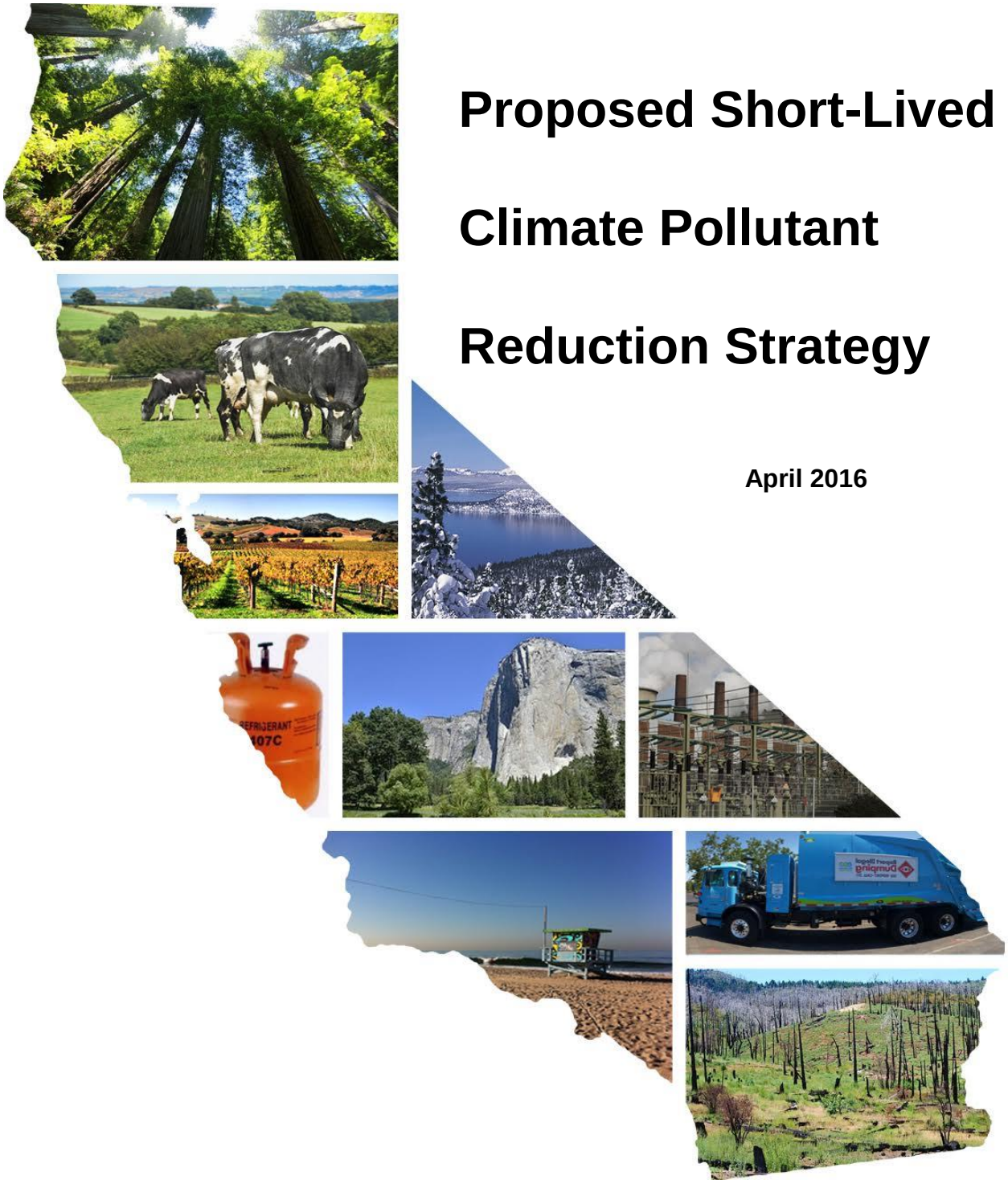

Proposed Short-Lived Climate Pollutant Reduction Strategy

April 2016

California Environmental Protection Agency

Air Resources Board

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EXECUTIVE SUMMARY

Eureka! Synonymous with discovery and opportunity, California represents an ideal; a state of mind—stunning scenery, recreational opportunities, a thriving economy and a culturally diverse people. However, climate change is threatening this ideal, and our very way of life. It is clear that the impacts of climate change are already upon us. California continues to suffer through historic temperatures, persistent droughts, and more intense and frequent wildfires. 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 greenhouse gas (GHG) 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 harmful air pollutants that have an outsized impact on climate change in the near term, compared to longer-lived GHGs, such as carbon dioxide (CO_2). SLCPs are estimated to be responsible for about 40 percent of current net climate forcing. Action to reduce these powerful "super pollutants" today will provide immediate benefits as the effects of our policies to reduce long-lived GHGs further unfold.

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. Deploying existing technologies and resource management strategies globally to reduce SLCP emissions can cut the expected rate of global warming in half and keep average warming below the dangerous 2°C 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 global 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 would be required for 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.

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. Many other countries included SLCP emissions in their commitments made at the Paris climate conference, or are targeting them through separate policies to improve air quality and promote sustainable agriculture and transportation, among other efforts.

California's seminal Global Warming Solutions Act, AB 32 (Nuñez, Chapter 488, Statutes of 2006), charges the California Air Resources Board (ARB or Board) with achieving and maintaining a statewide GHG emission limit, while seeking continuing GHG emission reductions. SLCP emission reductions are critical to achieving this mandate. California is committed to taking further action to reduce SLCP emissions by 2030. Senate Bill 605 (Lara, Chapter 523, Statutes of 2014) requires the ARB to develop a plan 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 proposed SLCP Reduction Strategy (Proposed Strategy) was developed pursuant to SB 605 and lays out a range of options to accelerate SLCP emission reductions in California, including regulations, incentives, and other market-supporting activities. Governor Brown's 2016-2017 Proposed Budget includes $215 million from Cap-and-Trade expenditures specifically targeting SLCP emission reductions. These include $40 million for black carbon residential woodsmoke reductions, $20 million for HFC reductions from refrigerants, $100 million for waste diversion, $20 million for Healthy Soils, and $35 million for dairy digester development.

An Opportunity for California

Historic action is not enough. Many opportunities to reduce emissions of SLCPs still exist, and California is doubling down on its efforts to control these emissions from all sources. A dedicated commitment, as described in this Proposed Strategy, to achieve sustainable reductions in SLCP emissions in California will provide significant benefits throughout the State.

In this Proposed Strategy, we outline SLCP emission reduction actions that provide a wide array of climate, health, and economic benefits throughout the State. The State's organic waste should be put to beneficial use, such as for soil amendments/compost,

electrical generation, transportation fuel, and pipeline-injected renewable natural gas. Practical solutions must be developed and implemented to overcome barriers to waste gas utilization for pipeline injection and grid interconnection. Additional data on SLCP sources must be collected in order to improve California's SLCP emission inventory and better understand potential mitigation measures. Finally, the State should provide incentives to accelerate market transitions to cleaner technologies that foster significant system-wide solutions to cut emissions of SLCPs. 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.

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 and waste sectors, build sustainable freight systems, encourage low-Global Warming Potential (GWP) refrigerants 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 quality, climate, and water quality 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 will help to secure financing to accelerate and scale project development.

Building on California Leadership

This Proposed 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, industry, and environmental justice representatives. 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 and academics to evaluate options and costs 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 air pollutants, as well. Many of the concepts described in this Proposed Strategy have already been discussed in the context of the California Sustainable Freight Action Plan, 2016 Mobile Source Strategy and other efforts related to developing 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 2030 Target Scoping Plan Update, 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 began in fall 2015 and is scheduled for completion by 2017.

State agencies and the air districts are committed to continuing to work together to ensure that the concepts outlined in this Proposed Strategy are implemented in a coordinated and synergistic way. The sections below describe goals, regulations, incentives, and other efforts that would:

- Encourage national and international deployment of California's well-established and proven measures to reduce black carbon emissions;
- Further reduce black carbon emissions from off-road and non-mobile sources, including forests;
- Cut in half methane emissions from dairy operations and effectively eliminate disposal of organics in landfills;
- Create and expand industries to capture value from organic waste resources in California;
- Significantly reduce fugitive methane emissions from oil and gas systems and other sources; and
- Accelerate the transition to low-GWP refrigerants and more energy efficient refrigeration systems.

ARB staff will receive and consider comments on this Proposed Strategy and prepare a final Strategy to present to the Board for consideration in fall 2016.

Achieving Significant Emission Reductions

Based on stakeholder feedback on the Concept Paper released in May 2015 and the subsequent Draft Strategy, ARB is proposing planning targets to reduce emissions of methane and HFCs by 40 percent below current (2013) levels by 2030, and

anthropogenic (non-forest) black carbon emissions by 50 percent below current levels by 2030. Meeting these targets will help to achieve the Governor's goal to cut all GHG emissions in California by 40 percent below 1990 levels by 2030 and help meet federal air quality standards for 2031 and beyond.

The proposed targets are summarized in Table 1. The goals and proposed measures included in this Proposed Strategy will reduce SLCP emissions to levels in line with these targets. Due to the urgency of the issue, and recognizing the climate potency of SLCPs in the near-term, we use 20-year global warming potential values (GWPs) in this report to quantify emissions of SLCPs.

Table 1: California SLCP Emissions and Proposed Target Emission Levels (MMTCO2e)*

Pollutant	2013	2030 BAU**	2030 Proposed Strategy
Black carbon (non-forest)	38	26	19
Methane	118	117	71
Hydrofluorocarbons (HFCs)	40	65	24

*Using 20-year GWPs from the 4th Assessment report of the IPCC for methane and HFCs, and 5th Assessment report for black carbon (the first report to define a GWP for black carbon)

**Business As Usual (BAU) forecasted inventory includes reductions from implementation of current regulations

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 the State'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 U.S. 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 woodstoves and fireplaces will account for more than three-quarters of anthropogenic 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 woodstoves and fireplaces, taking steps to meet federal health-based air quality standards by 2031, and developing and implementing a sustainable freight system—will continue to reduce black carbon emissions and should allow us to meet the targets established in this Proposed Strategy. The State's 2016 Mobile Source Strategy, 2030 Target Scoping Plan Update, and Sustainable Freight Action Plan, a multi-agency effort to deploy a sustainable and efficient system for goods movement, will build on these measures to reduce black carbon. Additionally, ARB will work with local air districts to further reduce particulate matter and black carbon emissions from woodstoves and fireplaces. Governor Brown's 2016-17 proposed budget includes $40 million to reduce black carbon from woodsmoke.

The largest source of black carbon emissions in California is, by far, 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, pursuant to Governor Brown's Proclamation of a State of Emergency on Tree Mortality and through other forums.

This Proposed Strategy focuses on actions to reduce wildfire risk and black carbon emissions by increasing the rate of fuel reduction to improve forest health, aligning financial incentives with beneficial uses of woody waste, supporting management efforts and market development through research, and integrating state planning efforts. The State's Forest Carbon Plan and the 2030 Target Scoping Plan Update will identify additional goals and measures to improve forest health. Goals and actions identified in the 2030 Target Scoping Plan Update and Forest Carbon Plan will include those related to forest carbon storage, which is beyond the scope of this Proposed Strategy. State agencies are coordinating to ensure that the goals and recommendations in each of

these plans complement one another. Any proposed targets or actions will be considered through those public planning processes.

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 capturing or altogether avoiding 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 capacity and reduce emissions through existing incentives and accelerated efforts to overcome barriers and foster markets. Government agencies and stakeholders will work to foster market conditions to support private sector investment in expanded or new 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 Proposed Strategy.

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 dairies, California will aim to reduce methane emissions from dairy manure management by at least 20 percent in 2020, 50 percent in 2025, and 75 percent in 2030. The State will encourage and support near-term actions by dairies to reduce emissions through financial incentives, collaboration to overcome barriers, and other market support, before subsequent regulations take hold. Following ARB approval of the final SLCP strategy, and in coordination with CDFA and local air quality and water quality agencies, ARB will initiate a rulemaking process to reduce manure methane emissions from the dairy industry in-line with the objectives in this Proposed Strategy. The regulatory process will include consideration of available financial incentives, market support, and the potential for emissions leakage in identifying appropriate timelines and requirements for the industry.

The rulemaking will also include requirements for mandatory reporting and recordkeeping of parameters affecting GHG emissions at California dairy farms. Reported information will be used to refine inventory quantification, evaluate policy effectiveness, and aid in future policy planning and regulatory development. ARB will work with other State agencies and industry groups to improve outreach on new

reporting requirements, as well as merge and streamline reporting activities with current forms and requirements to avoid duplicative reporting wherever feasible.

For landfills, ARB will work with CalRecycle to develop a regulation by 2018 to effectively eliminate organic disposal in landfills by 2025. To support this, CalRecycle will build on its partnerships with local governments, industry, nonprofits, local air districts and water boards to support regional planning efforts and identify ways to safely and effectively develop necessary organics recycling capacity. CalRecycle will also explore new ways to foster food waste prevention and food rescue, to help meet a goal of 10 percent food rescue by 2020, and 20 percent by 2025. Recovering and utilizing food that would otherwise be landfilled can help to reduce methane emissions and increase access to healthy foods for millions of Californians who suffer from food insecurity. Additionally, ARB and CalRecycle 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, and opportunities for co-digestion of food waste at existing or new anaerobic digesters at wastewater treatment plants.

This Proposed 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 Obama Administration goal of reducing 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 systems. 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. 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. Ultimately, to

eliminate fugitive methane emissions, the State needs to transition away from its use of oil and natural gas.

HFCs

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. The annual Meeting of Parties in November 2015 resulted in a decision to continue working on an HFC phasedown schedule in 2016. In the absence of a sufficiently rigorous international agreement by the end of 2016, 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 HFC 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. Without early action to reduce unnecessary emissions now and into the future, the State would need to take additional—likely more costly—steps to meet its 2030 climate targets. An important step would be 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. The Governor's proposed 2016-2017 budget includes $20 million for incentives to reduce HFC emissions from refrigerants. Also, as effective alternatives become available, ARB will consider developing bans on the use of high-GWP refrigerants in sectors and applications not covered by U.S. EPA regulations.

This Proposed Strategy identifies measures that can reduce HFC emissions by 40 percent in California by 2030 and potentially capture additional, available reductions in HFC emissions now, and into the future. Many of these measures could have associated energy efficiency benefits, as well.

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 (MMTCO2e)*

Measure Name	2030 Annual Emission Reductions	2030 Annual Emissions
BLACK CARBON (NON-FOREST)		
2030 BAU**		**26**
Residential Fireplace and Woodstove Conversion	3	
California Sustainable Freight Action Plan State Implementation Plans Clean Energy Goals***	4	
2030 BAU with new measures		**19**
METHANE		
2030 BAU**		**117**
Dairy Manure	21	
Dairy and Livestock Enteric Fermentation	5	
Landfill	5	
Wastewater, industrial and Other Miscellaneous Sources	7	
Oil and Gas Sector	8	
2030 BAU with new measures		**71**
HYDROFLUOROCARBONS		
2030 BAU**		**65**
Financial Incentive for Low-GWP Refrigeration Early Adoption	2	
HFC Supply Phasedown	19	
Sales ban of very-high GWP refrigerants	5	
Prohibition on new equipment with high-GWP Refrigerants	15	
2030 BAU with new measures		**24**

*Using 20-year GWPs from the 4th Assessment report of the IPCC for methane and HFCs, and 5th Assessment report for black carbon (the first report to define a GWP for black carbon)

**Business As Usual (BAU) forecasted inventory includes reductions from implementation of current regulations

***Future emission reduction measures that will be developed to help the State meet its air quality and climate change goals are also expected to help the State meet the black carbon target by 2030. However, an estimate of emission reductions is not currently available, but will be developed as part of these planning efforts.

Cost-Effective Measures with Significant Health Benefits

Significantly reducing SLCP emissions in line with the targets presented in this Proposed Strategy 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 contribute to health, environmental, and economic benefits that will positively impact Californian businesses and individuals. Many of these benefits will be concentrated in disadvantaged communities or other parts of the State most in need of economic development opportunities, including the San Joaquin Valley, rural areas where wood smoke is a primary health concern, and communities along freight corridors.

Collectively, implementing these measures would bring thousands of jobs from several billion dollars of investment in clean technologies and strategies that would lead to significant reductions in SLCP emissions. Potential revenues and efficiency savings could also be significant – and potentially outweigh the costs of some measures. In particular, for projects that utilize organic waste to create transportation fuel, the value of LCFS credits and RIN credits from the federal Renewable Fuel Standard can make these projects profitable. However, there remain significant institutional, market, and technical uncertainties that must be addressed, and continued incentives and State support can help to demonstrate and scale these strategies. In other cases, there may be net costs, but associated SLCP emission reductions may come at relatively low cost or provide other environmental and health benefits. For example, strategies at dairies that may not include energy production and associated revenues can still reduce emissions at low cost, and may deliver other environmental benefits, as well. And the collection of HFC measures identified in this Proposed Strategy could reduce GHG emissions by 260 $MMTCO_2e$ cumulatively through 2030 (20-year GWP) at a very low cost per tonne.

Achieving the targets identified in this Proposed Strategy would help reduce ambient levels of ozone and particulate matter, and the cardiovascular and respiratory health effects associated with air pollution. These and other health benefits can be maximized as part of an integrated approach to ensure that strategies used to reduce SLCP emissions also help to improve air quality and water quality on a regional basis. Many of these benefits would accrue in disadvantaged communities, which are often located near sources of SLCP emissions.

The proposed actions are supported through an integrated set of air quality and climate policies in the State, including the Low Carbon Fuel Standard, Bioenergy Feed-In-Tariff, utility investments to defray the costs of connecting renewable natural gas supplies to the pipeline, and direct investments from State funds. Together, and with additional targeted State support, we can meet the goals identified in this Proposed Strategy and capture additional economic, environmental and health benefits.

Putting the Strategy into Action

All regulatory measures developed pursuant to the SLCP Reduction Strategy would undergo a complete, public rulemaking process including workshops, and economic and environmental evaluations. While this Proposed 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 Proposed Strategy will require working with local, regional, federal and international partners, and strategically 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 127 jurisdictions have signed or endorsed the Under 2 MOU, collectively representing more than 729 million people and $20.4 trillion in GDP, equivalent to more than a quarter of the global economy. 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 Proposed 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 impacts 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.

In December 2015, at the 21st Conference of Parties (COP21), 25,000 delegates from 196 countries gathered recognizing that "climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions." An agreement was reached to substantially reduce GHG emissions with the aim of limiting a global temperature increase to below 2°C, mobilize investments to support low-carbon development, and create a pathway for long-term de-carbonization. Additionally, the agreement aims to strengthen the ability to deal with the impacts of climate change.

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. [1,2,3,4,5]

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

[2] 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]

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

California has taken significant steps to reduce SLCP emissions, especially black carbon from transportation, methane from oil and gas operations and landfill emissions, and HFC 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 HFC emissions from refrigeration and air conditioning systems.

The State is committed to further reducing SLCP emissions. SLCP emission reductions are important, first of all, to continuing and maintaining the GHG emission reductions called for by AB 32, and to ensuring emissions meet the statewide GHG emission limit it established. The Proposed Strategy is identified in the First Update to the Climate Change Scoping Plan as one of the recommended actions to achieve additional GHG emission reductions. Growing SLCP emissions (such as from fluorinated gases) threaten to erode the State's progress towards this limit; in other sectors (such as from oil and gas and agriculture) continued emissions will put increased pressure on the remainder of ARB's regulatory structure to maintain overall emissions below the GHG limit and to continue reductions. Conversely, addressing SLCP emissions will help to ensure that the AB 32 limit is maintained, and will fulfill AB 32's mandate to continue to seek the maximum technologically feasible and cost-effective reductions of GHG emissions. Reducing these powerful climate-forcers early also produces a compound-interest effect through which the effectiveness of future reductions are magnified: those future reductions start from a baseline substantially lower than where they would have started in the absence of aggressive early reduction efforts.

The Legislature directly 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°C through 2050, while highlighting the role that action to cut SLCPs must play in this effort. In April 2015, 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.

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[4] 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

[5] 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/

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.[6,7] 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.[8] Additionally, a new proposed global phase down of HFCs under the Montreal Protocol (if adopted) and other efforts could cut the expected production of HFCs by up to 70 percent by 2030, and up to 85 percent by 2035.[9,10]

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^{o}C,[11,12] which would reduce the risk of dangerous climate

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[6] 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

[7] 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

[8] 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

[9] 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

[10] 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/.

[11] 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]

[12] 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

feedbacks such as accelerated Arctic melting and sea level rise.[13] It would also increase the probability of staying below the 2°C threshold to more than 90 percent through 2050.[14,15]

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.[16] Slowing climate change impacts in the Arctic 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.[17,18] 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.[19]

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 of nitrogen (NO_x) emissions by 35 percent, and carbon monoxide (CO) emissions by 60 percent.[20] 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.[21] 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

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[13] 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

[14] 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

[15] 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

[16] 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

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

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

[19] 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

[20] 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

[21] 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

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 sustainably sequester carbon and mitigate black carbon emissions from wildfires can help bring investment, economic, and climate resiliency benefits throughout the Sierra, the North Coast, and other rural parts of California.
- Switching to low-GWP refrigerants can also improve the energy efficiency of refrigeration and air conditioning equipment, 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, 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,[22] essentially offsetting one to two decades' worth of CO_2 emissions.[23]
- *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

[22] 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

[23] 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

sector, and the natural gas pipeline system. These efforts are serving to keep methane emissions fairly steady in the State.

- *HFCs*: The State has regulations in place to reduce emissions from refrigerants, motor vehicle air-conditioning, and consumer products that together will cut emissions of HFCs by 25 percent below otherwise projected levels in 2020.

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. Global methane emissions are responsible for about 20 percent of current global warming, [24] and its emissions continue to increase. 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. Senate Bill 605 (Lara, Chapter 523, Statutes of 2014) requires ARB to develop a plan 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. Senate Bill 605 (Lara, Chapter 523, Statutes of 2014), requires ARB to develop a comprehensive strategy to reduce emissions of SLCPs in the State, 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 air 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.

[24] 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

ARB developed this proposed SLCP Reduction Strategy report (Proposed Strategy) pursuant to SB 605, in coordination with other State agencies and local air quality management and air pollution control districts. The Proposed 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[25] and current and future research needs are 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

This Proposed Strategy is designed to meet planning targets of reducing methane and HFC emissions by 40 percent below current (2013) levels by 2030, and black carbon emissions by 50 percent below current levels by 2030. The targets are translated into millions of metric tonnes of CO_2-equivalent ($MMTCO_2e$) in Table 3. These proposed targets are in-line with science-based assessments of reductions needed globally to limit warming below 2°C through at least 2050, as well as efforts needed in California to reduce overall GHG emissions by 40 percent below 1990 levels by 2030.

