works extensively with local air districts and stakeholders during the development and implementation of all programs to respond to any and all concerns about environmental justice and has committed to modify any program, if deemed appropriate.

The Office of Environmental Health Hazard Assessment, on behalf of the California Environmental Protection Agency and pursuant to Senate Bill 535 (De León, Chapter 830, Statutes of 2012), has identified the communities in California that are most disproportionately burdened by pollution. Of the 12 indicators of pollution included in their methodology, three are directly related to SLCP emissions (fine particle emissions, diesel particulate emissions, and solid waste sites and facilities), and at least six others (mostly related to water quality and air quality) are at least inter-related to sources of SLCP emissions.

These communities are closely aligned with locations of SLCP emission sources, such as organic waste and dairies in the Central Valley; ports and freight corridors in the East Bay, Los Angeles area and Inland Empire; and oil production, landfills and other sources of SLCP emissions throughout the State. Many communities in these areas, along with forested and rural communities in the northern part of the State and the Sierra, have some of the worst pollution burdens in the State and high rates of poverty and unemployment. They are also where many billions of dollars in public and private investment will accrue in the coming years to reduce SLCP and CO_2 emissions and strengthen our agricultural sector, build sustainable freight systems, and grow healthy forests.

The integrated strategy to reduce SLCP emissions from agriculture and waste, featured in this Draft Strategy, will improve the health of Californians living in agriculture regions, such as in the San Joaquin Valley. Additionally, the Healthy Soils Initiative will improve California’s agriculture economy and support further economic development in these communities. California’s commitment to improve the health and management of forests will boost California’s forest economy and limit black carbon emissions from wildfires and biomass burning.

Each measure included in the State’s strategy to reduce SLCP emissions will be further developed in a formal public process and given specific considerations to environmental justice during the development, adoption, implementation and enforcement of each measure. Opportunities for public participation will be provided during the development of each measure and regulatory language will be made

available in easily understood and useful formats, such as program-specific webpages and slide presentations.

ARB is committed to continue strengthening its outreach efforts to ensure that all California communities have the opportunity to participate in its public processes and reap the benefits of the State's climate-related programs, policies, and regulations.

D. Environmental Analysis

ARB will prepare an environmental analysis (EA) of the SLCP Reduction Strategy pursuant to its regulatory program certified by the Secretary of the Natural Resources Agency (14 CCR 15251(d); 17 CCR 60000–60008). The EA will be included as an appendix to the Strategy. In accordance with Public Resources Code section 21080.5 of CEQA, public agencies with certified regulatory programs are exempt from certain CEQA requirements, including but not limited to those preparing environmental impact reports, negative declarations, and initial studies (14 CCR 15250). The resource areas from the CEQA Guidelines Environmental Checklist are being used as a framework for assessing the potential for significant impacts (17 CCR 60005(b)).

An EA will be released for a 45-day public review. ARB will summarize and respond in writing to all comments submitted on the EA in a supplemental response document for the Board to consider for approval prior to final action on the Strategy.

IX. Next Steps

The proposals and emission estimates presented in this report are preliminary, and will be further evaluated through a public process before a proposed Strategy is presented to the Board in late 2015. ARB will hold workshops to solicit comments on this Draft Strategy, including comments related to the development of a California Environmental Quality Act (CEQA) document. After consideration of public comments received, ARB will develop a proposed strategy and an accompanying draft Environmental Analysis (EA), to be presented to the Board in late 2015. Staff will present the final proposed SLCP Reduction Strategy, the final EA, and written responses to comments received on the EA to the Board for consideration at a public hearing in Spring 2016.

Additional economic analysis will be included in the proposed strategy released later this year. While the goals and actions identified in this Draft Strategy offer potentially significant economic, climate and health benefits, a more thorough accounting of costs and benefits will be presented in the proposed strategy. Several analyses consider the costs and benefits of actions like those described in this Draft Strategy to cut SLCP emissions, and find that efforts to do so can deliver relatively low-cost GHG reductions. However, additional references with California-specific information would be helpful to inform our economic analysis. During the public review process, ARB welcomes this type of information, along with other comments. A macroeconomic analysis of the measures identified in the proposed strategy will be developed as part of a broader analysis in the 2016 Scoping Plan Update.

To the extent that the proposals in the SLCP Reduction Strategy result in regulatory action, each proposed regulation will be subject to its own public process with workshops, opportunities for stakeholder discussion, consideration of environmental justice, and legally required analyses of the economic and environmental impacts.

While this Draft Strategy is intended to be comprehensive, it is not exhaustive. We will continue to pursue new cost-effective programs and measures as technology and research on SLCP emission sources and potential mitigation measures advances. Effectively implementing this Draft Strategy will require working with local, regional, federal and international partners, and diligently investing time and money to overcome market barriers that hinder progress. The extent to which we do so will drive results, which can include a wide range of significant economic and environmental benefits for California broadly, and many of the State’s most disadvantaged communities, specifically.

Appendix A: California SLCP Emissions

California SLCP Emissions

ARB develops an annual statewide GHG emission inventory to track GHG emission trends and progress towards California's GHG emission reduction goals. The 2015 GHG emission inventory includes emissions from 2000 to 2013 for carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride.[1]

California's GHG inventory includes two short-lived climate pollutants: methane and F-gases. Because not all F-gases in the GHG emission inventory are short-lived, the SLCP inventory used for this Draft Strategy includes only those hydrofluorocarbons (HFC) with lifetimes of a few decades[2] which represent about 97 percent of total F-gas emissions in California. Methane and short-lived F-gas emissions in this Appendix are presented using 20-year global warming potential (GWP) values from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).

Unlike methane and F-gases, black carbon is not routinely inventoried by ARB. Per SB 605 and to support this Draft Strategy, ARB has developed a black carbon emission inventory for key years. Black carbon emission data in this discussion are presented using the 20-year GWP value from the IPCC Fifth Assessment Report (AR5), the first report to define a GWP for black carbon.

A. Black Carbon

1. Emission Sources

Black carbon is emitted from combustion processes, primarily from diesel engines and biomass burning. Black carbon sources can be separated into two categories, anthropogenic non-forestry sources and forest-related sources.

