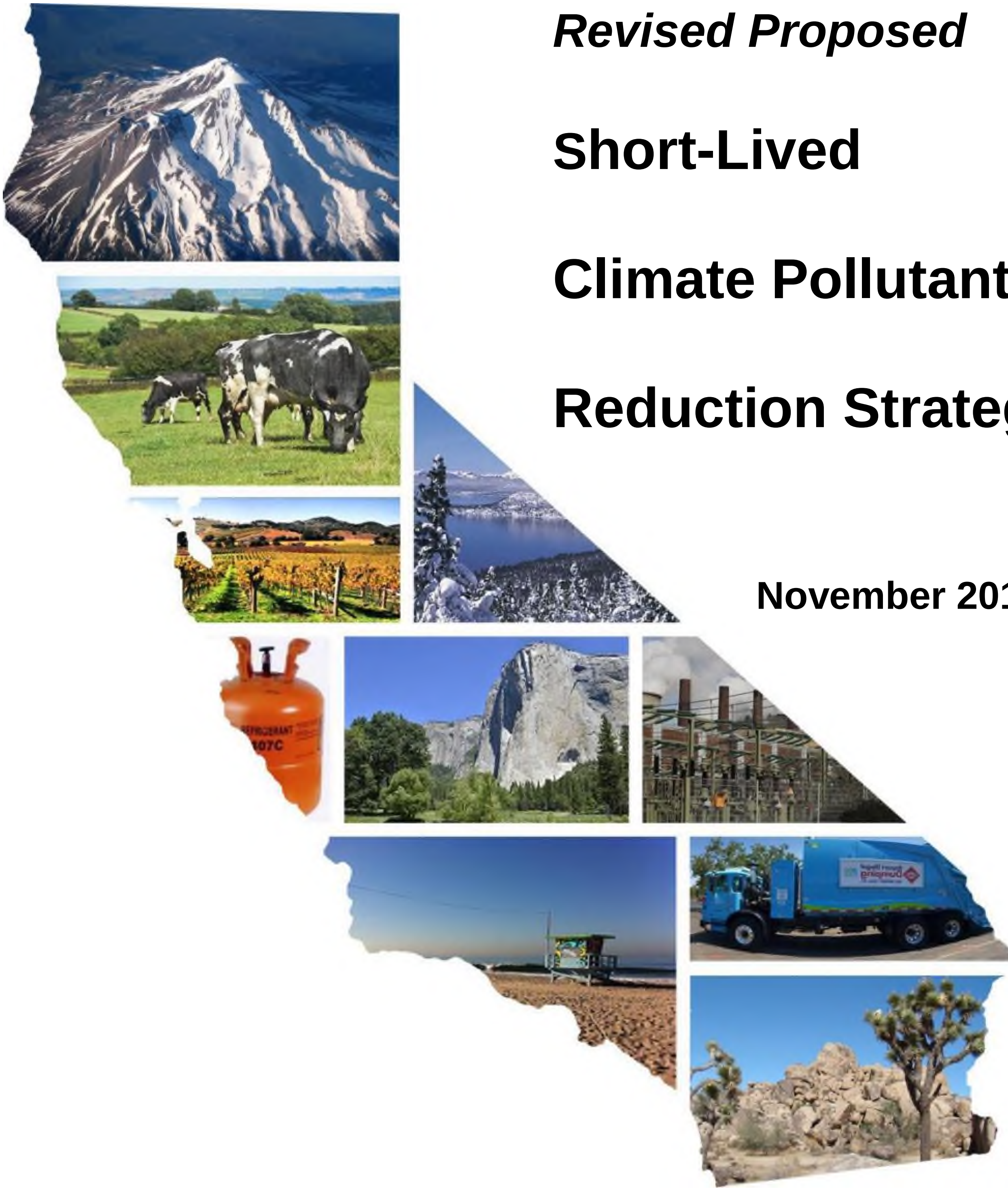

Revised Proposed

Short-Lived Climate Pollutant Reduction Strategy

November 2016

California Environmental Protection Agency
Air Resources Board

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EXECUTIVE SUMMARY

California's dramatic landscapes—including deserts, mountains, valleys, and coastlines—and abundant natural resources, have drawn early explorers and settlers and today's residents. However, climate change is threatening Californian's way of life. The State suffers 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 Need for an SLCP Strategy

- SLCP's are the most potent short-term GHGs
- Significant reductions are needed to minimize the impact of these powerful climate forcers
- Viable opportunities exist to reduce emissions locally and globally
- Reduction measures would provide co-benefits (valuable energy and soil amendment products, reduced reliance on fossil fuel, public health benefits, co-pollutant benefits, etc.)

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.

California's Global Warming Solutions Act, AB 32 (Nuñez, Chapter 488, Statutes of 2006), charges the California Air Resources Board (ARB or Board) with reducing statewide GHG emissions to 1990 emission levels by 2020 and maintaining a statewide GHG emission limit, while seeking continuing GHG emission reductions. In September 2016, Governor Brown signed SB 32 (Pavley, Chapter 249, Statutes of 2016), codifying a reductions target for statewide GHG emissions of 40 percent below 1990 emission levels by 2030. SLCP emission reductions will support achieving these targets. Indeed, specific to SLCP emission reductions, Senate Bill 605 (Lara, Chapter 523, Statutes of 2014) requires the ARB to develop a plan to reduce emissions of SLCPs, and Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) requires the Board to approve and begin implementing the plan by January 1, 2018. SB 1383 also sets targets for statewide reductions in SLCP emissions of 40 percent below 2013 levels by 2030 for methane and HFCs and 50 percent below 2013 levels by 2030 for anthropogenic black carbon, as well as provides specific direction for reductions from dairy and livestock operations and from landfills by diverting organic materials.

This revised proposed SLCP Reduction Strategy (SLCP Strategy) was developed pursuant to SB 605 and SB 1383 and lays out a range of options to accelerate SLCP emission reductions in California, including regulations, incentives, and other market-supporting activities. The SLCP Strategy 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 a comprehensive plan for achieving the SB 32 statewide 2030 GHG limit of 40 percent below 1990 levels. The process for updating the Scoping Plan began in fall 2015 and is scheduled for completion in 2017.

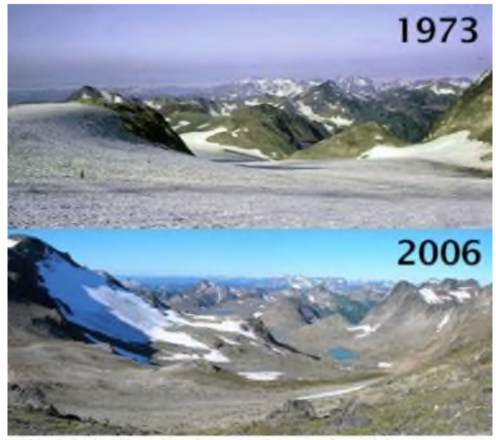
Achievable Goals through Implementing the SLCP Strategy:

- Achieve the following reductions by 2030 (from 2013 levels): ...
    - 50% for anthropogenic Black Carbon
    - 40% for Methane, and
    - 40% for HFCs
- Convert manure and organic wastes into valuable energy and soil amendment products
- Reduce disposal of edible foods by diverting them to food banks and other outlets
- Reduce harmful emissions from residential wood stoves
- Accelerate the reductions of the fastest-growing source of GHG emissions by building on global HFC phasedown agreements.

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. 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.



Glacial decline in the Glacier Peak Wilderness (Washington state) from 1973 to 2006.

Assembly Bill 1613 (Committee on Budget, Chapter 370, Statutes of 2016) and Senate Bill 859 (Committee on Budget and Fiscal Review, Chapter 368, Statutes of 2016) lays out a spending plan for Cap-and-Trade revenues which specifically target SLCP emission reductions. These include $5 million for black carbon wood smoke reductions, $40 million for waste reduction and management, $7.5 million for Healthy Soils, and $50 million for methane emission reductions from dairy and livestock operations.

An Opportunity for California

In this SLCP 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. Organic wastes converted to biogas could supply enough renewable natural gas for about 2 million residential units.[1] 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


Dairy gas cleanup system (gas scrubber)

[1] For illustrative purposes only. This SLCP Strategy calls for a variety of waste management approaches, some of which do not yield energy products.

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, and encourage low-Global Warming Potential (GWP) refrigerants. 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, as called for in SB 1383. 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 such as a uniform fertilizer that come from compost or anaerobic digestion facilities will help to secure financing to accelerate and scale project development.

Building on California Leadership

This SLCP 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

SLCP Guiding Principles

Measures to reduce SLCP emissions should be:

- Commercially and technologically feasible
- Informed by sound science and best available information
- Designed to maximize air pollution reductions and other co-benefits, especially considering disadvantaged communities
- Leveraged with other market programs, incentives, and investments to maximize the measures' efficacy
- Developed in consultation with disadvantaged communities, affected industries, relevant local and State agencies, and other stakeholders

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 SLCP 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.

State agencies and the air districts are committed to continuing to work together to ensure that the concepts outlined in this SLCP 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;
- Significantly cut methane emissions from dairy and livestock operations while providing farmers with new, potentially lucrative revenue streams;
- Significantly reduce disposal of organics in landfills and 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.

Achieving Significant Emission Reductions

SB 1383 sets statewide emission reduction targets of 40 percent below 2013 levels by 2030 for methane and HFCs, and 50 percent below 2013 levels by 2030 for anthropogenic black carbon emissions, codifying the proposed targets included in earlier versions of this SLCP Strategy. These targets will assist the State in meeting its SB 32 goals and federal air quality standards for 2031 and beyond.

The emission reductions associated with these targets are summarized in Table 1. The goals and proposed measures included in this SLCP Strategy will reduce SLCP emissions to levels in line with these targets. Recognizing how damaging SLCPs can be over the short-term, 20-year GWPs are used in this report to quantify emissions of SLCPs, as opposed to 100-year GWPs, which are used in the State's official GHG inventory and for accounting for emissions in programs adopted under AB 32.

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

Pollutant	2013	2030 BAU**	2030 Emission Reduction Target (percent reduction from 2013)
Black carbon (anthropogenic)	38	26	19 (50%)
Methane	118	117	71 (40%)
Hydrofluorocarbons (HFCs)	40	65	24 (40%)

*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 anthropogenic 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 SLCP 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 recently signed legislation allocating $5 million to reduce black carbon from wood smoke.

Wildfire is the largest source of black carbon in California. Prescribed fires also emit black carbon, but are an important tool for forest managers. However, since the legislative direction and intent of SB 1383 is to include only non-forest sources of black carbon in the target, a target for forest-derived black carbon emission reductions is not included in this SLCP Strategy. In general, forests are burning at increasing rates and at increasing levels of severity. This trend raises concern over the long-term health of these forests and ability to sequester carbon and provide resource amenities. Fuel treatments are key elements of forest restoration strategies, and are embedded in management strategies at local, state and national levels. The Forest Carbon Plan, as well as the 2030 Target Scoping Plan Update, will continue to explore the interrelation of climate change and natural lands.

Methane

Methane is responsible for about 20 percent of current net climate forcing globally. In California, about half of methane emissions come from dairy and livestock manure or organic waste streams that are landfilled. These resources could be put to valuable use as sources of renewable energy or fuel, soil amendments, and other products. 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, pursuing opportunities to reduce methane emissions from enteric fermentation, significantly reducing 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, soil amendments, and low carbon transportation fuels; overcoming barriers to pipeline injection of biomethane, grid connection for electricity or another best-use alternative; and identifying effective financing mechanisms and levels to reach the goals in this SLCP Strategy.

Ultimately, a combination of incentives, State and private sector collaboration and investment, and regulations will be necessary to capture the value in organic waste streams and ensure lasting emission reductions in order to achieve an economy-wide 40 percent reduction in methane.

Manure is responsible for 25 percent of California's methane emissions and improved manure management offers significant, near-term potential to achieve deep reductions in the State's methane emissions. Before ARB regulates dairy and livestock manure emissions, as required by SB 1383, California agencies will encourage and support near-term actions by dairies to reduce manure emissions through financial incentives, collaboration to overcome barriers, development of policies to encourage renewable natural gas production, and other market support.

Enteric fermentation from all livestock is responsible for roughly 30 percent of the State's methane emissions and is a critical source to control, but development of effective control measures face a unique set of challenges. The State will support and monitor research and explore voluntary, incentive-based approaches to reduce enteric fermentation emissions from dairy and non-dairy livestock sectors until cost-effective and scientifically-proven methods to reducing these emissions are available and regulatory actions can be evaluated.

Any regulations will be developed according to the time frames and requirements set forth in SB 1383 and AB 32, and in coordination with CDFA, CPUC, and local air quality and water quality agencies. The development of measures to reduce methane will be done in close coordination with dairy industry and will consider public input; available financial incentives; technical, market, and regulatory barriers to the development of dairy methane emission reduction projects; research on dairy methane emission reduction projects; and the potential for emissions leakage. A key effort will include working with CPUC and the dairy industry to implement a series of pilot projects that will help to better inform the opportunities for economically viable methane reduction strategies as well as the barriers that must be addressed. SB 1383 stipulates that manure methane emission control regulations are to be implemented on or after January 1, 2024. However, the statute allows ARB to require monitoring and reporting of emissions from dairy and livestock operations before that date. Consistent with SB 1383, ARB, in consultation with CDFA, will analyze the progress dairies are making in achieving the goals in this SLCP Strategy by July 1, 2020, and may adjust those goals as necessary.

For organic waste currently landfilled, the California Department of Resources Recycling and Recovery (CalRecycle) will consult with ARB to develop regulations by 2018 to reduce the level of the statewide disposal of organic waste by 50 percent of 2014 levels by 2020 and 75 percent of 2014 levels by 2025. These regulations will take effect on or after January 1, 2022. CalRecycle plans to consider the regulations for adoption by the end of 2018, which will: 1) allow jurisdictions that want to adopt early the ability to do so, thus contributing to the 2020 goal; and 2) provide clear direction to all jurisdictions, their service providers, and regulated businesses so that they can plan and budget for the required program changes that will need to take effect in 2022.

To support this, CalRecycle, with assistance from ARB, 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. Key issues include quantifying the co-benefits and the GHG emission reduction benefits of applying compost, addressing the cross-media regulatory tradeoffs between product use benefits relative to compost facility impacts, making beneficial use of biomethane generated from anaerobic digestion projects, and overcoming difficult issues associated with siting, social acceptance, CEQA mitigation, and other issues associated with new organics processing facilities.

Under SB 1383, 20 percent of the edible food destined for the organic waste stream is to be recovered to feed people in need by 2025. CalRecycle will explore new ways to foster food waste prevention and food rescue. Recovering and utilizing food that would otherwise be landfilled can help to reduce methane emissions and increase access to healthy foods for millions Californians lacking access to an adequate food supply. Additionally, CalRecycle and ARB will work with the State and regional Water Boards to assess the feasibility and benefits of actions to require capturing and effectively utilizing methane generated from wastewater treatment, and opportunities for co-digestion of food waste at existing or new anaerobic digesters at wastewater treatment plants.

This SLCP Strategy also establishes a goal of reducing fugitive methane emissions from oil and gas by 40 percent below current levels in 2025 and a minimum 45 percent in 2030, and from all other sources by 40 percent in 2030. This aligns with the federal government's 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

(CPUC) 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. In addition, AB 1496 (Thurmond, Chapter 604, Statutes of 2015) requires ARB, in consultation with the local air districts, to monitor and measure high-emission methane hot spots in the State. 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.

The annual Montreal Protocol Meeting of Parties in October 2016 in Kigali, Rwanda, resulted in an historic international agreement, known as the "Kigali Amendment", to phase down the production of HFCs globally. The agreement requires a reduction in the production and supply of HFCs for developed countries, including the U.S., as follows: 10 percent reduction in 2019; 40 percent in 2024, 70 percent in 2029, 80 percent in 2034, and 85 percent in 2036. Developing countries will not have to begin the phasedown until 2029, and will be allowed until 2045 to reach the 85 percent reductions in HFC consumption. Although the HFC phasedown will result in significant reductions, a long lag time of 10-20 years exists between a production phase-out and an equivalent emission reduction, due to an average 15-year lifetime for refrigeration equipment. During the equipment lifetime, it continues to use and emit the high-GWP refrigerants it was designed to use.

ARB will sponsor a third-party assessment of the impact of the Kigali Amendment on HFC emissions and reductions in California, especially as they pertain to meeting the 40 percent emission reduction goal. The assessment will be completed in early 2017, and pending results of the assessment, specific HFC reduction measures described in this SLCP Strategy may be revised accordingly. ARB will focus on measures that can move low-GWP alternatives and technologies forward both nationally and internationally. For example, as effective alternatives become available, ARB will consider developing limitations on the use of high-GWP refrigerants in new refrigeration and air-conditioning equipment where lower-GWP alternatives are feasible and readily available. California has a wide range of climate zones from alpine conditions to hot desert environments. As such, California could be instrumental as a proving ground for low-GWP refrigeration and air-conditioning technologies that can be used in extreme environments across the world.

A summary of all proposed SLCP emission reduction measures and estimated reductions is presented in Table 2. These estimates may change as more information on emission sources becomes available and as programs or regulations are developed.

Table 2: Summary of Proposed New SLCP Measures and Estimated Emission Reductions (MMTCO2e)[1]

Measure Name	2030 Annual Emission Reductions	2030 Annual Emissions
BLACK CARBON (ANTHROPOGENIC)		
2030 BAU[2]		**26**
Residential Fireplace and Woodstove Conversion	3	
State Implementation Plan Measures and Clean Energy Goals[3]	4	
2030 BAU with new measures		**19**
METHANE		
2030 BAU[2]		**117**
Dairy and Other Livestock (Manure and Enteric Fermentation)	26	
Landfill	4	
Wastewater, industrial and Other Miscellaneous Sources	7	
Oil and Gas Sector	8	
2030 BAU with new measures		**71**[4]
HYDROFLUOROCARBONS		
2030 BAU[2]		**65**
Financial Incentive for Low-GWP Refrigeration Early Adoption	2	
HFC Supply Phasedown (to be achieved through the global HFC phasedown)[5]	19	
Prohibition on sales of very-high GWP refrigerants	5	
Prohibition on new equipment with high-GWP Refrigerants	15	
2030 BAU with new measures		**24**

[1]Using 20-year GWPs from the 4th Assessment report of the IPCC for methane and HFCs, and 5th Assessment report for black carbon (the first report to define a GWP for black carbon)
[2]Business As Usual (BAU) forecasted inventory includes reductions from implementation of current regulations
[3]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
[4] The specific annual reduction values shown above do not sum exactly to the total shown due to rounding error.
[5] A global HFC production and consumption phasedown was agreed to on October 15, 2016, in Kigali, Rwanda. ARB is currently evaluating the impact upon HFC emission reductions in California and plans to utilize the results from the assessment to inform future updates to BAU projections for HFC emissions.

Cost-Effective Measures with Significant Health Benefits

Significantly reducing SLCP emissions in line with the targets presented in this SLCP 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 in this SLCP Strategy can contribute to health, environmental, and economic benefits that will positively impact Californian businesses and individuals. As California industry and households shift to cleaner technologies, many benefits will be concentrated in disadvantaged communities or other parts of the State most in need of economic development opportunities. The San Joaquin Valley, rural areas where wood smoke is a primary health concern, and communities along freight corridors are anticipated to see improvements in health as well as green job growth and environmental benefit.

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 Low Carbon Fuel Standard (LCFS) credits and RIN credits from the federal Renewable Fuel Standard can make these projects profitable. However, there remain market barriers 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 SLCP Strategy could significantly reduce GHG emissions through 2030 at a very low cost per tonne.