Table 3: California SLCP Emissions and Proposed Target Emission Levels ($MMTCO_2e$)*

Pollutant	Inventory 2013	Forecast** 2030	Targets 2030
Black Carbon***	38	26	19
Methane	118	117	71
Hydrofluorocarbons	40	65	24

*Using 20-year Global Warming Potentials and AR4 except Black Carbon, which uses AR5 (the first report to define a GWP for black carbon)
**Includes reductions from implementation of current regulations
***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 EO B-30-15, further charge ARB with continuing and

[25] Inventory methodology and detailed inventory tables available at: http://www.arb.ca.gov/cc/inventory/slcp/slcp.htm

maintaining emission reductions. The measures identified in this Proposed Strategy and their expected emission reductions will feed into the update to the Climate Change Scoping Plan that is currently being developed pursuant to EO B-30-15. The 2030 Target Scoping Plan Update 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 Proposed Strategy, there is an emphasis on early actions, often 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 Proposed 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.[26] 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.[27] 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 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 Proposed 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 Proposed 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

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

development of this Proposed Strategy.[28] 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. After consideration of comments received, staff developed a Draft SLCP Reduction Strategy,[29] which was released for public comment on September 30, 2015. Comments received on the Draft Strategy are posted at:
http://www.arb.ca.gov/lispub/comm2/bccommlog.php?listname=slcpdraftstrategy-ws

ARB held workshops in October 2015 to solicit comments on the Draft Strategy, including comments related to the development of a California Environmental Quality Act (CEQA) document. After consideration of public comments received, ARB developed this Proposed Strategy and an accompanying draft Environmental Analysis (Appendix C). Additional workshops will be held to solicit comments on this Proposed Strategy, before it is presented to the Board in May 2016. 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 fall 2016.

[28] http://www.arb.ca.gov/cc/shortlived/concept_paper.pdf
[29] http://www.arb.ca.gov/cc/shortlived/2015draft.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 Proposed Strategy. Additionally, California's approach to reducing SLCP emissions is framed by the principles 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 Proposed 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 soil-enhancing resource. Effectively implementing the measures described in this Proposed 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 other beneficial soil amendments, and other products. Adopting state policies to promote biogas from organic waste would provide a strong durable market signal to industry, agencies, and investors. In addition, this biogas can help the State meet its 33 percent renewable mandate for hydrogen transportation fuel. The State's new 50 percent renewable portfolio standard may drive renewable hydrogen production even higher. Collectively, products from organic waste streams in California, and potential environmental credits from them, could represent a market worth billions of dollars in California.

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

[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

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 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 may make diverting organic material relatively costly in some cases. Developing projects to generate renewable energy and soil amendments 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 a SLCP 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 Proposed 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. For example, the Low Carbon Fuel Standard (LCFS) and federal Renewable Fuel Standard provide strong economic incentives to utilize organic waste resources for production of transportation fuels. At current LCFS and RIN credit prices, anaerobic digestion projects that generate transportation fuels at dairies, wastewater treatment plants, or elsewhere can be profitable (see Chapter VIII). In order to enable this market, however, barriers to pipeline injection of biogas, among others, must be addressed. The CPUC has authorized an incentive program, capped at $40 million, to offset half of renewable natural gas interconnection costs, up to $1.5 million per project. State agencies are already collaborating to overcome barriers to pipeline injection of biogas, pursuant to the Governor's call to make heating fuels cleaner,[32] and 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 natural gas.

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 organic waste streams in California represent a potential $200-400 million market in California, exceeding the likely value of energy products from the resource.[33] 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.

[32] https://www.gov.ca.gov/news.php?id=18828
[33] Informa Economics (2013) National Market Value of Anaerobic Digester Products, Prepared for the Innovation Center for U.S. Dairy, February.

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 and in organic waste management; throughout the freight system; in commercial refrigeration applications; and from the management of woody waste materials in the urban, 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 State support for infrastructure to meet the goals identified in this Proposed Strategy is similar for both the waste sector and dairy sector. CalRecycle and CDFA both estimate that direct investments or incentives on the order of $100 million per year for five years could significantly scale project development to cut SLCP emissions associated with dairy manure and waste management. There could also be some opportunity to optimize investments and co-locate infrastructure or utilize existing infrastructure, including 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 Proposed 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),[34] the Alternative and Renewable Fuel and Vehicle Technology Program (AB 118), Electric Program Investment Charge (EPIC) Program, Carl Moyer program, Air Quality Improvement

[34] 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.

Program, and Proposition 39 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, Federal Renewable Fuel Standard, utility incentives pursuant to Assembly Bill 1900 (Gatto, Chapter 602, Statutes of 2012), 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 full cost of managing organic materials and landfills, state procurement contracts for renewable natural gas and other fuels in buildings or vehicles as well as for compost and mulch products in landscaping and erosion control, or labeling programs to 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 Proposed Strategy, including Appendices A and B, describes several coordinated research efforts under way and potential new ones. 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 HFCs and black carbon emissions, others not identified here also may be considered in the future.

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 Proposed 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,[35] and the sources align with those covered by federal reporting programs.[36] In contrast, most fugitive emissions[37] (a category into which SLCP emissions generally fall) do not meet these criteria.[38] They are frequently difficult to measure, measurements have high

[35] *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.

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

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

[38] 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/.

uncertainties,[39] measurement methods are often difficult and less precise,[40] and carbon costs are hard to assign with the same reliability as for combustion sources of CO_2.[41] 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 Proposed Strategy does not recommend expanding Cap-and-Trade Program coverage.[42] Instead, the Proposed 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 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 Proposed Strategy focuses on direct measures, consistent with the necessity of reducing SLCP emissions from the dairy sector specifically, and in-line with the design principles that underlie the State's climate strategy and the Cap-and-Trade Regulation.[43]

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[39] 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/.

[40] 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.

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

[42] ARB considered this option in detail, however. Further discussion is available in the California Environmental Quality Act (CEQA) appendix to this Proposed Strategy (Appendix C).

[43] 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,[44,45] 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.[46,47,48,49,50]

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[44] 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

[45] 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

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

[47] 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/

[48] 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]

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

[50] Akbar, Sameer; Ebinger, Jane; Kleiman, Gary; Oguah, Samuel. (2013) *Integration of short-lived climate*

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.[51] 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.[52,53] Accelerated warming in the Arctic could also lead to irreversible climate "tipping points," such as the release of vast quantities of CO_2 and methane from melting permafrost.[54]

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.[55] A recent study raises the possibility of a more rapid rate of sea level rise in this century than forecast

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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

[51] 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

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

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

[54] 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].

[55] 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.

by the U.N.'s Intergovernmental Panel on Climate Change (IPCC).[56] The authors conclude that 2° 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.[57]

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.[58] California droughts may be increasingly intensified due to declining availability of 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.[59] The current California drought highlights the critical need for developing drought resilience, even if wet conditions mitigate the current drought.[60,61]

Achieving Climate Stabilization

Scientific research indicates that an increase in the global average temperature of 2°C (3.6°F) above pre-industrial levels, which is only 1.1°C (2.0°F) above present levels, poses severe risks to natural systems and human health and well-being. Increased climate extremes, already apparent at present day climate warming (~0.9°C), will be

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[56] 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

[57] 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

[58] 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.

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

[60] 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*

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

more severe. 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.[62] Additionally, a new proposed global phase down of HFCs under the Montreal Protocol (if adopted) and other efforts could cut the expected production of HFCs by up to 70 percent by 2030, and up to 85 percent by 2035.[63,64] 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^{o}C,[65,66] which would reduce the risk of dangerous climate feedbacks such as accelerated Arctic melting and sea level rise.[67] It would also increase the probability of staying below the 2°C threshold to more than 90 percent through 2050.[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

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[62] 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

[63] 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

[64] 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/.

[65] 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]

[66] 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

[67] 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

[68] 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

[69] 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

radiative forcing published by Bond et al.[70] This Proposed Strategy uses AR4 values for methane and HFCs, 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 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[1]

Pollutant	Lifetime (years)	20-year GWP
Carbon dioxide	~100[2]	1
Methane	12	72
F-Gases (Hydrofluorocarbons)	1.4 – 52	437 – 6350
Black carbon	Days to weeks	3,200

[1]All AR4 except black carbon which uses AR5 (the first report to define a GWP for black carbon)
[2]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.

[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

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 a light-reflecting compound.

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.

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[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

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 arctic 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 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

[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

[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

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 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 100-year GWP of the current mix of HFCs being used is about 1600, and the average 20-year GWP is about 3500. The major concern with respect to HFCs is that their contribution to climate forcing is expected to increase rapidly in the future as

[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.

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 an 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 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.

[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.

IV. Reducing Black Carbon Emissions

Black carbon is the light-absorbing component of fine particulate matter (PM) produced during incomplete combustion of fuels. Black carbon does not account for the warming effects of brown carbon. 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.

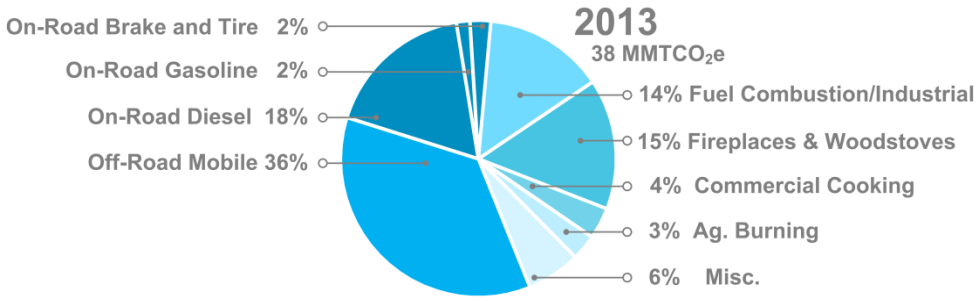
For purposes of this report, black carbon emissions are discussed in two categories, anthropogenic (non-forest) sources and forest-related sources. Anthropogenic sources include on- and off-road transportation, residential wood burning, fuel combustion, and industrial processes. Forest-related sources 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 approximately two-thirds 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 (non-forest) Black Carbon Emission Sources*

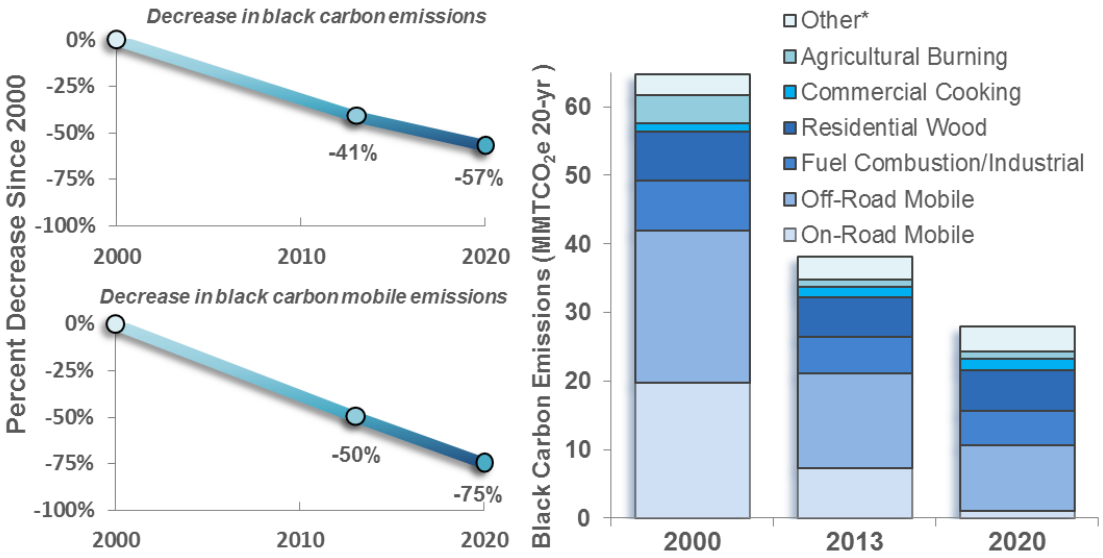


*Using 20-year GWP

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 diesel particulate filter-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 source emissions by 75 percent and total anthropogenic (non-forest) 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 and at international climate conferences in 2015. 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

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

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 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.

ARB is developing an integrated mobile source strategy to meet California's air quality and climate mandates, reduce petroleum use, and reduce near source risk. Accomplishing this will require a transformation to near-zero and zero emission technologies, cleaner renewable fuels, greater system and operational efficiencies, and

[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

new approaches to passenger and freight mobility. These coordinated efforts will provide California a clear path forward to reduce the State's impacts on climate change including reductions in black carbon emissions.

In April 2015, ARB released the *Sustainable Freight Pathways to Zero and Near-Zero Discussion Document* that outlines initial steps ARB is taking to accelerate progress toward zero and near-zero emission freight vehicle and equipment technology in California.[87] In July 2015, the Governor signed Executive Order B-32-15, that directs the Secretaries of Transportation, Environmental Protection, and Natural Resources to lead staff from the California Department of Transportation (Caltrans), ARB, the California Energy Commission (Energy Commission), and the Governor's Office of Business and Economic Development (GO-Biz), in the development of an integrated action plan, the California Sustainable Freight Action Plan (Action Plan). The agencies must develop the Action Plan by July 2016 that establishes targets, identifies actions to achieve the targets, and initiates work on pilot projects.

In September 2015, ARB staff released the *Mobile Source Strategy Discussion Draft*, which introduced a comprehensive plan to control emissions from mobile sources in order to meet critical air quality and climate goals over the next fifteen years.[88] Since October, developments in planning efforts have continued to shape staff's mobile source approach. The Mobile Source Strategy will be released in April 2016, reflecting these developments.

Specifically for criteria pollutants, the ARB staff developed the State SIP Strategy that will propose measures to meet federal air quality standards for ozone and fine particulate matter (PM2.5). SIPs are due to U.S. EPA in 2016. Building on measures first introduced in the *Mobile Source Strategy Discussion Draft,* the State SIP Strategy will be also released in April 2016.

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 public health.[89] Strategies in place to reduce emissions from residential wood combustion

[87] http://www.arb.ca.gov/gmp/sfti/sustainable-freight-pathways-to-zero-and-near-zero-emissions-discussion-document.pdf
[88] http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc_dd.pdf
[89] 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.

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.

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.

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

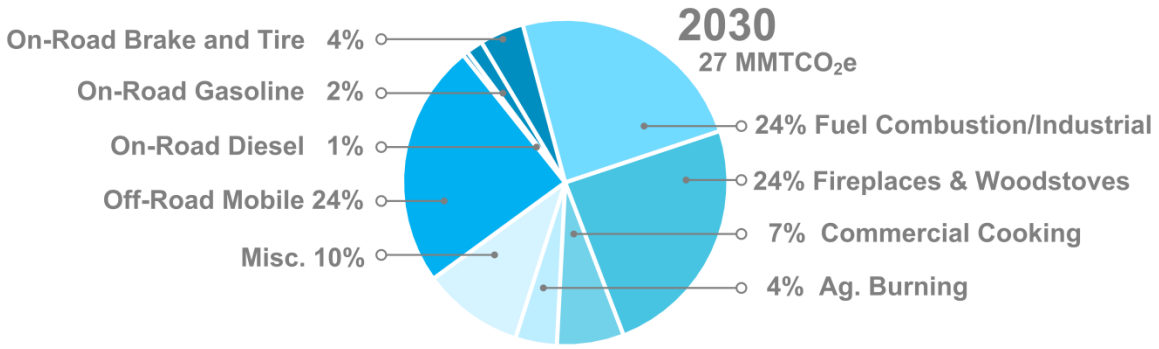
coordination with ARB to reasonably regulate agricultural burning as required by state law. The Sacramento Valley Rice Straw Burning Phasedown Program, local district Smoke Management Programs, and San Joaquin Valley agricultural burning phase down efforts have resulted in an approximately 70 percent reduction in black carbon emissions from agricultural burning between 2000 and 2013. Some agricultural waste that was previously burned went to bioenergy facilities; however, many of these facilities have shut down over the last few years due to their inability to procure long-term power purchase contracts. If this trend continues, the diminishing agricultural waste utilization options could result in the potential for increased agricultural burning. The San Joaquin Valley Air Pollution Control District is considering the need to allow increased agriculture burning of certain crops due to the lack of feasible alternatives to removing this waste in the fields. Programs to support clean energy and fuel production and markets for wood products, similar to the recommendations later in this section for forest woody biomass, would provide opportunities for alternative beneficial uses for this waste material.

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.

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 Proposed Strategy (for non-forest 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 (Figure 3). Additional 2030 reductions will be realized through implementation of measures identified in plans currently being developed, including the California Sustainable Freight Action Plan 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 (non-forest) Black Carbon Emission Sources with Existing Measures*



*Using 20-year GWP

2. Recommended Actions to Further Reduce Non-Forest Black Carbon Emissions

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 Name	2030 Annual Emission Reductions	2030 Annual Emissions
2030 BAU[2]		**26**
Residential Fireplace and Woodstove Conversion	3	
California Sustainable Freight Action Plan State Implementation Plans Clean Energy Goals[3]	4	
2030 BAU with new measures		**19**

[1]Using 20-year GWPs from the 5th Assessment report of the IPCC
[2]Business As Usual (BAU) 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 in this Proposed Strategy.

Removal of old fireplaces and woodstoves and replacement with EPA-Certified wood-burning devices, electric heaters, or gas fireplaces 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. The Governor's 2016-2017 proposed budget includes $40 million of Cap-and-Trade expenditure for a residential woodstove replacement incentive program, but this potential incentive program will not be developed and implemented until the Legislature appropriates funds for this Program.

In addition, 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 non-wood burning centralized heating in new construction. In areas where central heat is cost-prohibitive, the cleanest available burning technology could be required.

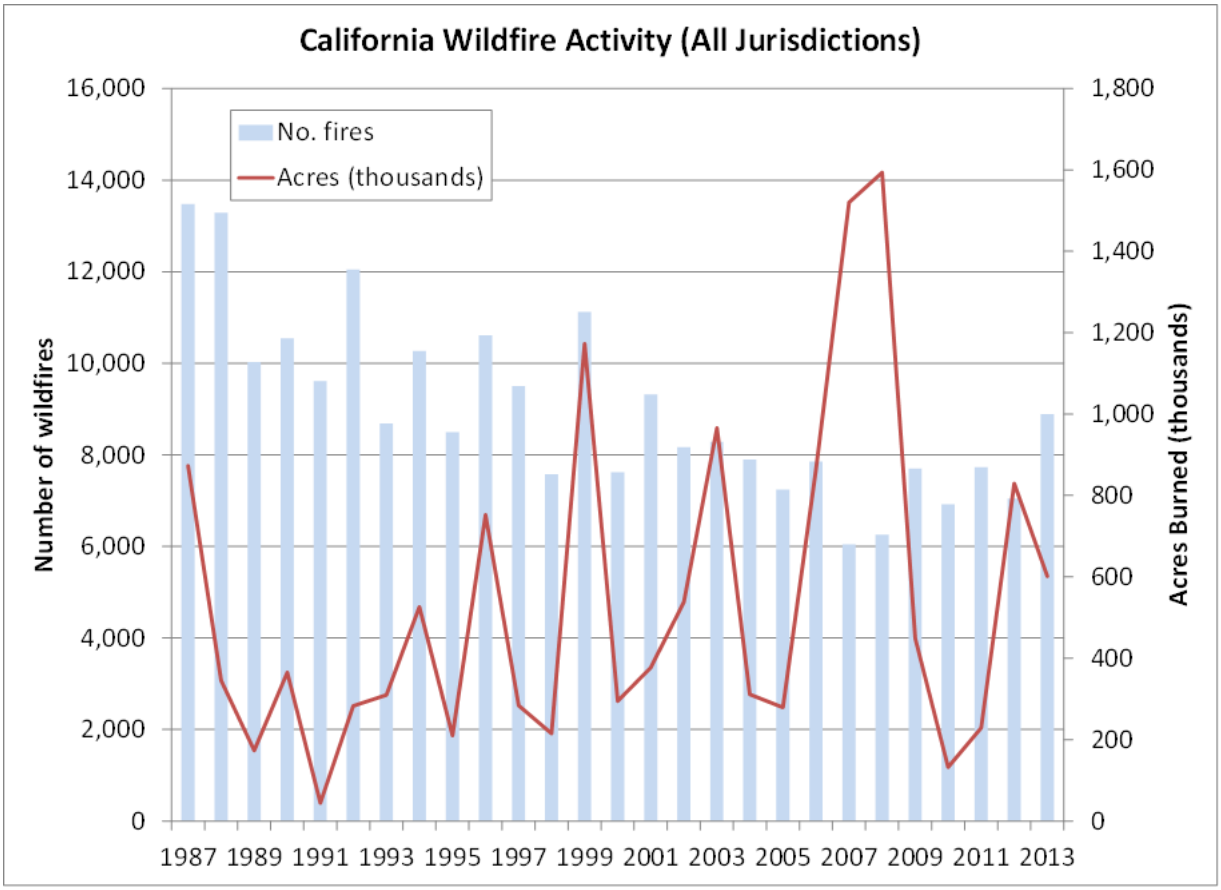
Education and outreach are important tools to reduce emissions from residential wood combustion. A broader public understanding of the health and environmental impacts of wood smoke may cause voluntary changes in behavior to use other heating sources and may cause individuals to avoid unnecessary burning 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

Wildfires account for the majority of black carbon emissions during a typical year in California. On average, an area the size of Las Vegas burns each year. The extent and severity of wildfire varies significantly from one year to the next and is impacted by forest conditions that are influenced by historic management, drought, and climate change (see Figure 4).

While we must act to reduce wildfire risk in the State, we will never be able to fully control wildfire and associated black carbon emissions to meet specific targets in any given year. Consequently, forest-related emissions are not included in the anthropogenic black carbon emission reduction target identified in this Proposed Strategy. Still, efforts to reduce black carbon from wildfires are critical to California's efforts to cut SLCP emissions. As part of an integrated and long-term effort to sustainably manage forests, California can reduce the risk of catastrophic wildfire and forest-related black carbon emissions in California over time.