Anthropogenic Sources

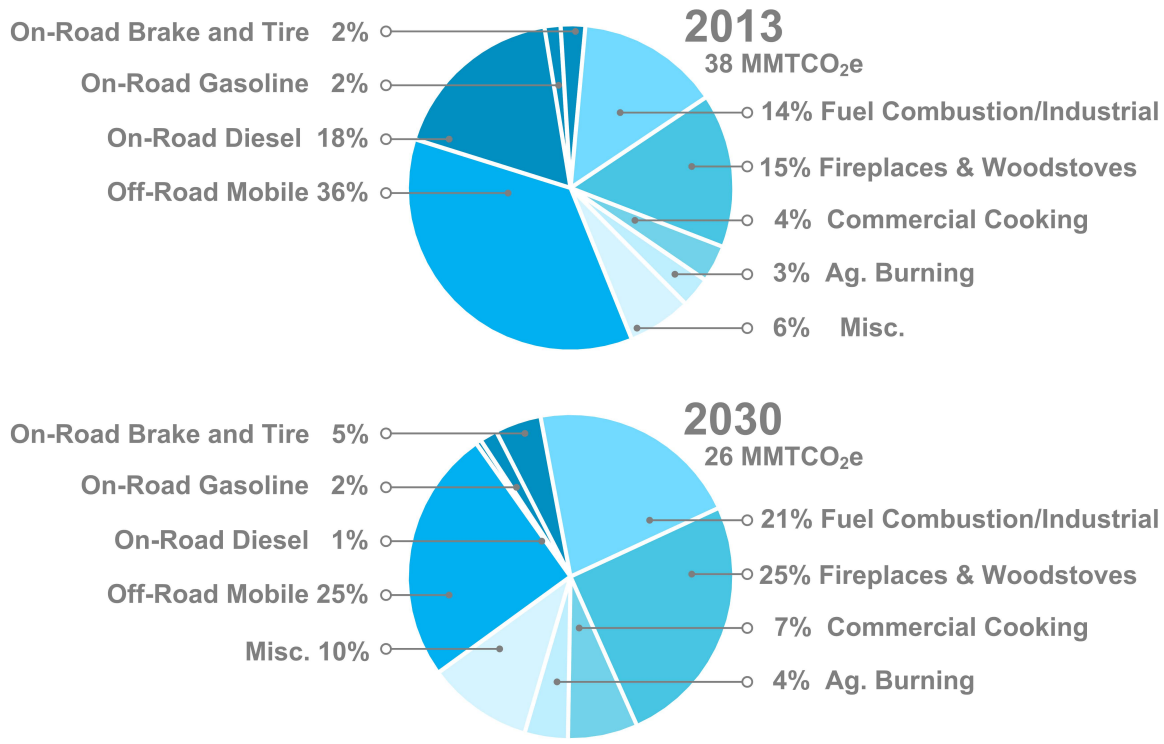
The major anthropogenic, non-forestry sources of black carbon in 2013 include diesel-fueled mobile sources, fuel combustion and industrial processes, and residential fireplaces and woodstoves. Off-road mobile emissions account for over a third of statewide black carbon emissions. On-road mobile sources account for nearly a quarter of emissions, primarily from on-road diesel combustion. Fuel combustion and industrial processes are also an important source of black carbon. This emission category consists of a large number of engines and industrial processes, with a wide variety of applications including electricity production, manufacturing, concrete, asphalt, pulp and paper, and service and commercial sectors. Residential fireplaces and woodstoves account for approximately 15 percent of black carbon emissions in 2013. On-road

[1] ARB (2015). California's Greenhouse Gas Emission Inventory – 2015 Edition. http://www.arb.ca.gov/cc/inventory/data/data.htm

[2] Short-lived F-gases include the nine short-lived hydrofluorocarbons: HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-245fa, HFC-32, HFC-365mfc, and HFC-43-10mee.

gasoline and brake and tire wear emissions are small. Miscellaneous sources include dust, waste disposal, residential natural gas combustion, and unplanned structure and car fires. Figure 1 presents 2013 and projected 2030 black carbon emissions and sources.

Figure 1. 2013 Black Carbon Emissions and Projected 2030 Emissions* with Existing Measures[3]

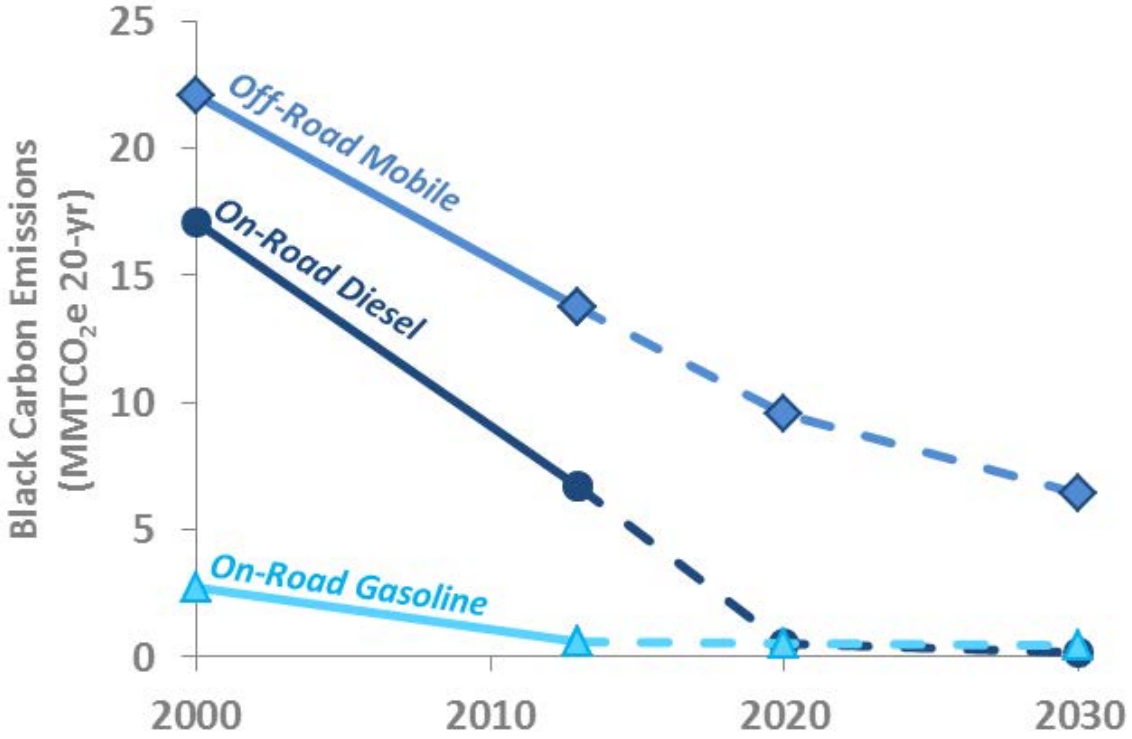


***Using 20-yr GWPs**

As illustrated in Figure 2, on-road mobile source emissions are projected to decline significantly by 2030 due to ARB's regulatory actions to reduce diesel emissions. On-road black carbon emissions have decreased by 62 percent since 2000 and are projected to decrease another 92 percent by 2030. Emissions from off-road vehicles are projected to decline by over 70 percent between 2000 and 2030 but remain an important source of black carbon, accounting for approximately one quarter of emissions in 2030. Non-mobile source categories will become a larger share of statewide emissions as mobile sources decline in the future. In 2030, fuel combustion and industrial processes will account for one quarter of emissions as will residential wood combustion.