Achieving the targets identified in this SLCP 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 LCFS, 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 SLCP Strategy and capture additional economic, environmental and health benefits.

Putting the Strategy into Action

SB 1383 requires ARB to begin implementing the SLCP Strategy by January 1, 2018, as well as stipulates timeframes for other requirements (Table 3).   All regulatory measures developed pursuant to the SLCP Strategy would undergo a complete, public rulemaking process including workshops, and economic and environmental evaluations. While this SLCP 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. Staff will track the progress of implementation of the SLCP measures and provide periodic updates to the Board. This information, as well as updates to the SLCP emission inventory, will be posted to ARB's SLCP website.

Table 3: Timeline for SB 1383 Mandates

Action	Deadline
ARB approves SLCP Strategy and begins Implementation Expected approval date Statutory deadline	 First Quarter 2017 By January 1, 2018
ARB, CDFA, State Water Resources Control Board and Regional Water Quality Control Boards in coordination with the energy agencies, will work with the dairy industry to establish a dairy workgroup to identify and address barriers to the collection and utilization of biomethane.	First Quarter 2017
ARB, in consultation with CPUC and CEC, develops policies to encourage development of infrastructure and biomethane projects at dairy and livestock operations	By January 1, 2018
ARB develops a pilot financial mechanism to reduce LCFS credit value uncertainty from dairy-related projects and makes recommendations to the Legislature to expand the mechanism to other biogas sources	By January 1, 2018
ARB provides guidance on the impact of regulations on LCFS credits and compliance offsets	By January 1, 2018
CPUC, in consultation with ARB and CDFA, directs utilities to develop at least 5 dairy biomethane pipeline injection projects	By January 1, 2018
CEC develops recommendations for the development and use of renewable gas as part of its 2017 Integrated Energy Policy Report	By early 2018
PUC renewable gas policies based on CEC IEPR	Ongoing
ARB, in consultation with CDFA, evaluates the feasibility of enteric fermentation methane reduction incentives and regulations and develops regulations as appropriate	Ongoing

Action	Deadline
ARB, in consultation with CDFA, analyzes and reports on the methane reduction progress of the dairy and livestock sector	By July 1, 2020
CalRecycle, in consultation with ARB, evaluates progress towards meeting the 2020 and 2025 organics waste reduction goals, the status of organics markets and barriers, and recommendations for additional incentives	By July 1, 2020
CalRecycle adopts an organics disposal reduction regulation	2018
CalRecycle implements an organics disposal reduction regulation	On or after January 1, 2022
ARB begins developing and considers for adoption a manure management methane reduction regulation	Before January 1, 2024
ARB implements a manure management methane reduction regulation	On or after January 1, 2024

Effectively implementing this SLCP 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.

Implementing the SLCP Strategy will also require overcoming barriers to connecting distributed electricity, generated from renewable natural gas (RNG), to the grid and injecting renewable natural gas into the pipeline. To address these obstacles, SB 1383 calls for ARB to establish energy infrastructure development and procurement policies needed to encourage dairy biomethane projects and calls on the CPUC to direct gas companies to implement no fewer than five dairy biomethane pilot projects to demonstrate interconnection to the common carrier pipeline system. The same issues also apply to organic waste biomethane projects. On a broader scale, SB 1383 requires CEC to develop recommendations for the development and use of renewable gas as a part of its 2017 Integrated Energy Policy Report. Based on CEC's recommendations, State agencies will strive to meet the State's climate change, renewable energy, low carbon fuel, and SLCP goals by considering and adopting policies and incentives to significantly increase the sustainable production and use of renewable gas. CPUC will consider additional policies to support the development and use in-State of renewable gas that reduces SLCPs. These policies shall prioritize fuels with the greatest GHG emission benefits, taking into account RNG carbon intensity and reductions in SLCP emissions.

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 165 jurisdictions have signed or endorsed the Under 2 MOU, collectively representing more than one billion people and nearly $26 trillion in GDP, equivalent to 35 percent of the global economy.[2] As it implements the actions identified in this SLCP 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.

[2] http://under2mou.org/

I. Introduction: Showing the Way to 2^{o}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^{o}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^{o}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^{o}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. [3,4,5,6,7]

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

[4] 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]

[5] 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 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 SB 32, and to ensuring emissions meet the statewide GHG emission limits as codified. This SLCP 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 statewide GHG limits are 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 two bills: Senate Bill 605 (Lara, Chapter 523, Statutes of 2014), which requires the Air Resources Board (ARB or Board) to develop a strategy to reduce SLCP emissions; and Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016), which requires the Board to approve and begin implementation of the SLCP Strategy by January 1, 2018, and sets 2030 reduction targets for SLCPs emissions.

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

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[6] 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

[7] 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/

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.[8,9] 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 relative to a "reference" scenario by 2030.[10,11] Additionally, a new proposed global phase down of HFCs under the Montreal Protocol that was adopted in October 2016, is expected to cut the production of HFCs by up to 70 percent by 2030, and up to 85 percent by 2036 in developed countries including the U.S.[12,13]

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 $0.6^{o}C$,[14,15] which would reduce the risk of dangerous climate

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[8] 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

[9] 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

[10] 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

[11] 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

[12] UNEP (2016). United Nations Environment Programme (UNEP). Further Amendment of the Montreal Protocol submitted by the Contact Group on HFCs. 14 October 2016. http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=27086&ArticleID=36283&l=en

[13] IGSD (2016) Institute for Governance and Sustainable Development (IGSD) "Nations Agree to Kigali Amendment: Largest Near-Term Temperature Reduction from Single Agreement", 15 October 2016. http://www.igsd.org/nations-agree-to-kigali-amendment-largest-near-term-temperature-reduction-from-single-agreement/.

[14] 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]

[15] 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.[16] It would also increase the probability of staying below the 2°C threshold to more than 90 percent through 2050.[17,18]

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.[19] 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.[20,21] 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.[22]

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.[23] 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.[24] 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

[16] 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

[17] 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

[18] 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

[19] 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

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

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

[22] 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

[23] 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

[24] 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 rail yards 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.
- 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,[25] essentially offsetting one to two decades' worth of CO_2 emissions.[26]
- *Methane*: California has the nation's strongest standards for limiting methane emissions from landfills, has offset protocols under our Cap-and-Trade Program to encourage the reduction of methane emissions, and has rules under development and being implemented to create a comprehensive approach to limit methane leaks from the oil and gas production, processing, and storage sector, and the natural gas pipeline system. These efforts are serving to keep methane emissions fairly steady in the State.

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[25] 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

[26] 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

- *HFCs*: The State has regulations in place to reduce emissions from refrigerants, motor vehicle air-conditioning, and consumer products that together are expected to 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, [27] 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. In September 2016, the Legislature passed and Governor Brown signed SB 32 (Pavley, Chapter 249, Statutes of 2016), which codifies an earlier Executive Order, and reinforces direction already in AB 32 by requiring statewide GHG emissions to be reduced to 40 percent below 1990 emission levels by 2030. Specific to SLCP emission reductions, Senate Bill 605 requires ARB to develop a plan to reduce emissions of SLCPs, and Senate Bill 1383 requires the Board to approve and begin implementation of the SLCP Strategy by January 1, 2018, and sets SLCP emission reduction targets for 2030 that are in-line with the 40 percent reductions called for in SB 32.

Senate Bill 605 (Appendix A), requires ARB to develop a comprehensive strategy, in consultation with other State agencies and the air districts, to reduce emissions of SLCPs in the State, including completing an inventory of SLCPs in the State, identifying research gaps, identifying existing and potential new control measures to reduce emissions, and prioritizing the development of new measures for SLCPs that offer co-benefits.

Senate Bill 1383 (Appendix B) requires ARB to approve and begin implementing the SLCP Strategy by 2018, codifies the statewide SLCP emission reduction targets that were in earlier versions of the SLCP Strategy, provides specific direction for reductions from dairy and livestock operations and from landfills by diverting organic materials, requires actions to support in-State production and use of renewable natural gas, and stipulates guidelines and analyses that will shape the implementation of this SLCP Strategy.

ARB developed this revised proposed SLCP Reduction Strategy (SLCP Strategy) pursuant to SB 605 and SB 1383, in coordination with other State agencies and local air

[27] 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

quality management and air pollution control districts. The SLCP Strategy has been developed with input from interested stakeholders in an open and public process and describes a 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[28] and current and future research needs are included in Appendix C, and research efforts to evaluate potential mitigation measures for each SLCP is included in Appendix D.

Measures included in this SLCP Strategy will be developed under future public regulatory processes with the appropriate public process, economic analyses, environmental analyses, and consideration of environmental justice. ARB's rulemaking process includes extensive stakeholder input. California law and policy require a careful, deliberative process when regulations are being developed, that includes extensive review and analysis of economic and environmental impacts as required by the Administrative Procedure Act (APA) and California Environmental Quality Act (CEQA). SB 1383, and SB 605 also make clear that ARB is to carefully consider such matters, including potential effects on compliance with state programs to reduce criteria pollutants, potential interactions with other environmental challenges, the risk of leakage (a reduction in GHG emissions within the State that is offset by an increase in out of State GHG emissions), and impacts on disadvantaged communities.

D. Achieving Science-Based Targets

SB 1383 sets statewide SLCP emission reduction targets of 40 percent below 2013 levels by 2030 for methane and HFCs, and 50 percent below 2013 levels by 2030 for anthropogenic black carbon emissions, codifying the proposed targets included in earlier versions of this Strategy. For purposes of this SLCP Strategy, anthropogenic black carbon emissions do not include forest-related sources (wildfires and prescribed burning). The emission reductions associated with these targets are translated into millions of metric tonnes of CO_2-equivalent ($MMTCO_2e$) in Table 4.

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

Table 4: California SLCP Emissions and Emission Reduction Target Levels ($MMTCO_2e$)*

Pollutant	2013	2030 BAU**	2030 Emission Reduction Target (percent reduction from 2013)
Black carbon (anthropogenic)	38	26	19 (50%)
Methane	118	117	71 (40%)
Hydrofluorocarbons (HFCs)	40	65	24 (40%)

*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

The measures identified in this SLCP Strategy and their expected emission reductions will feed into the update to the Climate Change Scoping Plan that is currently being developed. 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 SLCP 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 SLCP Strategy to meet these targets would put California on the path to meet the State'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.[29] 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.[30] 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 this SLCP 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 SLCP 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

Gas monitoring probe at an unnamed state landfill.

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

local air districts to identify SLCP emission reduction measures that could be implemented through district action, such as residential wood burning incentive programs

ARB released for public review, a Concept Paper for the SLCP Strategy in May 2015, a Draft SLCP Reduction Strategy in September 2015, and a Proposed Strategy and an accompanying draft Environmental Analysis (EA) in April 2016. Staff reported to the Board on the Proposed Strategy in May 2016.

With the enactment of SB 1383, ARB took a fresh look at the SLCP Strategy and is re-issuing it in a revised form. Accordingly, this revised Proposed SLCP Reduction Strategy, which incorporates requirements of SB 1383, was released in November 2016. Additionally, ARB revised the Draft Environmental Analysis (EA) that was initially released for review on April 11, 2016, to address changes that were made to the SLCP Strategy (Appendix E). Since the entire Draft EA has been substantially revised and is being recirculated for a new 45-day public comment period, new comments must be submitted on the Revised Draft EA, and ARB will respond only to those comments received on the recirculated Revised Draft EA. Staff will hold public workshops to solicit public input on the revised SLCP Strategy and Revised Draft EA by the end of 2016. The Final SLCP Strategy, the final EA, and written responses to comments received on the Revised Draft EA will be presented to the Board for consideration at a public hearing in early 2017.

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 the targets in this SLCP Strategy, as well as other requirements in SB 1383 and SB 605. 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;
- 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 SLCP 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 SLCP 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.[31,32] This infrastructure could provide valuable new sources of renewable electricity or biogas, clean transportation fuels, compost as well as 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. SB 1383 requires CEC, CPUC, and ARB to develop policies to support the development and use of in-state renewable natural gas to support dairy and other biomethane project developments. It also requires CalRecycle, in consultation with ARB, to adopt regulations to achieve the landfill organics disposal reduction goals, assess progress towards meeting those goals, to conduct a product markets analysis and identify project barriers to best use biomethane (pipeline and grid connections, products, etc.), and to make recommendations for additional policies if warranted. Collectively, products from organic waste streams in California, and potential environmental credits from them, could represent a market worth billions of dollars in California.

Covered dairy digester lagoon

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

[31] 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/

[32] 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

uncovered lagoons and use lagoon water to fertilize on-site forage crops. This approach to managing manure has helped to improve the efficiency of dairy farms and milk production over the years. However, these lagoons also create one of the largest sources of methane emissions in the State, and—when combined with imprecise or improper land application of nutrients, water, and salts via flood irrigation of lagoon effluent—can create adverse groundwater and nutrient management issues on farms. Alternatively, manure can be managed in a way to reduce or avoid methane emissions and open up opportunities for improving farm nutrient management activities. For composting, utilizing clean technologies such as aerated static piles results in reduced emissions of volatile organic compounds at the compost facilities, as well as GHG emission reductions in the form of avoided landfill emissions and realization of co-benefits such as increased soil health when the compost product is applied to soils.

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, streamlining various governmental and utility permitting processes, and quantifying the co-benefits of using compost and incorporating that information into cross-media regulatory decisions.

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.

These barriers are not insurmountable, however. 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 SLCP 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. SB 1383 requires ARB, CalRecycle, and CDFA to work with stakeholders to identify and address technical, market, regulatory and other challenges to putting California's waste resources, including diverted landfill organics and dairy manure, to beneficial use.

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 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 self-sustaining (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 in total, to offset half of renewable natural gas interconnection costs of individual projects. AB 2313 (Williams, Chapter 531, Statues of 2016) raised the incentives cap on dairy cluster projects to $5 million and on other individual projects from $1.5 million to $3 million. State agencies are already collaborating to overcome barriers to pipeline injection of biogas, pursuant to the Governor's call to make heating fuels cleaner,[33] 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. Additional research regarding constituents of concern in biomethane produced from different feedstocks may lead to refinements in testing requirements for pipeline injection and associated cost savings. 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.

Dairy manure separator

SB 1383 places biomethane development requirements on ARB, CPUC, and CEC. By January 1, 2018, ARB is to establish energy

[33] https://www.gov.ca.gov/news.php?id=18828

infrastructure development and procurement policies needed to encourage dairy biomethane projects. CPUC is required to direct gas companies to implement no fewer than five dairy biomethane pilot projects to demonstrate interconnection to the common carrier pipeline system. On a broader scale, SB 1383 requires CEC to develop recommendations for the development and use of renewable gas as a part of its 2017 Integrated Energy Policy Report, including identifying cost-effective strategies that are consistent with existing State policies, including the Renewable Portfolio Standard, LCFS, Cap-and-Trade, the State's waste diversion goals, and the SLCP Strategy. Based on CEC's recommendations, State agencies will strive to meet the State's climate change, renewable energy, low carbon fuel, and SLCP goals by considering and adopting policies and incentives to significantly increase the sustainable production and use of renewable gas. CPUC will consider additional policies to support the development and use in-State of renewable gas that reduces SLCPs. These policies shall prioritize fuels with the greatest GHG emission benefits, taking into account RNG carbon intensity and reductions in SLCP emissions.

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.[34] 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, in cooperation with CalRecycle, has developed a quantification methodology to estimate GHG emission reductions from composting and anaerobic digestion projects funded through the Greenhouse Gas Reduction Fund (GGRF). ARB is also coordinating with CDFA, CalRecycle, and other agencies working on the Healthy Soils Initiative to identify additional research needs to inform the science and accounting methods necessary to quantify the benefits of using compost and other soil amendments and address any potential problems such as buildup of salts or heavy metals in soil. Collaboration among state agencies, water districts, and local governments will help quantify the benefits of using compost for urban storm water management, soil remediation, water conservation, and other beneficial uses.

D. Invest in SLCP Emission Reductions and Communities

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

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

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 agricultural and other 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 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 and build sustainable freight systems.

Initial estimates regarding State support for infrastructure to meet the goals identified in this SLCP Strategy is similar for both the waste sector and dairy sector. CalRecycle and CDFA both estimate that direct State 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 SLCP 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),[35] the Alternative and Renewable Fuel and Vehicle Technology Program (AB 118), Electric Program Investment Charge (EPIC) Program, Carl Moyer program, Air Quality Improvement Program, and 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.

[35] 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.

Potential new funding mechanisms and incentive structures must also be considered. These could include adjusting the waste disposal tipping fee and establishing a waste generator fee 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 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.


Rooftop HVAC system

This SLCP Strategy, including Appendices C and D, 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 SLCP 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,[36] and the sources align with those covered by federal reporting programs.[37] In contrast, most fugitive emissions[38] (a category into which SLCP emissions generally fall) do not meet these criteria.[39] They are frequently difficult to measure, measurements have high uncertainties,[40] measurement methods are often difficult and less precise,[41] and carbon costs are hard to assign with the same reliability as for combustion sources of CO_2.[42]

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[36] *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.

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

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

[39] 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/.

[40] 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/.

[41] 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.

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

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 SLCP Strategy does not recommend expanding Cap-and-Trade Program coverage.[43] Instead, the SLCP 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 SLCP 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.[44]

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

[44] 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,[45,46] which is needed to keep average warming below 2^{o}C this century.


Mount Shasta

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.[47,48,49,50,51]

45 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

46 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

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

48 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/

49 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]

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

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

Co-Benefits of Reducing SLCPs

Flood damage from Hurricane Sandy at Assateague Island National Seashore Park (Virginia)

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.[52] 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.[53,54] 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.[55]

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 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

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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

52 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

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

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

55 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].

warming and increased loss of mass from glaciers and ice sheets.[56] A recent study raises the possibility of a more rapid rate of sea level rise in this century than forecast by the U.N.'s Intergovernmental Panel on Climate Change (IPCC).[57] The authors conclude that 2^o C global warming above the preindustrial level would spur ice shelf melt sufficient to cause a sea level rise of several meters. Sea level rise is an important impact of climate change on California due to the long coastline and large population that lives near coastal waters. Mitigating SLCP emissions can have significant benefits for slowing sea level rise, reducing the rate by 24-50 percent by 2100, if it begins now. Mitigating emissions of both CO_2 and SLCPs can reduce the projected rate of sea level rise by 50–67 percent by 2100.[58]

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.[59] 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.[60] The current California drought highlights the critical need for developing drought resilience, even if wet conditions mitigate the current drought.[61,62]

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

[56] 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.

[57] 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

[58] 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

[59] 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.

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

[61] 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*

[62] 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 relative to a "reference" scenario by 2030".[63,64] Additionally, a new proposed global phase down of HFCs under the Montreal Protocol that was adopted in October 2016, is expected to cut the production of HFCs by up to 70 percent by 2030, and up to 85 percent by 2036 in developed countries including the U.S.[65,66] 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,[67,68] which would reduce the risk of dangerous climate feedbacks such as accelerated Arctic melting and sea level rise.[69] It would also increase the probability of staying below the 2^{o}C threshold to more than 90 percent through 2050.[70,71]

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

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[63] 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

[64] UNEP and WMO (2011) Integrated Assessment of Black Carbon and Tropospheric Ozone, United Nations Environment Programme and World Meteorological

[65] UNEP (2016). United Nations Environment Programme (UNEP). Further Amendment of the Montreal Protocol submitted by the Contact Group on HFCs. 14 October 2016. http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=27086&ArticleID=36283&l=en

[66] IGSD (2016) Institute for Governance and Sustainable Development (IGSD) "Nations Agree to Kigali Amendment: Largest Near-Term Temperature Reduction from Single Agreement", 15 October 2016. http://www.igsd.org/nations-agree-to-kigali-amendment-largest-near-term-temperature-reduction-from-single-agreement/.