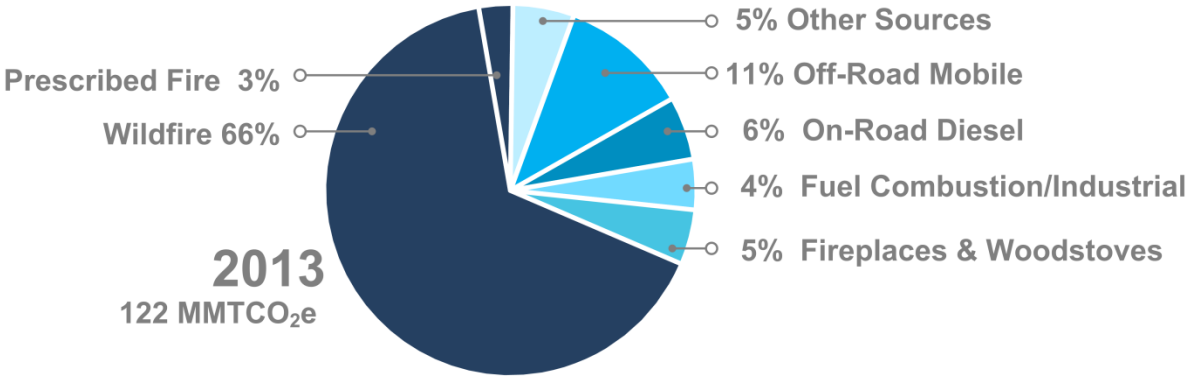
Figure 4: Wildfire Activity in California.[90]



California's black carbon inventory uses the 10-year average from 2001-2011 of PM2.5 emissions from wildfire to represent average conditions and avoid large year-to-year variations in the inventory. Based on these methods, a typical recent wildfire year would account for two-thirds of the State's black carbon emissions in 2013 (Figure 5). The frequency of large fire events and the associated emissions will likely increase in the future, due to climate change, heavy fuel loading, historic fire suppression practices, and development in forested areas.[91,92]

[90] http://calfire.ca.gov/communications/downloads/fact_sheets/AllAgenciesAcres&Fires.pdf
[91] Westerling et al. 2006. Warming and earlier spring increase western US forest wildfire activity. Science, 313(5789), 940-943.

Figure 5: California 2013 Black Carbon Emissions (including 10-year average emissions from forest-related sources)*



*Using 20-year GWP. "Prescribed Fire" does not include agriculture.

California's forests consist of a range of ecosystems, managed under various regulatory structures by different landowners. This patchwork of regulation and ownership, as well as physical accessibility, affects forest conditions and management practices. Private forests and areas designated as timberlands tend to be less susceptible to wildfire, as they are managed to minimize fuel loads and protect commercial assets. The value of timber harvest can help offset forest management costs, but may not be optimal from an ecological standpoint. More than 35 percent of California's forests are privately-owned, 60 percent of which is managed as timberlands. Federal agencies manage well over half of the nearly 33 million acres of forestland in California. Federal lands are managed for multiple objectives, including timber harvest, but also with ecological restoration as a focal point. Continued coordination with private and federal land owners is necessary to ensure that improved management practices, resulting in overall black carbon and GHG benefits, reach throughout California's forest lands.

1. Progress to Date

After a century of fire suppression, chronic underfunding for forest management at the State and Federal level, and exacerbating impacts of climate change, bark beetle infestations and drought, California's forests are highly vulnerable and potentially a source of increasing black carbon emissions. The current rate of fuel reduction activity is insufficient to improve forest health, avoid catastrophic wildfire, produce resilient forests, and reduce black carbon emissions. For example, the U.S. Forest Service estimates that less than 20 percent of the Forest Service lands in need of fuels reduction treatment have been treated.[93] Once treated, these forest stands must be retreated every 15-30 years to be properly maintained. California is accelerating its efforts to improve forest health and reduce wildfire risk, but doing so requires

[92] Hurteau et al. 2014. Projected effects of climate and development on California wildfire emissions through 2100. Environmental Science & Technology, 48(4), 2298-2304.
[93] North, M., Collins, B.M., and Scott Stephens (2012) Using Fire to Increase the Scale, Benefits, and Future Maintenance of Fuels Treatments, *Journal of Forestry* 110**(7)**:392-401.

comprehensive planning and strategic investment and will take time before there is a steady trend toward declining wildfire and associated black carbon emissions.

In response to the current epidemic of tree mortality, Governor Brown issued a Proclamation of a State of Emergency on Tree Mortality (Proclamation) in October 2015.[94] It requires State agencies to identify high hazard zones for wildfire and falling trees and prioritize tree removal in those areas. Among several actions to reduce wildfire risk and support forest management operations, the Proclamation calls for expanding the practice of prescribed burns, extending operation of existing biomass power plants that receive feedstock from high hazard zones, and facilitating power contracts for new facilities. To help implement the Proclamation, the Governor launched the State Tree Mortality Task Force in November 2015. The group includes State, Federal, and local government agencies, as well as key stakeholders, and will also monitor tree removal efforts and forest health and resilience.

This Proposed Strategy is one in a series of planning efforts underway that collectively contribute towards an integrated forest management and climate strategy for the State. Here, the focus is on actions to help reduce wildfire risk and black carbon emissions. The State's Forest Carbon Plan will identify climate-related targets for the natural and working lands sector, including forests, for incorporation into the 2030 Target Scoping Plan Update that will build on these recommendations. Goals and actions identified in the 2030 Target Scoping Plan Update and Forest Carbon Plan will include those related to forest carbon storage, which is beyond the scope of this Proposed Strategy. State agencies are coordinating to ensure that the goals and recommendations in each of these plans complement one another. And any proposed targets or actions will be considered through those public planning processes.

Reducing wildfire risk requires active management to reduce fuel availability and returning forests to more resilient states that can withstand fire. This starts with thinning overstocked forests, removing dead and dying trees, and altering stand characteristics to allow mature, larger trees to proliferate and thrive. Forests may be thinned manually, mechanically, or through the use of prescribed fire. These activities also reduce competition from understory vegetation and remove “ladder fuels” that allow ground fires to propagate into the forest canopy and quickly spread.

Prescribed fire can be a useful management tool, particularly in areas that are not suitable for other fuel reduction treatments. While prescribed fire emits black carbon, it can reduce the risk of crown fires, which are a driver for large, catastrophic wildfires.[95,96] Unlike wildfire, prescribed fire can be timed with favorable atmospheric conditions and managed to minimize air quality impacts. ARB and the local air districts have smoke

[94] http://gov.ca.gov/docs/10.30.15_Tree_Mortality_State_of_Emergency.pdf
[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.

management programs in place to manage the timing and location of prescribed burns to protect public health.

Mechanical or manual thinning produces a large amount of woody biomass. While much of this is not marketable as commercial timber, it represents a potentially valuable resource that can support new industries in rural parts of the State and elsewhere. Currently, however, more than half of it is likely left in the forest, where it is often simply piled up and burned. This produces uncontrolled black carbon emissions and wastes a resource that could preferably be used to produce renewable electricity or low-carbon fuels, create wood products or landscaping materials, or potentially as a soil amendment in the form of biochar. These uses can help to reduce forest-related black carbon emissions, while creating jobs and fostering rural economic development. In addition, enabling markets that would capture value from this resource would help foster broader investment in active forest management practices that are needed to improve forest health and reduce wildfire risk on a lasting basis.

Utilizing more of this resource in a beneficial way to avoid open pile burning requires additional infrastructure to generate clean energy, fuels, or other products in areas near the resource base. Current capacity, mostly in the form of electricity production, is aging and insufficient for the existing resource, much less increased volumes that could come from increased forest management activities. Additionally, many of these facilities face expiring power contracts and are shutting down or in danger of doing so. In the near term, a priority is to keep existing facilities operating that receive woody biomass from high hazard areas, as called for in the Governor's Proclamation.

A longer-term, sustainable biomass management strategy requires increasing the capacity and diversity of uses and prioritizing community-scaled facilities near the forest. The most value from woody biomass may come from converting the feedstock into liquid or gaseous transportation fuels, which is supported by the State's Low Carbon Fuel Standard (LCFS). Additionally, the State's bioenergy feed-in tariff (Senate Bill 1122, Rubio, Statutes of 2012) requires the State's large investor-owned utilities to procure 50 MW of electricity from new, small scale bioenergy facilities using byproducts of sustainable forest management. Finally, part of the funding from the State's Electric Program Investment Charge (EPIC) is dedicated to research and development, deployment, and market facilitation for biomass-fueled facilities.

California, in partnership with Tuolumne County and the U.S. Department of Agriculture Forest Service (USFS), was awarded a $70 million grant as part of the National Disaster Resilience Competition to develop and implement such an integrated community-scale strategy.[97] The proposed $117 million project would create a replicable model for community and watershed resilience that could facilitate transitions to sustainable forest economies in rural parts of California. It includes three pillars related to recovery from the catastrophic Rim Fire in 2013:

[97] http://www.hcd.ca.gov/nationaldisaster/ndrc-application.html

- Forest and Watershed Health: Thinning, biomass removal, restoration, and reforestation activities in the Rim Fire burn area.
- Integrated Biomass and Wood Products Campus: The campus hosts facilities that will provide clean power, cooling and heating, and wood products to utilize biomass material and serve communities near the impacted disaster area.
- Community Resilience Centers: These facilities will provide services during an emergency and also provide year-round services, including education and job training to support forest and watershed work and the biomass facility.

As recent years of historic drought and wildfire have made abundantly clear, California needs to adjust historic forest management practices to reduce wildfire risk in the face of a changing climate. The State is responding quickly and effectively, but more needs to be done to build resiliency into our forests.

2. Recommended Actions to Reduce Wildfire Risk and Black Carbon Emissions

Reducing black carbon emissions from forests requires reducing wildfire risk by actively managing forests to reduce the threats posed by historic fire suppression activities and the increasing effects of drought and climate change. The U.S. Forest Service, which owns and manages approximately 20 million acres in California, has established a restoration goal of 500,000 acres/year in the State, including fuels reduction. Reaching that goal would require an additional $300 million per year to more than double the current pace of restoration, but could potentially save $800 million per year in fire suppression costs.[98] A matching goal for the State and private landowners to treat 500,000 acres per year of non-federal forestlands could require annual investment on the order of $500 million to $1 billion [99]

There is a clear need to identify sustainable funding streams to support this level of treatment. Increased State and Federal funding is needed, as well as private sector investment. Enabling markets for the beneficial use of woody biomass can help to support and maximize these investments. For example, coupled with the Low Carbon Fuel Standard, additional steps to help to facilitate affordable and reliable supplies of sustainably harvested woody biomass could help spur a biofuels industry in rural parts of the State that could foster significant private sector investment in forest management activities.

The recommendations below will help reduce wildfire risk by improving forest management, putting woody waste resources to beneficial use to create value from forest management activities, and supporting these efforts with research and ongoing coordination. These actions will help increase public and private investment to unlock a broad array of economic and environmental benefits in rural communities and Statewide.

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[98] http://www.fs.usda.gov/detail/r5/landmanagement/?cid=stelprdb5412095

[99] Assuming average treatment costs of $1,000-2,000/acre. Actual treatment costs will vary across the landscape.

Increase Rate of Fuel Reduction to Reduce Wildfire Risk

The State is committed to increasing active management of its forests to reduce fuel loadings, wildfire risk, and black carbon emissions. Wherever possible, material should be thinned and put to beneficial use, which in turn, can help to finance fuel reduction activities. Prescribed fire has an important role to play, and should be utilized in manners protective of public health and as part of a scaled effort to improve forest and ecosystem health. Throughout, activities to reduce wildfire risk should be coordinated to support various State priorities, including enhancing forest health, protecting air quality, addressing climate change, and supporting watersheds, biodiversity and other ecosystem services. The State will work in these regards, and with federal and private land owners, to accelerate activities to reduce wildfire risk and associated black carbon emissions:

- **Increase investment in forest health programs.** Governor Brown's Cap-and-Trade Expenditure Plan in his proposed budget for fiscal years 2016-17 includes $140 million for CAL FIRE to support forest health and resiliency programs that reduce GHG emissions. While additional public and private investment is needed on an ongoing basis, this represents an appropriate and significant increase beyond the $24 million that these efforts received in the 2014-15 budget year.
- **Foster private sector investment.** The State will continue to support programs such as the Low Carbon Fuel Standard and Bioenergy Feed-In Tariff that support private sector investment to support sustainable forest management and utilization of woody biomass. Additionally, in developing the Scoping Plan and Forest Carbon Plan, State agencies will consider opportunities to support thinning, collecting, and transporting woody biomass to facilities that can beneficially use it. This may come in the form of direct investment, coordination to streamline facility development, or other activities as described below. These efforts will help to scale private sector investment in forest management and clean energy efforts, and reduce black carbon emissions from pile burning and wildfire.
- **Implement Governor Brown's Proclamation.** Among other activities, the Proclamation calls for ARB and CAL FIRE to work with federal agencies and land managers to "expand the practice of prescribed burns, which reduce fire risk and avoid significant pollution from major wildfires, and increase the number of allowable days on a temporary basis to burn tree waste that has been removed in high hazard areas." The agencies will implement this Proclamation to reduce the wildfire risk posed by dead and dying trees, through the public process of the Tree Mortality Task Force.
- **Collaborate with federal and private landowners.** The State is targeting investments to achieve net GHG emission benefits in areas that have high rates of carbon stock and face heightened wildfire risk from overstocked forests and dead or dying trees. Coordinating with public and private land owners in shared watersheds or firesheds is important to maximize the positive impacts of these treatments beyond the immediately treated area. Additionally, CAL FIRE will

continue working with Federal agencies, local jurisdictions and private land owners through existing agreements and mechanisms to support forest management operations.

Align Financial Incentives with Beneficial Use of Woody Waste

Current volumes of woody waste from forests and other sources, let alone increased volumes that will come from improved forest management practices, far exceed the markets and available uses for this material. By helping to develop markets for industries that can utilize this material, the State can help unlock the value intrinsic in California's woody biomass waste streams and capture additional economic and environmental benefits associated with forest management. This will help improve the economics associated with transporting residues from the forest, providing alternatives to pile burning and reducing black carbon emissions associated with forest management. It will also help to scale investment to help sustain forest management operations at necessary levels. Accordingly, the State will take additional steps to support beneficial uses of woody waste:

- **Demonstrate and prioritize integrated, community-based models.** Projects like the one awarded to California as part of the National Disaster Resilience Competition offer a wide array of benefits, including community-scale benefits much broader than those just associated with forest health. This project can serve as a model for rural communities near forested lands to support ecological restoration and hazardous fuels reduction, while supporting economic growth and diversification and community wildfire protection. The State will work with its partners to secure financing and develop this project, with a key focus on replicability and scalability.
- **Support clean energy and fuel production.** As described above, California has several programs in place to support clean energy and fuel production from sustainably harvested forest waste and other organic resources. Some of these programs, such as the bioenergy feed-in tariff, LCFS, and Cap-and-Trade, are relatively new programs and could support more clean projects moving forward. The State will encourage policies, strategies and investments, from both private and public funds, to further support clean energy and fuel production from forest biomass. One potential source of public funding is the $140 million for healthy forests in the Governor's 2016-17 budget proposal, which includes support for biomass electricity generation projects. Governor Brown's Proclamation directs the CEC to prioritize EPIC grant funding for woody biomass-to-energy technology development and deployment. CEC is now accelerating the schedule for more than $15 million in EPIC research funding to support woody biomass to energy projects. The State is also evaluating a variety of potential policies that could reduce the cost to collect and transport woody biomass to energy and fuel production facilities, modernize existing biomass facilities, build new community-scale facilities that use the best available emission control technologies, and develop and transfer new technologies to market. To the extent possible,

policies will support technologies and strategies that minimize criteria and air toxic pollutants.

- **Foster markets for sustainably harvested wood products.** A diversified industry infrastructure is necessary to allow different species and sizes of woody biomass to be effectively utilized. Wood products industries are an important element of this infrastructure. They can also be an important part of integrated, community-based models that the State will continue to prioritize. In addition to scaling these models, and pursuant to Governor Brown's Proclamation, State agencies will work to expand and diversify markets for sustainably harvested wood products.

Support Management Efforts and Market Development through Research

Additional research will help support the actions identified above to further target forest management activities to reduce black carbon emissions, accelerate market development for beneficial use of woody biomass, and to maximize the economic and environmental benefits provided by California's forests. Several benefits associated with forest management practices are not well-understood or valued in current markets or policy programs. For example, 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. Healthy, resilient forests provide water supply and quality benefits to major metropolitan areas and agricultural landowners but management is not supported through user fees.[100] Quantifying and verifying these benefits could allow them to be captured in State policies or commercial transactions, supporting private investment in healthy forest management.

- **Improve understanding of the feedstock.** Pursuant to the Emergency Proclamation on Tree Mortality, CAL FIRE and CEC will work with land managers to estimate biomass feedstock availability, storage locations, and volumes that may be available for use as bioenergy feedstock at existing and new facilities. These data will be used to develop medium- and long-range plans to diversify biomass markets, expand existing ones, and for the identification and distribution of incentives.
- **Identify a broad scope of benefits and options to value them.** Resilient forests and healthy watersheds provide valuable goods and services, including but not limited to secure water supply and water quality, wildlife habitat, clean air, carbon storage and reduced forest GHG emissions, timber resources and local economic development opportunities. Investing in forest health has a large multiplier impact, however several of these goods and services are difficult to quantify and even those that can be quantified are often not accounted for when evaluating economic benefits. State agencies will support research and demonstration projects to improve accounting of potential benefits associated with healthy forest management, and will consider incorporating the range of

[100] R Bales, M Conklin et al. (2015) Sierra Nevada Adaptation Management Project, Appendix E: Water Team Final Report.

benefits into programs and cost/benefit calculations where they can be appropriately quantified. If they can be reliably quantified and valued, these benefits may provide a revenue source to support forest management.

Integrate State Planning Efforts and Goals

The actions identified in this Proposed Strategy, and those already underway pursuant to Governor Brown's Proclamation on Tree Mortality, represent immediate steps that the State can take to reduce wildfire risk and black carbon emissions. Additional planning efforts underway will flesh out a broader vision and set of activities to improve forest health and enhance carbon storage over time. Throughout these and other efforts, State agencies will coordinate efforts to align priorities and actions. They will also increase information sharing associated with research, monitoring, and the state of forest management practices.

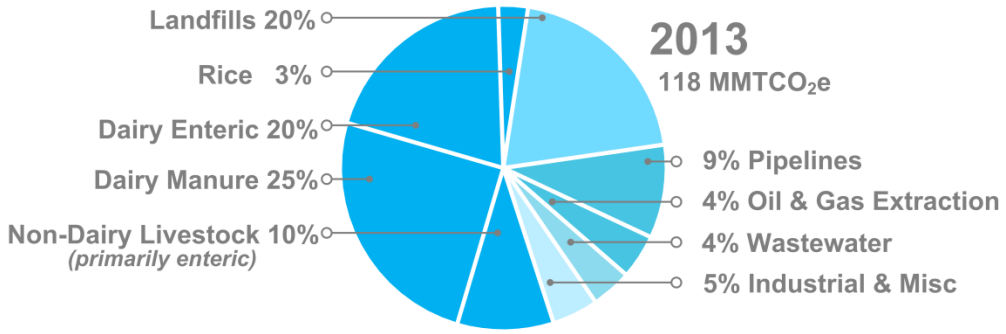
- **Identify targets for forest and climate planning in 2030 Target Scoping Plan Update.** The 2030 Target Scoping Plan Update will include specific climate-related planning targets for natural and working lands, including forests, and an accounting and monitoring framework for monitoring progress toward meeting the targets. Agencies will work together to develop methods for monitoring the black carbon and GHG emission reductions and carbon sequestration associated with these targets, and will report on progress in regular updates to the Scoping Plan.
- Develop Forest Carbon Plan to outline implementation activities to meet 2030 Target Scoping Plan Update and other targets. The Forest Climate Action Team (F-CAT) will complete a Forest Carbon Plan, which will cover a broad range of management and conservation priorities for California's forests and implementation mechanisms and strategies for achieving them, including the targets and recommendations included in this Proposed Strategy and the 2030 Target Scoping Plan Update. This coordinated planning process will provide for an ongoing and collaborative forum guiding sustainable forest management activities in California moving forward.

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 6). 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 6: 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.

- 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) established a State target to reduce the amount of solid waste sent to landfills by 75 percent 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 recently took 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. CalRecycle will provide an annual public update on the disposal, diversion, and recycling of organics, beginning in 2016, pursuant to this mandate. 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. AB 876 (McCarty, Chapter 593, Statutes of 2015) requires local governments, beginning August 2017, to assess the amount of organic waste that will be generated in a region during a 15-year period and identify locations

for new or expanded organic waste recycling facilities capable of handling this material.

- Methane emissions from landfills are controlled under ARB's Landfill Methane Control Measure, which was approved in 2009. The regulation requires owners and operators of certain previously 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. .

- 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. In doing so, it provides a market signal to incentivize developing clean fuel options, including capturing or avoiding methane emissions and using associated renewable natural gas as a transportation fuel. Some LCFS pathways related to renewable natural gas have the lowest carbon intensities of pathways to date. Specifically, the production of biomethane from high solids anaerobic digestion of organic (food and green) wastes has a carbon intensity of -15 gCO_2/MJ, and a recently approved pathway for biogas from a dairy digester project has a carbon intensity of -276 gCO_2/MJ. If LCFS credit prices are $100/MT, as they have been recently, the value of LCFS credits from these pathways is about $1.50 per diesel-gallon equivalent and $5.00 per diesel gallon equivalent, respectively (or about $11/MMBtu and $36/MMBtu of natural gas, respectively). 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, which could add additional value to these types of projects.

- 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 program to offset a portion of gas

producers' costs of connecting to utility pipelines by providing up to $1.5 million per biomethane project, up to a cap of $40 million total.

- Pursuant to Assembly Bill 1257 (Bocanegra, Chapter 749, Statutes of 2013), the CEC has released a report identifying strategies for maximizing the benefits obtained from natural gas as an energy source.[101] The report examines 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 also examines infrastructure and storage needs and pipeline and system reliability concerns.

- ARB's Cap-and-Trade Program will reduce demand of fossil fuels and provide incentives to accelerate efficiency and clean energy. Compliance Offset Protocols under the Cap-and-Trade Program provide methods to quantify, report, and credit GHG emission reductions from sectors not covered by the Cap-and-Trade Program. The Offset Protocols include a livestock protocol, rice cultivation protocol, and mine methane capture protocol.[102] 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.

A broad array of these and other state programs reducing dependence on fossil fuels are also already working to reduce methane emissions, especially from the oil and gas sector. Ultimately, fugitive methane emissions in the oil and gas sector are a function of our demand for these products. As state policies continue pushing our evolution away from conventional oil and natural gas, they will also help to reduce emissions of methane from the production and distribution of fossil fuels. In particular, efforts to improve efficiency or electrify appliances, buildings, and vehicles will not only reduce energy use and CO_2 emissions, but also serve to reduce or avoid fugitive methane

[101] *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

[102] As is discussed in more length in the CEQA document accompanying this document, the livestock offset protocol would likely cease accepting new projects for offset credits after the effective date of substantive regulations controlling agricultural methane from dairies; however, existing projects could continue generating credits throughout their crediting periods. ARB expects this continued funding stream, along with increased focus on regulatory and incentive measures in this area, to mean many projects now receiving offsets to continue functioning at the end of the crediting period; this, along with new regulations, will produce significant net reductions in methane even if some offset projects cease to function. This transition from offset protocols towards regulations has long been ARB policy.

emissions from the production, and potentially transmission and distribution, of oil and natural gas.