[3] Excludes wildfire and prescribed fire emissions.

Figure 2. Black Carbon Emissions from On-Road and Off-Road Mobile Sources with Existing Measures.



Wildfire and Prescribed Fire

Wildfire is the largest source of black carbon emissions in California, accounting for over one half of total emissions in a typical year. Wildfires are difficult to prevent, and there is high uncertainty in the emission estimation. Prescribed fires are also a source of black carbon, but in practice can reduce overall black carbon emissions by preventing severe catastrophic wildfires. Wildfires may result in as much as 87 $MMTCO_2e$ (20-yr GWP) of black carbon emissions in a typical year. In recognition of the unique challenges associated with managing forests and other lands, wildfire and prescribed fire emissions are discussed separately in the Forest-Related Sources of Black Carbon Emissions (Chapter IV).

2. Inventory Methods

California's black carbon emission inventory was developed using existing particulate matter (PM2.5) emission estimates, combined with speciation profiles that define the fraction of PM2.5 that is elemental carbon. Elemental carbon is the "best available indicator"[4] of black carbon, but is not a perfect proxy for warming effects, which depend on the physical and chemical properties of the particles. The PM2.5 inventory was

[4] USEPA (2012). United States Environmental Protection Agency, Department of the Interior, Environment and Related Agencies. "Report to Congress on Black Carbon". http://www.epa.gov/blackcarbon/

assembled using a wide variety of techniques including models, data reported by local air districts, and ARB inventory calculation methodologies.

Speciation profiles were developed by ARB as part of photochemical modeling efforts. Black carbon emissions depend on a variety of factors including fuel, engine operating conditions, age, maintenance, emission control technology, load, and drive cycle. Variability in these factors and their impact on speciation profiles remains a large source of uncertainty in black carbon inventory development.

The PM2.5 inventory, excluding wildfire, was projected using a 2012 base year, and includes both growth assumptions and existing control measures. Growth and control assumptions are defined for each source and air basin, in collaboration with applicable air districts.

Wildfire PM2.5 emissions are large, and can vary significantly from year to year. California's black carbon inventory uses the ten-year average wildfire PM2.5 emissions from 2001 to 2011 to avoid large year-to-year variations in the inventory. Emissions of black carbon from biomass burning varies dramatically depending on fire conditions, such as the fuel type, moisture content, oxygen availability, and local meteorology. This variation leads to high uncertainty in speciation assumptions, and adequate speciation profiles to account for various fire conditions are not available. For these reasons, the wildfire emission estimate contains very high uncertainty, and should be understood to be an order-of-magnitude estimate of emissions for a typical year.

3. Inventory Improvement

California's black carbon inventory relies on particulate matter inventories coupled with speciation profiles that define the fraction of particulate matter that is black carbon. The sources that emit black carbon are well understood from a control prospective, and major sources are regulated in California. However, it is a challenge to estimate statewide black carbon emissions, and to define speciation profiles for all sources because of: 1) the diversity and large number of sources, 2) the wide variety of engines, after treatment, operating conditions, and fuels, and 3) the difficulty in measuring black carbon and its co-pollutants.

Additional representative source measurements are needed to better characterize black carbon speciation profiles by emissions source, fuel type, and combustion conditions. Better characterization of emissions from wildfire, open biomass burning, commercial charbroiling, and residential wood combustion can help improve inventory estimates. The scientific literature reports large variability in black carbon speciation profiles from biomass burning due to the many variables that affect emissions. Future research is needed to provide a scientific consensus on speciation profile choice and best practices to produce biomass burning emission inventories. In general, mobile source emissions are among the best characterized, but improved information is still needed for some sectors, such as off-road mobile sources.

Quantifying emissions from wildfires is an active area of research in the earth science and air quality community, but is technically challenging due to the inherent variability in vegetation fuel loads, fire behavior, and consumption. Ongoing efforts to improve the scientific understanding of the ecological role and air quality effects of wildland fire are occurring as part of the federal Joint Fire Science Program[5] and special projects such as the NOAA Fire Influence on Regional and Global Environments Experiment (FIREX)[6]. Research areas include development and evaluation of emission models and underlying model parameters, smoke in context of health and air quality standards, fire in a changing climate, and ecosystem health in relation to fire.

ARB is also in the process of comparing the black carbon emission inventory to field observations at the Mount Wilson monitoring station located above the Los Angeles basin. Air masses from Los Angeles exhibit consistent agreement between black carbon and carbon monoxide, indicating a well-mixed air mass and similar sources. This monitoring data will be used to derive a 'top down' observation for comparison to the 'bottom up' black carbon inventory.