[67] 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]

[68] 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

[69] 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

[70] 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

[71] 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

4th Assessment Report of the IPCC (AR4), which was released in 2007. For the first time, GWP estimates for black carbon are reported in the 5th Assessment Report of the IPCC (AR5), which includes the independent scientific assessment of black carbon radiative forcing published by Bond et al.[72] This SLCP 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.[73] 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 5 illustrates the lifetime and 20-year GWP for each SLCP.

Table 5: 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

[72] 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
[73] 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

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

A. Black Carbon

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

Black carbon is emitted from burning fuels such as coal, diesel, and biomass, as well as from various forms of non-fuel biomass combustion (destruction of excess woody wastes, wildfires, etc.). 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.[74,75] 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

[74] 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
[75] 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

climate forcing in California. This project will improve our understanding of the fundamental processes that dominate brown carbon formation, and help to determine the potential climate benefit of mitigating sources of brown carbon emissions in California.

B. Methane

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

Methane is responsible for about 20 percent of current global warming,[76] 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.[77] 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.

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[76] 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

[77] 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

Ozone negatively impacts human health, and can lead to asthma attacks, hospitalizations, and even premature death. It impairs the ability of plants to absorb CO_2, thereby suppressing crop yields and harming ecosystems. Ozone also affects evaporation rates, cloud formation, and precipitation levels. In addition to the direct climate benefits of cutting methane emissions, it can also reduce global background levels of ozone pollution and provide additional climate, health, and other benefits.[78,79,80]

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

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[78] 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.

[79] 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.

[80] 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.

(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 1700, and the average 20-year GWP is about 3800. The major concern with respect to HFCs is that their contribution to climate forcing is expected to increase rapidly in the future as they continue to replace ozone depleting substances (ODS), such that they will become very significant contributors. Studies indicate that a lack of action to prevent the growth of HFCs would greatly undermine efforts to address climate change. A recent study concluded that replacing high-GWP HFCs with low-GWP alternatives could avoid 0.1°C of warming by 2050 and warming of up to 0.5°C by 2100,[81] 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.[82,83] Between 1990 and 2010 the Montreal Protocol reduced CO_2e emissions nearly twenty times more than the initial commitment period of the Kyoto Protocol.[84] 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.

[81] 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.
[82] Velders G. J. M. *et al.* (2007) *The importance of the Montreal Protocol in protecting climate*, Proc. Nat'l. Acad. Sci. USA 104:4814.
[83] 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
[84] UNEP (2012) The Montreal Protocol and the Green Economy: Assessing the contributions and co-benefits of a Multilateral Environmental Agreement.

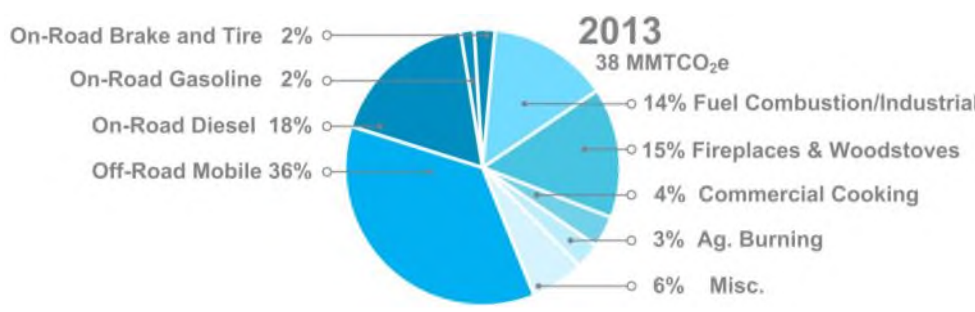
IV. Reducing Anthropogenic Black Carbon Emissions

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.[85] 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 blueprint for other jurisdictions to reduce SLCP emissions and improve public health. Existing programs will continue to reduce black carbon emissions. For example, complying with federal air quality standards and reducing localized health risk will require substantial reductions in smog-forming and PM emissions from mobile sources and other source categories.

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).

Figure 1: California 2013 Anthropogenic Black Carbon Emission Sources*



*Using 20-year GWP

Wildfire is the largest source of black carbon in California. Prescribed fires also emit black carbon, but are an important tool for forest managers. However, since the

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[85] 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

legislative direction and intent of SB 1383 is to include only non-forest sources of black carbon in the target, a target for forest-derived black carbon emission reductions is not included in this SLCP Strategy. For reference, estimates for 10-year annual average black carbon emissions from fires that occurred in forests and other lands are provided in Table 6. Emissions from fires in forests and other lands vary dramatically from year-to-year, and these inventories contain higher uncertainty[86] than the anthropogenic sources in Figure 1.

Table 6: 10-Year Average California Black Carbon Emissions: Wild and Prescribed Fire

Source	10-Year Average Emissions (MMTCO2e)*
Prescribed Burning	3.6
Wildfire	86.7

*Using 20-year GWP

In general, forests are burning at increasing rates and at increasing levels of severity.[87] This trend raises concern over the long-term health of these forests and ability to sequester carbon and provide resource amenities.[88] Many studies have demonstrated net benefits for fuel treatments and forest management activities designed to reduce both fire spread and fire severity at the experimental unit or stand level, both in modeled and real world scenarios.[89,90,91,92,93,94,95,96,97,98,99] Fuel treatments are key

[86] California Air Resources Board 2015 Edition of California's Black Carbon Emission Inventory. https://www.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf

[87] Hurteau, M. D., Westerling, A. L., Wiedinmyer, C. and Bryant, B. P. 2014. Projected effects of climate and development on California wildfire emissions through 2100. *Environmental Science & Technology*, 48(4), pp.2298-2304.

[88] North, M. P. and Hurteau, M. D., 2011. High-severity wildfire effects on carbon stocks and emissions in fuels treated and untreated forest. *Forest Ecology and Management*, 261(6), pp.1115-1120.

[89] Finney, M. A., McHugh, C. W., & Grenfell, I. C. (2005). Stand-and landscape-level effects of prescribed burning on two Arizona wildfires. Canadian Journal of Forest Research, 35(7): 1714-1722.

[90] Ritchie, M. W., Skinner, C. N., & Hamilton, T. A. (2007). Probability of tree survival after wildfire in an interior pine forest of northern California: effects of thinning and prescribed fire. Forest Ecology and Management, 247(1), 200-208.

[91] Safford, H. D., Schmidt, D. A., & Carlson, C. H. (2009). Effects of fuel treatments on fire severity in an area of wildland–urban interface, Angora Fire, Lake Tahoe Basin, California. Forest Ecology and Management, 258(5), 773-787.

[92] Schwilk, D. W., Keeley, J. E., Knapp, E. E., McIver, J., Bailey, J. D., Fettig, C. J., Fiedler, C. E., Harrod, R. J., Moghaddas, J. J., Outcalt, K. W. and Skinner, C. N. (2009). The national Fire and Fire Surrogate study: effects of fuel reduction methods on forest vegetation structure and fuels. Ecological Applications, 19(2): 285-304.

[93] Ager, A. A., Vaillant, N. M., & Finney, M. A. (2010). A comparison of landscape fuel treatment strategies to mitigate wildland fire risk in the urban interface and preserve old forest structure. Forest Ecology and Management, 259(8), 1556-1570.

[94] Moghaddas, J. J., Collins, B. M., Menning, K., Moghaddas, E. E., & Stephens, S. L. (2010). Fuel treatment effects on modeled landscape-level fire behavior in the northern Sierra Nevada. Canadian Journal of Forest Research, 40(9), 1751-1765.

[95] Collins, B. M., Stephens, S. L., Roller, G. B., & Battles, J. J. (2011). Simulating fire and forest dynamics for a landscape fuel treatment project in the Sierra Nevada. Forest Science, 57(2): 77-88.

[96] Safford, H. D., Stevens, J. T., Merriam, K., Meyer, M. D., & Latimer, A. M. (2012). Fuel treatment effectiveness in California yellow pine and mixed conifer forests. Forest Ecology and Management, 274, 17-28.

[97] Stephens, S. L., McIver, J. D., Boerner, R. E., Fettig, C. J., Fontaine, J. B., Hartsough, B. R., Kennedy, P. L. and Schwilk, D. W. (2012). The effects of forest fuel-reduction treatments in the United States. BioScience, 62(6): 549-560.

elements of forest restoration strategies,[100] and are embedded in management strategies at local, state and national levels.[101,102] The Forest Carbon Plan, as well as the 2030 Target Scoping Plan Update, will continue to explore the interrelation of climate change and natural lands.

A. 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 emissions by nearly 60 percent between 2000 and 2020 (Figure 2).

[98] Martinson, E. J., & Omi, P. N. (2013). Fuel treatments and fire severity: a meta-analysis. USDA For Service Research Paper RMRS-RP103.

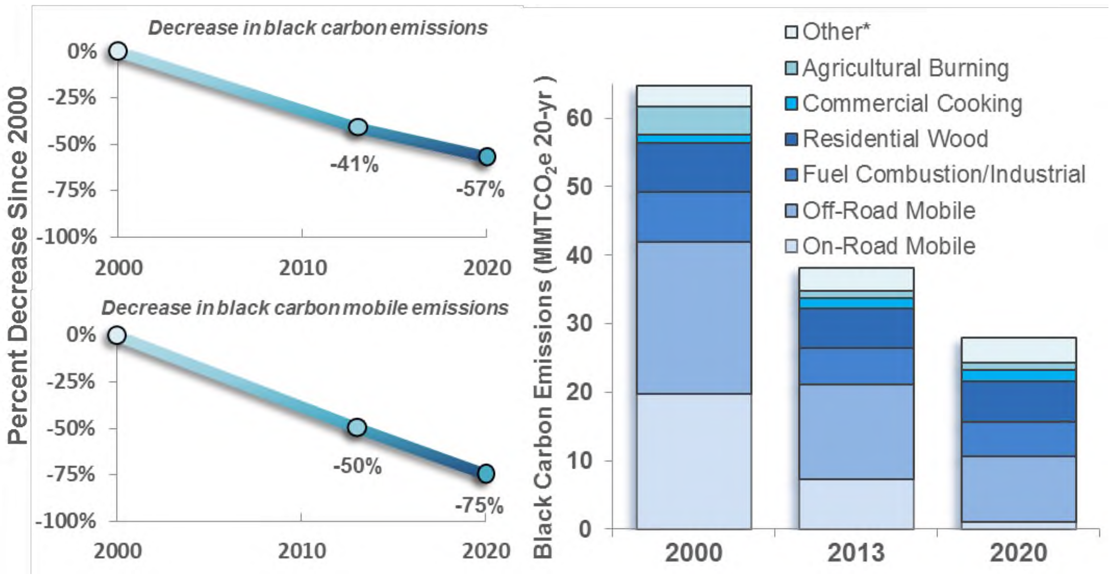
[99] Stevens, J. T., Safford, H. D., & Latimer, A. M. (2014). Wildfire-contingent effects of fuel treatments can promote ecological resilience in seasonally dry conifer forests. Canadian Journal of Forest Research, 44(8), 843-854.

[100] Hessburg, P. F., Churchill, D. J., Larson, A. J., Haugo, R. D., Miller, C., Spies, T. A., North, M. P., Povak, N. A., Belote, R. T., Singleton, P. H. and Gaines, W. L. (2015). Restoring fire-prone Inland Pacific landscapes: seven core principles. Landscape Ecology, 30(10): 1805-1835.

[101] Wildland Fire Leadership Council. (2014). National Cohesive Wildland Fire Management Strategy. Available at: https://www.forestsandrangelands.gov/strategy/ (Accessed 8/30/2016).

[102] State of California. (2010). 2010 Strategic Fire Plan for California. Available at: http://cdfdata.fire.ca.gov/fire_er/fpp_planning_cafireplan (Accessed 8/30/2016)

Figure 2: California's Anthropogenic 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.[103] Diesel engines often operate for decades after they are purchased, so while lower emission standards provide major emission reductions, those reductions can take time to materialize as older engines are replaced with new ones meeting the standard. To reduce risk and speed emission reductions, ARB implemented in-use rules for on-road and off-road fleets to meet performance standards through the use of alternative fuels, after-treatment retrofits, or replacement of older vehicles with newer vehicles manufactured to current emission standards. In-use on-road rules are expected to reduce black carbon emissions from on-road sources by 80 percent between 2000 and 2020. ARB's off-road rules apply to approximately 150,000 off-road vehicles and are expected to reduce diesel PM emissions by 20 percent between 2009 and 2023.

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

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

ports and rail yards.[104] 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 rail yards.

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.[105] 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 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

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[104] 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.

[105] Draft 2015 ZEV Action Plan available at: http://gov.ca.gov/docs/DRAFT_2015_ZEV_Action_Plan_042415.pdf

toward zero and near-zero emission freight vehicle and equipment technology in California.[106] In July 2015, the Governor signed Executive Order B-32-15, which directs the Secretaries of Transportation, Environmental Protection, and Natural Resources to lead staff from the California Department of Transportation (Caltrans), ARB, CEC, and the Governor's Office of Business and Economic Development (GO-Biz), in the development of the California Sustainable Freight Action Plan (Action Plan). The Action Plan, released in July 2016, includes a long-term 2050 vision and guiding principles for California's future freight transport system along with targets for 2030:

- Improve freight system efficiency 25 percent by 2030;
- Deploy over 100,000 zero-emission vehicles/equipment and maximize near-zero by 2030; and
- Foster future economic growth within the freight and goods movement industry.

The Action Plan also identifies opportunities to leverage State freight transport system investments, pinpoints actions to initiate over the next five years to meet goals, and lists possible pilot projects to achieve concrete progress in the near term.

In April 2016, ARB released the Mobile Source Strategy, which includes a comprehensive plan to control emissions from mobile sources in order to meet critical air quality and climate goals over the next fifteen years. [107] In May 2016, ARB released the *Proposed 2016 State Strategy for the State Implementation Plan* (SIP),[108] which represents the elements of the Mobile Source Strategy necessary for the State to meet federal air quality standards for ozone and fine particulate matter (PM2.5). The State SIP Strategy contains measures to reduce particulate matter and, thus, black carbon emissions from mobile sources including implementation of low emission diesel fuel, transitioning to zero-emission technologies and implementing additional emission standards for some engine types. Particulate matter and black carbon emission reductions will be realized from this and other proposed SIP measures, but have not yet been quantified.

As emissions from mobile sources decrease, non-mobile sources will become an increasingly important fraction of the black carbon inventory. The main non-mobile, anthropogenic 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

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106 http://www.arb.ca.gov/gmp/sfti/sustainable-freight-pathways-to-zero-and-near-zero-emissions-discussion-document.pdf
107 http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc_dd.pdf
108 https://www.arb.ca.gov/planning/sip/2016sip/2016sip.htm

public health.[109] Strategies in place to reduce emissions from residential wood combustion include winter burning curtailment, opacity emission limits, incentives to replace old wood burning devices with more efficient models, and banning or limiting wood burning devices in new and existing housing. Recently signed legislation allocated $5 million of Cap-and-Trade revenue towards an incentives program to reduce emissions from residential wood smoke. 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 new lower 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

[109] 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.

will develop rules for these emissions once cost-effective control technologies have been identified.

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.

Agricultural burning is controlled by the air districts whose programs must consider the cost-effectiveness of alternatives (e.g., SB 705, H&SC 41855.5). 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. The reduction in bioenergy capacity has already resulted in some increase in agricultural burning due to a lack of cost-effective alternatives.[110] ARB staff is targeting spring 2017 for a series of summits to elevate the discussion on these and other waste-related issues. The challenges with reducing agricultural waste burning, bioenergy production, and related issues specific to the Central Valley will be explored as part of a Central Valley Ag-Waste Burning Summit. Further, staff is planning with sister agencies to hold a Bio-Economy Summit on the broader discussion of how to establish a California bioeconomy based on a holistic approach to processing woody waste (forest and agriculture), dairy manure, wastewater effluent, landfills, and other organic waste streams, and capturing from these organic waste streams economically valuable bioenergy, biofuels, engineered lumber, soil amendments including uniform fertilizer products, and other beneficial products while maintaining or improving environmental and public health protections.

In the short term, districts are forming working groups and evaluating additional funding opportunities to help limit agricultural burning to the extent possible. However, there are few proven cost-effective alternatives that can be deployed in the short term. One option is to chip and grind the material for compost, incorporation into the soil, or to provide to the public with mulch to replace lawns and reduce water consumption. In the long term, advanced low emission technologies such as gasification or transportation fuels production should be explored to provide beneficial use for agricultural residues. Programs to support clean energy and fuel production and markets for wood products, would help provide opportunities for alternative beneficial uses for this waste material.

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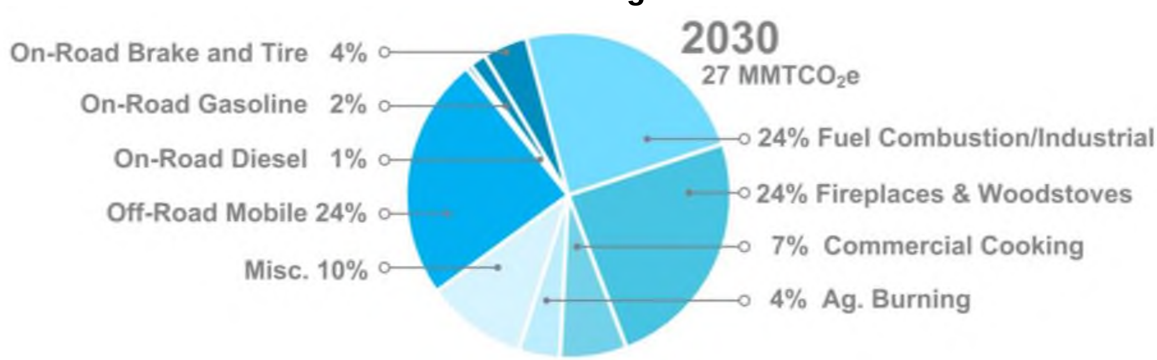
http://www.valleyair.org/Board_meetings/GB/agenda_minutes/Agenda/2016/May/StudySession/final/i5.pdf

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 anthropogenic black carbon emission target identified in this SLCP Strategy 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 State Implementation Plans (SIPs). Additional reductions are also expected through a district-lead commercial cooking regulation, but the magnitude of emission reductions is currently unknown.

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



*Using 20-year GWP

B. Recommended Actions to Further Reduce Black Carbon Emissions

This section describes proposed new measures (summarized in Table 7 below) to assist the State in meeting the proposed 2030 anthropogenic black carbon emission target.

Table 7: 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	
State Implementation Plan Measures, and 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 SLCP 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, criteria pollutants, and air toxics in residential neighborhoods. Conversion to electric heating or gas fireplaces provides more certain emission reductions than conversion to certified wood-burning devices. While certified wood-burning devices reduce fine particulate emissions, certification values may not correlate well with in-home performance of wood heaters,[111] and emission reductions are not as large as for non-wood technologies. Electric heating or gas devices (including central HVAC) ensure local reductions of particulate matter, black carbon and air toxics. To protect public health and use incentive dollars efficiently, non-wood burning devices should be prioritized where possible. If wood burning devices are used, they should be the cleanest available technologies, currently those adhering to the 2020 EPA emission standard. Some areas may require the use of wood burning equipment for safety, especially areas that experience heavy snow which traps residents in homes, and where distributed natural gas is not available or electricity loss is frequent. Additionally, natural gas, propane, or electricity may cost

[111] U.S. EPA (2016). Process for developing improved cordwood test methods for wood heaters. https://www.epa.gov/burnwise/process-developing-improved-cordwood-test-methods-wood-heaters

more than wood in some regions, placing an additional financial burden on homeowners.