The State has strong targets to reduce the use of natural gas and petroleum by 2030, and several studies show that California must virtually eliminate the use of all fossil fuels to meet its 2050 climate targets. Notably, Governor Brown has called for reducing on-road petroleum use by up to 50 percent by 2030, and Senate Bill 350 (De León, Chapter 547, Statutes of 2015) requires the State to procure 50 percent of its electricity from renewable resources by 2030 and double the rate of natural gas and electricity efficiency savings. ARB's draft 2016 Mobile Source Strategy describes actions to achieve the State's air quality and climate targets from the transportation sector, and cut petroleum use by 50 percent by 2030. The State's Low Carbon Fuel Standard is sending a clear signal to the market that is leading to investment and use of a broad spectrum of cleaner transportation fuels in California including electricity, biogas, as well as biodiesel and renewable diesel, all of which are displacing petroleum. Further, the State's Cap-and-Trade program encourages efficiency and use of non-fossil energy sources across all sectors of the economy, and various programs provide billions of dollars in incentives to support energy efficiency throughout the State.

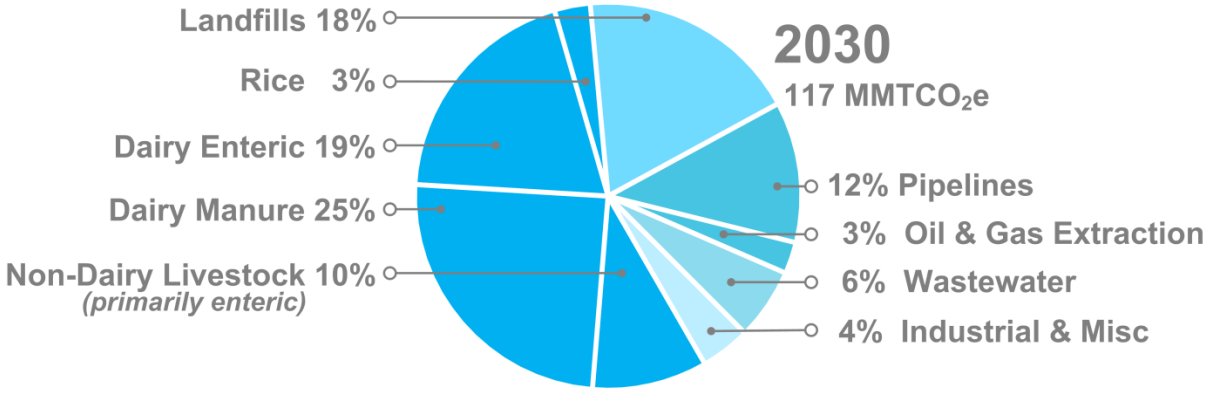
Effectively implementing these actions and programs will significantly cut demand for fossil fuels and associated CO_2 emissions on trajectories we need, while further reducing methane emissions from oil and gas systems. As State agencies implement and refine these programs and plans, they will seek opportunities to better align them with these objectives. Additionally, State agencies will support research to inform appropriate approaches to continue its transition away from fossil fuels.

Further, several efforts are underway at the CEC and ARB to improve emissions monitoring to help identify sources of fugitive methane emissions and reduce them. For example, the CEC provided research funding for operation of a mobile leak detection platform. In 2016, 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 wastewater 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. These efforts will help identify significant fugitive methane sources in California and improve leak detection.

Collectively, these measures will help to keep methane emissions in California fairly steady through 2030. However, the science-based pathway to limiting global warming

below 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 7). 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 7: 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 partnerships, systematic planning, and regulatory efforts. California's strategy to reduce methane emissions reflects and supports the variety of approaches and options available to achieve the goal in the most efficient, cost-effective, and environmentally-sensitive manner. This Proposed Strategy promotes and encourages opportunities for industry innovation, the efficient use of existing infrastructure and facilities, and supports the development of integrated systems across various sectors to handle, process, and reuse waste materials and captured methane. For example, significant anaerobic digestion and composting infrastructure capacity needs to be established, and appropriate market opportunities developed for compost and captured methane, before the State can fully use existing organic waste streams for beneficial purposes. State agencies will work with industry and other stakeholders to support and accelerate new project development and activities to maximize methane emission reduction at existing facilities. The State will also work with communities and regional stakeholders to plan and develop integrated infrastructure systems and markets to reduce wastes and associated emissions in the most environmentally-sensitive manner. By investing early and committing to the immediate resolution of issues that hinder progress, California can make significant progress in the near-term, and capture associated benefits.

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. 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, and overall, 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. The expected emission reductions for each sector are: 75 percent reduction of dairy manure methane from 2013 levels by 2030; 25 percent reduction of enteric fermentation methane by 2030; 90 percent diversion of organic waste by 2025; 40 percent reduction of wastewater and other industrial sources methane by 2030; and 45 percent reduction of oil and gas methane 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	
Wastewater, industrial and Other Miscellaneous Sources	7	
Oil and Gas Sector	8	
2030 BAU with new measures		**71**

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

1. Dairy Manure

California's dairy and livestock industries account for roughly half of the State's total methane emissions and 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.

California has the most dairy cows in the country and the highest aggregated dairy methane emissions. The State also has higher per-milking cow 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 solid-scrape (i.e. slurry) or dry 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 solid-scrape manure collection practices. The use of manure systems such as vacuum or scrape also allows for easier transport and storage of manure off-site or to centralized digester systems, which can improve economies of scale, biogas production efficiencies, and nutrient management on the dairy. Dairy manure can also be mixed with other organic materials diverted from landfills or at 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.

Dairies with flush water lagoon systems typically flood irrigate dairy feed crops, such as corn silage and alfalfa, to dilute and disperse nutrients from manure in the lagoon. This practice can lead to soil and groundwater contamination despite being subject to regulation by regional water quality control boards, including the Dairy General Order in the Central Valley. Solid-scrape 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 issues and animal welfare concerns due to heat exposure. Pasture dairy operations may still face potential nutrient management and groundwater

issues, and still must maintain some capacity to store liquid coming from milking parlor operations (chilling milk, cleaning facilities, etc.) for the required 100 year stormwater retention. 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. Pasture-based systems are a viable option that is appropriate in some cases, but likely challenging to implement at many existing, larger dairies in the Central Valley.

Captured biogas from dairy manure 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. However, tapping into this resource in California has been complicated in the past due to air quality constraints, especially in the Central Valley and Southern California. Utilizing newer and clean technologies can help to overcome air quality permitting issues that have previously hindered project development. In particular, technologies or strategies 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. For example, using ARB-certified distributed generation technologies, such as microturbines or fuel cells, can significantly cut NO_x emissions compared to internal combustion engines. Injecting biogas into the natural gas pipeline can avoid most new combustion or associated emissions altogether. As part of an integrated strategy that includes replacing diesel trucks and equipment with certified ultra-low NO_x vehicles or equipment, fueling vehicles with dairy-derived biogas could help to reduce criteria pollution in impacted air basins.

California will aim to reduce methane emissions from dairy manure management by at least 20 percent in 2020, 50 percent in 2025, and 75 percent in 2030. If dairy cow populations don't grow in California, in line with current forecasts, these reductions would reduce overall methane emissions from the dairy industry by more than 40 percent in 2030. Through this Proposed Strategy and related efforts, we can quickly and effectively reduce methane emissions from the State's largest source, while creating economic value in farming communities. 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 (see Chapter VIII). 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.

These targets can be achieved by capturing or avoiding methane currently emitted from lagoons or other anaerobically stored manure at a relatively small fraction of the State's dairies. For example, dairy manure emissions can be reduced by 75 percent by capturing or avoiding the methane generated by about 60 percent of the State's milking cows (1.05 million) on about 30-35 percent of the State's dairies (about 500 dairies).[103]

[103] California has over 1,400 dairies, with approximately 1,000 having more than 500 milking cows which might be suitable for methane capture or abatement (refer to Chapter VIII for a discussion on potential manure methane mitigation options and cost estimates).

The 2020 and 2025 targets could be met by capturing or avoiding methane generated by about 15 percent and 40 percent of the State's milking cows, respectively.

Depending on the strategies pursued to reduce emissions, individual dairies may be able to reduce emissions profitably, and the industry as a whole may be able to meet these targets at little or no net cost (see Chapter VIII). However, revenues in some cases are highly dependent on uncertain environmental credit and energy markets, as well as the ability to interconnect to natural gas pipeline systems, where economic and institutional barriers remain. If regulations impose costs on the industry that cannot be recouped, a result could be emissions leakage, if some dairies relocate outside of California or herd sizes grow elsewhere. This could include places where milk production efficiencies are lower and associated enteric fermentation emissions are higher and could increase mobile source emissions from heavy duty vehicles associated with transport of dairy products to established processing facilities and distribution centers.

Accordingly, the State will encourage and support near-term actions by dairies to reduce emissions through market support and financial incentives. At the same time, ARB will initiate a rulemaking process to develop regulations for dairy manure management in California. This coordinated approach will aim to develop a competitive, low-carbon dairy industry in California and avoid emissions leakage. Specifically, California will take the following steps to significantly cut methane emissions from manure management at dairies:

Accelerate Project Development and Emission Reductions at Dairies

The State will support the industry to accelerate project development and help the industry reduce emissions before regulatory requirements take effect. In particular, the State will work to support improved manure management practices through financial incentives, collaboration to overcome barriers, and other market support.

Continued State funding or incentives should support initial infrastructure investments to convert dairies away from flushwater management systems and support market opportunities for the use of captured or produced biomethane. CDFA estimates that at least $100 million will be needed for each of the next five years to support the development of necessary manure management infrastructure in the form of grants, loans, or other incentive payments. The economic analysis in Chapter VIII suggests that this level of funding could significantly accelerate project development by reducing capital costs and economic risks. Different types of funding mechanisms and level of support may be appropriate for different types of projects.

ARB and CDFA staff will establish a working group with other relevant agencies and stakeholders to focus specifically on solutions to barriers to dairy manure projects. The group will aim to ensure and accelerate market and institutional progress. It may cover several topics, including: project finance, permit coordination, CEQA, feed-in tariffs, simplified interconnection procedures and contracts, credits under the LCFS, increasing the market value of manure products, and uniform biogas pipeline standards. This group will be coordinated with similar working group efforts related to anaerobic digestion, composting, energy, healthy soils, and water. Additionally, 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 and with the air districts to ensure opportunities for air quality efforts are developed jointly.

In many cases, converting to scrape systems or installing anaerobic digesters at dairies may not yet be cost-effective, if the only marketable product is energy. However, if compost or other 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.[104] Markets for these other products need further support, however, before they can offer reliable returns to help finance projects. 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 LCFS and RIN credits, which could provide an especially valuable revenue stream.[105] The State will continue to support these efforts.

Develop Regulations to Ensure Emission Reductions

While the State will encourage early emission reduction actions by dairies through market support and financial incentives, regulations will be necessary to ensure manure management practices lead to lasting emission reductions. In 2017, and in coordination with CDFA and local air quality and water quality agencies, ARB will initiate a rulemaking process to reduce manure methane emissions from the dairy industry in-line with the objectives in this Proposed Strategy. The regulatory process will include

[104] For example, one report estimates that the average internal rate of return for dairy digester projects in the U.S. that only capture value from energy production would be about 8 percent in a mid-valuation scenario, but would increase to 38 percent if value can be captured from soil amendments and markets for environmental credits.
Informa Economics (2013) National Market Value of Anaerobic Digester Products, Prepared for the Innovation Center for U.S. Dairy, February.
[105] Under the LCFS, ARB recently approved a dairy digester fuel pathway with a carbon intensity of -276 gCO_2e/MJ. http://www.arb.ca.gov/fuels/lcfs/2a2b/apps/calbio-sum-122115.pdf
At credit prices of $100/MT, these credits could be worth about $5 per diesel gallon equivalent.

consideration of available financial incentives, market support, and the potential for emissions leakage in identifying appropriate timelines and requirements for the industry.

The rulemaking will also include requirements for mandatory reporting and recordkeeping of parameters affecting GHG emissions at California dairy farms. Reported information will be used to refine inventory quantification, evaluate policy effectiveness, and aid in future policy planning and regulatory development. ARB will work with other State agencies and industry groups to improve outreach on new reporting requirements, as well as merge and streamline reporting activities with current forms and requirements to avoid duplicative reporting wherever feasible.

Regulatory requirements to achieve large emission reductions from the industry will affect incentives for dairy methane reduction projects, such as the availability and amount of credits under the Cap-and-Trade program and LCFS. Once a regulation is in place, credits for avoided methane emissions under the LCFS or the Cap-and-Trade Programs would not be available for new projects as the reductions would not be additional to regulation or business-as-usual. However, projects in place before the regulation takes effect would still be able to generate credits for avoided methane emissions for their current crediting period, which is ten years of operation. For new projects after a regulation takes effect, credits under the LCFS would still be available, but would only consider the displacement of petroleum fuel. ARB will clarify the impact of potential regulations on LCFS credits before finalizing a regulation, and will make appropriate adjustments to the Cap-and-Trade Program to ensure only reductions that meet the AB32 offset criteria are credited. Sufficient lead time will be provided before regulatory requirements take affect to allow the market to react.

Research the Reduction Potential of Manure Management Practices

While the need and potential to reduce methane emissions from dairy manure is clear, some potentially effective strategies are still in the development stage. In particular, the use of solid separators and converting flush systems to dry manure management systems could be potentially low cost methods to reduce methane emissions. However, little data exists to quantify costs and benefits associated with these practices. Additionally, some uncertainty remains regarding cross-media impacts and accounting of various dairy manure management practices. ARB and CDFA will continue to support research to eliminate information gaps and improve understanding of potential manure management practices and their associated methane reduction benefits, as well as potential air quality or water quality impacts.

2. Dairy and Livestock Enteric Fermentation

Methane is also produced by the microorganisms involved in the digestive processes in the stomachs of dairy cows and other ruminants, such as sheep, goats, buffalo and cattle. This process is referred to as enteric fermentation. These emissions account for 29 percent of California's methane inventory, making 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 production efficiencies to reduce the amount of methane produced for a given amount of product, 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. Strategies to produce more easily digestible feed that lowers enteric fermentation might increase emissions associated with GHG-intensive feed production and transport. Therefore, regionally-specific lifecycle emission assessments of enteric fermentation emission reduction strategies would need to be used to account for any unintended emission increases in other sectors.

The dairy industry in California and the U.S. has been working to increase efficiencies associated with their operations and product. A broad coalition of the national dairy industry set GHG sustainability targets for 2020. The targets include reducing the GHG intensity of fluid milk by 25 percent,[106] and enteric fermentation emissions by 25 percent.[107] If a 25 percent reduction in enteric fermentation emissions from California's dairy cows were achieved by 2030, it would reduce the State's methane emissions by 5 $MMTCO_2e$ (based on a 20-year GWP).

This Proposed Strategy sets those levels as a goal for reducing methane emissions from enteric fermentation in California. Combined with the goals for manure management, this would bring emissions for the dairy industry down by 40 percent below current levels in 2030. By continuing historic annual improvements in milk production efficiency and progressing toward their established voluntary targets, the industry may meet this goal independently. Additionally, various studies are pointing to new feed supplements that have the potential to reduce enteric fermentation emissions 20-30 percent without affecting milk production.[108,109]

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

[107] 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

[108] Hristov et al (2015) An inhibitor persistently decreased enteric methane emission from dairy cows with no negative effect on milk production, *Proceedings of the National Academy of Sciences,* 112**(34)**:10663-10668. www.pnas.org/cgi/doi/10.1073/pnas.1515515112

[109] Moate et al (2014) Grape marc reduces methane emissions when fed to dairy cows, *Journal of Dairy Science,* 97**(8)**:5073-5087. http://dx.doi.org/10.3168/jds.2013-7588

Research Mitigation Strategies for Enteric Fermentation

Federal and State agencies, industry, and academia will support research through available funding mechanisms (e.g. ARB's annual research program, Greenhouse Gas Reduction Fund), 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. As ARB develops an emission reduction regulation for manure management, staff will continue to evaluate the latest science of enteric fermentation and identify the best approach to addressing these emissions.

3. Landfills

Landfilling 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 40 percent 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 through source reduction or diversion, but also improving the infrastructure for diverting and/or recycling organics, including minimizing and salvaging edible food wastes, composting, anaerobic digestion and other novel processes for energy recovery. In particular, 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 food recovery or waste avoidance, compost , soil amendments, mulch for erosion control, 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. Food rescue or recovery is the practice of utilizing edible foods that would otherwise go to waste from restaurants, grocery stores, dining facilities and produce markets and distributing it to local food programs. Food recovered from farms, which would otherwise be plowed under, is typically gathered by volunteers. The main benefit of food rescue programs is that they provide healthy foods to those in need, but they also reduce organic waste disposal. Food wastes that may not be easily utilized for human consumption may alternatively be used as animal feed. Composting returns nutrients to the soil, builds soil organic matter, improves water holding capacity, increases carbon sequestration in the landscape, and avoids the use of fossil fuel-intense inorganic fertilizers. Anaerobic digestion can 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 II, 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 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 divert 90 percent of organics from landfills by 2025, effectively eliminating the disposal of organics in landfills.[110] 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,[111] 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

[110] Specifics of this measure will be developed during the regulatory process. For the sake of calculating emission reductions in this plan, it is estimated that 75 percent of organics will be diverted from landfills by 2020 and 90 percent will be diverted by 2025 (this would amount to an 80 percent reduction below current levels).

[111] 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 Proposed Strategy.

average of collection efficiencies at California landfills is 78 percent.[112] However, this data is self-reported and the emission estimation method does not incorporate emission changes due 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. Continuing evaluation of major sources of methane in the State is necessary, and this includes landfill emissions.

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.

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

Require Organics Diversion from Landfills

ARB, in conjunction with CalRecycle, will develop a regulation by 2018 to effectively eliminate the disposal of organics in landfills by 2025. Under this proposed regulation, the agencies will explore and prioritize opportunities to recover organic materials through local food waste prevention and rescue programs, which could account for 10 percent food waste reduction by 2020 and 20 percent reduction by 2025 in California. Food waste prevention includes activities such as education regarding food preparation and storage, refining food purchasing practices, and software that can help inform food ordering and menu selections. Rescue includes local organizations such as homeless shelters, food banks and community kitchens that provide food for people in need. Material that cannot be effectively recovered would be diverted to organics recycling facilities to make useful products,

[112] 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

including compost, fuel or energy. These facilities may be developed at existing landfills, other waste management sites, or at new stand-alone sites. Organic wastes could also be diverted to regional wastewater treatment plants or dairies for co-digestion with wastewater sludge, biosolids, or manure. Local governments must play an important role in diverting organics both as land use and permitting authorities for recycling facilities and as partners in implementing diversion requirements. The State will work with its local partners to develop helpful tools such as programmatic EIRs or guidance documents. Community engagement in the planning and environmental review processes is critical, both for understanding and mitigating potential negative health and environmental impacts and for understanding the positive economic and health and environmental benefits afforded by such projects.

Align Financial Incentives with Organics Diversion

Eliminating organics disposal in landfill will require additional infrastructure capacity to process and reuse diverted organic waste from landfills—through composting (including chipping and grinding), anaerobic digestion, or other methods. Continued, increased State funding is critical to building this necessary infrastructure. An increase in California's Integrated Waste Management Fee is also needed to support the establishment of food rescue programs, discourage the landfilling of organic waste and other recyclables, and provide funding to support organics recycling infrastructure. CalRecycle estimates that State support of at least $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 and provide 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 to guide the direct application of organic materials on land and ensure this activity does not pose a threat to human or environmental health.

Foster Recovery Programs and Markets

CalRecycle will work collaboratively with other agencies and departments to help establish food rescue programs and to identify, develop, and expand markets for the use of compost, mulch, and renewable fuels and energy. CalRecycle and CDFA will continue their efforts to incentivize the use of compost on agricultural lands in support of the 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 mulch and 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 and other potential 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. 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.

4. Wastewater Treatment and other Miscellaneous Sources

Wastewater treatment, industrial operations, rice cultivation, septic tanks, and other sources of methane account for about nine percent of the State's methane inventory.

Wastewater treatment plants provide a promising complementary opportunity to help divert a portion of organic wastes from landfills and create useful byproducts such as electricity, biofuels and soil amendments. Wastewater treatment plants are designed to remove contaminants from wastewater, primarily from household sewage, but with infrastructure improvements could increase acceptance of food waste and fats, oils, and grease (FOG) for co-digestion. Anaerobic digestion is a typical part of the wastewater treatment process employed at most of the larger plants, with many plants capturing the methane they currently generate for on-site heating or electricity needs.

Many of these plants may have spare capacity, and can potentially take in additional sources of organic waste for anaerobic digestion. Existing or new digesters at these facilities can be designed to co-digest materials such as food waste and FOG from residential, commercial, or industrial facilities. Many of the largest plants are ideally located close to population centers and could potentially obtain and process significant amounts of food and other suitable waste streams within the region. The State proposes to take the following actions to evaluate this opportunity.

Develop Regional Opportunities to Co-Digest Waste

ARB will work with CalRecycle, the State Water Resources Control Board, Regional Water Quality Control Boards, and others to determine opportunities to support the co-digestion of food-related waste streams at existing and new digester facilities, including wastewater treatment plants.

Align Financial Incentives with Methane Capture and Reuse at Wastewater Treatment Facilities

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 (ideally to produce on-site renewable electricity, transportation fuel, or pipeline biogas), and maximize digestion of regional organic materials. The potential actions would need to be tailored to each wastewater treatment plant based on size or capacity, and other factors such as potential for co-digestion expansion, proximity of organic 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.

Collaborate to Overcome Barriers

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. In addition, the beneficial use of methane generated at wastewater treatment facilities faces many of the same hurdles faced by dairy digesters and organic waste composting facilities. Support for technologies and strategies to capture biogas to generate electricity, supplement natural gas pipeline fuel, or for use as a transportation fuel, is needed to overcome some of these barriers and may open up more valuable fuel and credit markets. ARB will work with other relevant State and local agencies to identify and remove financial and regulatory barriers that hinder the productive use of waste streams processed at wastewater treatment plants.

5. 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; 22 compressor stations; and 25,000 metering and regulating stations (M&R) stations. Natural gas is currently California's largest source of fuel for electricity generation, 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 the residential and commercial sectors.

Much of the equipment in the oil and gas industry has been regulated for decades by the local air districts. 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. In 2015, U.S. EPA proposed additional federal measures that could address methane primarily at new oil and natural gas sources, with coverage at some existing sources. 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 oil and gas infrastructure. Effectively implementing this framework can reduce methane emissions from oil and gas systems by 40-45 percent in 2025, matching federal commitments.[113] Additional opportunities may emerge to further reduce emissions from infrastructure and will be considered when they do. But further reducing methane emissions from the oil and gas sector will ultimately require reducing in-state demand. A rapid decline for demand for oil and natural gas is also necessary to meet the State's 2030 and 2050 climate targets, more broadly.