B. Methane

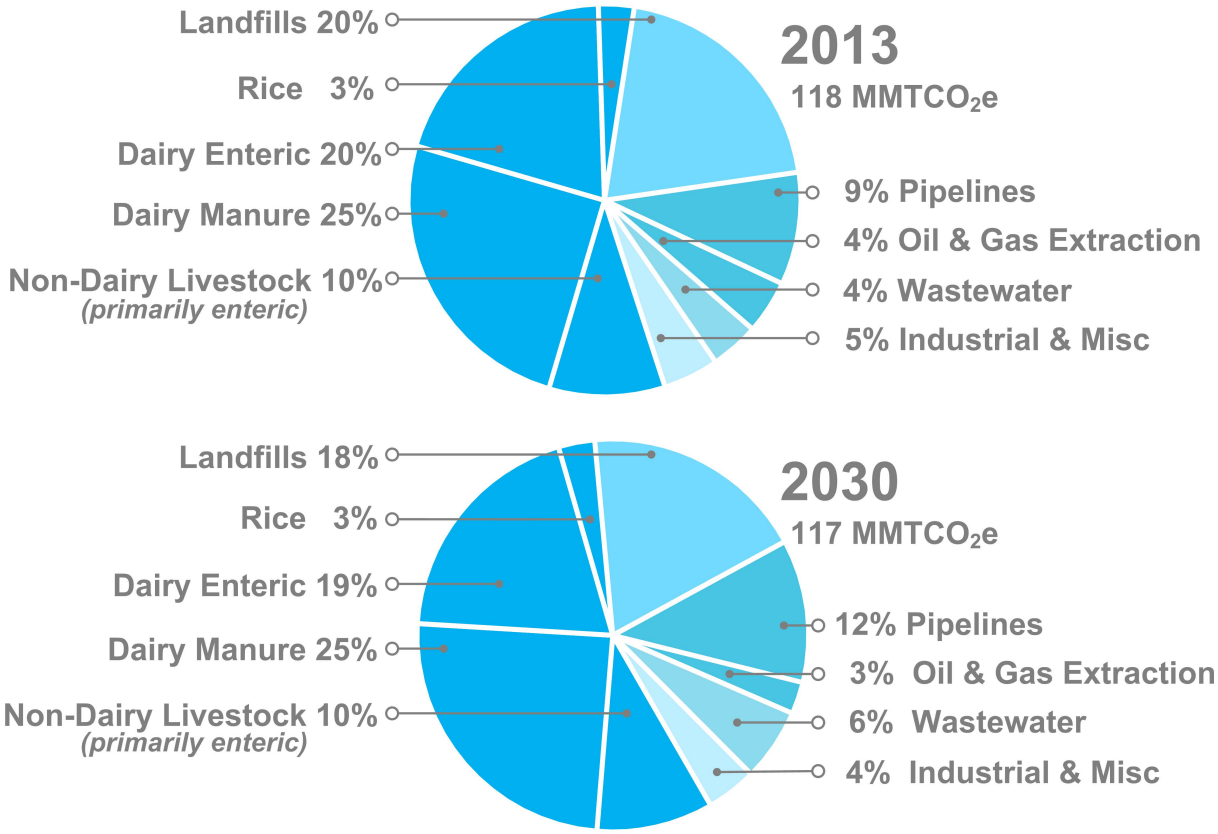
1. Emission Sources

Methane is emitted from a wide range of fugitive sources and biological processes. In 2013, agriculture represented the largest methane source, accounting for nearly 60 percent of emissions. Enteric fermentation and manure management from dairy operations produced almost 80 percent of these agricultural emissions. Enteric fermentation and manure management from non-dairy livestock and rice emissions are smaller agricultural sources. 90 percent of non-dairy livestock emissions are from enteric fermentation, and the remaining emissions are from manure management. Landfills are the next largest source of methane, accounting for one fifth of statewide methane emissions. Natural gas pipeline leaks, oil and gas extraction, wastewater, and other industrial and miscellaneous sources make up the remainder of emissions. Miscellaneous sources include industrial fugitive emissions, methane produced as a byproduct of fuel combustion, composting, and petroleum seeps. Figure 3 presents 2013 and projected 2030 methane emissions and sources.

Compared to current emissions, projected 2030 methane emission sources and levels are not expected to change dramatically. Natural gas pipeline leaks are projected to increase slightly due to aging infrastructure and expansion of the pipeline system.

[5] http://www.firescience.gov/
[6] http://www.esrl.noaa.gov/csd/projects/firex/

Figure 3. 2013 Methane Emissions and Projected 2030 Emissions with Existing Measures*



*** Using 20-yr GWPs**

2. Inventory Methods

Statewide methane emission estimates rely on state, regional, or federal data sources using calculation methodologies consistent with the 2006 Intergovernmental Panel on Climate Change guidelines.[7] Landfill emissions are calculated using a First-Order Decay Model with California-specific waste characterization. This model is supplemented with emission data for individual landfills provided by ARB surveys, CalRecycle, and U.S. EPA mandatory reporting. California's livestock methane inventory is based on U.S. EPA modeling of enteric fermentation and manure management. The model estimates methane emissions using detailed parameters by animal type such as age, size, volatile solids excretion, feed, and manure management pathways. Emissions from oil and gas extraction and pipeline leaks are estimated

[7] IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/

based on survey data conducted by ARB and other federal data sources. A complete description of the methodologies is available online.[8]

Methane emissions are projected for 2030 by applying sector-specific growth factors to base-year emissions. Base-year emissions use the average emissions from 2009 to 2011 to dampen the effects of year-to-year variability in factors that influence emissions. The sector-specific growth factors come from projection analysis prepared by other state and federal agencies. A complete description of forecast methodology is available online.[9]

3. Inventory Improvement

While improving inventory quality is not a prerequisite for many actions to reduce SLCP emissions, it is nonetheless important to inform ongoing efforts. ARB staff continually assesses ways to improve the methane inventory using the latest scientific understanding of methane sources and the best available activity data. The improvements made to the 2015 edition of the statewide methane inventory include incorporation of ARB oil and gas survey data for fugitive methane emission estimates, use of the new EMFAC 2014 on-road mobile emissions model, and updates to the emissions of non-citrus fruit wastewater methane emissions.

ARB is further improving the methane emission inventory with ongoing coordinated research with other agencies. ARB and the California Energy Commission (CEC) have several ongoing partnerships for measurement and evaluation of methane emission sources in the energy sector. ARB operates a statewide methane monitoring network that provides a record of real time methane concentrations in California, supported by CEC and other sister agencies. Data from this network were used in several research contracts, and formed the basis of a comprehensive statewide inverse receptor-oriented modeling and various trends assessment analyses to verify and inform the statewide GHG inventory.

ARB is also actively participating in the Megacities Carbon Project in the South Coast Air Basin which is developing and testing methods for monitoring various GHG emissions to link measured concentrations to emission activity. In addition, researchers at ARB and NASA's Jet Propulsion Laboratory are collaborating to identify large "hot spot" methane sources through a systematic survey of high methane emitters using aerial and ground measurement to survey various sources in the agriculture, waste, and oil and gas sectors. The researchers have completed pilot studies in the San Joaquin valley, and plan to expand the study throughout California with research funding contributions from NASA and CEC. Collectively, these efforts are expected to improve our understanding of the various methane emission sectors and aid in developing effective mitigation programs to reduce GHG emissions in California.

[8] ARB 2015 Edition GHG Inventory. http://www.arb.ca.gov/cc/inventory/data/data.htm
[9] 2020 Business-as-Usual (BAU) Emissions Projection. http://www.arb.ca.gov/cc/inventory/data/bau.htm

In addition, CalRecycle is currently working with ARB to better quantify fugitive methane emissions from landfills by measuring methane fluxes at a representative sample of landfills across California. This study will provide information on landfill gas collection system efficiencies, and improve the State's ability to estimate the benefits associated with the diversion of organics from landfills.

ARB has also funded a study to gather updated emission factors for natural gas pipeline leaks and is also developing a contract to study methane leakage from inactive oil and gas wells. This contract will provide data on the spatial distribution, type of well, and the volume of methane gas emitted. The CEC is sponsoring several research contracts to identify the main sources of emissions from the natural gas distribution system. Research activities also include methane surveys of residential housing, which may be an important and unrecognized source of methane.