Monetary incentives to stimulate removal of old wood burning devices are popular and can achieve significant emission reductions. Incentive programs should prioritize replacing the highest emitting devices used for primary sources of residential heating. Removed wood burning devices should be destroyed and recycled to ensure permanent 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. Assembly Bill 1613 includes Cap-and-Trade expenditures of $5 million from the Fiscal Year 2016-2017 budget for a residential woodstove replacement incentive program.

The 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.

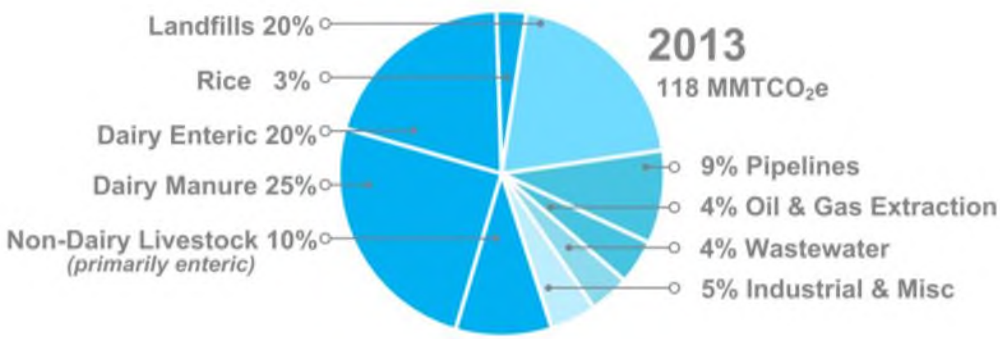
Education and outreach are important tools to reduce emissions from residential wood combustion. A broader public understanding of the health and environmental impacts of wood smoke may cause voluntary changes in behavior to use other heating sources and may cause individuals to avoid unnecessary burning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

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 4). 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 relies 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 4: 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, pursuing opportunities to reduce methane emissions from enteric fermentation, significantly reducing disposal of organics in landfills, and reducing fugitive methane emissions by 40 percent or more from other 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.

Gas flow meter for natural gas made at a dairy digester

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. For example, aside from the provisions in Senate Bill 1383:

- 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. AB 1045 (Irwin, Chapter 596, Statutes of 2015) directs CalEPA and CalRecycle to coordinate with ARB, the State Water Resources Control Board, and CDFA to develop and implement policies to aid in diverting organic waste from landfills by promoting the composting of organic waste and by promoting the appropriate use of that compost throughout the State. SB 1383 requires CalRecycle to develop regulations that will reduce disposal of organic waste by 50 percent of 2014 levels in 2020 and by 75 percent of 2014 levels in 2025.

- Methane emissions from landfills are controlled under ARB's Landfill Methane Control Measure, which was approved in 2009. The regulation complements previously existing federal and local air district landfill rules by requiring 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), directs 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. This program is currently funded at $40 million, and may offset half of interconnection costs, up to $3 million per project or $5 million for a dairy cluster project, per Assembly Bill 2313 (Williams, Chapter 571, Statutes of 2016). Assembly Bill 2313 also requires the CPUC to extend this program through December 31, 2016.

- 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.[112] 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.[113] 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

[112] *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

[113] 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.

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 reductions in overall energy use and 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 emissions from the production, and potentially transmission and distribution, of oil and natural gas.

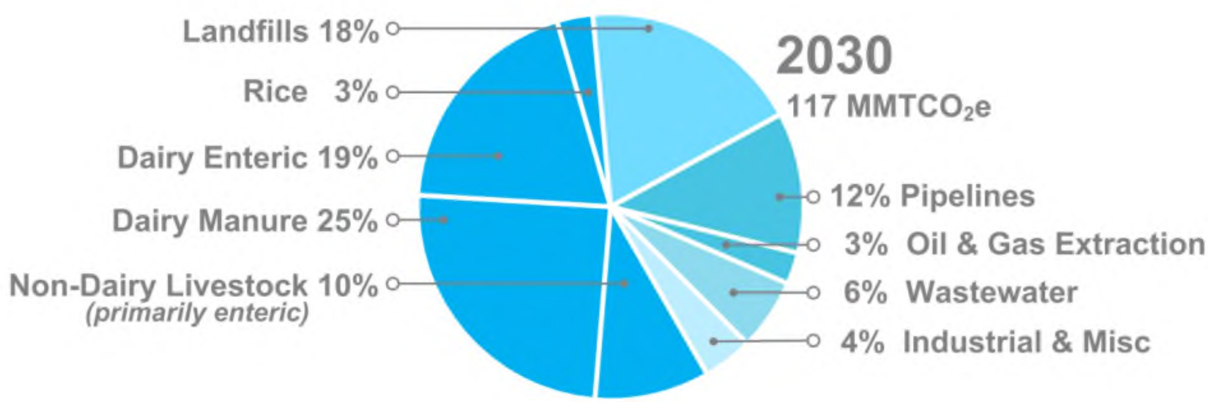
The State has strong targets to reduce the use of natural gas and petroleum by 2030, and several studies show that California must virtually eliminate the use of all fossil fuels to meet its 2050 climate targets. Notably, Governor Brown has called for reducing on-road petroleum use by up to 50 percent 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 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 2017, ARB will release a Request for Proposal (RFP) to collect emissions data from oil production wastewater ponds. Results from this contract are expected in 2018-2019, 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. Additionally, Assembly Bill 1496 (Thurmond, Statues of 2015, Chapter 604) requires ARB 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. 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^{o}C—including meeting the State'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 5). 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 5: 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 SLCP 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 additional composting infrastructure capacity needs to be established and expanded, and appropriate market opportunities need to be 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 federal government's goals 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 8, below, identifies emission reductions by sector to reduce economy-wide methane emissions by 40 percent below current levels by 2030. The expected 2030 annual emission reductions for each sector are based on: 40 percent reduction in dairy and livestock sectors' emissions from 2013 levels by 2030; 50 percent diversion of organic waste by 2020 and 75 percent diversion of organic waste by 2025 from 2014 levels; 40 percent reduction of wastewater and other industrial sources methane by 2030; and 45 percent reduction of oil and gas methane by 2030. The emission estimates in the table are based on currently available information and projections. They may change as new information becomes available or as measures are more fully developed.

Table 8: Proposed New Methane Emission Reduction Measures and 2030 Estimated Emission Reductions ($MMTCO_2e$)[1]

Measure	2030 Annual Emission Reductions	2030 Annual Emissions
2030 BAU[2]		**117**
Dairy and Other Livestock (Manure and Enteric Fermentation)	26	
Landfill	4	
Wastewater, Industrial and Other Miscellaneous Sources	7	
Oil and Gas Sector	8	
2030 BAU with new measures		**71**[3]

[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
[3] The specific annual reduction values shown above do not sum exactly to the total shown due to rounding error.

1. Dairy Manure

California's dairy and livestock industries account for more than half of the State's total methane emissions and for about five percent of the State's GHG inventory, based on 100-year GWPs (using 20-year GWPs, the industries account for about 12 percent of California's GHG emissions). Twenty-five percent of the State's methane emissions comes from manure management practices at dairies, primarily from lagoon storage of flushed manure from the State's milking cows. Nearly 20 percent of the State's methane emissions come from enteric fermentation (mostly belching) of dairy cows, and another ten percent comes from enteric fermentation of non-dairy livestock (primarily other cattle).

California has the most dairy cows in the country and the highest aggregated (from manure management and enteric fermentation) 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, making enteric fermentation emissions per gallon of milk from California dairy cows relatively low.

Senate Bill 1383 directs ARB to develop a manure management strategy that will reduce dairy and livestock sector methane emissions by up to 40 percent from 2013 levels by 2030. In doing so, SB 1383 recognizes the importance of addressing California's largest source of methane and the opportunity presented by modifications to manure management practices (See Appendix B). Manure management at dairies offers one of the greatest opportunities to reduce methane emissions from these sectors (methane from manure management at California's non-dairy livestock operations comprise less than five percent of overall manure methane). Accordingly, California will aim to structure incentives, policies, regulations, and research to support significant methane emission reductions from dairy manure management. The extent to which regulations will be needed in achieving these reductions will be evaluated and may be adjusted as necessary, commensurate with the SB 1383 provisions.

Through this SLCP Strategy and related efforts, we have a tremendous opportunity to work with the industry to reduce methane emissions from the State's largest source, while creating economic value in farming communities. If markets are fully enabled, efforts to reduce methane from manure management at California dairies could lead to billions of dollars of investment and thousands of new jobs, concentrated in the Central Valley. Depending on the strategies pursued to reduce emissions, individual dairies may be able to reduce emissions while generating new revenue streams, and the industry as a whole may be able to meet the targets established in this SLCP Strategy at little or no net cost (see Chapter VIII).

However, revenues in some cases are highly dependent on environmental credit and energy markets, as well as on improving access to the common carrier natural gas pipeline system. Recent legislation, including SB 1383 and AB 2313, establish frameworks and priorities to help address these potential barriers. SB 1383 requires ARB, CPUC, and CEC to institute measures to increase the economic certainty associated with environmental credit generation and to encourage development of dairy RNG projects and associated infrastructure. Additionally, AB 2313 increases utility incentives to help offset costs of pipeline interconnection, especially for projects from dairy clusters. And AB 1613 commits $50 million in Cap-and-Trade funds to support methane reductions at dairies during the 2016/2017 fiscal year.

Ultimately, a mix of tools will be used to reduce methane emissions from dairy and livestock manure management. The process for developing strategies will be built around extensive stakeholder involvement, consistent with SB 1383, AB 32 and other relevant laws. Among other factors, the process to develop recommended strategies will require close coordination with the dairy industry and will consider public input; available financial incentives; technical, market, and regulatory barriers to the development of dairy methane emission reduction projects; research on dairy methane emission reduction projects; and the potential for emissions leakage, as well as steps to minimize any leakage that might otherwise occur.

Among the emission reduction measures ARB, CDFA, and stakeholders will consider in developing these strategies are the following:

Switching from Flush Water Lagoon Systems

Dairy methane emissions may be significantly reduced by switching from flush water open lagoon systems to anaerobic digesters or other systems such as solid manure management practices. Using solid (e.g. slurry vacuum or scrape) manure systems with a digester (e.g. plug-flow, above ground tank) can enable easier transport and storage of manure off-site or to centralized digester systems. The benefits can include improved economies of scale, biogas production efficiencies, nutrient management, water efficiency, and water quality compared to flush systems paired with flood irrigation systems. Dairy manure can also be mixed with other organic materials—such as those diverted from landfills or processed at wastewater treatment plants—to improve digester performance and economics. Centralized digesters designed and sited so as to efficiently process these waste streams can play a key role in helping California meet its organic diversion and climate 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. Some agricultural practices have historically led to legacy pollutants contaminating groundwater, which could continue if unabated. To address this, regional water boards issue waste discharge requirements that include development and implementation of nutrient management plans, water quality monitoring, and corrective actions when impairments are found. Switching to systems such as solid manure management may lead to air or water 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- and location-specific factors.

Pasture-Based Dairy Management

In some instances, pasture-based systems may be a viable option, but tradeoffs can limit their feasibility. In a pasture system, manure decomposes aerobically, avoiding all but trace amounts of methane emissions, though potential nitrogen impacts may arise. Many organic milk producers rely on pasture systems, and pasture systems are commonly used in other states and at smaller dairies in the coastal and northern parts of California. For larger dairies and those in the Central Valley, pasturage would require using significantly more irrigated land, may require supplemental feed, and (in the case of Central Valley dairies) may require construction of shade structures and other infrastructure to alleviate heat exposure-related impacts on animal welfare. Pasture dairies may face potential nutrient management and water quality issues, and are required to maintain the capacity to store liquids from milking parlor operations (chilling milk, cleaning facilities, etc.) for a 100-year stormwater event. Additionally, milk production and feed efficiencies are lower in pasture systems, requiring more cows to produce the same amount of milk. Pasture systems also limit the ability to manage manure as a valuable organic waste resource.

While there are potential limitations to using pasture dairy models, there may also be potential benefits associated with these systems that need further evaluation. Among these potential benefits are improved animal welfare, lower on-farm air emissions, improved aesthetics, and reduced impacts to water quality. Further evaluation of pasture systems can fully characterize their potential benefits, costs and limitations relative to conventional dairy models. Additionally, hybrid models that employ aspects of both pasture and conventional systems should also be investigated for their potential benefits and impacts for dairy and livestock operations.

Installing Anaerobic Digestion Systems

Dairy operators may determine that capturing and utilizing manure methane by installing an anaerobic digestion system is more advantageous than avoiding methane emissions through conversion to practices such as a pasture-based dairy model, providing the current barriers can be sufficiently addressed. Captured biogas from dairy manure can be used to power farm trucks and equipment, upgraded for injection 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 part due to air quality constraints, especially in the Central Valley and Southern California. Utilizing newer, cleaner technologies can help to overcome the 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. Using ARB-certified distributed generation technologies, such as microturbines or fuel cells, can significantly cut NO_x emissions compared to internal combustion-based power generation. Injecting upgraded biomethane into the natural gas pipeline can avoid most new combustion or associated emissions. As part of an integrated strategy that includes replacing diesel trucks and equipment with certified ultra-low NO_x equipment, fueling vehicles with dairy-derived biomethane could help to reduce criteria pollution in impacted air basins.

Given existing incentives and complementary climate and energy programs, manure-management conversions that produce electricity and vehicle fuel are potentially profitable; however, most require significant up-front capital investment. Among the most promising are those that produce biomethane for injection into a common-carrier pipeline. This approach involves construction of connecting pipeline segments, and installation of biogas upgrading equipment capable of meeting the pipeline-quality biomethane standards developed in response to AB 1900 (Gatto, Chapter 602, Statutes of 2012). While these barriers have not been overcome completely, AB 2313 and SB 1383 clearly demonstrate the State's commitment to developing policies to encourage infrastructure development and procurement of biomethane from dairy biogas projects.

In consideration of potential emission reduction measures, including those described above, the State will encourage and support research and near-term actions by dairies to reduce emissions through market support and financial incentives. Initially, as the recently appropriated $50 million in Cap-and-Trade funds become available, the State will incorporate lessons learned from previous incentive programs to improve the effectiveness and efficiency of new incentives, while overcoming persistent barriers and challenges. At the same time, ARB will initiate a rulemaking process, pursuant to SB 1383, to develop regulations for reducing dairy and livestock manure emissions in California. The process will include considering research on manure management practices and developing reporting and recordkeeping regulations to improve California-specific data and ARB's GHG emission inventory. This information will shape the emission control regulations pursuant to this SLCP Strategy, along with information obtained through other collaborative efforts. 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 Early Project Development through Incentives and Market Development

As provided under SB 1383, the State will support efforts 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 secure methane emission reductions, support future low-carbon biomethane utilization goals, increase resource use efficiency (e.g. conserve water), improve nitrogen application precision, and support market opportunities for the use of biomethane and soil amendment products. 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 incentives. The economic analysis in Chapter VIII suggests that this level of funding could significantly accelerate project development by offsetting capital costs and economic risks. The SB 1383 requirement that ARB develop a pilot financial mechanism to reduce the economic uncertainty associated with the value of environmental credits from dairy-related transportation fuel projects should further accelerate project development. Different types of funding mechanisms and levels of support may be appropriate for different types of projects.

ARB, CDFA, State Water Resources Control Board, and Regional Water Quality Control Boards' staff will establish a working group with other relevant agencies and stakeholders to focus specifically on developing measures to overcome the barriers that have constrained dairy manure projects in the past. The group will aim to monitor, ensure, and accelerate market and institutional progress and report its findings to the Legislature. 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 capitalize on opportunities for joint development of measures that conserve water and improve water quality. Similarly, ARB will work with the air districts to ensure opportunities for air quality efforts are developed jointly.

In many cases, converting to solid manure management systems or installing anaerobic digesters at dairies may not yet be cost-effective if the only marketable products are renewable electricity and/or renewable natural gas. If these revenue streams can be augmented with revenues from compost or other soil amendment products, and from environmental credits, these conversions may offer attractive rates of return for farmers and investors.[114] However, markets for these other products need further support before they can offer returns that are reliable enough to help secure project financing. 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 direct dairy biogas into the transportation sector and allow for the generation of LCFS and RIN credits, which could provide an especially valuable revenue stream.[115] The State will continue to support these efforts.

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. ARB will work with other state agencies through the Climate Action Team Research Working Group, the dairy industry, and other stakeholders to establish mechanisms to identify and fill information gaps, as required by SB 1383. In particular, SB 1383 directs the agencies to consider research about the emissions-reduction potential of solids separation, enteric fermentation, and conversion of flush systems to solid manure management

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[114] 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.
[115] 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.

systems. However, little data exists to quantify costs and benefits associated with these practices. Additionally, some uncertainty remains regarding cross-media impacts and appropriate emissions-accounting methods. 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.

Develop Regulations to Ensure Emission Reductions

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 sector consistent with the objectives in this SLCP Strategy. As noted earlier, the rulemaking process will involve extensive stakeholder engagement and consideration of multiple factors. The regulations are to be implemented on or after January 1, 2024. Pursuant to SB 1383, ARB, in consultation with CDFA, will analyze the progress dairies are making in achieving the goals in the Strategy by July 1, 2020, and may make adjustments to those goals if sufficient progress has not been made.

The rulemaking process will first focus on developing measures to require regulated parties to both report and maintain records covering the parameters that affect GHG emissions at California dairies and other livestock operations. Reported information will be used to refine inventory quantification, evaluate policy effectiveness, assess methane reduction progress, 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 reporting activities with current forms and requirements to avoid duplicative reporting wherever feasible.

Emission control regulations will be designed to support and complement existing programs. In particular, regulatory requirements to achieve large emission reductions from the sector will affect incentives for methane reduction projects, such as the availability and amount of credits under the Cap-and-Trade Program and LCFS. Once the regulatory requirements are in effect, 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 (which becomes the business-as-usual case). However, projects in place before the new requirements take effect would still be able to generate credits for avoided methane emissions for their current crediting period, which is ten years of operation. After a regulation takes effect, credits for new projects under the LCFS would still be available, but would be based only on the displacement of petroleum fuel. ARB will clarify the impact of potential regulations and provide guidance on LCFS credits by January 1, 2018, as required by SB 1383, and will make appropriate adjustments to the Cap-and-Trade Program to ensure only reductions that meet the AB 32 offset criteria are credited. Sufficient lead time will be provided before regulatory requirements take effect to allow the market to react.

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 approximately 30 percent of California's methane inventory, making it important to explore strategies to reduce emissions from these sources to meet the State's 40 percent economy-wide methane emission reduction target.

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. Various studies are pointing to new feed supplements or dietary changes that show potential for reducing enteric fermentation emissions significantly without affecting milk production.[116,117] However, further research is needed to validate initial findings, fully evaluate the viability of these strategies to California, assess their associated costs and co-benefits, potential impacts on animal productivity, effects on animal and human health, other environmental impacts, and GHG and air toxic emissions associated with feed lifecycles.

The Legislature recognized the important role of enteric fermentation emission reductions in meeting the goals in SB 1383 by requiring consideration of enteric fermentation research, allowing voluntary reductions to be considered in the design of dairy and livestock emission reduction measures, and by providing that these reductions count towards economy-wide methane emission reductions targets. It also recognized the limited available information and potential impacts associated with achieving enteric fermentation emission reductions, allowing only incentive-based approaches to these reductions until ARB, in consultation with CDFA, determines that cost-effective and scientifically validated methods for reducing enteric emissions are available. In addition, adoption of an enteric emission reduction method must not compromise animal health, public health, or consumer acceptance of dairy products.