About 90 percent of California's natural gas comes from out of State, and ultimately, action by other jurisdictions is needed to minimize leaks associated with our natural gas use. The Obama administration has taken steps to address oil and gas sector methane emissions, especially at the point of production, but more may need to be done to reduce emissions from pipelines and other equipment out-of-state. There may be steps that California agencies or utilities can take to ensure that infrastructure supplying gas to the state has minimal leakage, and to ensure that natural gas is providing environmental benefits compared to use of other fossil fuels in the State.

The State's framework on oil and gas methane emissions includes the following elements:

Adopt and Implement a Greenhouse Gas Emission Standards For Crude Oil and Natural Gas Facilities Regulation

ARB is currently working with local air districts and other stakeholders to develop a regulation for Board consideration by mid-2016. The proposed regulation, still being developed, will likely require:

[113] For the purposes of calculating emission reductions in 2030, Table 6 assumes a 45 percent reduction below current levels by 2030.

- 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, as well as from soil at underground natural gas storage well sites;
- 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";
- "No bleed" pneumatic devices and pumps; and
- More frequent methane monitoring at underground natural gas storage facilities.

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 to ensure that any combustion-based controls will not interfere with efforts to achieve and maintain compliance with ambient air quality standards in cases where methane and VOC emissions cannot be sent into existing sales lines, fuel lines, or reinjection wells, and are instead captured by installing new vapor collection on existing storage tanks, with the collected vapors being sent to a low-NOx incinerator that will replace an existing flare.

Improve Monitoring and Standards to Detect and Minimize Emissions

ARB and DOGGR are working together to ensure that both above and below ground monitoring of storage facilities is improved. As mentioned above, ARB is considering improved above-ground methane monitoring of underground storage facilities in its upcoming Oil and Gas Production, Processing, and Storage Regulation. In January 2016, DOGGR released notice of an emergency regulatory action to implement protective standards specifically designed to ensure that operators of underground gas storage facilities are properly minimizing risks and taking all appropriate steps to prevent uncontrolled releases, blowouts, and other infrastructure-related accidents. The emergency regulations will ensure that operators of existing underground gas storage facilities monitor for and report leaks to DOGGR, function test all safety valve systems, perform inspections of wellheads and surrounding area and equipment, develop risk management plans that require verification of mechanical integrity and corrosion assessment and monitoring, and provide DOGGR with complete project data and risk assessment results. Immediate implementation of these standards will ensure that underground gas storage facilities are properly operated, minimizing the potential that an incident such as the gas leak at the Aliso Canyon Natural Gas Storage Facility does

not recur.[114] ARB and DOGGR will coordinate on the monitoring provisions to ensure consistency and comprehensiveness while limiting duplication.

Additionally, Assembly Bill 1496 (Thurmond, Statues of 2015, Chapter 604) requires ARB, in consultation with scientific experts and other state, local, and federal agencies, to undertake monitoring and measurements of high-emission methane "hot spots" and conduct lifecycle GHG emission analysis for natural gas produced in and imported into California. Pursuant to this bill, ARB will continue its efforts related to hot spots monitoring and lifecycle greenhouse gas accounting for fuels, and will host a scientific workshop to collect the best available knowledge on these topics. ARB will update relevant policies and programs to incorporate any new information gathered as a result of these efforts.

Effectively Implement SB 1371 to Reduce Emissions from Pipelines

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 2015, 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 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;

[114] Preliminary estimates suggest the incident resulted in about 8 $MMTCO_2e$ (AR5 20-year GWP) of methane emissions, an approximately 20 percent increase in statewide methane emissions for the duration of the leak (October 23, 2015–February 17, 2016). Governor Brown's January 2016 Aliso Canyon Proclamation directs the ARB to develop a mitigation plan for the leaked methane emissions by March 31, 2016. It can be accessed at: http://www.arb.ca.gov/research/aliso_canyon/arb_aliso_canyon_methane_leak_climate_impacts_mitigation_program.pdf

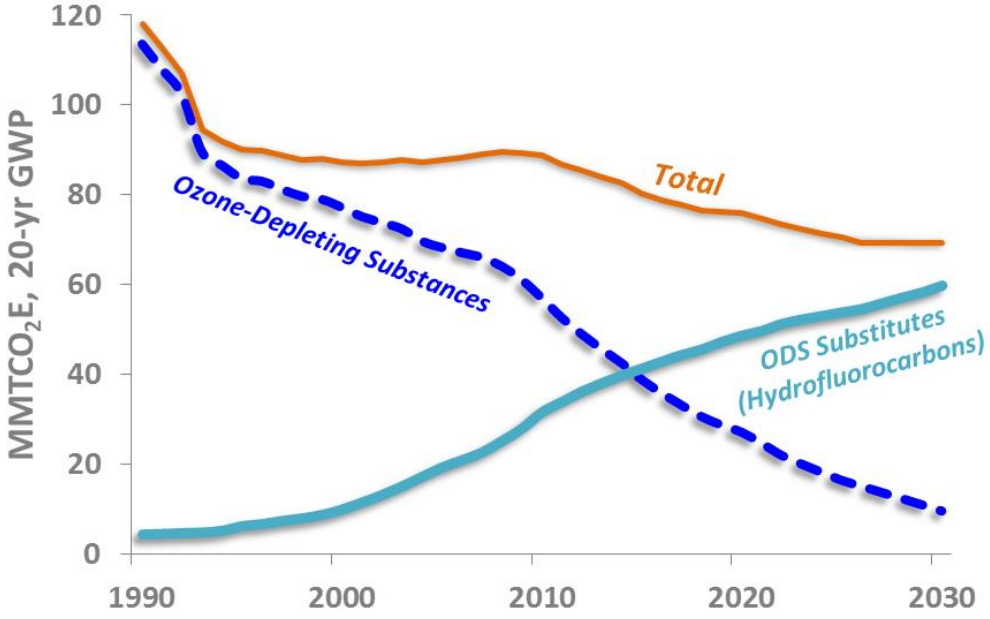
- Analyzing emission data to determine potential mitigation strategies. For example, the proceeding may require the replacement of older pipelines or pipelines constructed of a certain material;
- Identifying any remaining data gaps;
- Establishing procedures for the development and use of metrics to 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.

VI. Reducing HFC Emissions

Hydrofluorocarbons (HFCs) are the fastest-growing source of GHG emissions both globally and in California. HFCs are fluorinated gases (F-gases), which also include the ozone-depleting substances (ODS) that are being phased out under the Montreal Protocol. HFCs 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 8).

Figure 8: Emission Trends of ODS and ODS substitutes (hydrofluorocarbons) – (as ODS are phased out, HFCs increase)

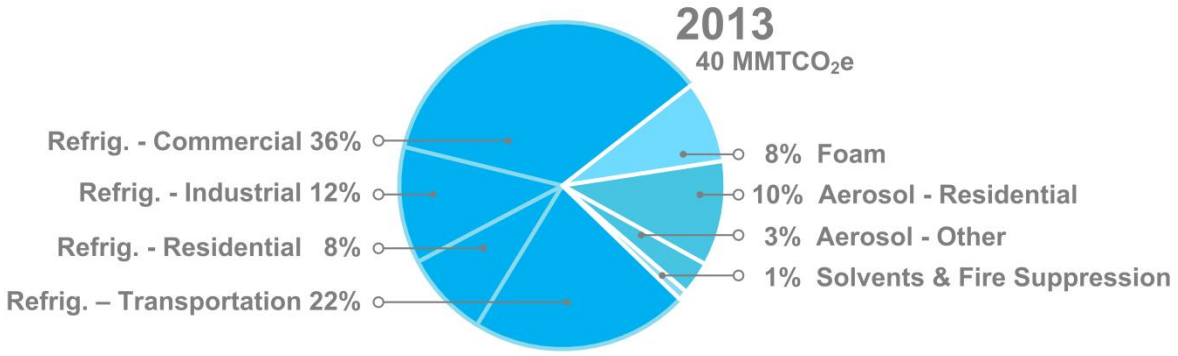


The majority of HFC emissions come from fugitive emissions of refrigerants used in refrigeration and air-conditioning (AC) systems. The largest uses of HFCs are in commercial and industrial refrigeration and air-conditioning, which comprise 48 percent of HFC emissions. More than half of refrigeration 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. by 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 by 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.

HFC 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 HFC emissions from the transportation sector will decline. Aerosol propellants (industrial, consumer, and medical dose inhalers) comprise 13 percent of HFC emissions, and insulating foam expansion agents contribute another eight percent of HFC emissions. Solvents and fire suppressant emissions contribute one percent of all HFC emissions. Figure 9 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 9: California 2013 Hydrofluorocarbons (HFCs) Emission Sources*



*Using 20-year GWP

This Draft Proposal identifies measures that can reduce HFC emissions by 40 percent in California by 2030. They represent a reasonable path forward for California, but the State's approach on HFCs could be affected by a potential international agreement that may be reached in 2016 to phase down the use of HFCs globally.

A. Progress to Date

California is among the world's leaders in reducing HFCs and other F-gas emissions. Measures adopted under AB 32 have reduced emissions from a variety of sources. The State's Cap-and-Trade offset protocol for ozone depleting substances incentivizes the capture and destruction of ODS refrigerants and foam expansion agents. 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 future 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.[115] 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 2014 levels by 2030.[116,117]

Additionally, in response to President Obama's Climate Action Plan, in September 2014, and again in October 2015, the White House announced private sector commitments and executive actions to reduce emissions of hydrofluorocarbons (HFCs).[118,119] U.S. industry is leading the way by investing billions 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.

Further private sector commitments were made in February 2016, when both the Air Conditioning Heating & Refrigeration Institute (AHRI) and the Association of Home Appliance Manufacturers (AHAM) made voluntary commitments to phase down the use of high-GWP HFCs in new equipment.[120,121]

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[115] 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

[116] 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/.

[117] 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

[118] Fact Sheet: Obama Administration Partners with Private Sector on New Commitments to Slash Emissions of Potent Greenhouse Gases and Catalyze Global HFC Phase Down. September 16, 2014: http://www.igsd.org/documents/20140916HFCFactSheet.pdf

[119] Fact Sheet: Obama Administration and Private-Sector Leaders Announce Ambitious Commitments and Robust Progress to Address Potent Greenhouse Gases. October 15, 2015. https://www.whitehouse.gov/the-press-office/2015/10/15/fact-sheet-obama-administration-and-private-sector-leaders-announce.

[120] AHRI and Natural Resources Defense Council (NRDC) February 1, 2016 petition to U.S. EPA Significant New Alternatives Policy (SNAP) Program to remove high-GWP HFCs from the list of

In March 2016, the U.S. EPA proposed additional bans on high-GWP HFCs in new retail food refrigeration, cold storage, chillers used for air-conditioning, and household refrigerator-freezers.[122] The proposal had not been adopted as of April 2016.

Substantial progress has also been made to safely use natural refrigerants (such as CO_2, ammonia (NH_3), and hydrocarbons (HCs), with GWPs at or near zero) 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 250 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.

In addition to the natural refrigerants, a new generation of fluorinated refrigerants known as hydrofluoro-olefins (HFOs) have been developed that are non-ODS and have GWP values less than five. HFOs can be used in pure form for some cooling applications, such as motor vehicle AC, and are also used in blends with HFCs for other cooling applications, such as commercial and industrial refrigeration. Initial results indicate that the newest generation of fluorinated refrigerants perform as well as the high-GWP HFCs they replace.

These State and national efforts will lead to significant reductions in HFC emissions in California through 2030, compared to where they would be otherwise. Still, HFC emissions in California are expected to grow by more than 60 percent without additional action (Figure 10).

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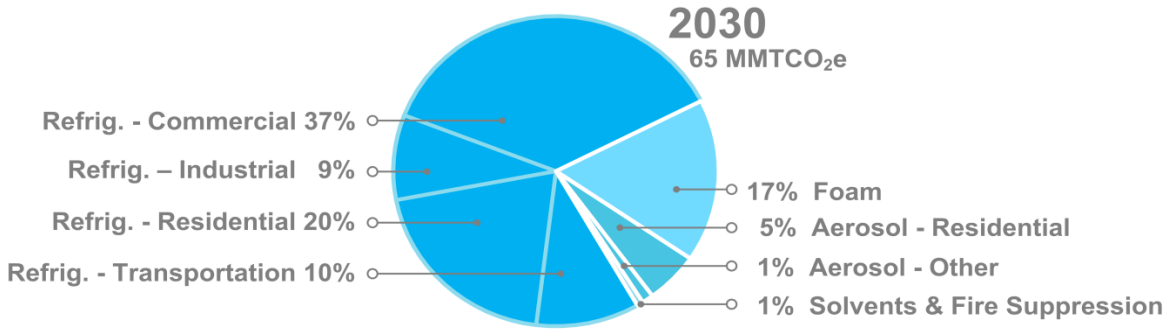
acceptable substitutes in new air-cooled and water-cooled chillers using centrifugal, screw, scroll, and all other compressor types.

[121] "Home Appliance Industry Sets Goal to Eliminate Use of HFC Refrigerants", Press Release February 9, 2016 from Association of Home Appliance Manufacturers (AHAM). http://www.prnewswire.com/news-releases/home-appliance-industry-sets-goal-to-eliminate-use-of-hfc-refrigerants-300217501.html.

[122] Fact Sheet. Proposed Rule - Protection of Stratospheric Ozone: New Listings of Substitutes; Changes of Listing Status; Reinterpretation of Unacceptability for Closed Cell Foam Products under the Significant New Alternatives Policy Program; and Revision of Clean Air Act Section 608's Venting Prohibition for Propane. U.S. EPA, March 29, 2016. https://www.epa.gov/snap/snap-regulations

Figure 10: California's 2030 HFC Emission Sources with Existing Measures*



*Using 20-year GWP

B. Recommended Actions to Further Reduce HFC Emissions

The State supports strong, national, and international actions to reduce HFC emissions. The U.S. EPA has already taken a number of steps to prohibit the use of new high-GWP HFCs in consumer product aerosol propellants, polyurethane insulating foam, and light-duty mobile vehicle air-conditioning. An international agreement could be reached in 2016 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 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 by the end of 2016, 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 remain to reduce their 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

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 Proposal describes a set of potential measures that can reduce HFC 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.

Table 7: Proposed New HFC Emission Reduction Measures and Estimated Emission Reductions ($MMTCO_2e$)[1]

Measure Name	2030 Annual Emission Reductions	2030 Annual Emissions
2030 BAU[2]		**65**
Financial Incentive for Low-GWP Refrigeration Early Adoption	2	
HFC Supply Phasedown	19	
Sales ban of very-high GWP refrigerants	5	
Prohibition on new equipment with high-GWP Refrigerants	15	
2030 BAU with new measures		**24**

[1]Using 20-year GWPs from the 4th Assessment report of the IPCC
[2]"Business as Usual" (BAU) forecasted inventory includes reductions from implementation of current ARB and U.S. EPA regulations

Incentive Programs

In his 2016-2017 Proposed Budget, Governor Brown includes $20 million for a financial incentive program to defray the potential added cost of installing new low-GWP refrigeration equipment or converting existing high-GWP systems to lower-GWP options. This program could provide immediate and ongoing 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 with large commercial refrigeration systems in California currently use HCFC-22 refrigerant. This refrigerant has not been allowed in new equipment since January 2010, and 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 can be cost effective, in most 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.

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. Broad-based national or international agreements are the most effective phasedown approaches, minimizing the possibility of simply displacing emissions to other locations.

In the international arena, countries met in Dubai in November 2015 to discuss an HFC phasedown amendment to the Montreal Protocol. The meeting did not result in a specific phase-down agreement, but the outcome was viewed as positive by most participants, with countries agreeing to a series of meetings in 2016 designed to reach an international phase-down. If a national or international HFC phasedown agreement cannot be reached in 2016, ARB may pursue a California HFC phasedown schedule that will help meet the State GHG emission reduction goals. California would seek a partnership with the EU, Canada, Japan, and Australia, all of which are 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 HFCs allowed. A broad-based phasedown program significantly reduces the number of regulated entities compared to downstream regulation, causes minimum disruption to industry, and guarantees emission reductions. Industry stakeholders generally favor a phasedown approach as a technically feasible, fair, 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 100-year GWP values of 2500 or greater, beginning January 1, 2020. Refrigerants that are certified reclaimed or recycled would be exempt from the sales ban.

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 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, as follows:

Stationary Refrigeration or Stationary Air-Conditioning Sector	**Refrigerants Prohibited in New Equipment with a 100-year GWP Value:**	**Proposed Start Date**
Non-residential refrigeration	150 or greater	January 1, 2020
Air-conditioning (non-residential and residential)	750 or greater	January 1, 2021
Residential refrigerator-freezers	150 or greater	January 1, 2021

Certain exceptions could be made to any maximum GWP limit if a low-GWP refrigerant is not technically feasible in a specific application. GWP limits may be subject to change as additional low-GWP refrigerants become available. For example, low and medium-pressure chillers used for air-conditioning may be able to use refrigerants with a GWP less than 150.

Low-GWP commercial refrigeration using ammonia is already extensively used in food processing and cold storage. Additionally, more than 250 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 5,200 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, although newly demonstrated adiabatic cooling technology has promise to neutralize energy efficiency concerns. Alternatively, 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 88 and 1400, and their use would reduce GHGs in these systems by

more than 75 percent compared to business as usual.[123] 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.

Current fire and appliance codes do not allow the use of hydrocarbon refrigerants, which are flammable, unless the system is below a small charge size threshold of 150 grams for commercial refrigerators, and 57 grams for household refrigerators. Experience in Europe and other jurisdictions demonstrates that these codes can be designed to allow for the use of these refrigerants while ensuring safety, where current limits are 150 grams for household refrigerators and up to 1.5 kg for commercial uses. 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.

Additional measures that may be more effectively addressed at the Federal level include prohibitions on high-GWP HFCs 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 HFC emissions from these sectors, and may pursue state-level measures if progress is not made on the Federal level.

[123] HFOs are hydrofluoro-olefins, an emerging class of F-gas with very low GWPs of 1-5, but which are classified as slightly flammable (A2L). By blending HFOs with HFCs, refrigerant blends which are non-flammable have been created and U.S. EPA SNAP-approved for certain applications.

C. Sulfuryl Fluoride

Sulfuryl fluoride (SO_2F_2) is a pesticide fumigant and one of the most common replacements for methyl bromide, an ozone-depleting substance whose use is being phased out. Sulfuryl fluoride is regulated by the California Department of Pesticide Regulation (DPR), and was listed as a toxic air contaminant (TAC) in 2006. As a pesticide and TAC, sulfuryl fluoride's use is strictly controlled. In December 2015, DPR submitted a report to the Legislature, which provided an update on adopted control measures for sulfuryl fluoride,[124] as required by AB 304 (Williams, Chapter 584, Statutes of 2013). DPR plans to develop additional mitigation measures by September 2016, to address unacceptable exposures of sulfuryl fluoride to bystanders and residents. Sulfuryl fluoride is not registered for use as a field soil fumigant and is not used on agricultural fields.

Until 2009, sulfuryl fluoride was believed to have a negligible GWP. Further research concluded that SO_2F_2 has a 20-year GWP of 6840, with a lifetime of several decades. According to the DPR, 3 million pounds of sulfuryl fluoride were used in California in 2013 (most recent data available).[125] Its main use is as a structural pest control fumigant to kill drywood termites in homes and buildings, accounting for 82 percent of all usage in 2013. Sulfuryl fluoride is also a common fumigant for dried fruits, nuts, and other agricultural commodities that must be kept pest-free during storage prior to shipping (15 percent of all usage in 2013). The remaining three percent of sulfuryl fluoride application was for other fumigation uses. A complete listing of sulfuryl fluoride usage in California by commodity is listed in Appendix A.

Because sulfuryl fluoride was not identified as a high-GWP gas by the time AB 32 was enacted, it was not initially included as a part of ARB's statewide GHG inventory. However, the annual usage of sulfuryl fluoride is inventoried by DPR as a highly-regulated pesticide and ARB uses this data to track emissions. In 2013, the 3 million pounds of SO_2F_2 usage was equivalent to 9.4 $MMTCO_2E$ emissions (using 20-year GWP values), or approximately 20 percent of all F-gas emissions.

Identifying less toxic or lower-GWP alternatives to sulfuryl fluoride remains problematic. Methyl bromide (CH_3Br), with a 20-year GWP of 17, was the pesticide fumigant of choice for many applications until its use was almost completely phased-out by the Montreal Protocol because of its ozone-depleting potential. Currently, sulfuryl fluoride is the only fumigant registered for treating structural pests in California. Termites or other wood-destroying pests are detected in over 250,000 California homes each year, with the cost of control and repair of damage from dry-wood termites in California exceeding $300 million annually (with 80 percent of fumigations occurring in Southern California).

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[124] Report to the Legislature Required by AB 3014 (2013) Food & Agricultural Code Section 140124(c)(2)(A): Update on the Adoption of Control Measures for the Toxic Air Contaminant Sulfuryl Fluoride. Report submitted by the California Department of Pesticide Regulation to the California Legislature, December 22, 2015.

[125] Summary of Pesticide Use Report Data 2013 - Indexed by Commodity, California. California Department of Pesticide Regulation, May 2015. Available at: http://www.cdpr.ca.gov/docs/pur/pur13rep/13_pur.htm.

For agricultural commodity fumigation storage (primarily dried fruits and nuts), methyl bromide is still used on a limited basis through special use exemptions, although its use is decreasing annually. An alternative fumigant, phosphine (PH_3), with a GWP of 0, is also used as an alternative to methyl bromide and sulfuryl fluoride. However, reported insect tolerance to phosphine has limited its widespread usage.[126] Non-chemical commodity treatment has been studied since 1995, including irradiation, and controlling the atmosphere to "suffocate" insects in either low-oxygen or high carbon dioxide environments.[127] Chemical treatment remains dominant due to cost and feasibility issues of non-chemical alternatives.

The effectiveness of less toxic (and lower-GWP) alternatives to sulfuryl fluoride in structural fumigation for drywood termites is the subject of much research, opinion, and disagreement. Structural fumigation generally includes tenting the entire structure and treating it to kill termites, or more rarely, wood-boring beetles and other pests living in the structure. While many termite control companies only use sulfuryl fluoride, many others have begun using alternative termite control methods, including orange oil, structure heating or extreme cooling, microwaves, and electricity. Additional research is required before sulfuryl fluoride mitigation measures can be proposed. ARB will continue working with the DPR to assess mitigation measures to sulfuryl fluoride emissions. Additional discussion on potential research of sulfuryl fluoride mitigation is included in Appendix B.

[126] Phosphine Fumigation of Stored Agricultural Commodity - Programmatic Environmental Assessment. November 2013. United States Agency for International Development (USAID), prepared under USAID's Global Environmental Management Support (GEMS) project. Available at: http://www.usaidgems.org/documents/fumigationpea/fumigationpeafeb24_2014.pdf.

[127] Alternatives to Methyl Bromide: Research Needs for California - Report of the Methyl Bromide Research Task Force To The Department of Pesticide Regulation and The California Department of Food and Agriculture. September, 1995. Available at: http://www.cdpr.ca.gov/docs/emon/methbrom/mb4chg.htm.