Future research will be necessary to continue refining the methane inventory, and provide California-specific activity data. Emissions from enteric fermentation and manure management are currently modeled using international or national default parameters due to a lack of California-specific data. The ARB has committed to fund research on California-specific feed data, and its effect on methane emissions. This research will better reflect on-farm realities and inform the inventory. Additional research will fully characterize the diverse dairy manure management system in California, and help understand the effect of management practices on methane emissions.

Organic waste in landfills will remain a source of methane for years to come. More research is needed to help understand how methane emissions change as landfills age, and to verify the efficiency of methane capture systems over time.

Research to better quantify fugitive methane emissions from the natural gas and oil systems, as well as from anaerobic digesters, are necessary to inform the emission inventory. Methane emissions from anaerobic digesters in domestic wastewater treatment facilities, and pulp and paper mill wastewater are currently estimated using activity data from U.S. EPA. Future research is needed to update these estimates with California-specific data to improve inventory estimates. Research into fugitive emissions from new infrastructure and technologies, including dairy anaerobic digesters, is also necessary to understand the impact of these new technologies on methane emissions.

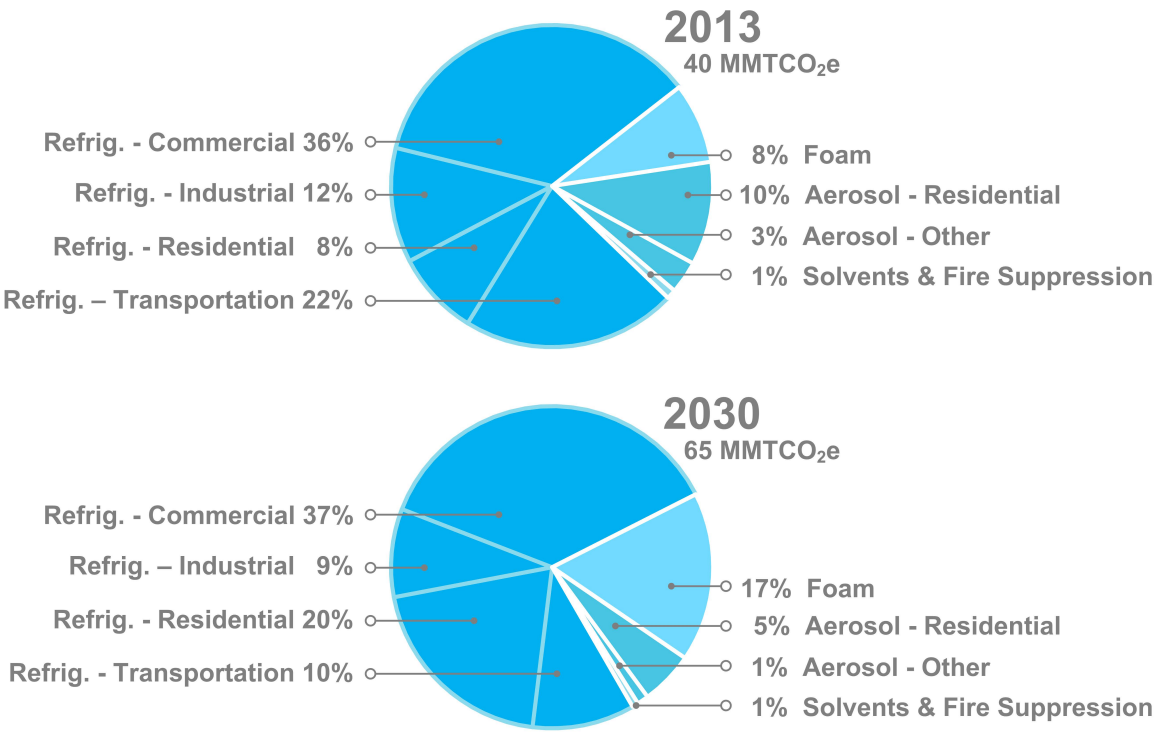
C. F-Gases

1. Emission Sources

F-gases are used in refrigeration and air conditioning, insulating foams, solvents, aerosol products, and fire protection. Nearly 80 percent of F-gas emissions in California are from refrigeration and air conditioning equipment. Commercial refrigeration is the single largest source of short-lived F-gases, followed by commercial and residential air

conditioning. Figure 4 presents the 2013 and projected 2030 F-gas emissions and sources. The F-gas inventory includes nine short-lived HFCs: (HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-245fa, HFC-32, HFC-365mfc, and HFC-43-10mee), but excludes two long-lived HFCs with negligible emissions.

Figure 4. 2013 F-Gas Emissions and Projected 2030 Emissions* with Existing Measures[10]

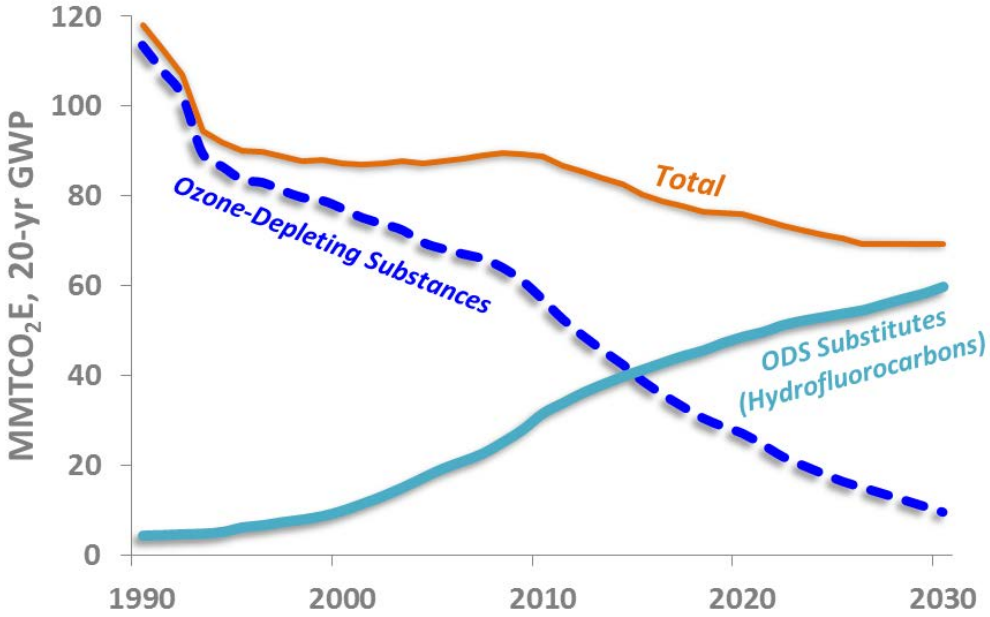


***Using 20-yr GWPs**

Annual F-gas emissions are expected to increase 60 percent by 2030, even with current ARB and U.S. EPA regulations in place. This is primarily because HFCs continue to replace ODS that have been phased-down or phased-out of new production by the 1987 Montreal Protocol. ODS are not included in the California GHG emission inventory since they are not listed in AB 32. However, ODS emissions are declining rapidly as HFC emissions increase (Figure 5). The net warming impact is declining overall, but emissions of high GWP compounds must be reduced to meet California's climate goals.

