# Research in Review

Issue 3: 2015 - 2016

## August 2016

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## Upcoming Seminars

**8/25/2016**

**Source Speciation of Central Valley GHG Emissions**

Allen Goldstein, Ph.D.
UC Berkeley

**9/1/2016**

**Probing the Intrinsic Ability of Particles to Generate Reactive Oxygen Species**

Suzanne Paulson, Ph.D.
UC Los Angeles

Check out these and upcoming Research Seminars on our webpage at *arb.ca.gov/research/seminars/seminars.htm*

## For More Information


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We are pleased to present the third issue of *Research in Review*, a newsletter that will keep you informed about the Air Resources Board's (ARB's) recently completed research projects. The past year's completed research projects cover a range of topics from agricultural emissions, smart growth strategies, atmospheric modeling, and more.

Each issue of Research in Review presents a brief description of completed projects and results along with the ARB Contract Number that you can use to look up the full project description. Learn more about these projects including their final reports, public seminars, articles in scientific journals, and other products by visiting *www.arb.ca.gov/research*.

# Project Showcase

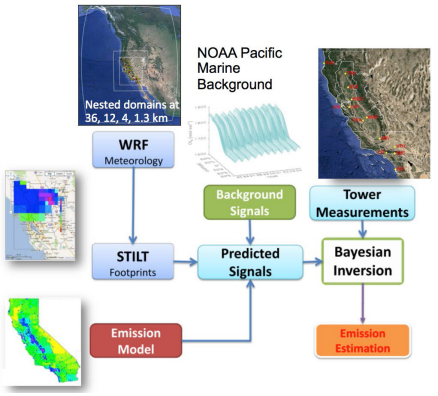
### Reducing In-Home Exposure to Air Pollution by Filtration

The California Title 24 Energy Code requires mechanical ventilation in new homes, primarily to reduce air pollution generated indoors. Reducing outdoor air pollution entering homes is also important, particularly for homes in areas that exceed ambient air quality standards and those near large emissions sources such as high volume roadways. This project assessed eight different combinations of ventilation and air filtration systems in a test house located near Interstate 80 in Sacramento for their effectiveness in reducing indoor pollutant levels and their energy use. Focusing on PM2.5, ultrafine particles, and black carbon, investigators found substantial benefits of high efficiency filtration, with a range of energy costs. Use of a high efficiency filter [Minimum Efficiency Reporting Value (MERV) 16] on a supply ventilation system showed the greatest reduction in indoor concentrations of outdoor-origin particles (97-98% reduction), with low energy costs. High efficiency filtration on the central forced air system was similarly effective but with higher energy use; however, a variable power central system motor would lower the energy cost. The results provide crucial information that can be used to improve California's building ventilation codes and therefore reduce indoor exposures to air pollution.
*ARB Contract 11-311*

# Greenhouse Gas Emissions

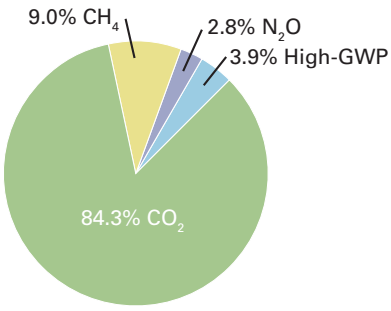
## Improving Greenhouse Gas Emission Estimates with Atmospheric Measurement and Inverse Modeling

Accurate accounting of greenhouse gas (GHG) emissions is necessary to track GHG emission trends and assess progress towards achieving Assembly Bill 32 emission reduction goals. This project produced top-down estimates of GHG emissions, including fossil fuel $CO_2$, methane ($CH_4$) and nitrous oxide ($N_2O$) in California, based on atmospheric measurements from networks of towers, and inverse modeling using the Weather Research and Forecasting and Stochastic Time-Inverted Lagrangian Transport (WRF-STILT) model. The analysis indicates annual emission estimates for $CH_4$ were 1.0-1.6 times higher and $N_2O$ estimates were 1.3-2.3 times higher than the current ARB inventory for each. The top-down estimate for fossil fuel $CO_2$ was within 10% of the statewide inventory. Combined with other studies, results of this analysis suggest that the livestock sector is the major contributor to statewide $CH_4$ emissions, while agricultural activities are likely a significant source of anthropogenic $N_2O$ emissions in California, in agreement with the ARB GHG inventory. *ARB Contract 11-306*




## Greenhouse Gas Emissions Measurements in Central Valley

California's statewide greenhouse gas emissions inventory specifies how much of a greenhouse gas is produced by any single emissions source; for example, how much methane dairies produce. California has many regions with different economic, climate, agriculture, and industry profiles, and as a result, emissions are unique to each region. Measurements in the Central Valley tested differences between regional greenhouse gas emissions compared to the statewide inventory, and whether such differences are detectable through seasonal measurements. Using advanced measurement instruments over an entire year at the Walnut Grove Tower, researchers found dairy and livestock emissions are the largest regional source of methane while contributions from motor vehicles and oil/gas extraction was not as significant, likely because of the rural location. Moreover, agricultural emissions while strong in warm seasons, declined precipitously in cooler seasons. The results indicate multi-month measurements help validate the greenhouse gas emissions inventory, and regional emission inventories are likely to add refinement and specificity to statewide inventories. *ARB Contract 11-315*