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 Proposed Strategy acknowledges that further reductions in black carbon from California's freight system will be realized through strategies identified in the California Sustainable Freight Action Plan. 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 SLCP Emission Reduction Goals
CalRecycle AB 341 Report to the Legislature
California Sustainable Freight Action Plan
Additional Scoping Plan Updates
2016 California State Implementation Plan
Auction Proceeds Investment Plan
Caltrans Strategic Management Plan for 2015-2020
Funding Plan for Low Carbon Transportation Investments and the Air Quality Improvement Program
Mobile Source Strategy
ARB Annual Research Plan
Climate Change Research Plan for California
California Water Action Plan
CEC Electric Program Investment Charge Program
Annual Investment Plan for Alternative and Renewable Fuels and Vehicle Technology Program
DWR Climate Action Plan
Bioenergy Action Plan
Forest Carbon Plan
Healthy Soils Initiative

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 Proposed 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, especially if these action plans begin to incorporate SLCP emission inventories and mitigation actions.

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 emissions of SLCPs. Many GHG emission 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.

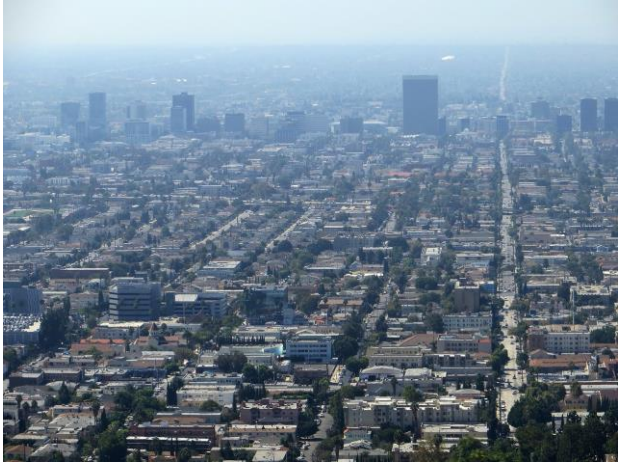
Methane

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 utilizing methane beneficially at wastewater treatment plants. Many local agencies own and operate wastewater treatment facilities and are implementing strategies 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 sectors. Wastewater treatment plants offer a tremendous opportunity to divert organics from landfills and utilize them for producing energy, transportation fuel, 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 wastewater 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, in October 2015, the Bay Area Air Quality Management District adopted a new rule banning all wood burning devices in new construction. 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 Pollution Control 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.

HFCs and other F-gases

Local air districts can play an instrumental role in aiding the reduction of HFC emissions, 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 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. To guide the investment of Cap-and-Trade auction proceeds, the Department of Finance, in consultation with the Air Resources Board and other State agencies, is required to submit a triennial Investment Plan to the Legislature. The Investment Plan identifies priority investments that will help California achieve its GHG emission reduction goals while realizing additional health, economic, and environmental benefits. The Investment Plan is required to identify near-term and long-term greenhouse gas emission reduction goals and targets, analyze gaps in current State funding for meeting these goals, and identify priority investments that facilitate GHG emission reduction. The second Investment Plan for Fiscal Years 2016-17 through 2018-19 was submitted to the Legislature in January 2016. The Second Investment Plan identifies potential State investment priorities to help achieve GHG emission reduction goals, benefit disadvantaged communities, and yield valuable co-benefits within the Transportation & Sustainable Communities, Clean Energy & Energy Efficiency, and the Natural Resources and Waste Diversion categories. The priorities identified in the Second Investment Plan would reduce a range of GHGs, including short-lived climate pollutant emissions. The Second Investment Plan informed Governor Brown's 2016-2017 Proposed Budget, which includes $215 million of Cap-and-Trade expenditures specifically targeting SLCP emission reductions. These include $40 million for black carbon residential woodsmoke reductions, $20 million for HFC reductions from refrigerants, $100 million for waste diversion, $20 million for Healthy Soils, and $35 million for dairy digester development.

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. CalRecycle administers greenhouse gas reduction grant and loan programs that include incentives for infrastructure supporting organics diversion.

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.

At the 2014 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. At UN climate meetings in New York and Paris in 2015, Governor Brown presented the targets described in this Proposed Strategy, and suggested that action on SLCPs may be the most important and most immediate need to address climate change. 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 Proposed 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.[128] These types

[128] NEA (2014) Summary of Proposed Action Plan for Norwegian Emissions of Short lived Climate Forcers, Norwegian Environment Agency, March.

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.

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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 Proposed Strategy. It also discusses the environmental analysis that was prepared for the Proposed Strategy. It should be noted that to the extent that any of the proposals in the Proposed 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.

A. Economic Assessment of Measures in the Proposed Strategy

This section presents the economic analyses for the new measures identified in this Proposed Strategy. Supporting documentation for this analysis is presented in Appendix D. Activities already underway separately—including development of the California State Implementation Plan to meet federal health-based air quality standards, the California Sustainable Freight Action Plan, the 2030 Target Scoping Plan, and implementation of Senate Bill 1371 (Leno, Chapter 525, Statutes of 2014)—will have important impacts on SLCP emissions in California, but are not evaluated here. Also, economic impacts associated with improved forest management to reduce black carbon emissions from wildfires and address additional State goals for forest management are not considered here, as many of those goals and potential actions to are currently under development through separate planning processes. As described in Chapter IV, improving forest management in California requires a significant financial commitment, on the order of $500 million to $1 billion annually, which can complement efforts to put organic waste resources to beneficial use in California, as described in this section for the dairy and waste sectors.

The analyses presented here consider direct economic costs associated with new technologies and management strategies that can help to reduce SLCP emissions. They also consider direct economic benefits in the form of savings as a result of efficiency improvements, or revenue from marketable products. This analysis does not include a macroeconomic analysis at the statewide level, nor does it include a monetary accounting of societal benefits, such as the value of reducing exposure to fine particulate pollution or reducing the impacts of climate change.

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

Long-term regulatory signals can play a vital role in facilitating low cost SLCP emission reductions. The Low Carbon Fuel Standard (LCFS) and the federal Renewable Fuel

Standard (RFS) incentivize the use of renewable natural gas as a transportation fuel, creating large revenue potential within the dairy manure and organic diversion measures. These programs in particular can help support cost-effective projects to reduce methane from the dairy and waste sectors. Without the LCFS and RFS programs, additional sources for financial incentives and funding may be needed.

The measures laid out in this Proposed Strategy are transformative, leading to uncertainty in the potential costs and revenue of proposed measures as well as the ultimate pathway to compliance. There is a wide range of potential costs and savings, uncertainty in how the strategies will be met, and uncertainty in some cases for how costs in literature translate in the California context. In conjunction with State agencies, ARB will continue to work closely with stakeholders and manufacturers to evaluate the feasibility and costs of existing and developing technologies to determine the best approaches to meeting the targets in the Proposed Strategy.

The measures included in the Proposed Strategy will also strengthen California's environment and the economy by developing infrastructure, generating cost savings, and creating jobs. Measures that reduce methane emissions through waste digestion will have a large impact on the California economy, including disadvantaged communities.

The dairy manure measure has the potential to create jobs in California's Central Valley. These jobs include construction jobs to build digesters and farm and waste management jobs to operate and maintain the facilities. In this analysis, it is assumed that the construction of an anaerobic digester for a 2,000 head dairy farm can result in 25 to 60 construction jobs and 2 to 5 full-time farm jobs.[129] As the dairy manure measure is estimated to impact 1.05 million dairy cows, many in the San Joaquin Valley, the measure could result in over 30,000 construction jobs and 2,500 permanent jobs potentially providing employment opportunities in disadvantaged communities.

Diverting organic waste can also result in increased employment, providing an estimated 2 jobs per 1,000 tons of diverted organic material.[130] In 2030, this could result in 32,000 jobs in waste management and garbage collecting, food recovery and distribution. As demonstrated in the CalRecycle funded Food to Share project, food waste prevention programs not only produce emission reductions, but employment and nutritious meals to California's most vulnerable populations.[131]

The proposed measures will also build on and support existing California efforts related to climate change and air quality. Measures will support infrastructure, research, development, and deployment of advanced technologies that will help achieve

[129] Sample of industry information relied upon for the estimate: http://www.gundersenenvision.org/renewable-energy/turning-cow-waste-into-energy-middleton and http://www.usda.gov/oce/reports/energy/Biogas_Opportunities_Roadmap_8-1-14.pdf.
[130] http://www.calrecycle.ca.gov/publications/Documents/1463%5C20131463.pdf
[131] More information available at: http://greenlining.org/wp-content/uploads/2015/10/CAClimateInvestmentsCaseStudies.pdf.

California's near- and long-term climate and air quality goals. Encouraging the collection of methane gas from waste streams, for example, can provide renewable fuel to reduce the carbon footprint of the transportation sector. Plans that stand to benefit from proposed SLCP measures include the 2030 Target Scoping Plan Update, the California State Implementation Plan, and California's Sustainable Freight Action Plan.

The 2030 Target Scoping Plan, expected to be finalized in 2016, will include a detailed macroeconomic assessment of ARB's complete climate change strategy, including those contained in the final SLCP Strategy. While this Proposed Strategy begins to explore the costs and benefits of proposed measures, detailed economic analyses will allow for a comprehensive assessment of the impact of California's climate strategy on Californians, businesses, and the California economy.

All proposed regulatory SLCP strategies will also be subject to the economic requirements of the Administrative Procedures Act (APA) as part of the public regulatory 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. Therefore, there will be many opportunities to assess the economic impact of measures in the Proposed Strategy.

The costs, savings, and potential revenue streams of the five measures are assessed in the following sections, 1 through 5. Collectively, implementing these measures would require several billion dollars of investment in clean technologies and strategies that would lead to significant reductions in SLCP emissions. Potential revenues and efficiency gains could also be significant - potentially outweighing the costs of some measures. In other cases, there may be net costs, but associated SLCP emission reductions may come at relatively low cost or provide other environmental and health benefits. While uncertainties remain – especially for costs and revenues associated with some strategies that utilize either emerging technologies or those that haven't been widely deployed already in California – these measures can help to significantly cut SLCP emissions in California at reasonable cost. With ongoing, targeted financial and market support, coordinated with regulatory development and other economic and environmental priorities where appropriate, California can meet the targets identified in the Proposed Strategy plan while delivering a broad range of benefits.

1. Residential Wood Combustion Black Carbon Emission Reductions

Residential wood combustion (RWC) constitutes 15 percent of California's non-forestry back carbon (BC) emissions, and is projected to be the largest individual source of BC by 2030. This Strategy recommends a 3.0 MMTCO2e (20-yr GWP) reduction in RWC BC emissions by 2030 to meet the SLCP BC emission reduction target.

There are a variety of ways to reduce RWC emissions, and multiple air districts have already put measures in place. Past incentive programs to replace old polluting wood-burning devices with the cleanest EPA-certified devices have been popular and

effective. However, rural districts that rely most heavily on RWC for their primary source of heat are largely located outside of regions that provide incentives. Additionally, past incentive programs have not acquired sufficient funding to achieve the substantial emission reductions proposed in this strategy.

The cost share of this strategy between homeowners and governmental incentives primarily depends on the incentive amount provided per device, and total costs depend on the emission reduction achieved per device. Both of these factors will vary by region and by household, thus incentives funding and homeowners share of costs are calculated as a range. The cost to replace a device can range between $3,000 and $5,000.[132] Purchase and installation of woodstoves was assumed to cost $4,000 while gas devices were assumed to cost $4,500. Incentives typically cover a portion of the cost, from $1,000[133] up to the full installation price.[134] In many rural areas that rely heavily on wood combustion as a source of heat will require nearly full coverage of the installation price to spur voluntary participation; therefore, the incentive range was assumed to be $1,000 to $4,500.

The BC emission reduction per household depends on how much wood is burnt per year, the density and moisture content of the wood, the old device type, and the new device type. Emissions were calculated for two replacement cases. The "wood to wood" case assumes conversion of non-certified woodstove to EPA certified wood stove.[135] The "wood to gas" case assumes conversion of non-certified woodstove to gas device. An incentives program may contain a mixture of different replacement types and these two cases are used to bound potential reductions and costs. Other parameters used in emission reduction calculations were provided by the US EPA residential wood combustion replacement calculator, which includes California-specific data when available (Table 8).[136] The calculator was updated to account for replacement with cleaner EPA certified wood burning devices that will be required by 2020.

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[132] USEPA (2014). How to Implement a Wood-Burning Appliance Change out Program. Available at: http://www.epa.gov/sites/production/files/201508/documents/howtoimplementawoodstovechangeout.pdf

[133] SJVAPCD (2016). Burn Cleaner Program. http://valleyair.org/grants/burncleaner.htm

[134] http://www.epa.gov/sites/production/files/201508/documents/howtoimplementawoodstovechangeout.pdf

[135] Specifically, a woodstove that meets the U.S. EPA 2020 new source performance standard (2.0 grams particulate matter per hour) USEPA (2015). Fact Sheet: Summary of Requirements for Woodstoves and Pellet Stoves. Available at: http://www.epa.gov/residential-wood-heaters/fact-sheet-summary-requirements-woodstoves-and-pellet-stoves

[136] USEPA (2009). Burn Wise Additional Resources - Emission Calculator. http://www.epa.gov/burnwise/burn-wise-additional-resources.

Table 8: Emission Summary

Parameter	Wood to Wood	Wood to Gas
Cords wood burnt per year[137]	1.5	1.5
Wood Density (tons/cord)[138]	1.04	1.04
$PM_{2.5}$ Emissions Reduction per device (tons/yr)[139]	0.0218	0.0245
BC Speciation (fraction of $PM_{2.5}$)[140]	0.125	0.125
BC Reduction per device per year (MTCO2e, 20-yr GWP)	7.9	8.9
BC Emissions Target 2030 (MTCO2e, 20-yr GWP)	3,000,000	3,000,000
Number of average replacements needed to meet target	379,000	337,000

The cost of incentives was calculated by multiplying the number of replacements needed to meet the target (Table 8) by the range of incentives that could be provided, from $1,000 to the full cost of replacement.[141] The cost to homeowners was calculated as the total replacement cost, minus the portion covered by incentives. The "low incentives" case in Table 9 is a scenario where only $1,000 in incentives is paid, and homeowners pay a portion of the replacement. In the "high incentives" case, incentives cover 100 percent of replacement costs and homeowners pay no money out of pocket. Costs to oversee and administer the incentives program were assumed to be similar in either case, because a similar number of devices are replaced (Table 8), and were calculated as 10 percent of the lower incentive value.[142] Educational and outreach costs were estimated at 1 percent of the lower incentives value. Education and outreach includes education about the health effects of wood smoke and educating residents about proper use of their new devices to minimize emissions and maximize the lifetime of the equipment. Studies indicate that education and outreach are vital components of RWC replacement programs.[143] A summary of costs can be found in Table 9. The results in Table 9 show that the total costs for either a low incentives or high incentives case would be the same, but the distribution of costs between incentives and homeowner responsibility is different. These scenarios represent extremes use to bound the range of possible costs; actual program implementation may lie between the low and high incentives cases presented in Table 9.

[137] Based on average California Climate, from USEPA Emission Calculator.
[138] Average California wood density, from USEPA Emission Calculator.
[139] Results are from USEPA Emission Calculator for wood to gas conversion. This result assumes approximately 100% reduction in PM.
[140] ARB (2015). 2015 Edition Black Carbon Technical Support Document. Available at: http://www.arb.ca.gov/cc/inventory/slcp/slcp.htm
[141] $4,000 for woodstove installation and $4,500 for gas devices.
[142] http://www.epa.gov/sites/production/files/201508/documents/howtoimplementawoodstovechangeout.pdf
[143] http://www.epa.gov/sites/production/files/201508/documents/howtoimplementawoodstovechangeout.pdf

Table 9: Range of Costs (Million Dollars)[144]

Cost	Low Incentives	High Incentives
Incentives	$340	$1,500
Oversight and Administration	$34	$34
Cost to Homeowners	$1,180	$0
Education and Outreach	$3.4	$3.4
Total Cost	**$1,557**	**$1,537**

Savings associated with this plan include reduced wood use in more efficient devices or any savings (or cost) to convert from wood fuel to natural gas. US EPA estimates that EPA-certified devices burn a third less wood for the same heat output.[145] Table 10 summarizes the range of potential savings depending on the conversion scenario.

Wood to wood total savings were calculated using the average annual amount of wood burnt (Table 8), the fraction of residents who pay for wood,[146] the cost of a cord of wood, and the assumption that a third less wood is used by the replaced devices. This analysis assumes 20 percent of wood is gathered for free, and would not provide a savings to the resident. The cost of a cord of wood will vary from approximately $100 to $480 depending on location and type of wood[147]. This analysis uses the midpoint value of $290 per cord. Reducing annual wood consumption from 1.5 to 1 cord per year would save the average resident $145 per year. Approximately 379,000 wood to wood conversions (Table 9) would result in savings of approximately 44 million dollars per year to consumers receiving incentives to replace their inefficient wood stove.

Wood to gas savings can be calculated assuming 1.5 cords of wood are not purchased (Table 8), the cost of wood is $290 a cord, and that the heat-equivalent amount of natural gas must be purchased, and assuming 337,000 devices are replaced (Table 9). The price of natural gas was assumed to be $11.51 per thousand standard cubic feet.[148] The savings from not purchasing wood is nearly in balance with the additional cost of purchasing natural gas using these assumptions (Table 10).

[144] Low incentives are $1,000 and high incentives cover 100 percent of device purchase and installation costs ($4,000-$4,500 depending on the device). Under the high incentive there is no out of pocket expense to homeowners.

[145] http://www.epa.gov/sites/production/files/201508/documents/howtoimplementawoodstovechangeout.pdf

[146] A portion of residents who rely on residential wood combustion for heat gather wood from local lands at no cost.

[147] CDFA (2010). California Department of Food and Agriculture News Release. Available at https://www.cdfa.ca.gov/egov/Press_Releases/Press_Release.asp?PRnum=10-074

[148] EIA (2015). California 2014 price of natural gas delivered to residential customers. Available at https://www.eia.gov/dnav/ng/ng_pri_sum_dcu_SCA_a.htm.

Table 10: Savings Associated with Residential Wood Stove Conversion (Million Dollars)

Conversion Scenario	Savings on Purchase of Wood	Increased Cost for Natural Gas	Net Fuel Savings
100 % Wood to Wood	$44	$0	$44
100 % Wood to Gas	$117	$109	$8

2. Methane Emission Reductions from Dairy Manure

As noted in Chapter V, emissions from dairy manure can be reduced by 75 percent by capturing or avoiding methane produced by about 1.05 million of the State's 1.4 million milking cows whose manure is managed anaerobically. Achieving these targets for the industry could lead to significant GHG emission reductions – 22 $MMTCO_2e$ annually by 2030, and 168 $MMTCO_2e$ cumulatively through 2030 (8 $MMTCO_2e$ and 58 $MMTCO_2$, respectively, using a 100-year GWP).

Several options exist to reduce methane emissions from manure management in California. Five strategies were considered in this analysis, which are described in further detail in Appendix D:

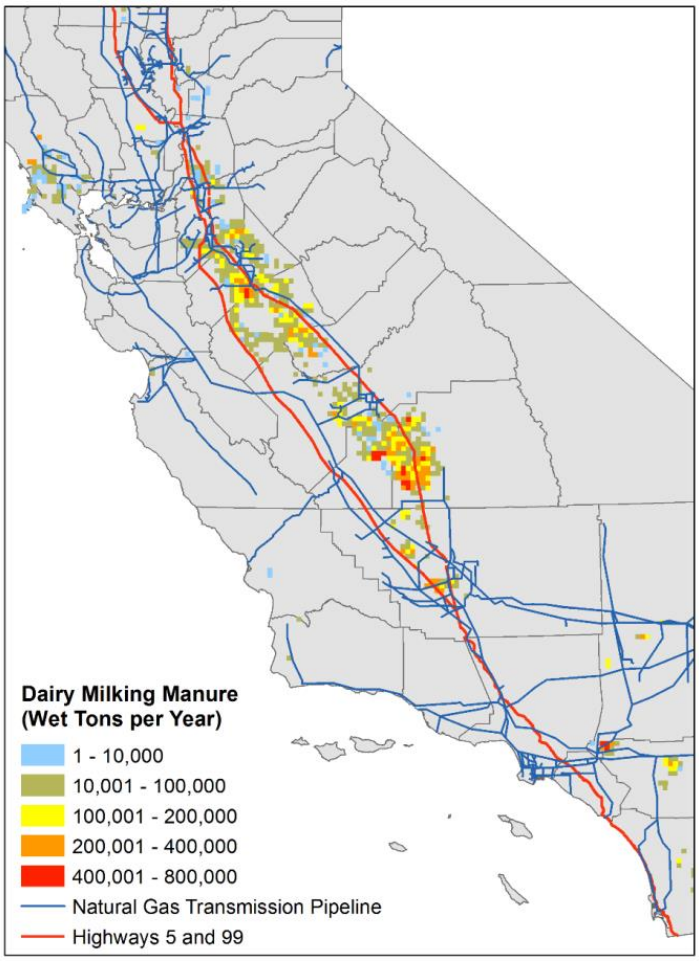
1. Scrape conversion and onsite manure digestion producing pipeline-injected renewable natural gas vehicle fuel
2. Scrape conversion and transport of manure offsite for centralized digestion producing pipeline injected renewable natural gas as a vehicle fuel
3. Scrape conversion, collection and open solar drying of manure onsite
4. Scrape conversion and onsite manure digestion for onsite production of renewable electricity
5. Conversion of dairy operations to pasture-based management

These represent example pathways that could be important to a sector-wide approach to reduce emissions, but they are not meant to rule out other solutions. The cost and efficacy of some options, such as solids separation, are not yet known with certainty and could not be included in this analysis. Solids separation and other potential mitigation methods deserve additional study of both emission reduction potential and economic feasibility.

The strategies considered here aim to balance cost and feasibility, while prioritizing economic and environmental benefits. Specifically, they aim to address water quality issues on dairies by including conversion to scrape systems, maximize renewable natural gas production by utilizing above ground tank/plug flow digesters, and avoid increases in criteria pollutant emissions (most notably oxides of nitrogen, or NOx) and maximize potential revenues by prioritizing pipeline injection of renewable natural gas. Prioritizing these goals adds costs compared to a pathway that focuses on methane mitigation only, but deliver important environmental, health and potential economic benefits.

ARB conducted a Geographic Information System (GIS) analysis of dairies throughout the State to inform the scenario development. GIS informed estimates related to the number of dairies that could feasibly inject renewable natural gas into the pipeline, associated costs, availability and costs associated with "clustering" dairies to centralize digestion and pipeline injection, and opportunities for converting to pasture-based operations. Figure 11 provides a spatial analysis of manure from milking cows in California.