Research Mitigation Strategies for Enteric Fermentation

Federal and State agencies, industry, and academia will collaborate on research and demonstration projects through available funding mechanisms (e.g. ARB's annual research solicitation program and CDFA's Dairy Digester Research and Development Program). As with research on manure management practices, the Climate Action Team Research Working Group can coordinate with other state agencies, the dairy industry, and other stakeholders to develop research on methane reductions from

[116] 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
[117] 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

enteric fermentation. In addition, progress will continue to be monitored 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.

The schedule for implementing the dairy- and livestock-related directives in SB 1383 is summarized in Table 9.

Table 9: Timeline for Dairy and Livestock Methane Reduction Measures

Action	Deadline
ARB approves SLCP Strategy and begins Implementation Expected Approval Date Statutory Date	 First Quarter 2017 By January 1, 2018
ARB, CDFA, State Water Resources Control Board and Regional Water Quality Control Boards in coordination with the energy agencies, will work with the dairy industry to establish a dairy workgroup to identify and address barriers to development of dairy methane emission reduction projects	First Quarter 2017 and ongoing
CDFA announces awardees for GGRF grant program for achieving early and extra methane emission reductions from dairy and livestock manure	June 2017 (funds encumbered June 2018)
ARB, in consultation with CPUC and CEC, develops policies to encourage development of infrastructure and biomethane projects at dairy and livestock operations	By January 1, 2018
ARB develops a pilot financial mechanism to reduce LCFS credit value uncertainty from dairy-related projects and makes recommendations to the Legislature to expand the mechanism to other biogas sources	By January 1, 2018
ARB provides guidance on the impact of regulations on LCFS credits and compliance offsets	By January 1, 2018
CPUC, in consultation with ARB and CDFA, directs utilities to develop at least 5 dairy biomethane pipeline injection projects	By January 1, 2018
ARB, in consultation with CDFA, evaluates the feasibility of enteric fermentation methane reduction incentives and regulations and develops regulations as appropriate	Ongoing
ARB, in consultation with CDFA, analyzes and reports on the methane reduction progress of the dairy and livestock sector	By July 1, 2020
ARB begins developing and considers for adoption a manure management methane reduction regulation	Before January 1, 2024
ARB implements a manure management methane reduction regulation	On or after January 1, 2024

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 a significant portion 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 recycling, but also improving the infrastructure for diverting and/or recycling organics, including minimizing and rescuing 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 rescue/recovery, 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, financial incentives, and cross-media regulatory structures 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 using edible foods that would otherwise go to waste from restaurants, grocery stores, dining facilities, food packing 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 used for human consumption may alternatively be used as animal feed if it meets all regulatory requirements. 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, significantly reducing 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 achieve zero-waste.

The State has already established its intent to phase out the disposal of organics from landfills. Existing law sets a goal to source reduce, recycle, or compost 75 percent of solid waste 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 reduce disposal of organics by 50 percent of 2014 levels by 2020 and 75 percent by 2025. Due to the multi-year timeframe required to breakdown landfilled organic material, emissions avoided by diverting organic material in one year are realized over several decades to come. These actions would reduce landfill emissions by 4 $MMTCO_2e$ in 2030,[118] but one year of waste diversion in 2030 is expected to avoid 14 MMTCO2e of emissions over the lifetime of waste decomposition.

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 vary widely. In the U.S. EPA landfill database, the weighted average of collection efficiencies at California landfills is 78 percent.[119] 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 is currently pursuing research opportunities to improve understanding of emissions from landfills and landfill gas collection efficiencies, and will engage stakeholders in potential opportunities to further control emissions from landfills in the

[118] Methane emission reductions from landfills (Table 8) are calculated assuming regulated landfills achieve methane capture efficiencies of 80 percent by 2030, and that an annual organics tonnage amount equal to 50 percent of the organics deposited in landfills in 2014 is diverted from the organics waste stream sent to landfills by 2020, and an annual organics tonnage amount equal to 75 percent of the organics deposited in landfills in 2014 is diverted from the organics waste stream sent to landfills by 2025 (i.e, meeting the organics diversion targets identified in this SLCP Strategy).

[119] 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

future. 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

CalRecycle, in consultation with ARB, will develop regulations to reduce disposal of organic waste by 50 percent of 2014 levels by 2020 and 75 percent by 2025, as required by SB 1383. These regulations shall take effect on or after January 1, 2022. CalRecycle is planning to adopt the regulations by the end of 2018, so that regulated entities (e.g., jurisdictions, generators, facilities and haulers) have a long lead time to plan budgetary and programmatic changes that will be needed to meet the requirements effective in 2022. Of the edible food in the organic waste stream, not less than 20 percent is to be recovered to feed people in need by 2025. This goal could be met through local food waste prevention and rescue programs, which may be independent of or through partnerships with haulers and jurisdictions. The regulations also will cover this provision. 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.

Food recovery program (City Harvest) delivering produce in New York

Material that cannot be effectively recovered would be diverted to organics recycling facilities to make useful products, including compost, fertilizer, fuel or energy. These facilities may be developed at existing landfills, other waste management sites, or at new stand-alone sites. Some organic wastes could also be diverted to regional wastewater treatment plants or dairies that have excess capacity for co-digestion. 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 SB 1383 and other statutory requirements. The State will work with its local partners to explore development of helpful tools such as programmatic EIRs or guidance documents. Community engagement, outreach and education in the planning and environmental review processes are 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 destined for 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 and markets. 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. However, as disposal in landfills decreases per the goals of this SLCP Strategy, so too would the funding from the Integrate Waste Management Fee. One option for stabilizing funding would be to establish a charge for waste generation, decoupling funding from landfill disposal.

Collaborate to Overcome Barriers

State agencies, including the AB 1045 working group and the Interagency Waste Working Group, are currently collaborating to evaluate and resolve existing constraints in the planning, siting, and permitting process, to provide clear standards and compliance pathways for all public health and environmental goals, and to quantify co-benefits. 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 working groups are collaborating to address barriers to beneficial use of organic waste streams. 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 as well as the potential impacts of land application of uncomposted organic materials. 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 strategic water conservation (e.g. seasonal groundwater recharge) and other potential benefits and consider developing mechanisms to account for and value them. If new funding sources are developed, as described above, then CalRecycle could also develop an incentive payment program to overcome the marginal costs associated with most beneficial end-uses of organics.

Improve Understanding of Landfill Emissions

ARB and CalRecycle are currently pursuing research opportunities to improve understanding of emissions from California landfills and landfill gas collection efficiencies and will support future research to 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.

Evaluate Progress towards Organic Diversion Goals

To evaluate progress towards meeting the 2020 and 2025 organics waste reduction goals, CalRecycle, in consultation with ARB, will complete a detailed analysis by July 1, 2020. This analysis will evaluate:

- The status of new organics infrastructure development;
- The status of efforts to reduce regulatory barriers to the siting of organics recycling facilities;
- The effectiveness of policies aimed at facilitating the permitting of organics recycling infrastructure; and
- The status of markets for products generated by organics recycling facilities.

The analysis may result in making additional requirements and/or incentives in the regulations, as required by SB 1383.

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, fertilizers, 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.


Sewer manhole cover manufactured and installed in Oakland, California

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 active oil wells, including off shore platforms, about 1,500 active natural gas wells and nearly 500 underground natural gas storage wells. 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.[120] 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 federal government 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 Regulation for Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities

In July 2016, the Board directed staff to continue working with local air districts and other stakeholders to develop a regulation for final Board consideration by early 2017. The proposed regulation will likely require:

- Vapor collection on uncontrolled oil and water separators and storage tanks with emissions above a set methane standard;
- Vapor collection on all uncontrolled well stimulation circulation tanks;
- Leak Detection and Repair (LDAR) on components, such as valves, flanges, and connectors, currently not covered by local air district rules;
- Vapor collection of large reciprocating compressors' vent gas, or require repair of the compressor when it is leaking above a set emission flow rate;
- Vapor collection of centrifugal compressor vent gas, or replacement of higher emitting "wet seals" with lower emitting "dry seals";
- "No bleed" pneumatic devices and pumps; and
- Ambient methane monitoring and more frequent well head methane monitoring at underground natural gas storage facilities.

This regulation would build upon some existing air districts' volatile organic compound based rules and include additional areas and 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

[120] For the purposes of calculating emission reductions in 2030, Table 8 assumes a 45 percent reduction below current levels by 2030.

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 February 2016, DOGGR adopted emergency regulations 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. In July 2016 DOGGR released a pre-rulemaking draft that will replace its emergency rulemaking; public comment for the discussion draft ended on August 22, 2016. The discussion draft contains much of the content included in the emergency rulemaking with the addition of, among other things, stricter well construction standards and mechanical integrity testing requirements to reduce the risk of wells leaking. DOGGR anticipates that the formal rulemaking process will conclude in the early part of 2017. 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.[121] ARB and DOGGR will coordinate on the monitoring provisions to ensure consistency and comprehensiveness while limiting duplication.

Additionally, Assembly Bill 1496 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 hosted a scientific workshop in June 2016 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.

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[121] 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

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 annually and best leak management practices. To date, the industry has submitted two consecutive emission inventories in 2015 and 2016, respectively. 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. In addition, several public workshops and workgroup meetings have been held in San Francisco and Sacramento.

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:

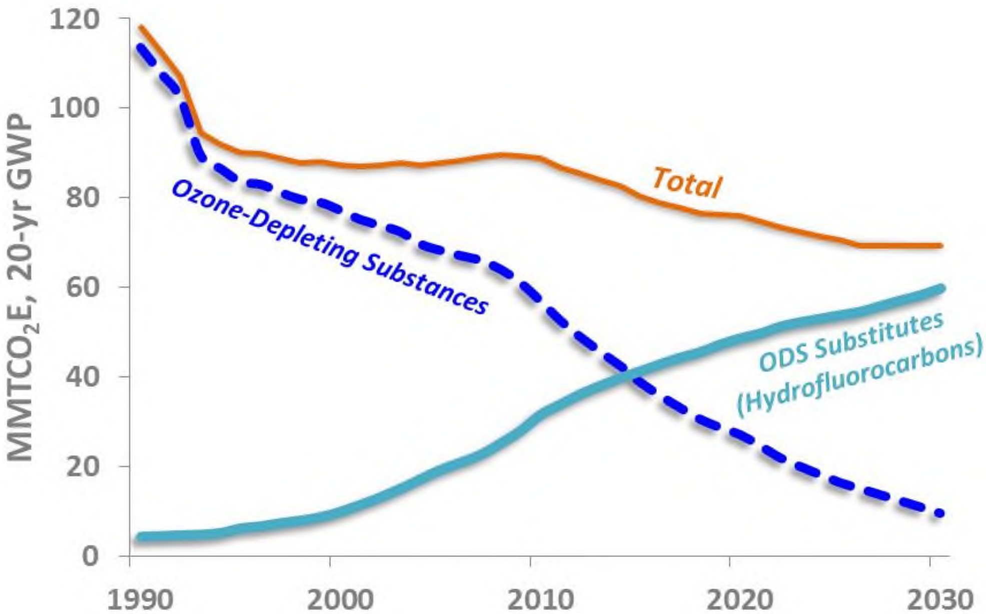
- Comparing the data collected under SB 1371 with the Mandatory Reporting Regulation;
- Analyzing emission data to determine potential mitigation strategies. For example, the proceeding may require the replacement of older pipelines or pipelines constructed of a certain material;
- Identifying any remaining data gaps;
- Establishing procedures for the development and use of metrics to quantify emissions;
- 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;
- Provide input on cost-effectiveness; and
- Funding studies to update emission factors from important leak sources, such as pipelines and customer meters.

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, and without a phasedown and additional emission reduction measures, annual HFC emissions would increase 60 percent under business-as-usual by 2030 as HFCs continue to replace ODS (Figure 6).

Figure 6: Emission Trends of ODS and ODS substitutes (hydrofluorocarbons) – (as ODS are phased out, HFCs increase).*

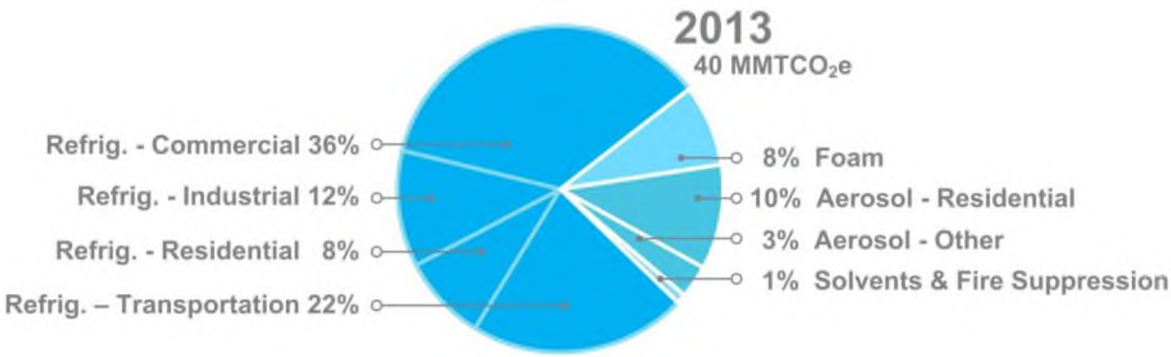


* Further analysis is needed to reflect the impact of the Kigali Amendment on HFC emission reductions in California

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 7 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 7: California 2013 Hydrofluorocarbons (HFCs) Emission Sources*



*Using 20-year GWP

This SLCP Strategy identifies measures that can reduce HFC emissions by 40 percent in California by 2030. They represent a reasonable path forward for California, and will complement the global HFC supply phasedown, agreed to in October 2016. Although the global phasedown will result in significant HFC emission reductions, the phasedown by itself will not be sufficient for California to reach the 40 percent HFC emission reduction goal by 2030.

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.

<u>A Global Phasedown in HFC Production and Consumption</u>

On October 15, 2016, an historic agreement was reached in Kigali, Rwanda, by nearly 200 countries to adopt a global phasedown in the production and consumption of HFCs. The international agreement was an outcome of the 28^{th} Meeting of the Parties to the Montreal Protocol, the 1987 agreement that initiated a phase-out of ODS. The HFC phasedown agreement is expected to prevent up to 0.5 degrees Celsius of global warming by the end of this century.

Developed countries must begin to phasedown HFC production and consumption in 2019, with an increasing cap until only 15 percent of production and consumption remains by 2036. Developing countries will begin a phasedown in 2029, and developing countries in hot ambient climates will have until 2032 to begin a phasedown. The phasedown schedule is shown in Table 10 below:

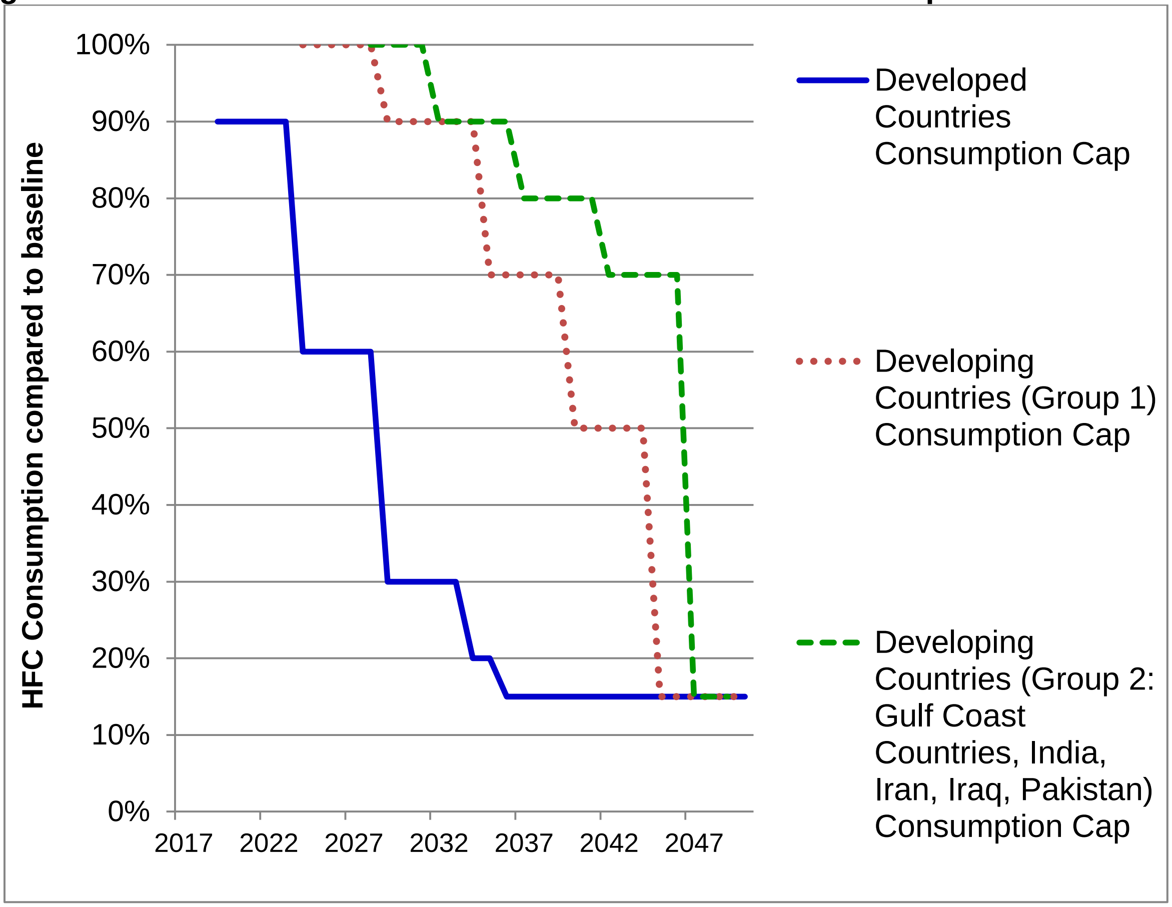
Table 10: Global HFC Phasedown Schedule

	HFC Production/Consumption Cap* Phasedown Schedule		
Year	**Developed Countries**	**Developing Countries Group 1**	**Developing Countries Group 2****
2017-2018	No Freeze		
2019	90%		
2024	60%	Freeze	
2028			Freeze
2029	30%	90%	
2032			90%
2034	20%		
2035		70%	
2036	15%		
2037			80%
2040		50%	
2042			70%
2045		15%	
2047			15%

* The baseline to calculate a production/consumption cap for developed countries is the annual average of HFC consumption (CO_2-equivalents) in 2011, 2012, and 2013, plus 15 percent of the annual average consumption of HCFCs in 2011-2013.
**Group 2 countries include the Gulf Coast Countries (Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain, and Oman), India, Iran, Iraq, and Pakistan.

The phasedown schedule is also shown in graph form in Figure 8 below.

Figure 8: Global HFC Phasedown Schedule for the Three Groups of Countries



As shown by the successful ODS phase-out, an HFC phasedown allows industry the flexibility to make market-based decisions on when and where to continue to use high-GWP HFCs before transitioning to lower-GWP options.

<u>Additional State, National, and International Efforts to Reduce HFC Emissions</u>

In addition to the Kigali Amendment to phasedown HFC production and consumption globally, other developments in the U.S. and internationally will further reduce HFC emissions as described below. 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.[122] 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

[122] 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

leading F-gas regulation that will phase down the production and import of HFCs by almost 80 percent from 2014 levels by 2030.[123,124]

Additionally, in response to the federal Climate Action Plan, in September 2014, and again in October 2015, the private sector made commitments and executive actions were taken to reduce emissions of hydrofluorocarbons (HFCs).[125,126] 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.[127,128]

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.[129] The proposal was adopted in September 2016.