2014 TOTAL CA EMISSIONS

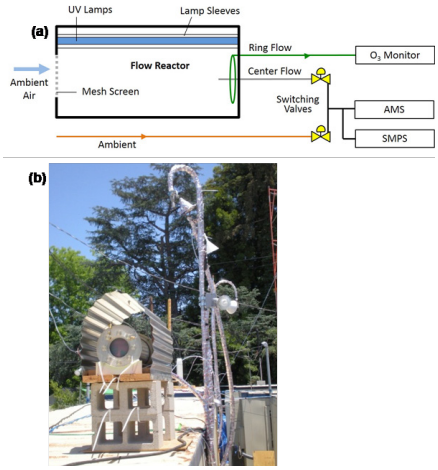
441.5 $MMTCO_2e$

## F-gas Emissions from Landfills Lower than Expected

Insulating foam from disposed appliances and demolished buildings ends up in landfills, where it emits fluorinated gases (F-gases), high-global warming potential greenhouse gases (GHGs) and ozone-depleting substances (ODS). Because previous research estimated that up to half of annual foam-related F-gas emissions in California came from landfills, data were needed to set standards for regulating end-of-life management of foam waste. This project fills data gaps in emission inventories by measuring GHG emissions, including F-gases, at landfill surfaces under various cover types, ages of waste, as well as before and after flare combustion. The study found that F-gas emissions represented only four percent of all GHG emissions from the landfill, with methane and $CO_2$ contributing the balance. In addition, the efficiency of landfill gas flare destruction was greater than 99 percent for all F-gases. The results indicate F-gas emissions from landfills are significantly lower than previously estimated. These results, combined with new federal regulations prohibiting the use of high global warming F-gases in insulating foam applications, suggest that new regulations to manage landfilled foam waste are not needed in California. *ARB Contract 11-308*

# Atmospheric Monitoring & Modeling

## Modeling Secondary Organic Aerosol




Organic aerosols can be directly emitted (primary organic aerosols or POA) or formed in the atmosphere by the oxidation of organic compounds (secondary organic aerosols or SOA). Secondary organic aerosols formed from oxidation of gaseous precursors can constitute a large fraction of the submicron particulate mass and are responsible for significant health and climate effects. Modeling the complex atmospheric reactions that produce SOA, however, is difficult and currently available models are not successful at reproducing real-world measurements. This project improved the modeling of SOA in California by using measurements from the *CalNex 2010 field campaign* to refine current SOA models. Researchers found that reactions of volatile organic compounds (VOCs) alone are insufficient to account for the variability in observed SOA. Including compounds with greater mass, primarily semi-volatile and intermediate volatility organic compounds, improved the model's ability to estimate ambient SOA concentrations. Results from this project will advance regulatory models such as the Community Multiscale Air Quality Improvement (WRF-CMAQ) model; and therefore improve ARB's modeling basis for State Implementation Plan development. *ARB Contract 11-305*

## Comparison of Different Source Locations and Particle Composition for the Generation of Reactive Oxygen Species

Particulate matter (PM) is responsible for a multitude of health effects including asthma hospitalizations and cardiovascular mortality. While the reason for these effects is the subject of ongoing research, it is generally accepted that production of reactive oxygen species (ROS) from PM is a critical first step leading to observed health effects. The goal of this project was to understand the components in particles responsible for ROS formation under physiological conditions. Researchers investigated how particulate matter collected at two locations in California (Claremont and Fresno) differs in composition and in ability to produce ROS when placed in simulated lung fluid. They found that ROS production from PM collected in Claremont was associated with metals, especially copper, iron and manganese. ROS production from PM collected in Fresno was found to be more associated with humic-like substances related to biomass burning. The results indicate dominant roles for selected metals and also biomass burning aerosol in the production of ROS from PM samples in simulated lung fluid. This project furthers the understanding of how ROS are formed from PM as well as the possible chemical components and source types that may be responsible for increased ROS production. Results will inform future health effects research, and will help guide future ARB PM monitoring and control programs. *ARB Contract 10-314*