[10] "Refrig." includes both refrigeration and air conditioning.

Figure 5. Emissions of ODS and ODS substitutes (hydrofluorocarbons) using 20-year GWPs.



Mobile air conditioning refrigerant emissions are one of the few HFC sources projected to decline by 2030 in response to State and federal programs to incentivize low-leak air conditioning systems and low GWP refrigerants for light-duty vehicles, and federal regulations prohibiting high GWP F-gases in new light-duty vehicles starting in model year 2021. The availability of low GWP refrigeration and air conditioning alternatives are increasing yearly, as industries anticipate a hydrofluorocarbon phase down in response to recent European Union F-gas regulations. Additionally, foam expansion agents, aerosol propellants, solvents, and fire suppressants are increasingly trending towards low GWP alternatives that are often less expensive.

2. Inventory Methods

ARB developed the F-gas emission inventory using California-specific data based on several research contracts funded by ARB. The inventory also leverages data from local and state regulations to inform emission estimates, including the South Coast Air Quality Management District Rule 1415 and ARB's Refrigeration Management Program.

Using these data, a California-specific F-gas emission model was developed by ARB, forming the basis for California's GHG emission inventory for F-gases. Equipment production, retirement, and F-gas usage and emissions are calculated annually for 37 F-gases. Historical F-gas emissions are backcast to 1990 from a 2008 base year using equipment inventories estimated by ARB research contracts. Future F-gas emissions are projected based on population growth, as F-gas emissions and population are shown to be highly correlated in California. The emission estimates account for the rapid replacement of ODS with hydrofluorocarbons as well as reductions

from existing regulations. Additional methodology details can be found in the GHG documentation[11] and in Gallagher, et al., 2014.[12]

Sulfuryl fluoride (SO_2F_2), is a fluorinated gas with a lifetime of several decades. It was believed to have a negligible GWP until 2009, when it was assigned a 20-year GWP of 6840. Because sulfuryl fluoride was not identified as a high-GWP gas at the time, it was not included as an AB 32 gas and is not annually inventoried as a part of ARB's statewide GHG inventory. Sulfuryl fluoride is used as a pesticide fumigant and is one of the most common replacements for methyl bromide. According to the California Department of Pesticide Regulation (DPR), 3 million pounds of sulfuryl fluoride were used in 2013. If sulfuryl fluoride were added to ARB's GHG inventory, it would increase the short-lived F-gas emission inventory by one quarter. Although both DPR and U.S. EPA have investigated lower-GWP alternatives to sulfuryl fluoride, no effective substitutes have yet been identified. ARB will continue to monitor the use of this fumigant as well as potential substitutes.

3. Inventory Improvement

The F-gas inventory is updated annually as new regulations change the projected emissions, and new reported data become available. The assumptions for the aerosol propellant F-gas emission baseline (last updated 2006) will be updated using the final 2014-2015 ARB consumer products survey data. ARB also funds research and measurements contracts to collect F-gas measurements at a monitoring site at the Mt. Wilson Observatory. These data are being analyzed to verify and track the emissions of various F-gases from the Southern California basin. Emissions from medical dose inhaler propellants are the only remaining F-gas subsector that relies on scaled-down national estimates. This inventory could be improved if California-specific usage was available, but confidentiality becomes a factor for medical devices.

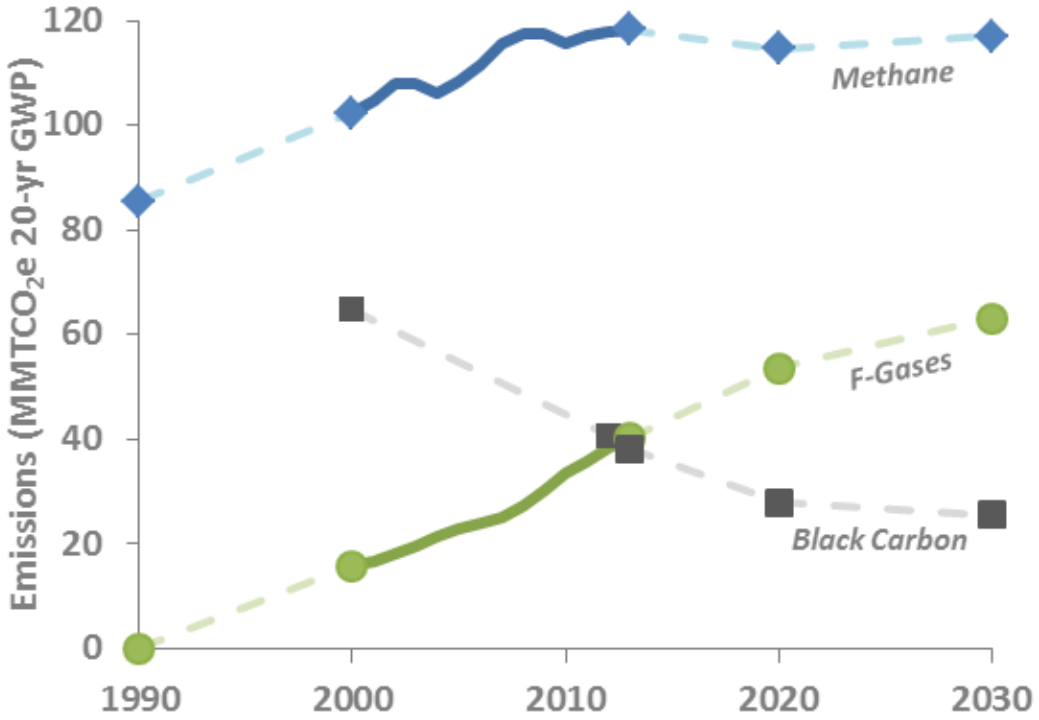
D. Emission Trends for SLCPs

Figure 6 shows the trends in emissions for methane, f-gases, and black carbon. Solid lines represent annual GHG emission inventory data available for 2000 to 2013. Symbols represent individual data years for 1990, 2013, 2020, and 2030. Dashed lines are meant to guide the eye, and do not represent emissions for intermediate years. 2020 and 2030 projections represent expected future emissions based on the current state of knowledge. The projections in the figure include existing control measures, but do not include measures under development or planned programs to reduce black carbon.