Figure 11: Location of Manure from Milking Cows in California



The analysis was informed by direct consultation with CDFA, academic researchers at UC Davis and elsewhere, project developers, and stakeholders. In particular, as part of developing this Proposed Strategy, ARB supported research at UC Davis to inform cost and performance estimates for dry scrape conversions, anaerobic digesters, and other

pathways.[149] Additional research was also used to inform the cost and performance parameters assumed for this analysis, which are detailed in Appendix D.[150]

Potential revenues from energy or electricity sales and environmental credits were included. For the value of energy and credits, the current or estimated average value through 2030 was used. No revenue was included for soil amendment products that could be potentially generated from these pathways, and provide value,[151] because their market potential remains uncertain at this time. The LCFS, Cap-and-Trade, and federal Renewable Fuel Standard program are all assumed to be in place through at least 2030. Cap-and-trade offsets are not available for projects built after a regulation takes effect, assumed here to be in 2025, and the carbon intensity for LCFS accounting is assumed to increase for new projects from -276 gCO_2e/MJ to +13 gCO_2e/MJ at that point, as well.

The first two strategies produce biomethane that is injected into the pipeline and used as transportation fuel. They receive revenue for energy sales at the price of wholesale natural gas ($3.46/Mscf), as well as LCFS credits ($100/MT) and cellulosic RIN credits ($1.85/RIN)[152] from the federal Renewable Fuel Standard program. In the first strategy, digesters are developed onsite at each dairy, while the second captures economies of scale by utilizing centralized digesters, biogas upgrading, and pipeline injection points for "clustered" dairies. The third pathway mitigates manure methane emissions by converting from flush management to scrape systems, but is assumed to generate no revenue. This represents a low cost option, but low value, as well. In the fourth strategy, manure is digested onsite to produce electricity using microturbines (to limit NOx emissions). This pathway receives revenue from electricity sales ($0.126/kWh) and Cap-and-Trade offsets ($13/$MTCO_2e$). Finally, in the fifth strategy, dairies convert to pasture-based operations. No revenue is assumed from this pathway.

Costs and revenues for these strategies, normalized to a dairy with 2,000 milking cows, are summarized in Table 11. The table includes the net present value for each over a 10-year time horizon, assuming a 10 year loan on capital at 7 percent interest, and a 5 percent discount rate.

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[149] Kaffka, S. et al (2016) Evaluation of Dairy Manure Management Practices for Greenhouse Gas Emissions Mitigation in California, Final Technical Report to the State of California Air Resources Board, February.

[150] In particular: Sustainable Conservation (2015) Combating Climate Change: Dairies Key in Reducing Methane, July: http://www.suscon.org/blog/2015/07/combating-climate-change-dairies-key-in-reducing-methane/.

[151] Soil amendment products from dairy digesters could provide greater potential revenues than energy sales from the digesters, potentially as much as $300 per cow per year in California.
Informa Economics (2013) National Market Value of Anaerobic Digester Products, Prepared for Innovation Center for U.S. Dairy, February.

[152] The assumed cellulosic RIN credit value of $1.85 includes a D5 RIN ($0.85), cellulosic waiver credit ($0.90) and value from the Blenders Tax Credit ($0.10 per D5 RIN).

Table 11: Economic Analysis for Projects at a Representative Dairy with 2,000 Milking cows Over 10-year Accounting Period[153]

	Strategy				
	1 Onsite Digestion to Fuel	2 Central Digestion to Fuel	3 Scrape Only	4 Onsite Digestion to Electricity	5 Convert to Pasture
Capital (million dollars)	$5.4	$3.3	$1.6	$5.8	$5.0
O&M (million dollars)	$3.5	$2.4	$0.4	$3.5	$2.8
Revenue (million dollars)	$11.3	$11.3	--	$3.6	--
NPV (million dollars)	$2.5	$5.5	–$2.1	–$5.7	–$7.8
$/MT CO_2e (20-yr GWP)	–$5.8	–$13.0	$4.9	$13.5	$18.2
$/MT CO_2e (100-yr GWP)	–$16.6	–$37.6	$14.2	$38.8	$52.5
Breakeven Upfront Grant (million dollars)	--	--	$1.9	$5.3	$7.1

Based on the assumptions used here, projects that generate transportation fuel and can capture LCFS credits can generate a positive return (strategies 1 and 2). These pathways may also contribute to regional air quality benefits, as part of an integrated approach to utilize renewable fuel in low-NOx engines. But revenue for these strategies, and the resulting project economics (as measured by net present value), are highly dependent on the value of LCFS and RIN credits. As shown in Table 12, the net present value can fluctuate by several million dollars, depending on the value of these revenue streams. Without these programs, these projects would have net present values similar to strategies 4 and 5.

Table 12: Net Present Value for Strategies Producing Transportation Fuel, as a Function of LCFS and RIN Credit Prices (Million Dollars)

		Strategy 1: Onsite Digestion to Vehicle Fuel					Strategy 2: Centralized Digestion to Vehicle Fuel				
		LCFS Credit Price					LCFS Credit Price				
		$0	**$50**	**$100**	**$150**	**$200**	**$0**	**$50**	**$100**	**$150**	**$200**
Cellulosic RIN Credit Price	**$0.00**	-$8.2	-$5.0	-$1.7	$1.6	$4.8	-$5.1	-$1.9	$1.4	$4.7	$7.9
	$0.50	-$7.1	-$3.8	-$0.6	$2.7	$6.0	-$4.0	-$0.7	$2.5	$5.8	$9.0
	$1.00	-$6.0	-$2.7	$0.5	$3.8	$7.1	-$2.9	$0.4	$3.6	$6.9	$10.2
	$1.85	-$4.1	-$0.8	$2.5	$5.7	$9.0	-$1.0	$2.3	$5.5	$8.8	$12.1
	$2.50	-$2.6	$0.6	$3.9	$7.2	$10.4	$0.5	$3.7	$7.0	$10.3	$13.5
	$3.00	-$1.5	$1.8	$5.0	$8.3	$11.6	$1.6	$4.9	$8.1	$11.4	$14.6
	$3.50	-$0.4	$2.9	$6.1	$9.4	$12.7	$2.7	$6.0	$9.2	$12.5	$15.8
	$4.00	$0.7	$4.0	$7.3	$10.5	$13.8	$3.8	$7.1	$10.4	$13.6	$16.9

[153]Summation may not be exact due to rounding. Capital costs amortized over 10 years with 7% interest. Discount rate is 5%. Costs normalized to representative 2,000 cow dairy.

Other types of dairy projects may not generate positive returns without additional support and/or other potential revenue streams, such as for soil amendments. The third strategy requires the lowest capital outlay among strategies considered in this analysis, but it is not assumed to generate any revenue, leading to a net present value loss of about $2.1 million over 10 years. Still, this pathway represents fairly low cost emission reductions ($4.9/MT using a 20-year GWP) and could break even with an upfront grant, or its equivalent, of about $1.9 million.

The fourth strategy provides revenue streams that are more stable than for the transportation fuel pathways in strategies 1 and 2, but they are also significantly lower, and the project economics are less favorable. The net present value of this project over ten years is -$5.7 million, and an upfront grant of $5.3 million would be needed to break even. Note, however, that if electricity generated from biogas is used to charge electric vehicles, biogas used to generate electricity can be credited with cellulosic RIN credits, which could add another valuable revenue stream. In this case, RIN credits would more than double revenue and add more than $4 million in net present value over 10 years. That type of project, based on the assumptions here, would still represent a net loss of $1.6 million over ten years, but it could break even with an upfront grant of $1.5 million. Costs of emission reductions over 10 years would fall to $4/MT$CO_2$e using a 20-year GWP ($11/MTCO_2e using a 100-year GWP).

Converting to pasture-based systems is assumed to have relatively high costs and no revenue, leading to a pathway with a net present value of -$7.8 million over 10 years. Three-quarters of the estimated capital cost and over 90 percent of the estimated operating costs come from irrigation, so if dairies were to convert to pasture in areas where less irrigation may be needed (perhaps in northern parts of the State), they might be able to significantly cut costs associated with reducing methane from their operations. In general, little information is available on the economics associated with converting to pasture, and additional research and potential demonstration projects could help to evaluate the viability of this strategy to reduce dairy methane emissions in California.

Costs and Revenues for Sector-Wide Scenarios to Meet Proposed Targets

These individual pathways were combined into three industry-wide scenarios (Table 13) for reducing methane emissions from manure management at California dairies by 20 percent in 2020, 50 percent in 2025 and 75 percent by 2030:

- Scenario A: All strategy 3 (scrape to manure collection and drying)
- Scenario B: Mixed approach (including all five strategies)
- Scenario C: All strategy 2 (centralized digestion and pipeline injection)

Table 13: Mix of Strategies in Scenarios:
Number of Milking cows Covered by Projects in 2030

Strategy	A	B	C
(1) Scrape conversion and onsite manure digestion producing pipeline-injected renewable natural gas vehicle fuel		350,000	
(2) Scrape conversion transport of manure offsite for centralized digestion producing pipeline injected renewable natural gas as a vehicle fuel		300,000	1,050,000
(3) Scrape conversion, collection and open solar drying of manure onsite	1,050,000	200,000	
(4) Scrape conversion and onsite manure digestion for onsite production of renewable electricity		150,000	
(5) Conversion of dairy operations to pasture-based management		50,000	
Total	**1,050,000**	**1,050,000**	**1,050,000**

Results for the scenarios are summarized in Table 14. Scenario A represents a low cost, zero revenue case where a sufficient number of dairies transition to scrape operations to reduce methane emissions from manure management by 75 percent by 2030. This could have potential benefits, as described in Chapter V, for nutrient management and water quality on the farm. There could also be potential revenue (along with added costs) if manure were composted and sold, which is not considered here. The sector-wide, net present value through 2030 for this scenario is -$636 million, which represents emission reductions of about $4/MTCO$_2$e using a 20-year GWP ($11/MTCO$_2$e using 100-year GWP).

Table 14: Economic Analysis for Sector-Wide Scenarios Through 2030 (Million Dollars)[154]

	Scenario		
	A	**B**	**C**
Capital	$493	$1,235	$995
O&M	$142	$837	$788
Revenue	$0	$2,157	$3,237
Net Present Value $100 LCFS Credit **$1.85 RIN Credit**	–$636	$84	$1,454
$/MT CO2e (20-yr GWP)	$3.8	–$0.5	–$8.7
$/MT CO2e (100-yr GWP)	$10.9	–$1.5	–$24.9
Net Present Value **$40 LCFS Credit** **$1.00 RIN Credit**	–$636	–$926	–$176

Scenario B includes a mix of all five strategies. Collectively, with LCFS credits assumed to be valued at $100/MT and RINs at $1.85, this scenario meets the targets in this Proposed Strategy with a positive net present value of $84 million through 2030. If the portion of milking cows in this scenario utilizing Strategy 4 were to use generated electricity for transportation fuel to capture RIN credits, it would increase revenues and net present value by about $200 million. Again, revenues are highly dependent on LCFS and RIN credit values. If LCFS credits were $40/MT and RINS were $1.00, the net present value of this scenario would fall by about $1 billion, to -$926 million (and -$823 million if the electricity is used as transportation fuel).

The value of LCFS and RIN credits is even more noticeable in Scenario C, where all emission reductions are achieved through centralized digestion that generates renewable natural gas for transportation fuel and LCFS credits. If instead of the assumptions used here, LCFS and RIN credits were valued at $40/MT and $1.00, respectively, the net present value would fall by $1.6 billion, and the scenario would have a net loss of $176 million through 2030.

Altogether, this analysis suggests that the dairy industry in California can significantly cut methane emissions and deliver low-cost GHG reductions. There are important uncertainties associated with project costs and potential revenues, however, which may limit project development without targeted support. And the State may wish to support

[154] Summation may not be exact due to rounding. Capital costs amortized over 10 years with 7% interest. Discount rate is 5%. In Scenarios B and C, beginning in 2025, regulation eliminates availability of C&T offsets for new electricity generating projects (Strategy 4) and for those that have been operating for 10 years. For projects producing transportation fuel (Strategy 1 and 2), beginning in 2025, the carbon intensity for LCFS credits for new projects and those that have been operating for 10 years increases from -276 to 13 gCO_2e/MJ. The impact of regulation on existing projects under the LCFS has not been determined, and this simply an assumption used for the sake of this analysis.

some higher cost strategies, including conversions to scrape or pasture-based systems, for other environmental reasons.

A mix of grants, especially for projects with lower revenues, and other mechanisms for pathways with higher revenues may be appropriate. This funding could come from federal sources, California's Greenhouse Gas Reduction Fund (GGRF), utility programs, the programs included in this analysis, or other sources. Limited federal grant funding is currently available, and more should be pursued. In his proposed 2016-17 Budget,[155] Governor Brown has proposed committing $55 million in GGRF funding for climate smart agriculture, including dairy digesters and healthy soils. And under a rulemaking by the CPUC pursuant to Assembly Bill 1900 (Gatto, Chapter 602, Statutes of 2012), California's natural gas utilities will offset half of renewable natural gas interconnection costs, up to $1.5 million per project and $40 million Statewide.

These programs provide a strong starting point for supporting the industry in reducing methane emissions and achieving the targets and benefits identified here. They should be built upon and bolstered. A financial working group may be helpful in recommending ways to leverage private sector investment and significantly scale efforts to rapidly cut methane emissions in California. Through careful investments and structured market-based incentives, project development may be accelerated to achieve emission reductions more quickly than the targets identified in this Proposed Strategy, and ahead of potential regulation of the industry.

3. Methane Emission Reductions from Diversion of Landfill Organic Waste

As noted in Chapter V, diverting organic materials from landfills can reduce landfill emissions by 5 $MMTCO_2e$ in 2030, increasing to 21 $MMTCO_2e$ by 2050 (using a 20-year GWP). Achieving these methane reduction targets requires optimized use and disposal of methane generating organic materials. To that end, the Proposed Strategy recommends reducing organics deposited to landfills by 90 percent by 2025, consistent with AB341. This ambitious target requires putting organic materials to the highest feasible use and developing infrastructure and markets to optimize the economic and environmental value of California's waste streams across sources.

When considering waste diversion options it is essential to balance environmental and economic benefits with any potential impacts on criteria pollutant emissions and ecosystem and human health, especially in disadvantaged communities. Avoiding organic waste generation entirely is the best option to reduce emissions, protect health, and minimize costs. However, once generated, there are many options for creating environmental and economic benefit through the appropriate utilization organic waste. Organics can be diverted to waste facilities with existing excess capacity, including composting facilities, stand-alone anaerobic digesters (AD), and wastewater treatment anaerobic digesters. New facilities can be also built in optimized locations.

[155] http://www.ebudget.ca.gov/2016-17/BudgetSummary/BSS/BSS.html

In this analysis three scenarios were considered that can achieve the organic diversion target outlined in the Proposed Strategy. The three scenarios are based on projected waste data and potential diversion outlined in Appendix D. The only difference between the scenarios is the waste utilization of grass and leaves. The three scenarios evaluate the costs and revenues for utilizing food waste and grass and leaves in three pathways:

1. New anaerobic digestion facilities
2. Existing excess capacity at wastewater treatment anaerobic digestion facilities
3. New compost facilities

The actual future utilization of food waste and grass and leaves will most likely be some mix of these options. Since it is not possible to predict the exact mix of utilization pathways, these three scenarios were developed to bound potential costs and revenues. The scenarios considered here aim to balance cost and feasibility, while prioritizing economic and environmental benefits. To this end, the analysis focuses on the capture and pipeline injection of renewable natural gas from diverted organic waste. Using renewable natural gas as a transportation fuel can result in significant potential revenue streams and reduce criteria pollutant emissions from the transportation sector. Prioritizing the use of biomethane as a transportation fuel may increase costs relative to scenarios that focus solely on methane mitigation. However, important environmental, health, and economic benefits may be realized by prioritizing pipeline injection of renewable natural gas.

Within scenario 1, food waste and a portion of grasses and leaves are handled through new centralized AD facilities and the resulting methane is pipeline injected. New AD facilities are assumed to accept 100,000 tons per year of organic waste. The costs of scenario 1 include facility construction and permitting, operating and maintenance (O&M), waste and digestate processing and transportation, and the costs associated with pipeline injection of renewable natural gas. These include pipeline, interconnection, and biogas upgrading costs. Potential revenue streams include tipping fees, the sale of biogas, LCFS credits, and RIN credits, as outlined in Appendix D.

Scenario 2 assumes that food waste is diverted to wastewater treatment facilities with existing excess capacity. The analysis assumes that, with modification, existing wastewater treatment facilities can accept 50,000 tons of organic material per year on average by 2030, with some facilities accepting more or less depending on size. Costs for this scenario include upgrading and permitting costs that may be required for facilities to accept food waste, waste and biosolid processing and transportation, O&M, as well as the costs associated with pipeline injection of renewable natural gas. Potential revenue streams include tipping fees, sale of biogas, LCFS credits, and RINs.

Scenario 3 assumes that all food waste and grasses and leaves are composted at new facilities with a throughput of 100,000 tons per year. Costs within the scenario include facility construction, O&M, and transportation of organic materials to the compost facility. The only revenue stream included in scenario 3 is the tipping fee, though additional revenue streams could result from the sale of compost.

A principal difference in outcomes from these three scenarios is the number of new facilities needed to achieve the organic diversion targets. Table 15 shows the number of new compost or AD facilities needed for each scenario.[156]

Table 15: Estimated Number of New Facilities

Scenario	Estimated Number of New Compost Facilities to Achieve Target			Estimated Number of New AD Facilities to Achieve Target		
	2020	2025	2030	2020	2025	2030
1. New AD	43	52	54	40	56	58
2. Existing WWTP	50	62	65	-	-	-
3. Compost Only	76	97	102	-	-	-

There is uncertainty regarding the costs, savings, and potential revenue streams associated with organic waste diversion. Social welfare impacts, including those related to health, noise, odor, ecosystem benefit, and water impacts, are not included in this analysis but require additional consideration and analysis prior to the implantation of any organic diversion measure. Additional uncertainty related to existing infrastructure and technology development may also create economic impacts not analyzed in this analysis, which relies on available data from California agencies, academic researchers, and industry to estimate the direct economic impact, including costs, fuel and energy savings, and potential revenue streams, of achieving the organic waste diversion target in the Proposed Strategy.

Net present value calculations were used to estimate the potential profitability of the three scenarios. By calculating the present value of future cost and organic diversion over a 10-year financing period, the net present value calculation provides insight into the feasibility of projects at the facility level, including the need for upfront grants and incentives as well as the significant opportunities and uncertainty surrounding revenue streams based on existing regulations.

Costs and revenues for the three scenarios are summarized in Table 16. The table includes the net present value for each scenario over a 10-year financing period

[156] This analysis assumes existing wastewater treatment facilities can handle 50,000 wet tons of food waste per year, while new AD facilities and compost facilities have a throughput of 100,000 wet tons per year. Additional information regarding the projected organic waste streams by waste , the assumptions surrounding required facilities, and the handling of residuals are presented in Appendix D.

Table 16: Cumulative Estimated Costs and Revenues by Scenario Over 10-Year Accounting Period (Million Dollars)

Scenario 1: New AD	Component	Capital Cost	O&M	Revenue
New AD New Compost	54 Facilities 58 Facilities	$1,200 $600	$2,100 $650	$5,800 $1,200
Total		**$1,800**	**$2,750**	**$7,000**
10-Year Net Present Value		**$2,500**		
Scenario 2: WWTP	**Component**	**Capital Cost**	**O&M**	**Revenue**
New Compost	65 Facilities	$720	$790	$1,500
Existing Wastewater Treatment	118 Facilities	$1,300	$3,700	$5,100
Total		**$2,020**	**$4,490**	**$6,600**
10-Year Net Present Value		**$162**		
Scenario 3: Compost	**Component**	**Capital Cost**	**O&M**	**Revenue**
New Compost	102 Facilities	$1,000	$1,100	$2,100
Total		**$1,000**	**$1,100**	**$2,100**
10-Year Net Present Value		**-$43**		

Table 16 suggests that under Scenario 1 and Scenario 2, organic waste diversion can generate a positive return. These scenarios may also contribute to regional air quality benefits, through reduced transportation emissions. However, revenue for these strategies, and the resulting net present value, is highly dependent on the value of LCFS and RIN credits. As shown in Table 17, for representative wastewater treatment and new AD facilities, the net present value of diverting organic materials – at the facility level – is negative without revenue from LCFS credits and RINs.

Table 17: Net Present Value of Representative Wastewater Treatment and New AD Facility under Varying LCFS Credit Prices and RIN Credit Prices (Million Dollars)

		Wastewater Treatment Facility					New AD Facility				
		LCFS credit price					LCFS credit price				
		$0	$50	$100	$150	$200	$0	$50	$100	$150	$200
Cellulosic RIN credit prices	$0.00	-$17.0	-$12.1	-$7.2	-$2.2	$2.7	-$34.4	-$18.9	-$3.4	$11.9	$27.3
	$0.50	-$8.1	-$3.1	$1.8	$6.7	$11.7	-$14.4	$0.9	$16.4	$31.8	$47.3
	$1.00	$0.9	$5.8	$10.8	$15.7	$20.7	$5.4	$20.9	$36.3	$51.8	$67.2
	$1.85	$16.3	$21.2	$26.1	$31.1	$30.0	$39.3	$54.8	$70.2	$85.6	$101.1
	$2.50	$27.9	$32.9	$37.8	$42.8	$47.8	$65.2	$80.7	$96.1	$116.7	$133.9
	$3.00	$36.9	$41.9	$46.9	$51.8	$56.8	$85.2	$100.6	$116.0	$131.5	$146.9
	$3.50	$46.0	$50.9	$55.9	$60.8	$65.8	$105.1	$120.5	$136.0	$151.4	$166.9
	$4.00	$55.0	$59.9	$64.9	$69.9	$74.8	$125.0	$140.5	$155.9	$171.4	$186.8

State resources could be deployed to supplement financing of biomethane projects through mechanisms such as upfront grants, loan assistance programs, and tax incentives. For example, the illustrative wastewater treatment facility in Table 17 would break even over a 10-year financing period with an upfront grant of $16 million. Looking at LCFS credits and RINs in isolation, without revenue from LCFS credits, this illustrative wastewater treatment facility would break even with a RIN price of $1 over the 10-year financing period. In the absence of revenue from RINs, the facility would breakeven at an LCFS credit price of $173. The US EPA's Renewable Fuel Standard (under which RINs are generated and sold) and California's LCFS program can offset large upfront capital costs that otherwise may prevent project development.

In the absence of revenue from the sale of LCFS credits, a RIN price of $0.87 is required for a representative new AD facility to breakeven over a 10-year financing period. In the absence of RIN credit revenue, an LCFS credit price of $112 is required for that same facility to breakeven over a 10-year financing period. Without revenue from RINs or LCFS credits, an upfront grant of $32 million would be required in order for the illustrative new AD facility to breakeven over a 10-year financing period.