In July 2016, ARB and CEC committed $500,000 to fund the completion of a research project to assess the feasibility and safety of low-GWP refrigerants, adding to the existing $5.3 million venture research funded by the Department of Energy (DOE), the AHRI, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). A goal of the study is to accelerate research and consideration

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[123] 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/.

[124] 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

[125] 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

[126] 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.

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

[128] "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.

[129] 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

by these bodies by up to three years sooner than the normal deliberative pace of standards and codes research. Commercial refrigeration and air conditioning are included in the research project, while domestic refrigeration is not within the project scope. The project is on an aggressive, tiered schedule to assess the safety of mildly flammable and flammable refrigerants, in order to update building codes and safety standards.[130] The study is critical for national and international HFC mitigation policies and will accelerate the time frame for low-GWP refrigerants that are necessary for the California to meet its SLCP emission reduction goals.

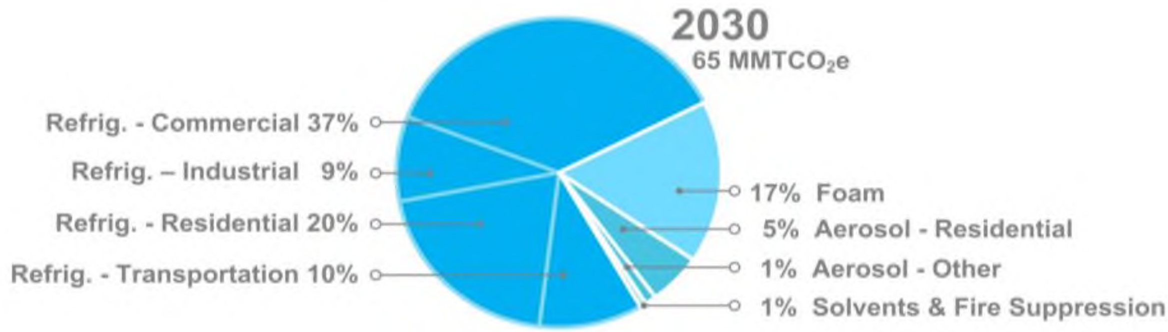
Substantial progress has also been made to safely use natural refrigerants (such as CO_2, ammonia [NH_3], and hydrocarbons [HCs]), with GWPs at or near zero) all over the world, especially in Europe and Asia. The refrigeration and air-conditioning industry is looking closely at which applications suit 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 six. 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 performs as well as the high-GWP HFCs they replace.

These State, national, and international efforts will lead to significant reductions in HFC emissions in California through 2030, compared to where they would be otherwise. With the global HFC phasedown agreement in place, HFC emissions in California will decrease significantly, but not enough to meet the reduction goal of 40 percent below 2013 levels by 2030 (Figure 9).

[130] White House Office of the Press Secretary June 2, 2016, "FACT SHEET: U.S. Hosts World's Energy Ministers to Scale Up Clean Energy and Drive Implementation of the Paris Agreement" Available at: https://www.whitehouse.gov/the-press-office/2016/06/02/fact-sheet-us-hosts-worlds-energy-ministers-scale-clean-energy-and-drive (accessed 2 June 2016).

Figure 9: 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 was reached in October 2016 to phase down the production and use of HFCs under the Montreal Protocol. The proposed Montreal Protocol HFC phase down amendments 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.

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.

Even with the strong international agreement to phase down the use of HFCs, under a best-case scenario, the currently proposed global phasedown schedule will not achieve the reductions needed to meet the 2030 HFC emission reduction goal for California. Therefore, additional opportunities may 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, as effective alternatives become available, ARB will consider developing limitations on the use of high-GWP refrigerants in new refrigeration and air-conditioning equipment where lower-GWP alternates are feasible and readily available. ARB will focus on measures that can move low-GWP alternatives and technologies forward both nationally and internationally. California has a wide range of climate zones from alpine conditions to hot desert environments. As such, California could be instrumental as a proving ground for low-GWP refrigeration and air-conditioning technologies that can be used in extreme environments across the world.

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.

This SLCP Strategy describes a set of potential measures that can reduce HFC emissions by 40 percent in California by 2030 (see Table 11). This set of measures has been designed to minimize regulatory requirements and achieve fast and assured emission reductions. Additional analysis is needed to determine the impact of the global HFC phasedown on future HFC reductions in California. When this analysis is complete, further evaluation will be conducted on the scope of the additional emission reduction measures identified in Table 11.

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

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

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

Incentive Programs

A voluntary early action measure recommended is an 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 emission reductions prior to any mandatory measures.

Phasedown in Supply of HFCs

Due to the global HFC phasedown agreement, a California-specific HFC phasedown will not be necessary. However, as previously noted, there is a long time lag between reductions in HFC production and actual emission reductions, due to the slow turnover of existing equipment that continue to emit high-GWP HFCs throughout their useful life. For example, a 40 percent reduction in HFC production may take 10-20 years to be realized in reduced emissions.

ARB will continue to assess the impact of the Kigali Amendment on HFC emission reductions in California. Additional reduction measures are likely to be needed to reach the 2030 HFC emission reduction goals set forth in SB 1383.

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. 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:***
Non-residential refrigeration	150 or greater**
Air-conditioning (non-residential and residential)	750 or greater
Residential refrigerator-freezers	150 or greater

*The need for specific GWP limits and the proposed start dates for each end-use sector will be further evaluated as ARB assesses the impact of the global HFC phasedown agreement (Kigali Amendment) on future HFC emissions and reductions in California.
**Does not apply to small HFC/HFO central charge (with GWP less than 1500) used in hybrid refrigeration such as secondary loop and cascade systems.

GWP limits for specific air conditioning equipment types could be made more stringent if low-GWP technologies develop more quickly than anticipated, such as the continued development of low and medium-pressure air-conditioning chillers that use refrigerants with a GWP less than 150.

Certain exceptions could be made to any maximum GWP limit if no low-GWP refrigerants are technically feasible in a specific application. Additionally, high-GWP prohibition dates could be extended for specific end-use sectors where codes and standards do not allow the use of feasible low-GWP refrigerants.

In addition to current safety testing of residential appliances, significant research is underway to assess the safety and feasibility of low-GWP refrigerants in commercial refrigeration, commercial AC, and residential AC. While not every end-use sector has low-GWP options commercially available today, rapid development of low-GWP options is expected to continue.

Energy efficiency of low-GWP refrigeration and AC is one of the most important factors in the transition from high-GWP to low-GWP technology. If energy consumption increases, the additional GHG emissions from electricity generation will defeat the purpose of the low-GWP requirements. Therefore, energy efficiencies and “energy penalties” of low-GWP technologies are taken under consideration in the development of HFC emission reduction measures. According to refrigerant manufacturers, the new low-GWP synthetic refrigerant hydrofluoro-olefin (HFO) blends are as energy efficient as the HFC refrigerants they replace. In some cases, the HFO blends exhibit better energy efficiency than baseline HFC refrigerants. Among the “natural” refrigerants, hydrocarbon and ammonia refrigerants exhibit well-known energy efficiencies compared to HFC refrigerants. Carbon dioxide refrigerant is generally the same efficiency or more energy-efficient in cooler climates, and less efficient in warmer climates compared to HFCs. Improving the efficiency of CO_2 refrigeration in warmer climates is currently the subject of a great deal of research and development by equipment manufacturers. We expect the end of the “energy penalty” of CO_2 refrigeration in the next few years as equipment is designed for increasingly warmer climate zones, including desert climates. Additional details on low-GWP refrigerants and energy efficiency are included in Appendix F.

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.[131] 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 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, and immediate HFC reductions that the global phasedown would not achieve until many years later. 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.

[131] 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,[132] 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).[133] 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 C.

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

[132] 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.

[133] 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.

exceeding $300 million annually (with 80 percent of fumigations occurring in Southern California).

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.[134] 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.[135] 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 D

[134] 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.

[135] 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 SLCP 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 was 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.

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 SLCP Strategy.

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
2030 Target Scoping Plan Update and Subsequent 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
Healthy Soils Initiative
Forest Carbon Plan

The ARB is embarking on the next update to the Scoping Plan to describe how the State can meet the State'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 SLCP Report. ARB is collaborating 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. Support 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. For example, the local air districts are participating in the Interagency Waste Working Group to find regulatory and permitting solutions that allow for new and expanded organics processing facilities that are protective of public health as well as reducing GHG emissions due to avoided landfill methane 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.

Anthropogenic 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. Districts have also enacted rules regulating commercial cooking and smoke management programs addressing agricultural and rangeland burning operations, which have reduced black carbon and PM emissions.


Particulate matter visible in the air located in the Los Angeles Basin area

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.

Russian Ridge Open Space Preserve (San Mateo County), photo by Steve Jurvetson / CCBY 2.0

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, SB 32, and SB 1383 and target investment in disadvantaged communities. To guide the investment of Cap-and-Trade auction proceeds, the Department of Finance, in consultation with the ARB 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 GHG 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 included $215 million of Cap-and-Trade expenditures specifically targeting SLCP emission reductions. These expenditures were revised in SB 1613, which appropriates $5 million for black carbon residential wood smoke reductions, $40 million for waste reduction and management, $7.5 million for Healthy Soils, and $50 million for methane emission reductions from dairy and livestock operations.

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 emission 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 GHG emissions on dairies. CalRecycle administers GHG emission reductions grant and loan programs that include incentives for infrastructure supporting organics diversion. Finally, ARB is developing an incentive program to replace residential wood burning devices in the State with cleaner, more efficient devices, thereby reducing GHG, black carbon, particulate matter and other air toxics emissions.

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, SB 32, and SB 1383 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 SLCP 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 SLCP 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; the federal government 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.[136] These types of commitments and planning efforts need to be adopted more broadly. By developing a comprehensive plan to achieve necessary SLCP emission reductions in an effective and beneficial way, California can foster broader action beyond its borders and demonstrate effective processes and strategies to address climate change.

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

VIII. Evaluations

This chapter discusses the economic, public health, and environmental justice evaluations of the proposed new measures in this SLCP Strategy. It also discusses the environmental analysis that was prepared for the SLCP Strategy. It should be noted that to the extent that any of the proposals in the SLCP 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. Staff will track the progress of implementation of the SLCP measures and provide periodic updates to the Board. This information, as well as updates to the SLCP emission inventory, will be posted to ARB's SLCP website.

A. Economic Assessment of Measures in the SLCP Strategy

This section presents the economic analyses for the new measures identified in this SLCP Strategy. Supporting documentation for this analysis is presented in Appendix F. 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 Update, 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.

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 SLCP 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 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 or RFS programs, additional sources for financial incentives and funding may be needed.

The measures laid out in this SLCP 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 SLCP Strategy.

The measures included in the SLCP 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.[137] If digesters were built on farms accounting for about 1 million dairy cows, many in the San Joaquin Valley, it 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 additional 2 jobs per 1,000 tons of diverted organic material.[138] In 2025, this could result in 25,000 additional 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.[139]

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 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. Associated efforts

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[137] 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.

[138] http://www.calrecycle.ca.gov/publications/Documents/1463%5C20131463.pdf

[139] More information available at: http://greenlining.org/wp-content/uploads/2015/10/CAClimateInvestmentsCaseStudies.pdf.

related to the 2030 Target Scoping Plan Update, the California State Implementation Plan, and California's Sustainable Freight Action Plan stand to benefit from activities to cut SLCP emissions

The 2030 Target Scoping Plan Update, expected to be finalized in 2017, will include a detailed macroeconomic assessment of California's complete climate change mitigation strategy, including those contained in the final SLCP Strategy. While this SLCP Strategy begins to explore the costs and benefits of proposed measures, the 2030 Target Scoping Plan Update will contain a detailed economic analysis including a comprehensive assessment of the impact of California's climate strategy on Californians, businesses, Disadvantaged Communities, and the California economy.

All proposed SLCP strategies that are implemented as regulations 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 for stakeholders to assess the economic impact of measures in the SLCP Strategy as they are being developed.

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 have not 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 this SLCP Strategy 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 anthropogenic black 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 reductions 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 with a certified wood burning or gas device can range between $3,000 and $5,000, while some options, such as full HVAC installation can cost up to $10,000.[140] Purchase and installation of woodstoves was assumed to cost $4,000 while gas or small electric devices were assumed to cost $4,500. Incentives typically cover a portion of the cost, from $1,000[141] up to the full installation price.[142] 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. The range of incentives was assumed to be $1,000 to $4,500 to cover various cases.

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.[143] This case assumes that new EPA-certified devices work as certified, but real-world use may lead to higher than certified emissions if proper burn practices are not followed. If emissions do not meet certified levels, the level of health benefits and cost effectiveness of incentive dollars may not be realized. Emission reductions are more certain in the "wood to gas or electric" case where a non-certified woodstove is replaced by a gas or electric heating device. Conversion to natural gas or electric heating devices assumes 100 percent reduction in local PM emissions.

Actual incentive programs will likely contain a mixture of different replacement types and these two cases are used to bound potential emission reductions and costs. Other parameters used in emission reduction calculations were provided by the U.S. EPA residential wood combustion replacement calculator, which includes California-specific data when available (Table 12).[144] The calculator was updated to account for

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[140] USEPA (2014). How to Implement a Wood-Burning Appliance Change out Program. Available at: http://www.epa.gov/sites/production/files/2015-08/documents/howtoimplementawoodstovechangeout.pdf

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

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

[143] 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

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

replacement with cleaner EPA-certified wood burning devices that will be required by 2020.

Table 12: Emission Summary

Parameter	Wood to Wood	Wood to Gas or Electric
Cords wood burnt per year[145]	1.5	1.5
Wood Density (tons/cord)[146]	1.04	1.04
$PM_{2.5}$ Emission Reductions per device (tons/yr)[147]	0.0218	0.0245
BC Speciation (fraction of $PM_{2.5}$)[148]	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 12) by the range of incentives that could be provided, from $1,000 to the full cost of replacement.[149] The cost to homeowners was calculated as the total replacement cost, minus the portion covered by incentives. The “low incentives” case in Table 13 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 12), and were calculated as 10 percent of the lower incentive value.[150] Educational and outreach costs were estimated at one 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.[151] A summary of costs can be found in Table 13. The results 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

[145] Based on average California Climate, from USEPA Emission Calculator.
[146] Average California wood density, from USEPA Emission Calculator.
[147] Results are from USEPA Emission Calculator for wood to gas conversion. This result assumes approximately 100% reduction in PM.
[148] ARB (2015). 2015 Edition Black Carbon Technical Support Document. Available at: http://www.arb.ca.gov/cc/inventory/slcp/slcp.htm
[149] $4,000 for woodstove installation and $4,500 for gas devices.
[150] http://www.epa.gov/sites/production/files/201508/documents/howtoimplementawoodstovechangeout.pdf
[151] http://www.epa.gov/sites/production/files/201508/documents/howtoimplementawoodstovechangeout.pdf

extremes use to bound the range of possible costs; actual program implementation may lie between the low and high incentives cases presented in Table 13.

Table 13: Range of Costs (Million Dollars)[152]

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 strategy include reduced wood use in more efficient devices or any savings (or cost) to convert from wood fuel to natural gas. U.S. EPA estimates that EPA-certified devices burn a third less wood for the same heat output.[153] Table 14 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 12), the fraction of residents who pay for wood,[154] 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[155]. 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 12) would result in savings of approximately 44 million dollars per year to consumers receiving incentives to replace their inefficient wood stove.

Wood to gas or wood to electric savings can be calculated assuming 1.5 cords of wood are not purchased (Table 12), the cost of wood is $290 a cord, and that the heat-equivalent amount of natural gas or electricity must be purchased, and assuming 337,000 devices are replaced (Table 12). The price of natural gas was assumed to be $11.51 per thousand standard cubic feet.[156] The price of electricity was assumed to be

[152] 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.
[153] http://www.epa.gov/sites/production/files/201508/documents/howtoimplementawoodstovechangeout.pdf
[154] A portion of residents who rely on residential wood combustion for heat gather wood from local lands at no cost.
[155] 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
[156] 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.

16.3 cents per kWh.[157] The savings from not purchasing wood is nearly in balance with the additional cost of purchasing natural gas using these assumptions, while electricity is estimated to cost about four times more than wood (Table 14). Thus, electricity purchase would likely represent an additional cost to homeowners.

Table 14: Savings Associated with Residential Wood Stove Conversion (Million Dollars)

Conversion Scenario	Savings on Purchase of Wood	Increased Cost for Natural Gas or Electricity	Net Fuel Savings
100 % Wood to Wood	$44	$0	$44
100 % Wood to Gas	$117	$109	$8
100 % Wood to Electricity	$117	$464	-$347

2. Methane Emission Reductions from Dairy Manure

The economic analysis investigated a reduction in dairy manure emissions that could come from a mix of voluntary and regulatory efforts to reduce emissions from the equivalent of about 1 million cows, equivalent to an annual methane reduction of 22 $MMTCO_2e$ by 2030, and a cumulative reduction of 166 $MMTCO_2e$ through 2030 using the assumptions in this analysis (7.8 $MMTCO_2e$ and 57.6 $MMTCO_2$, respectively, using a 100-year GWP). This analysis will be further refined in coordination with stakeholders as measures are developed.

The analysis included five potential pathways for dairies to mitigate manure methane. 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. Not every pathway may be feasible for every dairy, and a variety of pathways will be employed to reach the targets.

This analysis relies on a number of assumptions that may not fully account for all barriers a project could face, such as up-front financing challenges or permitting issues. On the other hand, cost estimates are based on current and past projects, and may over-represent future costs that could come down from economies of scale or learning. Still, this analysis shows the potential for strategies to improve management of dairy manure and produce revenue-positive, value-added products, such as transportation fuels, while providing GHG, and potentially also criteria pollutant, benefits.