[11] ARB 2015 Edition GHG Inventory. http://www.arb.ca.gov/cc/inventory/data/data.htm

[12] Gallagher, G.; Zhan, T.; Hsu, Y-K.; Gupta, P.; Pederson, J.; Croes, B.; Blake, D. R.; Barletta, B.; Meinardi, S.; Ashford, P.; Vetter, A.; Saba, S.; Slim, R.; Palandre, L.; Clodic, D.; Mathis, P.; Wagner, M.; Forgie, J.; Dwyer, H.; Wolf, K. 2014. "High-global Warming Potential F-gas Emissions in California: Comparison of Ambient-based versus Inventory-based Emission Estimates, and Implications of Refined Estimates". Environ Sci. Technol., 2014, 48, 1084−1093. dx.doi.org/10.1021/es403447v

Figure 6: Trends in Methane, F-gases and, Black Carbon Emissions with Existing Measures Using 20-year GWPs.[13]



Methane emissions have increased since 1990 but are expected to remain relatively constant going forward, as dairy cow populations are expected to stay flat. F-gas emissions increase between 1990 and 2030 as HFCs replace ozone depleting chlorofluorocarbons, which are also potent warming compounds. Black carbon emissions decline significantly from 2000 to 2020, primarily due to mobile source diesel regulations, but are projected to decrease only slightly between 2020 and 2030 as reductions from existing regulations are already realized.

[13] - F-gases include the nine short-lived F-gases: HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-245fa, HFC-32, HFC-365mfc, and HFC-43-10mee.
- Black carbon excludes prescribed fire and wildfire.
- Dashed lines are linearly interpolated between points to guide the eye but are not mean to represent emissions for intermediate years.

Appendix B: Research Related to Mitigation Measures

Research Related to Mitigation Measures

A. Black Carbon

Successful programs to reduce emissions of black carbon rely on scientific research to develop and deploy new technologies, quantify emission benefits and cost effectiveness, understand lifecycle emissions, and ensure continued emission reductions from programs in place. There are many active areas of research to reduce black carbon spanning the varied source categories and areas where additional research is needed.

1. Current Research

California has a long and successful history of adopting technology-advancing vehicle emission standards to protect public health, built on a strong research foundation. This research supports strategies to meet federal air quality standards, reduce health risk from toxic air contaminants, and meet GHG emission reduction goals. ARB-funded research on vehicles and associated emissions also monitors the effectiveness of emission reduction strategies to ensure that the expected air quality and public health benefits are achieved. Much of ARB's recent research on heavy-duty vehicles, and their emissions, has focused on tracking the results of regulatory efforts to meet the goal of the Diesel Risk Reduction Plan. Research included evaluating the emission reductions from in-use rules on heavy-duty diesel vehicles, and investigations into the durability, degradation, and failure rates of exhaust after treatment devices.

Additional research is underway to adapt diesel filter use to a wider variety of engines, develop and deploy zero-emission technology and infrastructure, and identify the emission benefits from alternative fuels. To support and inform the Sustainable Freight Strategy, the 2016 SIPs, and other ARB emission reduction planning efforts, ARB and the South Coast Air Quality Management District are conducting technology and fuel assessments for a variety of source categories. The assessments will provide essential information on the technologies and fuels that will provide the most benefit for California to meet its air quality and climate goals, including black carbon reductions.

In coordination with U.S. EPA and the National Highway Traffic Safety Administration, ARB passenger vehicle research has turned to understanding market forces and consumer acceptance of new vehicle technologies, such as plug-in hybrid electric vehicles and ZEVs. Sustainable community research is another active area that aims to investigate strategies to reduce emissions and improve health by reducing vehicle miles traveled through alternative land use planning practices. The results will inform local governments, planners, and other practitioners on the best strategies to reduce emissions from passenger vehicles.

Air districts are also researching and developing cost-effective air pollution controls for under-fired char broilers. Demonstration of air pollution control devices in restaurants

are in progress. Successful demonstration and installation of these control devices will further black carbon reductions from this source category.

An international research collaborative is also underway to help mitigate PM and black carbon emissions. The India-California Air Mitigation Pollution Program (ICAMP), launched in October 2013, devises ways to tackle the joint air pollution-and-climate change problem. ICAMP draws on California's decades of experience developing the scientific basis for understanding air pollution impacts, engine and fuel technologies that are proven to reduce pollution levels, and governance for effective implementation of mitigation polices. The Program has now established working groups on science, technology, and governance to design measures to reduce India's air pollution and propose an Action Plan to policy makers. The Program will also explore options for pilot projects to reduce diesel emissions in a major Indian cities and states.

2. Future Research

Future research will ensure continued emission reductions using the most cost-effective strategies, verify emission reductions from existing regulations, and support development of new strategies.

New technologies offer significant promise for continued emission reductions. It is important to evaluate emissions under real-world conditions and as the technologies age. For example, heavy duty trucks and some off-road engines are transitioning to Diesel Particulate Filters (DPFs), mitigating emissions in most cases. As with any new technology, real-world implementation reveals component deterioration or failure that needs to be addressed. There is a growing transition to gasoline direct injection for on-road light-duty vehicles, which emit more PM and a higher fraction of black carbon than conventional passenger vehicles. Similarly, it was expected that DPFs would be used to meet the stringent Tier 4 standards for off-road engines. However, many engine manufacturers are developing systems that meet certification standards without diesel particle filters. It will be important to characterize the particulate and black carbon emissions from these engines to understand the implication of new technologies. Research to monitor fleet performance and to support new regulations related to inspection and maintenance, repairs, and warranty requirements will help ensure continued black carbon emission reductions.

In the freight sector, continued black carbon emission reductions are expected through efficiency improvement, and electrification. The development of system-wide technology and economic models will help identify emission reductions at the least cost. While there is already a significant amount of data available for the development of these models, additional data on costs, duty cycles, and power use profiles is needed.

A better understanding of the costs and benefits of mitigation by sector and development of new or improved technologies will ensure continued black carbon emission reduction across the diverse black carbon emission sectors. This research

also allows for a comparison of emission reduction potential, cost, and benefit for climate and human health of various strategies.

California has made extraordinary progress to reduce PM and black carbon emissions, especially from on-road mobile sources. This record of success makes California an international leader in reducing harmful PM and black carbon emissions to protect health, the environment, and climate. Technology transfer is a fast-growing activity in the U.S. research and development system, and one which has received substantial attention from governments, industry, and universities. The strategies and technologies developed in California can also be applied to other regions to produce additional emission reductions.