Altogether, this analysis suggests that the diversion of organic waste can result in environmental and economic value to California. There are important uncertainties associated with facility costs and potential revenues, however, which may limit project development without additional support. In the absence of revenue from LCFS credits and RINs, significant financial support, may be required to achieve the target identified in this Proposed Strategy and deliver other environmental benefits. Through careful research, investments, and structured market-based incentives, the State can work with industry to significantly and permanently reduce methane emissions and divert organic waste.

4. Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities Regulation

The Proposed Strategy has a four-pronged approach to methane reductions in the oil and gas sector including regulation of production, processing, and storage facilities and implementation of SB 1371. The process to adopt rules and procedures to minimize natural gas leaks from natural gas pipelines under SB 1371 is just beginning and an analysis of the costs and potential benefits of SB 1371 will be conducted as measures are implemented.

ARB is developing a regulation to address methane from oil and gas production, processing, and storage facilities for Board consideration in 2016. The regulation is anticipated to deliver environmental benefits that include an estimated reduction in GHG emissions through 2030 of about 13.8 $MMTCO_2e$ from oil and gas related emissions in California. In addition, the measure is expected to save about 650 million standard cubic foot (scf) per year of industrial natural gas through reductions of leaks and through vapor recovery systems, the monetized value of which is approximately $2.7 million per year.[157]

While air districts are currently combatting volatile organic compounds (VOC) leaks locally, these rules vary by district and are not addressing any methane only leaks. This measure is designed to expand upon existing local rules, promote statewide uniformity, minimize the administrative burden on local air districts, harmonize state requirements with current and near-future local and federal requirements, and achieve further methane reductions to achieve the goal outlined in this strategy of reducing fugitive methane emissions from all sources in the oil and natural gas sector by 45% by 2030.

The Oil and Gas measure proposes eight main control provisions that are designed to achieve emission reductions in crude oil and natural gas operations. These provisions build upon and in some ways increase existing local air district requirements to monitor, replace, and expand current capital at crude oil and natural gas facilities.
The cost of this measure includes capital costs to: Install Vapor Recovery Units for tanks, well stimulations tanks, and centrifugal compressors; replace rod packing on reciprocating compressors; and change pneumatic devices. In addition, a leak detection and repair program (LDAR) as well as emissions reduction and leak monitoring plans will have ongoing costs in each year beginning in 2018. The amortized[158] capital cost plus the ongoing costs yield an overall cost of the measure of just over $190 million through 2030. These costs are offset by natural gas collection from the reduction in leaks and vapor recovery; these savings amount to savings of almost $33 million through 2030 and persisting thereafter. The costs, cost-savings, and emission reductions are outlined in Table 18 by each provision.

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[157] http://www.energy.ca.gov/2014publications/CEC-200-2014-001/CEC-200-2014-001-SF.pdf. Using a value of $4.10 per Mscf, which is the value of the natural gas prices are based upon wholesale prices that are forecasted by the California Energy Commission using their NAMGas general equilibrium model.
[158] Using a 5% discount rate.

Table 18: Costs and Emissions for Oil and Gas Measure

Segment of Regulation	Total Reductions to 2030 (MTCO2e)	Annual Cost	Annual Savings	Total Cost to 2030	Total Savings to 2030
VRU for Tanks	6,456,000	$4,674,000	$653,000	$56,088,000	$7,836,000
Reciprocating Compressors	804,000	$203,000	$230,000	$2,436,000	$2,760,000
LDAR	2,640,000	$8,902,000	$756,000	$115,726,000	$9,450,000
Pneumatic Devices	3,828,000	$1,153,000	$1,043,000	$13,836,000	$12,516,000
Well Stimulations	60,000	$186,000	$17,000	$2,232,000	$204,000
Centrifugal Compressors	36,000	$4,000	$12,000	$48,000	$144,000
Monitoring Plan	TBD	TBD	TBD	TBD	TBD
Total	**13,824,000**	**$15,122,000**	**$2,711,000**	**$190,366,000**	**$32,910,000**

5. Hydrofluorocarbon (HFC) Emission Reductions

Hydrofluorocarbons (HFCs) are used primarily as refrigerant substitutes to ozone-depleting refrigerants, and although not ozone-depleting, HFCs have high-global warming potentials (GWP) between 500 and 12,000 (20-year GWP values). HFCs currently account for 4 percent of California's GHG emissions, but are expected to double in emissions in the next few decades without additional reduction actions. Four HFC measures are proposed in this strategy to reduce cumulative HFC emissions by 260 $MMTCO_2E$ (20-year GWP) by 2030 to meet the SLCP emission reduction target.

The proposed reduction measures include the following:

- Financial incentive program to install new low-GWP refrigeration and air-conditioning (AC) equipment
- Sales ban on refrigerants with very-high GWPs
- Phasedown in the supply of high-GWP HFCs

- Prohibitions on high-GWP refrigerants in new stationary refrigeration and AC equipment

The cost of strategies to reduce HFCs is highly dependent upon assumptions of the added initial cost of low-GWP equipment, which is estimated to be approximately 10 percent higher than baseline high-GWP equipment, as detailed in Appendix D. The additional initial cost ranges from $500,000 for a large cold storage facility, and $200,000 for a supermarket; to $400 for a residential AC system, and $140 for a residential refrigerator-freezer. In many cases, the added initial cost is offset or reversed through energy savings of low-GWP refrigeration and AC. Additionally, low-GWP refrigerants such as carbon dioxide refrigerant, ammonia, and hydrocarbons are less expensive than HFCs. The main barrier to adoption of low-GWP refrigeration equipment is the added initial cost. For low-GWP AC, the barriers include added initial cost and current building codes that do not allow very slightly flammable low-GWP refrigerants.

Measure costs were derived using the incremental per-unit equipment cost over the number of new units replacing retiring units each year. The total cost savings result from less energy use and less expensive refrigerant over the lifetime of the equipment. The cumulative costs and savings are outlined in Table 19.

The cost and savings from HFC reduction measures were estimated separately for each measure and then summed together to show total estimated cost and total estimated savings from all measures. This approach was used to avoid double-counting emission reductions, cost, and savings from measures that overlap significantly. For example, businesses installing low-GWP refrigeration because of the early adoption incentive program would not be subject to required prohibitions of high-GWP refrigerant in new equipment, and would not be affected by an HFC phasedown. An HFC phasedown could incentivize new equipment to use low-GWP refrigeration and AC, and a prohibition on high-GWP refrigeration and AC would largely overlap with HFC phasedown requirements. Detailed cost and savings for each individual measure are presented in Appendix D.

Table 19: HFC Measure Costs and Savings Through 2030 (Million Dollars)

	Total Cost	Total Savings	Net Cost	Emission Reductions (MMTCO2e)
HFC Reduction Measures	$5,060	($4,850)	$210	260

GHG reductions from direct refrigerant emissions are estimated by modeling equipment sectors using a constant refrigerant charge size and annual leak rate, with the only variable that of the refrigerant's GWP. The reduction per unit per year is the difference between the emissions of the high-GWP equipment and the emissions expected from the new, low-GWP equipment. Indirect GHG emissions from less energy usage were also estimated using the default carbon intensity of California's

electricity from the Cap and Trade Program. Note that the indirect emission reductions account for less than 4 percent of GHG reductions from refrigeration and AC (the carbon intensity of electricity generation used to power cooling equipment is overwhelmed by the very-high GWPs of HFC refrigerants).

B. Public Health Assessment

Short-lived climate pollutants are not only powerful climate forcers but are also harmful air pollutants with many direct and indirect impacts on health. The focused efforts identified in this Proposed Strategy will not only help to limit the impacts of climate change that are already underway, but also reduce local air pollution and produce other co-benefits. The World Health Organization (WHO) describes the direct and indirect impacts of SLCP emissions, on a global level, as follows:[159]

> Since SLCPs contribute to ambient levels of ozone and PM2.5, SCLP [sic] emissions are directly associated with cardiovascular and respiratory diseases, including heart disease, pulmonary disease, respiratory infections and lung cancer. SLCP emissions thus contribute significantly to the more than 7 million premature deaths annually linked to air pollution.
>
> Indirectly, the SLCPs ozone and black carbon reduce plant photosynthesis and growth, thus decreasing agricultural yields, which in turn threatens food security. They also affect weather patterns and the melting of snow and ice, which may harm and endanger health through extreme weather events such as floods.

Furthermore, in its report on *Reducing global health risks through mitigation of short-lived climate pollutants,*[160] the WHO notes that certain efforts to cut emissions of SLCPs may provide other types of health benefits not associated with air pollution. These include improved diets or more opportunities for safe active travel and physical activity. As described in this Proposed Strategy, some strategies to cut emissions of SLCPs in California could have important benefits for water quality, and potentially for water supply in the State, as well.

The measures and goals identified in this Proposed Strategy could deliver many of these types of benefits in California, which might accrue especially in disadvantaged communities (see Section C). As they are further developed and implemented, it will be important to consider a broad array of potential impacts and benefits to ensure that prioritized strategies to cut SLCP emissions also maximize other health benefits. For example, as part of an integrated strategy that includes use of ultra-low-NOx vehicles

[159] World Health Organization, "Reducing global health risks through mitigation of short-lived climate pollutants," accessed April 1, 2016. http://www.who.int/phe/health_topics/outdoorair/climate-reducing-health-risks-faq/en/

[160] WHO (2015) Reducing global health risks through mitigation of short-lived climate pollutants, Summary report for policymakers, World Health Organization, October. http://www.who.int/phe/publications/climate-reducing-health-risks/en/

and renewable natural gas in the transportation sector, converting manure management operations to scrape systems and injecting renewable natural gas into the pipeline can help to improve air quality and water quality near dairies and elsewhere in California. A discussion of the health impacts associated with the measures in this Proposed Strategy is provided below. A more detailed public health impacts analysis will be developed as part of any potential subsequent regulatory process.

Black carbon is a component of fine particulate matter (PM2.5). A large number of studies, particularly epidemiological (population-based) studies, have linked exposure to PM2.5 to a number of adverse health effects, including premature death, hospital admissions for the worsening of chronic cardiovascular and lung diseases, and emergency room visits for asthma.[161,162,163] Diesel particulate matter is a subset of PM2.5, and consists of black carbon particle cores that are coated with a variety of other chemical substances, including over 40 carcinogenic organic compounds, nitrates, sulfates, and heavy metals. To date, no studies have directly investigated potential health effects of black carbon. However, since black carbon particulate matter is a subset of PM2.5, which has been clearly shown to be related to adverse health effects, the scientific community has concluded that diesel and black carbon particulate matter likely have similar adverse effects as PM2.5. As part of its periodic reviews of the national ambient air quality standards, the U.S. EPA draws conclusions as to the strength of the relationship between exposure to air pollution and broad categories of adverse health effects. In its most recent integrated science assessment for the PM standards, it concluded that PM2.5 plays a "causal" role in premature death and cardiovascular effects, and a "likely causal" role in respiratory effects.[164]

As a result of State and local efforts over the past decades to improve air quality, California has significantly cut particulate matter emissions from anthropogenic sources, especially from diesel engines. The result is that black carbon emissions are about 90 percent lower than they were in the 1960s and approximately 5,000 premature deaths are avoided in the State each year. Current NO_x and PM emission standards for on-road and off-road diesel engines that phase in between 2012 and 2020 will lead to significant additional reductions in primary PM2.5 emissions from

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[161] 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

[162] 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.

[163] 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.

[164] 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

diesel equipment.[165] (NO_X emissions are also projected to decrease, which could reduce ozone and secondary PM.) As a result, the health-related impacts associated with diesel PM2.5 are expected to continue to decrease through 2030.

Residential wood burning (fireplaces and woodstoves) is another important source of black carbon emissions and local air pollution, and its share of the State's black carbon inventory is increasing, as emissions from diesel engines fall. Fireplaces and woodstoves produce PM2.5, carbon monoxide, volatile organic compounds, and hazardous air pollutants. In ARB's black carbon inventory, emissions from these sources are assumed to increase between 2013 and 2030, due to increased residential construction. Actions outlined in this Proposed Strategy, such as restricting residential wood-burning fireplaces and promoting the conversion to cleaner wood-burning stoves, can help reduce these emissions and health-related impacts, which especially impact rural areas.

Methane contributes to global background levels of ozone in the lower atmosphere (troposphere). Global background ozone (tropospheric ozone) concentrations have roughly doubled since preindustrial times, and are projected to continue to increase. Ozone itself is a powerful SLCP as well as a regional ground level air pollutant. Ozone exposure has been linked to increases in emergency room visits for worsening of asthma, hospitalizations due to respiratory disease, and premature death. Additionally, ozone suppresses crop yields; harms ecosystems; and affects evaporation, cloud formation, and precipitation.[166] Thus, reducing methane emissions as part of a broader effort to address climate change can complement local and regional efforts to reduce ground-level ozone.

Strategies to reduce methane emissions from dairy manure management can deliver important health benefits, especially if developed as part of a systematic approach to addressing air quality and water quality. For example, converting operations to pasture-based systems would likely reduce concentrations of and exposure to potentially harmful constituents, such as hydrogen sulfide, ammonia, and particulate matter. One study suggests that ammonia emissions could be 30 percent lower for pasture-based than for confinement systems.[167] It could also improve nutrient management on farms, helping to reduce soil and groundwater contamination. This strategy could be an important element of a sector-wide approach to reducing dairy methane emissions, but may have limited applicability. ARB estimates that about 25

[165] Primary particles are directly released into the atmosphere by combustion processes (such as soot or black carbon and a large variety of organic carbons). "Secondary" particles also form in the atmosphere from other gaseous pollutants, particularly sulfur dioxide, nitrogen oxides (NO_X), ammonia, and volatile organic compounds (VOCs). The transportation sector is an important source of secondary particulate matter such as ammonium nitrate, especially in the winter.

[166] 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.

[167] Perry, A. (2011) Putting dairy cows out to pasture: An environmental plus, USDA-ARS Agricultural Research Magazine, May-June. http://www.ars.usda.gov/is/AR/2011/may11/cows0511.htm

dairies in the State could convert to pasture-based operations without reducing herd size or procuring new land.

Other strategies could also deliver environmental and health benefits. Converting dairies from flushwater manure management systems to dry manure management systems would also improve nutrient management, thereby helping to improve groundwater quality. It is possible that farms may choose some management strategies which could increase or decrease emissions of pollutants of concern. If emissions increase, measures should be implemented to mitigate the impacts as part of the permitting process.

Strategies that capture or produce methane and utilize it for production of renewable energy and fuels could lead to additional sources of combustion, but as part of a regional approach to utilize low-NO_x vehicles and renewable fuels, can displace diesel combustion and help to improve air quality. If electricity is generated onsite using dairy derived biogas, using microturbines or fuel cells can minimize new emissions of NO_x and PM, minimizing potential local health impacts. To the extent that renewable natural gas is produced and injected into the natural gas pipeline network, or used in low-NO_x engines to displace diesel combustion, air quality impacts can be avoided. Prioritizing pipeline injection and onsite usage in low-NOx vehicles, in addition to a coordinated effort to increase use of low-NO_x vehicles with renewable fuels in areas surrounding dairies and elsewhere can reduce air pollution regionally and statewide. These emission reductions translate directly into health benefits, especially in disadvantaged communities near dairies and along transportation corridors, and in areas of non-attainment for ambient air quality standards.

Diverting organics from landfills to compost facilities and anaerobic digestion facilities, along with implementing food rescue and recovery programs, will significantly reduce the need for further landfill development in California, and may help reduce the lifespan of existing landfills, many of which are located in or near environmental justice communities. Phasing out the landfilling of organic materials will also help reduce future levels of fugitive methane emissions from landfills during their operational and post-closure stages. The number and frequency of heavy vehicle or truck trips to existing landfills, through neighboring communities, could potentially be reduced as organic materials are directed to anaerobic digestion facilities and regional compost facilities. To the extent that truck trips are reduced to and from landfills, they could increase in areas where facilities handling diverted organic waste are located. The net effect on overall truck trips in the State and associated emissions is uncertain, and could potentially increase as a result of changes in organic waste management, depending on how strategies are implemented. Many of the same issues associated landfilling organic waste—potential criteria pollutant emissions, water quality impacts, and odors—could be issues at anaerobic digestion or compost facilities. In many cases, these can be effectively limited with available technologies and management strategies, including limiting trucking emissions by utilizing zero emission vehicles or renewable natural gas in low-NO_x engines associated with these operations.

Food rescue and recovery could deliver additional potential health benefits by utilizing useable food to relieve food insecurity and provide better access to healthy foods. Increasing edible food recovery—especially from large-scale food producers, processors, and users—and safely redirecting food to those in need could increase access to healthy fruits and vegetables and benefit millions of Californians who suffer from food insecurity.

Reducing leaks from the oil and gas sector will also reduce VOC emissions, which contributes to ground level ozone formation and related health impacts. For example, ARB's oil and gas regulation is expected to reduce VOC emissions and toxic air contaminants that are emitted from uncontrolled oil and water storage tanks and released from well stimulation recirculation tanks. The estimated reduction in VOCs from this measure is approximately 3,000 tons per year, or about 8 tons per day, statewide.

The measures identified in this Proposed Strategy for HFCs are unlikely to have noticeable health impacts. HFCs have negligible impacts on smog formation and are exempt from U.S. EPA's definition of volatile organic compounds. At higher concentrations that could result from an accidental release in occupational settings, they might be toxic, and emissions of vapors containing HFCs in the workplace environment should be prevented. But at ambient concentrations, HFCs pose no significant health risk, and efforts described in this Proposed Strategy to phase down their use are not expected to deliver noticeable health benefits. Some potential replacements for HFCs could result in emissions of VOCs and particulate matter, but they would be negligible.

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, implementation, and enforcement of environmental laws, regulations and policies." (Government Code Section 65040.12). ARB is committed to continuing to strengthen its outreach efforts to ensure that all California communities have the opportunity to participate in its public processes and benefit from the State's climate-related programs, policies, and regulations.

ARB endeavors to integrate environmental justice into all of its programs, policies, and regulations and is taking additional steps to strengthen its work with the environmental justice community. Specifically, every major program, policy, plan or strategy, and rulemaking explicitly discusses environmental justice and promotes the fair treatment of people from all races, cultures, geographic areas, and income levels—especially in disadvantaged communities. As part of the development and implementation of the AB 32 Scoping Plan, ARB convened an Environmental Justice Advisory Committee (EJAC). ARB has briefed the EJAC on this Proposed Strategy development multiple times, and at its April 2016 meeting, the EJAC discussed and made recommendations on this Proposed Strategy. ARB also works extensively with local air districts and

stakeholders during the development and implementation of its programs to respond to concerns about environmental justice.

The EJAC developed the following recommendations for inclusion in this Proposed Strategy:

> (1) Create a declining methane target specific to dairies that would lead to a 40% reduction mandate for dairies by 2030.
> (2) The dairy emission target should include all methane emissions from dairies, not just from manure handling.
> (3) The Proposed Strategy should explicitly say no disposal of food waste to landfills or incinerators.
> (4) Explore synergies with methane reductions from dairies and the management of organic waste, such as wood waste.
> (5) Include Concentrated Animal Feeding Operations (CAFO) in the methane emission reduction goal.
> (6) Mitigate all additional ancillary emissions generated through achieving the methane emission reduction goal.

This Proposed Strategy includes a measure that would create a regulatory program to achieve a 75 percent reduction in methane emissions from dairy manure management by 2030. It also includes a commitment to work to further examine enteric emissions and reduction opportunities. The GHG inventory includes methane emissions associated with CAFO facilities, which are primarily from enteric fermentation and manure management. The organic diversion measure identified in this Proposed Strategy will virtually eliminate organics from landfills, including food waste.

ARB staff has been working with staff from other state agencies to develop an holistic and synergistic approach to reducing methane emissions, and will continue to work with them to implement these measures. ARB staff will continue to consult with environmental justice communities as we implement the measures to ensure minimum impact and maximum benefit to environmental justice communities. Furthermore, the EJAC recommendations will be taken into consideration as specific actions and policies discussed in this Proposed Strategy are developed into regulatory measures.

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 for the purposes of expenditure of California Climate Change Investment Funds. Of the 12 indicators of pollution included in its 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 related to sources of SLCP emissions.

The distribution of these communities aligns with locations of SLCP emission sources, including sources of organic waste streams 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 have some of the worst pollution burdens in the State and high rates of poverty and unemployment. Forested and rural communities in the northern part of the State and the Sierra also are stricken with 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. To the extent new facilities are built to manage organic waste streams in the State, care must be taken to locate, design, and operate them in a manner that protects local air quality.

The integrated strategy to reduce SLCP emissions from agriculture and waste, developed in this Proposed Strategy, can be part of an integrated strategy to improve air and water quality in agriculture regions, such as in the Central 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 and many other air pollutants from wildfires.

The measures identified in this Proposed Strategy will be further developed in a formal public process that specifically considers environmental justice concerns. 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.

D. Environmental Analysis

ARB, as the lead agency for the Proposed Strategy, prepared a Draft Environmental Analysis (EA) in accordance with the requirements of the California Environmental Quality Act (CEQA) and ARB's regulatory program certified by the Secretary of Natural Resources (California Code of Regulation, title 17, sections 60006-60008; California Code of Regulation, title 14, section 15251, subdivision (d)). The resource areas from the CEQA Guidelines Environmental Checklist were used as a framework for a programmatic environmental analysis of the reasonably foreseeable compliance responses resulting from implementation of the proposed measures discussed in the Proposed Strategy. The Draft EA provides an analysis of both the beneficial and adverse impacts and feasible mitigation measures for the reasonably foreseeable compliance responses associated with the proposed measures under each of 17 environmental resource areas. Collectively, the Draft EA concluded implementation of these actions could result in the following short-term and long-term beneficial and adverse impacts : beneficial long-term impacts in reduced greenhouse gas emissions; less than significant impacts to air quality, biological resources, energy demand, geology and soils, greenhouse gases (short-term), hazards and hazardous materials, hydrology and water quality, resources related to land use planning, mineral resources, noise, population and housing, public services, and recreational services; and

potentially significant and unavoidable adverse impacts to aesthetics, agriculture and forest resources, air quality, biological resources, cultural resources, geology and soils, hazards and hazardous materials, hydrology and water quality, resources related to land use planning, noise, transportation/traffic, and utilities and service systems. The potentially significant and unavoidable adverse impacts are primarily related to short-term construction-related activities, which explains why some resource areas are identified above as having both less-than-significant impacts and potentially significant impacts. Please refer to the Draft EA in Appendix C for further details.

ARB will prepare written responses to all comments received on the Draft EA, which will be presented to the Board for consideration along with the Final EA.

IX. Next Steps

This Proposed Strategy and an accompanying draft Environmental Analysis (EA), was released for public comment. Staff will provide an update to the Board on the Proposed Strategy in May 2016. In fall 2016, 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.

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 Proposed 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 Proposed 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.