The five major pathways analyzed were:

1) Scrape conversion and onsite manure digestion producing:

[157] EIA (2015). Annual Average Retail Price of Electricity to Ultimate Customers by State and Utility. Table 6 - 2014 Utility Bundled Retail Sales – Residential filtered for California. Available at: http://www.eia.gov/electricity/data.cfm#sales

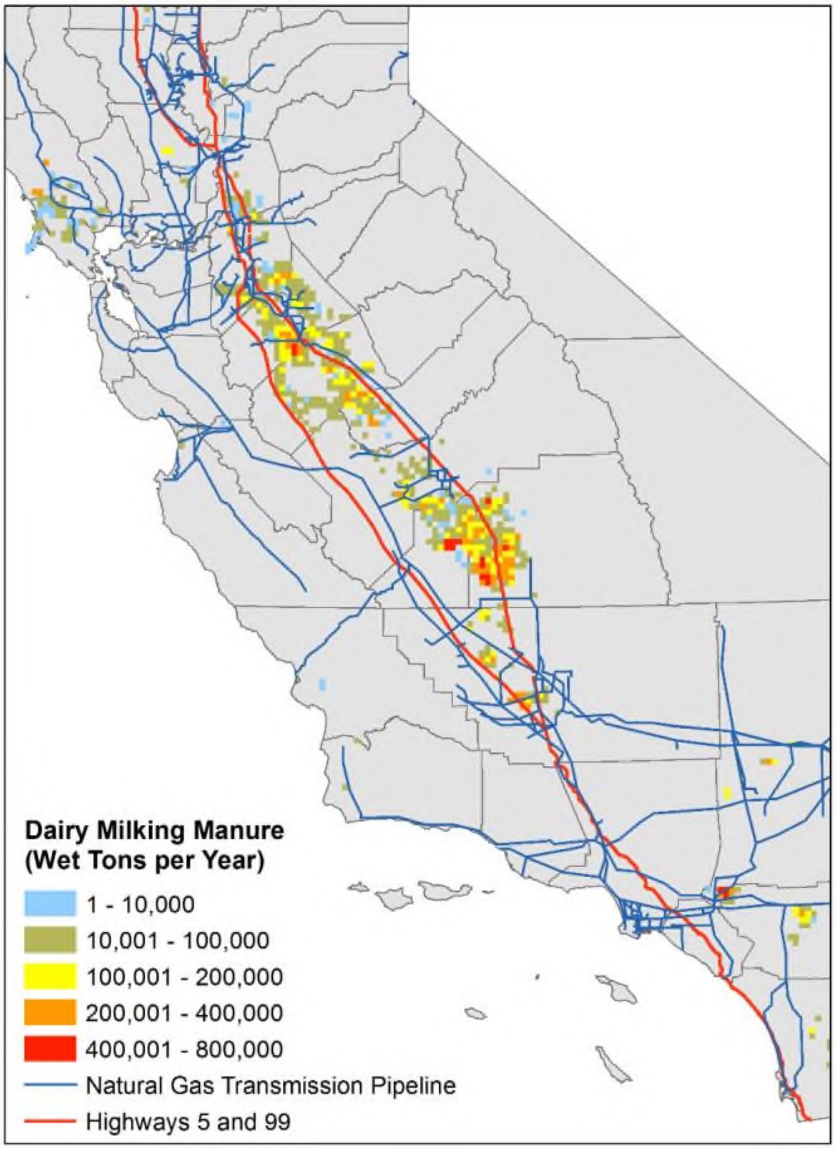
    a) electricity or
    b) pipeline-injected renewable natural gas vehicle fuel
2) Scrape conversion and transport of manure offsite for centralized digestion producing:
    a) electricity or
    b) pipeline injected renewable natural gas as a vehicle fuel
3) Retain existing manure lagoon management with onsite covered lagoon digestion producing:
    a) electricity or
    b) pipeline-injected renewable natural gas vehicle fuel
4) Conversion of dairy operations to pasture-based management
5) Scrape conversion, collection and open solar drying of manure onsite

The first pathway assumes conversion to solid manure management (scrape), and development on digesters onsite at each dairy to produce either electricity using micro turbines or transportation fuel. The second pathway is the same as the first, but captures economies of scale by utilizing centralized digesters for a “cluster” of dairies. In the second pathway, manure is assumed to be trucked to the central digestion point. Pathway 2 only includes a subset of California’s dairies that were within reasonable clustering distance using a GIS analysis (within 5 miles on average). The third pathway retains the existing lagoon manure management, utilizes a covered lagoon digester, with the resulting biomethane producing either electricity or transportation fuels. Pathway 3 only includes the subset of dairies practicing flush management. In the fourth strategy, dairies convert to pasture-based operations; no revenue is assumed from this pathway. Finally, the fifth pathway mitigates manure methane emissions by converting from flush management to scrape systems, but is assumed to generate no revenue. There could also be potential revenue (along with added costs) if manure were composted and sold, which is not considered here. This represents a relatively low cost option compared to the other pathways, but low value as well. The cost and efficacy of some mitigation options, such as solids separation, were 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.

Cost Analysis Methodology

Cost analyses were based on a Geographic Information System (GIS) analysis of dairies throughout the State. The GIS analysis used information about the size, associated crop land, and location of dairies to inform feasibility of pipeline injection, pasture-based management, and dairy-specific costs for each pathway listed above. Analyses were also performed to understand the feasibility and cost savings associated with “clustering” dairies to centralize digestion by defining 55 potential central cluster locations and identifying dairies to feed into each cluster. The dairy-specific economics were calculated for each pathway to account for cost differences in dairy herd size and distance from transmission pipelines or central digestion locations. Figure 10 provides a spatial analysis of manure from milking cows in California.

Figure 10: Location of Manure from Milking Cows in California



The economic analysis was informed with consultation from CDFA, academic researchers at UC Davis and elsewhere, project developers, and stakeholders. In particular, as part of developing this SLCP Strategy, ARB supported research at UC Davis to inform cost and performance estimates for dry scrape conversions, anaerobic digesters, and other pathways.[158] Additional research was also used to inform the cost

[158] 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 2016. http://biomass.ucdavis.edu/wp-content/uploads/2016/06/ARB-Report-Final-Draft-Transmittal-Feb-26-2016.pdf

and performance parameters assumed for this analysis, which are detailed in Appendix F.[159]

Pathways that inject biomethane into the pipeline for use as transportation fuel are assumed to 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)[160] from the federal Renewable Fuel Standard program. Dairies that receive LCFS credits cannot also receive Cap-and-Trade credits for the same volume of biomethane.[161] Pre-regulation and post-regulation LCFS carbon intensities and associated revenue were calculated using the same assumptions as the 2015 LCFS-certified California bioenergy Dairy Biogas prospective pathway.[162] Pathways that produce electricity assume the use of microturbines to limit NOx emissions and receive revenue from SB 1122 electricity sales subsidies ($0.126/kWh) and Cap-and-Trade offsets ($13/MTCO$_2$e). No revenue was included for soil amendment products that could potentially provide value,[163] because their market remains uncertain. Each pathway was analyzed using LCFS credits both pre and post regulation.

Biogas production for above ground or plug-flow digesters are assumed to use 100 percent of manure volatile solids from milking cows, while covered lagoon digesters are assumed to capture 60 percent of manure volatile solids due to losses during solids separation. In addition, above ground or plug-flow digesters are estimated to be 11 percent more efficient per pound of manure.[164] In balance, biogas production per cow is approximately two times larger for above ground or plug-flow digesters as covered lagoon digesters using these assumptions, though real-world technology implementation may differ from these assumptions. The baseline methane mitigated (destroyed) is similar regardless of technology so LCFS revenues are similar for covered lagoon and above ground tank or plug-flow digesters, while revenue from RIN credits varies in proportion to biogas production.

Example Economic Analysis for a 2,000 Milking Cow Dairy

A full economic analysis was performed for each pathway on a dairy-by-dairy basis to account for cost differences between dairies of different sizes. However, to provide an overview comparison by pathway, the costs and revenues for an example 2,000 cow

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[159] 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/.

[160] 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).

[161] ARB (2016). Staff Summary, Method 2B Application: Prospective Pathway Dairy Biogas to CNG. www.arb.ca.gov/fuels/lcfs/2a2b/apps/Calbio-122115.pdf

[162] Id

[163] Soil amendment products from dairy digesters could provide as much as $300 per cow per year in California. Informa Economics (2013) National Market Value of Anaerobic Digester Products.

[164] 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 2016. http://biomass.ucdavis.edu/wp-content/uploads/2016/06/ARB-Report-Final-Draft-Transmittal-Feb-26-2016.pdf

flush dairy are summarized in Table 15. The table includes the net present value for each pathway over a 10-year time horizon, assuming a 10 year loan on capital at 7 percent interest, and a 5 percent discount rate. Results are presented both pre-regulation, and post-regulation to examine the effects of regulation on LCFS credit generation and net present value of the project. Regulation would increase the carbon intensity of projects producing transportation fuels, reducing the revenue from LCFS credits, and would eliminate carbon offset credits for new projects that generate electricity and are built after the regulation is in place. However, the value of these revenue streams could also be higher than assumed in this analysis, which would increase revenues and net present values beyond those listed in the table. The detailed calculation methodology, assumptions, and references for Table 15 are included in Appendix F.

Table 15: Economic Analysis for Projects at an Example Flush Dairy with 2,000 Milking Cows Over a 10-year Period, considering value pre and post regulation.[165] (All costs and revenue in million dollars)

	Pathway							
	1a	**1b**	**2a**	**2b**	**3a**	**3b**	**4**	**5**
	Scrape, Onsite Digestion to Electricity	Scrape, Onsite Digestion to Fuel	Scrape, Central Digestion to Electricity	Scrape, Central Digestion to Fuel	Lagoon, Onsite Digestion to Electricity	Lagoon, Onsite Digestion to Fuel	Pasture	Scrape Only
Capital	$6.9	$7.2	$6.8	$5.3	$5.1	$7.2	$7.2	$1.6
O&M	$4.2	$5.3	$4.8	$4.5	$4.1	$5.5	$2.8	$0.4
Carbon Credits	*$1.5*	--	*$1.5*	--	*$1.5*	--	--	--
LCFS pre-reg	--	*$6.7*	--	*$6.7*	--	*$6.4*	--	--
LCFS post-reg	--	*$0.8*	--	*$0.8*	--	*$0.5*	--	--
RINS	--	*$4.1*	--	*$4.1*	--	*$2.2*	--	--
Other Revenue	*$2.1*	*$1.1*	*$2.1*	*$1.1*	*$1.1*	*$0.6*	--	--
Revenue pre-regulation[166]	$3.6	$11.9	$3.6	$11.9	$2.6	$9.2	--	--
Revenue post-regulation[167]	$2.1	$6.1	$2.1	$6.1	$1.1	$3.3	--	--
10-year net present value (NPV) and cost effectiveness pre-regulation								
NPV (million $)	–$7.5	–$0.5	–$8.0	$2.1	–$6.5	–$3.4	–$9.9	–$2.1
$/MT CO_2e (20-yr GWP)	18	1	19	–5	15	8	29	5
$/MT CO_2e (100-yr GWP)	51	3	55	–15	45	23	82	14
10-year net present value (NPV) and cost effectiveness post-regulation								
NPV (million $)	–$9.0	–$6.3	–$9.5	–$3.7	–$8.0	–$9.4	–$9.9	–$2.1
$/MT CO_2e (20-yr GWP)	21	15	23	9	19	22	29	5
$/MT CO_2e (100-yr GWP)	61	43	65	25	55	64	82	14

Table 15 shows the potential for large revenue from transportation fuels production. One pathway that produces transportation fuels and captures economies of scale by clustering dairies, pathway 2b, is potentially revenue positive if LCFS and RIN credits remain near recent prices. However, credit prices under these programs can be volatile, and securing funding for projects with uncertain revenue sources is challenging. Even with LCFS and RIN credits, these projects may need financing assistance, either in the form of up-front grants, or other mechanisms that can help to secure project financing, such as the pilot financial mechanism for diaries required by SB 1383. Regulation reduces the value of LCFS credits and eliminates carbon credits for new dairy projects. Table 15 shows that, with regulation in place, the revenue from

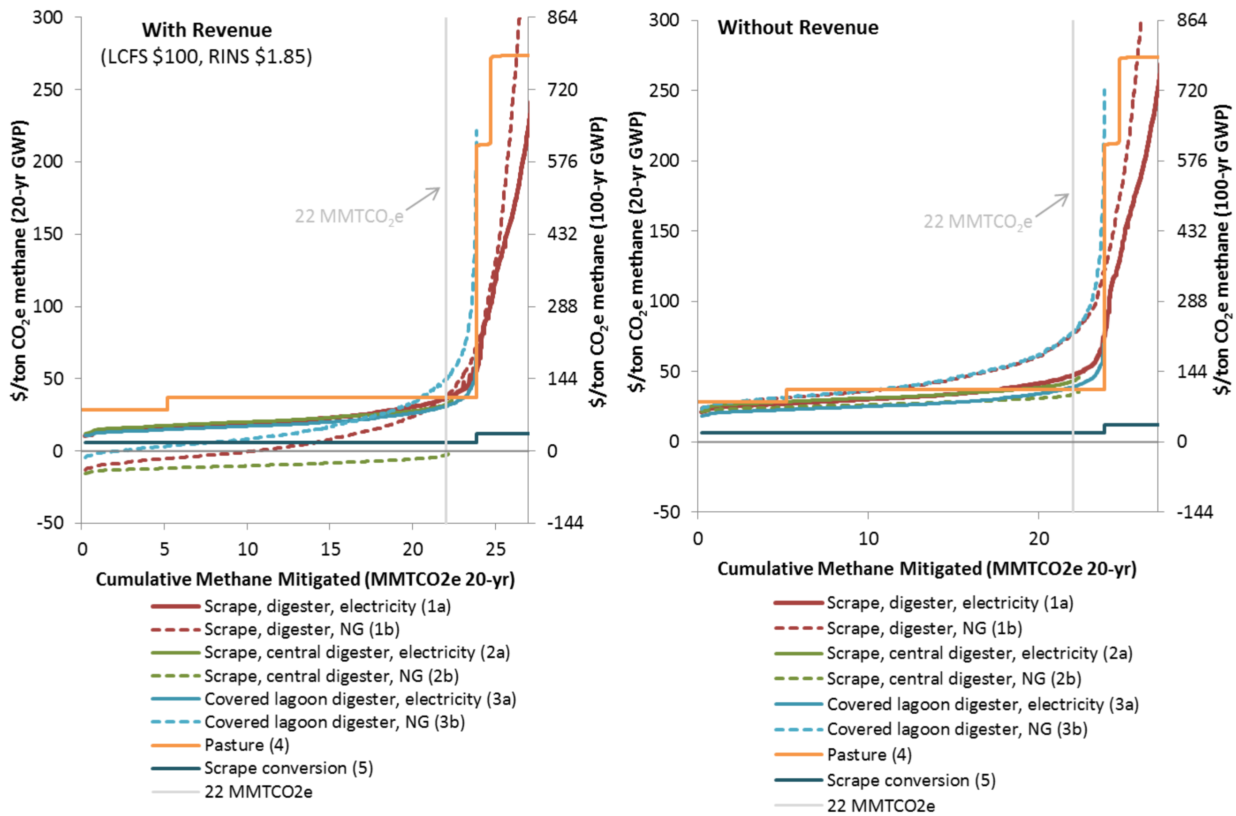
[165]Summation may not be exact due to rounding. Capital costs amortized over 10 years with 7% interest. Discount rate is 5%. Costs normalized to example 2,000 cow dairy.
[166] Pre-regulation revenue includes carbon credits, pre regulation LCFS value, RINS, and other revenue
[167] Post-regulation revenue includes post-regulation LCFS value, RINS, and other revenue

LCFS credits for new projects declines significantly, and the net present value of all projects is negative over their first 10 years.

Cost Curves for California's Dairies

Data in Table 16 represent a 2,000 milking cow dairy to compare the relative costs and revenue by pathway for a dairy, however, costs will not be consistent across dairy sizes or location. A dairy-by-dairy economic analysis was performed to better account for this. Capital, annual operations and maintenance, and annual revenue were calculated for each dairy in California to provide cost curves by pathway (Figure 11). To illustrate costs and cost-effectiveness, cost curves are presented both with and without revenue in Figure 11.

Figure 11: Individual Dairy Cost Curves by Pathway



Based on the assumptions used here, projects at dairies show the potential to reduce manure methane emissions, at fairly low (or negative) costs compared to other sources. However, dairies are unique because milk prices are fixed, thus dairy operations cannot pass on increased production costs. Many dairies in California are currently operating at a loss, so even comparably low-cost emission reduction options such as these could pose a financial burden to the dairy industry.

Projects that generate transportation fuel and capture LCFS credits (1b, 2b, and 3b) have the potential to generate significantly more revenue than other pathways, and have the potential to be revenue positive over 10 years for many dairies in California (Figure 11). All other pathways that do not generate transportation fuels are revenue negative over 10 years for any dairy in California, using the assumptions here, and would need additional financial assistance to be economically viable over that time frame. Additionally, no modeled project is revenue positive in the absence of LCFS and RIN credits.

Costs and Revenues for Sector-Wide Scenarios

The sector-wide total implementation cost to achieve a 22 $MMTCO_2e$ dairy manure methane reduction depends on the pathway utilized by each dairy, which is difficult to predict. To bound potential costs, this analysis assumes that dairies would choose the pathway with the highest net present value if LCFS and RIN credits were available (2b – scrape conversion with central digestion to fuel), or that dairies would choose the lowest cost option in the absence of revenue (5 – scrape conversion only). This provides a likely cost bounding considering scenarios with and without LCFS and RIN credits. It is important to note that these scenarios were selected as an economic bounding exercise, and they are not intended to suggest a preferred or expected path forward. For example, there are still outstanding questions about the costs and feasibility of converting California's dairies from lagoon flush management to scrape, which should be investigated going forward. Actual implementation of any regulatory requirements will likely include a suite of potential mitigation options, which will allow each dairy operation to select their preferred mitigation option.

Sector-wide costs, revenue, and cumulative methane mitigation were calculated through 2030, though additional costs and benefits would accrue after this date. Pathway 5 contains no revenue, while pathway 2b receives revenue from RIN and LCFS credits as well as sale of biogas. RIN credits were assumed to be available for all years through 2030. LCFS credits were calculated for three scenarios to account for the effect of regulation on revenue: no regulation, regulation in 2026, and regulation in 2024. Regulation effective dates were assumed to be January 1st of the regulation year. Any project started before the effective date of the regulation receives LCFS credits for methane destruction for 10 years. After 10 years, it is assumed that the dairy no longer receives credit for methane destruction which increases the carbon intensity score under the LCFS and significantly reduces LCFS revenue for any remaining year through 2030. Some dairies could potentially reapply for methane destruction credits for an additional 10 years but this option was excluded in this analysis for simplicity. Projects started after the regulation date do not receive credit for methane destruction and receive the higher carbon intensity score for LCFS credits through 2030. In the no regulation case, all projects receive the full LCFS credits for up to10 years and the higher CI LCFS credits for any remaining years through 2030. The detailed calculation methodology, assumptions, and references for Table 16 are included in Appendix F.

Table 16: Sector-wide costs for two bounding scenarios through 2030[168]

		Pathway			
		2b Scrape, Central Digestion to Fuel			**5**
		No Regulation	**2026 Regulation**	**2024 Regulation**	Scrape Only
Capital (billion $)		$1.5	$1.5	$1.5	$0.5
O&M (billion $)		$1.3	$1.3	$1.3	$0.1
Revenue (billion $)	**LCFS ($100)**	$2.1	$1.9	$1.6	--
	RINs ($1.85)	$1.4	$1.4	$1.4	--
	Other*	$0.4	$0.4	$0.4	--
NPV (billion $)		$1.1	$0.9	$0.6	–$0.7
$/MT CO_2e (20-yr GWP)		–7	–5	–4	4
$/MT CO_2e (100-yr GWP)		–19	–15	–5	11

*Sale of biogas at $3.46 per 1,000 SCF.

This analysis suggests that the dairy industry in California can cut methane emissions and deliver low-cost GHG reductions. Pathway 5, scrape conversion only, is a relatively low cost option compared to other pathways, but also assumed to be low value. Pathway 2b, cluster and fuel production, represents a potentially high value scenario, but would require significantly more technology and investment (including upfront capital), and relies on potentially volatile revenue sources.

Regulation has a significant effect on potential LCFS credits in pathway 2b. The sector-wide effect of regulation on LCFS revenue depends on the timeline that dairy projects come online. Regulating in 2024 versus 2026 reduces cumulative LCFS revenue to the industry by about $300 million, although the sector-wide net present value (NPV) with a 2024 regulation is estimated to be positive, at $0.6 billion through 2030. However, this positive sector-wide NPV does not mean all dairies are profitable. As exemplified in Table 16, regulation significantly reduces the LCFS revenue a dairy receives. In the 2024 regulation scenario, the 206 dairies that come online before the regulation are profitable without additional financial assistance, while the 337 dairies that come online after the regulation would lose money over a 10 year loan period using these assumptions and without additional financial support. It could make sense, then, for more dairies to pursue earlier project development, which could increase revenues, cost effectiveness, and emission reductions beyond those simulated here.