B. Methane

Methane mitigation research relative to oil and gas processing and distribution, dairies, and waste management are tightly linked and involve coordinated research efforts among multiple State agencies. In essence, these research efforts investigate the use of diverted waste and agricultural byproducts for beneficial purposes, such as to produce renewable fuels that can replace fossil-derived fuels through the most economically feasible and environmentally beneficial pathways.

1. Current Research

The CEC's sponsored research focuses on developing technologies for the production of renewable natural gas (RNG), and investigates the potential health and environmental impacts of biomethane production and use. This includes an RNG technology research roadmap, demonstration projects of technology to capture biogas from wastewater treatment plants and landfills, scrubbing and preconditioning technology to upgrade biogas to RNG, and feasibility studies for pipeline injection.

Research at the CEC is also evaluating and demonstrating technology to produce commercially-valuable products for use in conjunction with RNG production as a way to make this process more commercially competitive. Examples of this include the production of fertilizer products from digester effluent, the production of biochar, LNG and CNG production from green waste, and potential technologies to convert CO_2 into a variety of commercially-valuable products.

ARB sponsored research aims to assess the feasibility of RNG as a low carbon alternative fuel to meet the Low Carbon Fuel Standard, to evaluate the volume of fuel that could be made commercially available, and to estimate the savings in emissions and fuel prices compared to traditional hydrocarbon-based transportation fuels. The research is also assessing whether the use of RNG as a transportation fuel would impact other bioenergy pathways in California for heating, power generation, and liquid fuels.

ARB and CEC have both funded research on the air quality impacts of biogas production. ARB recently finalized a project that assessed the associated emissions of GHGs and criteria pollutants associated with the production of biogas. CEC is currently funding a project to look at toxic air emissions as a potential health threat from the combustion of biogas produced from different sources, and different levels of treatment. The results of these projects will improve our understanding of the air quality implications associated with different biogas adoption strategies.

ARB and CEC are also currently collaborating with scientists at NASA's Jet Propulsion Laboratory to identify large "hot spot" methane sources through a systematic survey of high-methane emitters in the agriculture, waste, and oil and gas sectors. This research will aid in future control and regulatory plans to reduce GHG emissions in California.

2. Future Research

Dairies and Livestock

Methane that is produced by the microorganisms involved in the digestive processes in the stomachs of ruminants, such as sheep, goats, buffalo and cattle, is referred to as enteric fermentation. Since these emissions account for 29 percent of California's methane inventory, it is essential to develop strategies to reduce emissions from these sources to meet State GHG reduction targets.

Strategies that have been investigated to reduce enteric fermentation include increasing rumen efficiency and reducing the amount of methane produced for a given amount of feed intake, breeding animals for lower methane production, gut microbial interventions, and changes to nutrition and animal management. Further research is needed to fully evaluate the viability of these strategies in California, and to assess their associated costs and co-benefits, potential impacts on animal and human health, other environmental impacts, and GHG and air toxic emissions associated with feed lifecycles.

Regionally-specific lifecycle emission assessments of enteric emission reduction strategies should be as expansive as possible to account for any unintended emission increases in other sectors. For example, strategies to produce more easily digestible feed that lowers enteric fermentation might increase emissions associated with GHG-intensive feed production and transport. Once mitigation strategies have been successfully evaluated, long-term emission reduction potential and goals can be established on a broader scale.

Additional research is needed to help identify financing options to reduce costs and improve the economic feasibility of dairy digester projects. In addition, the transaction costs of owning and operating a digester are not well understood. Assessments are needed to determine how much time, effort, and money dairy operators spend acquiring requisite permits from government agencies, and the amount of time, money, and effort to contract with energy service providers. Other research gaps include improving the

availability of information for potential markets for organic wastes co-digested with manure on dairy farms, and potential markets for materials other than biofuels and electricity.

Oil and Gas

In a recently concluded ARB-sponsored contract, emission measurements from well stimulation operations were collected from a limited number of samples. In this study, well recirculation tanks were identified as the only source of uncontrolled emissions. Well recirculation is a process whereby recirculated water is used to clear a well of excess sand using a temporary, open-top, portable tank. Accordingly, additional testing is necessary to obtain verifiable data and provide a quantification of recirculation tank GHG, VOC, and toxic air contaminant emissions.

The Western States Petroleum Association is now undertaking a study, with ARB and the San Joaquin Valley Unified Air Pollution Control District staff involvement, to collect more emissions data from well recirculation tanks. ARB also will be releasing an RFP this year to collect more emissions data from well stimulation operations in general, including well recirculation tanks.

In addition, ARB staff will be releasing an RFP to collect GHG, VOC, and toxic air contaminant emissions data from oil production wastewater ponds in the San Joaquin Valley. As part of the recent ARB well stimulation contract, limited measurements were taken at an oil production wastewater evaporation pond system. Again, because of the limited sampling, and because these ponds receive more than just well stimulation fluids, an additional contract is being pursued.

Wastewater Treatment

The amount of potential emission reductions that could be achieved by using wastewater treatment plants to co-digest food, agricultural, or other organic waste is currently unknown. Research is needed to quantify this potential and to determine the regional proximity and availability of organic waste streams for co-digestion on a facility-by-facility basis.

Research is also needed to determine if emerging technologies for wastewater treatment can more effectively reduce methane emissions. New treatment technologies are currently being piloted at Stanford University, UC Berkeley, and by some wastewater agencies, which may fundamentally change treatment processes. Moreover, future wastewater treatment could involve a shift away from large end-of-pipe facilities to smaller distributed systems. Understanding how these technology and infrastructure transitions may affect methane emissions is an important research topic.

Waste Management

Policy and economic analyses should explore potential mechanisms that could increase the diversion of organic waste from landfills, and use compost in innovative ways to support the development of healthy soils. Ideally, this research should be regionally focused to address the logistical challenges and potential co-digestion opportunities that exist in different areas of the State.

C. F-Gases

Low-GWP refrigeration and air-conditioning is currently the subject of major research and development globally, due to heightened concerns over the impact of F-gases on global warming. Incentivized by the adoption of the European F-gas regulation, which went into effect January 1, 2015, and ultimately requires a 79 percent reduction in new F-gas usage by 2029, chemical and equipment manufacturers have cumulatively spent billions of dollars to achieve low-GWP solutions. Although not all cooling applications currently have low-GWP options, research and development is proceeding rapidly to find low-GWP applications for all refrigeration and air-conditioning end-uses.

Current research overseen by ARB includes a study to determine the reductions, technical feasibility, and cost-effectiveness of low-GWP commercial refrigeration, with particular attention paid to the feasibility of low-GWP in high-ambient temperature climates. Results are expected in 2016. Lower-GWP alternatives to sulfuryl fluoride should continue to be assessed by DPR, ARB, and the U.S. EPA.