Appendix B: Research Related to Mitigation Measures

Research Related to Mitigation Measures

A. Black Carbon

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

1. Current Research

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

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

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

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

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

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

2. Future Research

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

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

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

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

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

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

B. Methane

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

1. Current Research

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

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

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

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

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

2. Future Research

Dairies and Livestock

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

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

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

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

availability of information for potential markets for organic wastes co-digested with manure on dairy farms, potential markets for materials other than biofuels and electricity, and costs and performance associated with other opportunities to reduce manure methane emissions, including solids separation and conversion to pasture-based operation, scrape management systems, or other dry manure management systems.

Oil and Gas

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

The Western States Petroleum Association undertook a study to collect more emissions data from well recirculation tanks. ARB also will be releasing an RFP this year to collect more emissions data from well stimulation operations in general, including well recirculation tanks.

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

Wastewater Treatment

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

Waste Management

Policy and economic analyses should explore potential mechanisms that could increase the diversion of organic waste from landfills, and use compost in innovative ways to support the development of healthy soils. Ideally, this research should be regionally

focused to address the logistical challenges and potential co-digestion opportunities that exist in different areas of the State.

C. F-Gases

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

Current research overseen by ARB includes a study to determine the reductions, technical feasibility, and cost-effectiveness of low-GWP commercial refrigeration, with particular attention paid to the feasibility of low-GWP in high-ambient temperature climates. Results are expected in 2016.

Alternatives to sulfuryl fluoride as a drywood termite fumigant have been the subject of several research projects.[1,2,3] Additionally, thousands of structures in the past twenty years have been treated for termites without using sulfuryl fluoride (or methyl bromide). Each treated structure could be considered its own real-world case study, although not necessarily subject to rigorous research controls. The peer-reviewed research studies indicate that sulfuryl fluoride fumigation is more effective than alternative means of termite eradication. However, many termite control companies refute these findings and report that orange oil or non-chemical treatments can be as effective as the use of sulfuryl fluoride.

The state of Florida Department of Agriculture and Consumer Services issued a guide for residential homeowners on termite treatment, which in part states:

> Alternative methods [to sulfuryl fluoride] now being performed by licensed pest control companies include: the electric gun, freezing with liquid nitrogen, heating, and chemical drill and injection control with termiticides

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[1] Simulated Field Evaluation of Six Techniques for Controlling the Drywood Termite Incisitermes minor (Isoptera: Kalotermitidae) in Residences, Vernard R. Lewis (UC Berkeley), and Michael I. Haverty (Forest Service, U.S. Dept. of Agriculture). Study conducted for the Structural Pest Control Board of California, 1996. Available at www.pestboard.ca.gov/howdoi/research/1996.pdf.

[2] Field Evaluations of Localized Treatments for Control of Drywood Termite Infestations in California, Final Report 2009 for the Structural Pest Control Board, Structural Pest Control Research Contract No. 084-4261-7. Vernard Lewis, Sara Moore, Robin Tabuchi, and Gail Getty of University of California, Berkeley. Available at: pestboard.ca.gov/howdoi/research/2009_field_rpt.pdf.

[3] Laboratory Evaluation of Efficacy of Orange Oil (XT-2000) for Control of Drywood Termites in Naturally-Infested Boards, Technical Release 2009, by Vernard Lewis for Dow AgroSciences. Available at: http://www.dowagro.com/vikane/images/pdfs/010-71269.pdf.

> and wood preservatives. All alternative methods have advantages and limitations which each pest control company should be willing to discuss with consumers.
>
> Consumers should be aware that these alternative treatments are considered spot treatments since the entire structure is not treated regardless of the warranty terms offered.
>
> This is not to imply that these alternative methods may be ineffective, but only to alert the consumer that these treatments cannot assure a complete treatment of all wood-destroying organisms infesting the wood within the entire structure. [4]

The University of California at Riverside Department of Entomology in July 2009 reviewed sulfuryl fluoride structural fumigation and concluded "No alternative treatments have been identified to date that have the same consistency, completeness, and degree of efficacy as sulfuryl fluoride fumigation for pest elimination."[5]

At the present time, it appears that total fumigation of structures is necessary in many cases for termite control, with sulfuryl fluoride proven as an effective fumigant. Similarly, insect treatment of dried fruit and nuts is often accomplished using sulfuryl fluoride, with lower-GWP alternatives such as phosphine being used less than previously due to insect resistance.[6] It should be noted that sulfuryl fluoride is not registered for use as a field soil fumigant and is not used on agricultural fields.

ARB will continue to work with the Department of Pesticide Regulation to assess alternatives to sulfuryl fluoride.

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[4] Florida Department of Agriculture and Consumer Services. "Alternative Methods of Treatment for Drywood Termites - A Guide for Residential Homeowners". Bureau of Inspection and Incident Response, Revised July 2014.

[5] Drywood Termites - Integrated Pest Management In and Around the Home, Pest Notes Publication 7740, August 2014. University of California, Agriculture and Natural Resources, Statewide Integrated Waste Management Program. Available at: http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7440.html

[6] 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.