Table 17 presents the sector-wide cumulative upfront capital costs and implementation assumptions for the two sector-wide scenarios. Upfront capital costs are a measure of investment needed to get projects off the ground and do not include annual operational costs or revenue. As noted previously, actual implementation will utilize a range of mitigation options and these two scenarios provide a possible bounding of upfront

[168] Summation may not be exact due to rounding. Capital costs amortized over 10 years with 7% interest. Discount rate is 5%. All costs and revenues are calculated through 2030, though additional costs and benefits will accrue after 2030.

costs. Cumulative capital investment of between $600 million and $1.7 billion would be needed by 2030 to meet the 22 $MMTCO_2e$ reductions using assumptions in this analysis. In the near term, $200 million to $500 million would be necessary to reduce dairy manure methane by 20 percent in 2020.

Table 17: Sector-wide implementation assumptions, and upfront capital costs[169]

	Pathway 2b Scrape, central digestion, fuel			**Pathway 5** Scrape only	
Year	**Cumulative Upfront Capital (Billion $)**	**Number of Clusters**	**Number of Dairies**	**Cumulative Upfront Capital (Billion $)**	**Number of Dairies**
2020	$0.5	11	95	$0.2	56
2025	$1.2	32	294	$0.4	213
2030	$1.7	55	543	$0.6	493

Funding support or incentives will likely be necessary to achieve rapid manure methane mitigation targets under any scenario. Several existing and potential funding sources are available, including those from federal sources, California's Greenhouse Gas Reduction Fund (GGRF), utility programs, private investors, the programs included in this analysis, or other sources. Limited federal grant funding is currently available, and more should be pursued. The legislature appropriated $50 million in GGRF funding for fiscal year 2016-2017 to achieve early and extra methane emission reductions from dairy and livestock operations, and an additional $7.5 million to support the Healthy Soils Program, including compost applications.[170] Additionally, AB 2313 provides utility incentives of up to $3 million to offset utility interconnection costs associated with biomethane projects, and up to $5 million for dairy cluster projects, including the costs of gathering pipelines. It directs the PUC to keep this program in place through December 31, 2021. Senate Bill 1383 directs state agencies to consider or develop additional policies to support dairy biomethane and other renewable gas projects–including energy infrastructure and procurement policies, financial mechanisms to reduce the uncertainty of value under the LCFS, rate-basing pipeline infrastructure for no fewer than five dairy biomethane pilot projects, and other policies and incentives to significantly increase the sustainable production and use of renewable gas in the state. Altogether, these policies provide a strong starting point for developing projects to reduce dairy manure emissions in California.

This analysis provides the initial framework for understanding costs and potential revenue associated with manure methane reductions in California. As mentioned previously, this analysis is purely economic and there are important uncertainties associated with project costs and potential revenues, as well as barriers to implementation that may limit project development without targeted support. State and local governments may wish to support some higher cost strategies for other environmental or health reasons. This document represents a starting point for discussion that should be built upon and bolstered. The working group referenced in

[169] Capital costs are discounted at 5%, does not include operating costs or revenue. Cumulative upfront capital represents anticipated financing needs.
[170] Assembly Bill 1613 (Chapter 370, Statutes of 2016)

Chapter V may be helpful in recommending ways to leverage private sector investment and scale efforts to rapidly cut methane emissions in California.

3. Methane Emission Reductions from Diversion of Landfill Organic Waste

As noted in Chapter V, meeting the SB 1383 organic diversion targets can reduce landfill emissions by 4 $MMTCO_2e$ in 2030, but one year of waste diversion in 2030 is expected to avoid 14 MMTCO2e of emissions over the lifetime of waste decomposition. Achieving these methane emission reduction targets requires 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.

In this analysis three scenarios were considered that can achieve the organic diversion target outlined in this SLCP Strategy. The three scenarios are based on projected waste data and potential diversion outlined in Appendix F. 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. Although ARB recognizes there are other beneficial uses of renewable natural gas, this 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 most realized in disadvantaged communities 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 F.

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 2025, 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 biosolids 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. Compost facility revenues are estimated in scenario 3 by only including tipping fees and not revenues associated with the sale of compost. This conservative approach represents the lower bound estimate of compost. However, these revenues vary depending on a number of factors such as seasonality, organic certification, and compost blend type

A principal difference in outcomes from these three scenarios is the number of new facilities needed to achieve the organic diversion targets. Table 18 shows the number of new compost or AD facilities needed for each scenario.[171]

Table 18: Estimated Number of New Facilities

Scenario	Estimated Number of New Compost Facilities		Estimated Number of New AD Facilities	
	2020	2025	2020	2025
1. New AD	15	26	39	47
2. Existing WWTP	22	35	--	--
3. Compost Only	47	65	--	--

[171] This analysis assumes existing wastewater treatment facilities can handle 50,000 wet tons of organic material 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 F

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 this SLCP 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 19. The table includes the net present value for each scenario over a 10-year financing period

Table 19: 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	47 Facilities 26 Facilities	\$1,700 \$400	\$2,600 \$700	\$7,000 \$1,300
Total		**\$2,100**	**\$3,300**	**\$8,300**
10-Year Net Present Value		**\$2,700**		
Scenario 2: WWTP	**Component**	**Capital Cost**	**O&M**	**Revenue**
New Compost	35 Facilities	\$600	\$900	\$1,800
Existing Wastewater Treatment	104 Facilities	\$1,600	\$2,800	\$5,700
Total		**\$2,200**	**\$3,700**	**\$7,500**
10-Year Net Present Value		**\$1,400**		
Scenario 3: Compost	**Component**	**Capital Cost**	**O&M**	**Revenue**
New Compost	65 Facilities	\$800	\$800	\$1,600
Total		**\$800**	**\$800**	**\$1,600**
10-Year Net Present Value		**-\$100**		

Table 19 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 20, 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 20: 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**	-$26.2	-$21.0	-$15.7	-$10.5	-$5.3	-$44.8	-$26.4	-$8.0	$10.3	$28.7
	$0.50	-$17.2	-$12.0	-$6.7	-$1.5	$3.7	-$24.9	-$6.5	$11.9	$30.2	$48.6
	$1.00	-$8.2	-$2.9	$2.3	$7.5	$12.7	-$5.0	$13.4	$31.8	$50.2	$68.6
	$1.85	$7.1	$12.4	$17.6	$22.9	$28.0	$28.9	$47.3	$65.7	$84.1	$102.5
	$2.50	$18.9	$24.1	$29.3	$34.6	$39.8	$54.8	$73.2	$91.6	$110.0	$128.4
	$3.00	$27.9	$33.1	$38.4	$43.6	$48.8	$74.7	$93.1	$111.5	$129.9	$148.3
	$3.50	$36.9	$42.1	$47.4	$52.6	$57.8	$94.7	$113.0	$131.5	$149.8	$168.2
	$4.00	$45.9	$51.2	$56.4	$61.6	$66.9	$114.6	$133.0	$151.4	$169.8	$188.2

State resources could be deployed to supplement financing of these types of biomethane projects through mechanisms such as upfront grants, loan assistance programs, and tax incentives. For example, the illustrative wastewater treatment facility in Table 19 would break even over a 10-year financing period with an upfront grant of $24 million. In the absence of revenue from the sale of LCFS or RIN credits, a representative new AD facility would require an upfront grant of $41 million to breakeven over a 10-year financing period. State agencies are collaborating to find solutions to these financial challenges.

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 targets identified in this SLCP 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

This SLCP 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 final Board consideration in 2017. The regulation is anticipated to deliver environmental benefits that include an estimated reduction in GHG emissions through 2030 of about 13.3 $MMTCO_2e$ from oil and gas related emissions in California. In addition, the measure is expected to save about 620 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 $2.6 million per year.[172]

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 percent 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 emission reductions and leak monitoring plans at underground gas storage facilities will have ongoing costs in each year beginning in 2018. The amortized[173] capital cost plus the ongoing costs yield an overall cost of the measure of just over $200 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 $31 million through 2030 and persisting

[172] 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.
[173] Using a 5% discount rate.

thereafter. The costs, cost-savings, and emission reductions are outlined in Table 21 by each provision.

Table 21: 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	2,112,000	$9,696,000	$596,000	$126,053,000	$7,744,000
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	**13,296,000**	**$15,916,000**	**$2,551,000**	**$200,693,000**	**$31,204,000**

5. Hydrofluorocarbon (HFC) Emission Reductions

Note: The following HFC section was written before the global phasedown of HFCs was agreed to on October 15, 2016 (the "Kigali Amendment"). ARB is currently evaluating the Kigali Amendment's impact upon HFC emissions in California; this section will be further updated to reflect changes in BAU emissions, additional needed reductions, and the cost and benefit of HFC reductions measures.

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 four 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 (to be enacted through the international agreement of the Montreal Protocol Meeting of the Parties, October 15, 2016, in Kigali, Rwanda)
- 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 F. 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 22.

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 F.

Table 22: 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 four 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 SLCP 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:[174]

> 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.

[174] 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/

Furthermore, in its report on *Reducing global health risks through mitigation of short-lived climate pollutants,*[175] 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 SLCP 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 SLCP 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 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 SLCP 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.[176,177,178] 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

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[175] 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/

[176] 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

[177] 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.

[178] 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.

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.[179]

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 diesel equipment.[180] (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 SLCP 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.[181] Thus, reducing methane emissions as part of a broader

[179] 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

[180] 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.

[181] 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.

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.[182] 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 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 could also improve nutrient management, thereby potentially 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 increase the efficacy of landfill gas management systems at existing landfills, many of which are located in or near environmental justice communities. Phasing out the landfilling of

[182] 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

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 with 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 3,600 tons per year, or about 10 tons per day, statewide.

The measures identified in this SLCP 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 SLCP 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 (EJ) 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 firmly committed to seeking fair treatment of all races, cultures, and incomes in the measures it develops and implements.[183] ARB works extensively with local air districts, EJ communities and other stakeholders during the development and implementation of its programs to respond to concerns about environmental justice.

AB 32 (Statutes of 2006, Chapter 488), directs ARB to convene an Environmental Justice Advisory Committee (EJAC) to advise the Board in developing the Scoping Plan, and any other pertinent matter associated with the implementation of AB 32. In January 2007, the Board appointed the first EJAC to advise it on the Initial Scoping Plan before that plan was approved by the Board in December 2008. The EJAC was reconstituted in March 2013 to advise the Board on the First Update to the Scoping Plan. The EJAC is now advising ARB on the development of the 2030 Target Scoping Plan Update. As part of that process, staff worked with the EJAC to hold eleven community meetings around the state. The recommendations that emerged from that process are being incorporated into or otherwise addressed in the 2030 Target Scoping Plan Update.

As part of its ongoing effort to fully integrate environmental justice considerations into its programs, ARB has created the position of Assistant Executive Officer (AEO) for Environmental Justice. The AEO will serve as the primary internal and external contact for ARB on EJ issues and concerns. The AEO will be responsible for providing policy consultation and recommendations to ARB staff, and will participate in decision making during the development and implementation of all major ARB programs to ensure that EJ concerns are fully considered. The AEO will develop and implement a program to ensure that EJ concepts, values and objectives are understood and considered throughout the development and implementation of the ARB's policies and programs. Further, the AEO will develop and maintain relationships with EJ stakeholders, and enhance communication between external stakeholders and ARB program staff.

ARB briefed the current EJAC on the development of the SLCP Strategy on several occasions. The EJAC has met ten times since December 2015, and that process culminated with Initial Recommendations from the EJAC, finalized on August 26, 2016. The Initial Recommendations consist of about 140 recommendations, sorted by six broad categories:

1) Overarching Issues;
2) Industry;
3) Energy, Green Buildings, and Water;
4) Transportation;
5) Natural and Working Lands, Agriculture, and Waste; and
6) California Climate Investments.

[183] See https://www.arb.ca.gov/ch/programs/ej/ejpolicies.pdf.

Recommendations falling under these broad categories were then further grouped into five subcategories:

(A) Partnership with Environmental Justice Communities;
(B) Equity;
(C) Coordination;
(D) Economic Opportunity; and
(E) Long-Term Vision.

The EJAC provided direction that their Initial Recommendations are intended "to be read and implemented holistically and not independently of each other." ARB will provide responses to each Initial Recommendation as the 2030 Target Scoping Plan is developed. The complete set of Initial Recommendations is available at: www.arb.ca.gov/cc/ejac/ejac_recommendations082616revised.pdf. The EJAC recommendations that are relevant to this SLCP Strategy, and ARB's responses to those recommendations, follow:

(1) Address localized impacts of short-lived climate pollutant emissions, such as black carbon from all sources.

This SLCP strategy describes a comprehensive array of measures to reduce methane, black carbon, and HFC emissions in California. SB 1383 directs ARB to develop measures to reduce black carbon from anthropogenic sources. As such, the strategy supports measures in place and under development that reduce black carbon from mobile sources, proposes new measures to reduce black carbon emissions from wood-burning stoves, and proposes next steps to foster emission reduction from other sources such as agricultural burning. These black carbon emission reductions will benefit climate, local air quality, and health.

(2) Divert dairy waste as fertilizer and for carbon sequestration before it can be converted to methane.

The dairy and livestock section of this SLPC Strategy describes a range of potential methane reduction measures that will be considered under future incentive and regulatory programs. Among them are measures in which manure would be used as a soil conditioner and fertilizer without first being digested. Because the measures developed under the SLCP program must be technically and economically feasible, and must not lead to emissions leakage, no measures can be ruled out at this point in the process. All measures eventually adopted under the SLCP program, however, must also avoid adverse impacts to disadvantaged communities.

(3) Perform a complete lifecycle analysis of dairy and other bio-digester technology and related infrastructure investment. If biogas from dairies is converted to bio-methane, ARB must mandate that vehicles servicing digesters and converters utilize that gas as a primary fuel source. This is a better use of the fuel than

building new pipelines and related infrastructure to transport the gas to other locations.

Before biomethane can generate credits under the LCFS, it must obtain a carbon intensity (CI) value. A CI is a full lifecycle GHG emissions value. Depending on credit values, much of the vehicle fuel produced from dairy manure biogas will have LCFS CI values. In general, however, ARB is obligated to account for all emissions in the measures it develops. SB 1383 is clear that we are not to develop methane measures that produce adverse air quality impacts. It will therefore be important to avoid significant increases in vehicular and equipment emissions. Measures that result in the use of dairy digester biomethane in vehicles and equipment servicing dairy digester projects is one way to achieve this goal. Digester biomethane in excess of what can feasibly be used locally, however, must be transported to markets.

(4) Identify and establish effective methods for implementing food rescue programs, with quality controls to avoid dumping inedible food on communities. Identify strategies for getting edible food to those who need it. Incentivize these programs and promote communication plans for projects, so all communities have access to successful plans.

SB 1383 requires CalRecycle, in consultation with ARB, to develop regulations to reduce disposal of organic waste by 50 percent of 2014 levels by 2020 and 75 percent by 2025. Of the edible food in the organic waste stream, not less than 20 percent is to be recovered to feed people in need by 2025.

(5) Develop more local agricultural processing centers so food is not being trucked long distances. Introduce a scoring system for food that indicates food-miles traveled. Encourage local food processing of food and meat, and educate people on the greenhouse gas reduction benefits of not eating meat. Establish public financing for healthy, environmentally sound food sources.

These are potentially viable measures. Staff will consider them in the development of measures to reduce methane emissions under this SLCP Strategy.

ARB staff has been working with staff from other state agencies to develop a holistic and synergistic approach to reducing methane emissions, and will continue to work with them to develop and implement these measures. ARB staff will continue to consult with EJ communities as we develop and 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 SLCP Strategy are developed into regulatory and non-regulatory measures and policies.

The California Environmental Protection Agency, 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.[184]

The distribution of these communities often 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. Rural communities in the northern part of the State and the Sierra also are stricken with high rates of poverty and unemployment. Many billions of dollars in public and private investment will flow to communities in all of these regions in the coming years to reduce SLCP and CO_2 emissions, strengthen our agricultural sector, and build sustainable freight systems.

The integrated strategy to reduce SLCP emissions from agriculture and waste, developed in this SLCP 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.

The measures identified in this SCLP 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 SLCP Strategy, has revised the Draft Environmental Analysis (EA) that was initially released for review on April 11, 2016, to address changes that were made to the SLCP Strategy in response to the requirements of SB 1383. The Revised Draft EA is being recirculated for public comment with the revised SLCP Strategy as Appendix E. Since the entire Draft EA has been substantially revised and is being recirculated for a new 45-day public comment period, new comments must be submitted on the Revised Draft EA, and ARB will respond only to those comments received on the recirculated Revised Draft EA.

The Revised Draft EA was prepared 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

[184] http://oehha.ca.gov/calenviroscreen/indicators

(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 this SLCP Strategy. The Revised 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 Revised Draft EA finds implementation of these actions could result in the following short-term and long-term beneficial and adverse impacts: beneficial long-term impacts to air quality and greenhouse gas emissions; less than significant impacts to aesthetics, agriculture and forest resources, air quality, biological resources, cultural 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, recreational services, transportation/traffic and utilities and service systems; 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 Revised Draft EA in Appendix E for further details.

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

IX. Next Steps

The final SLCP Strategy, the final Environmental Analysis (EA), and written responses to comments received on the Revised Draft EA will be presented to the Board for consideration for approval in early 2017.

SB 1383 requires ARB to begin implementing the SLCP Strategy by January 1, 2018, as well as specifies timeframes for other requirements (see Table 23).

Table 23: Timeline for SB 1383 Mandates

Action	**Deadline**
ARB approves SLCP Strategy and begins Implementation Expected approval date Statutory deadline	 First Quarter 2017 By January 1, 2018
ARB, CDFA, State Water Resources Control Board and Regional Water Quality Control Boards in coordination with the energy agencies, will work with the dairy industry to establish a dairy workgroup to identify and address barriers to the collection and utilization of biomethane.	First Quarter 2017
ARB, in consultation with CPUC and CEC, develops policies to encourage development of infrastructure and biomethane projects at dairy and livestock operations	By January 1, 2018
ARB develops a pilot financial mechanism to reduce LCFS credit value uncertainty from dairy-related projects and makes recommendations to the Legislature to expand the mechanism to other biogas sources	By January 1, 2018
ARB provides guidance on the impact of regulations on LCFS credits and compliance offsets	By January 1, 2018
CPUC, in consultation with ARB and CDFA, directs utilities to develop at least 5 dairy biomethane pipeline injection projects	By January 1, 2018
CEC develops recommendations for the development and use of renewable gas as part of its 2017 Integrated Energy Policy Report	By early 2018
PUC renewable gas policies based on CEC IEPR	Ongoing
ARB, in consultation with CDFA, evaluates the feasibility of enteric fermentation methane reduction incentives and regulations and develops regulations as appropriate	Ongoing
ARB, in consultation with CDFA, analyzes and reports on the methane reduction progress of the dairy and livestock sector	By July 1, 2020
CalRecycle, in consultation with ARB, evaluates progress towards meeting the 2020 and 2025 organics waste reduction goals, the status of organics markets and barriers, and recommendations for additional incentives	By July 1, 2020

Action	Deadline
CalRecycle adopts an organics disposal reduction regulation	2018
CalRecycle implements an organics disposal reduction regulation	On or after January 1, 2022
ARB begins developing and considers for adoption a manure management methane reduction regulation	Before January 1, 2024
ARB implements a manure management methane reduction regulation	On or after January 1, 2024

All regulatory measures developed pursuant to this SLCP Strategy 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 SLCP 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. Staff will track the progress of implementation of the SLCP measures and provide periodic updates to the Board. This information, as well as updates to the SLCP emission inventory, will be posted to ARB's SLCP website. Effectively implementing this SLCP 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.