# Sustainable Communities

## Effects of Complete Streets on Travel Behavior and Exposure to Vehicular Emissions

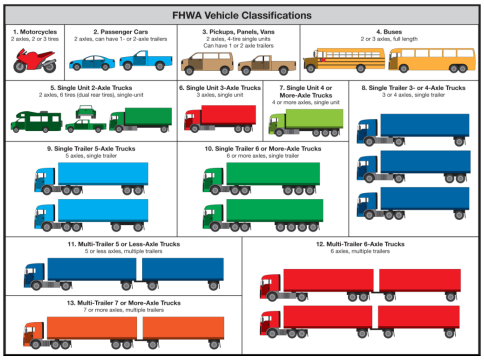

Smart growth projects – as foreseen by California *Senate Bill 375* of 2008 – are expected to reduce greenhouse gas emissions from mobile sources by changing land-use patterns in ways that reduce demand for transportation services. With the growing interest in smart growth, climate change mitigation, and social equity, an increasing number of communities have adopted complete street policies to make streets accessible for all users – drivers, transit riders, pedestrians, bicyclists, seniors, children, and people with disabilities. Complete streets are planned to reduce vehicle miles traveled (VMT) and associated emissions by enhancing active travel and decreasing dependence on passenger vehicles. However, there is limited data on the actual impacts of complete streets. This project provided ARB with an initial analysis of the effects of complete streets on travel behavior and street users' exposure to air pollution by collecting survey data and measuring air pollution before and after complete street conversion and on complete and matching incomplete streets. Although the results are preliminary and site specific, they suggest that complete streets located in densely populated downtown business settings may have more positive impacts than those in other land use contexts. Although more research is needed to investigate the potential of complete streets to change residents' travel behavior, this project found that surrounding road networks and street connectivity and the characteristics of the complete streets are important factors affecting travel behavior. *ARB Contract 11-312*

## Quantifying the Economic Impacts of Smart Growth in California


As more smart growth projects are planned and implemented, per SB 375, quantifying the economic impacts is a growing concern for local land use authorities and developers. For example, high-density "infill" projects are expected to shift development from distant suburbs to urban locations. Implementing such projects is a long, complex, sometimes controversial process requiring cooperation from real estate developers, local residents, regional planners, and local governments. To better understand the economic benefits and costs of smart growth projects for these diverse stakeholders, researchers analyzed five smart growth neighborhood-level plans already implemented in California, estimating their impacts on residential development, commercial development, municipal budgets, and vehicle travel. The smart growth projects generally resulted in increased multifamily housing in central locations with good transit facilities, thus reducing regional housing prices while improving transit accessibility. Property owners in project areas benefited as the market value of their assets appreciated. Construction costs increased as a result of project requirements, but neighborhood amenities, such as pedestrian infrastructure or parks, were enhanced. However, private vehicle travel was reduced less than expected where planners did not also reduce parking availability. Low-income households generally benefitted far less than other households, and smart growth project benefits were generally smaller than planners initially expected, because some of the development envisioned in the plans never materialized. Results suggest that there can indeed be economic and greenhouse gas benefits associated with smart growth, but also indicate that not all demographic groups tend to benefit equally from a particular smart growth policy (e.g., low income households), so policy makers and planners should take this into account when they develop policies and land use plans. *ARB Contract 11-326*

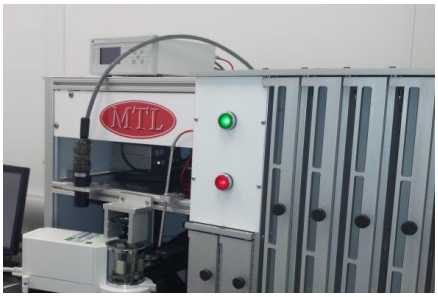
# Mobile Sources

## Development and Deployment of a Truck Activity Monitoring System




In California, on-road trucks are a significant source of criteria and greenhouse gas (GHG) emissions. Estimating the emissions from on-road trucks is complicated by the large number of trucks registered in other states that move goods into and out of California. The existing system for measuring truck activity does not provide enough detail, like truck and haul types, to develop control strategies to mitigate emissions from trucks traveling in California. This information is critical for goods movement studies and freight forecasting models. This project developed a method to provide detailed truck body classification for all on-road truck vehicle types. The method can predict up to 63 body classes with correct classification rates ranging from 75% to 96%. The results can be used to distinguish the proportion of long-haul and short-haul trips in major corridors, by haul type, which provides information on vehicle duty-cycles. This information can improve the heavy-duty vehicle classifications in ARB's Emission Factor (EMFAC) motor vehicle emissions model, and improve predictions of the effectiveness of various emissions control programs. The data from this study will also be used as a key input to the California Vehicle Activity Database (Cal-VAD) which estimates vehicle miles traveled. Ultimately, the results from this project will help develop strategies to reduce emissions from California's trucks for use in the State Implementation Plan, Scoping Plan, Short Lived Climate Pollutant Plan, and Sustainable Freight Action Plan.
*ARB Contract 11-316*

## Verification of Accurate Low-level PM Measurements for Light-Duty Vehicles




In 2012, ARB adopted stringent new particulate matter (PM) certification emissions standards as part of the *advanced clean car (ACC)* regulations. Auto makers, however, expressed concerns about making repeatable PM measurements at these very low emissions levels. To address these issues, this project investigated the feasibility of using current PM sampling and measurement methods, as well as several potential improvements to the sampling method, to accurately quantify PM from low emission test vehicles. The results demonstrate that repeatable PM measurements can be made at very low levels, and that several modifications to the test procedures can improve PM emissions measurements. These results will be used to support implementation of the ACC PM standards. *ARB Contract 12-320*

# Agricultural Emissions

## Dairy Silage Emissions and Mitigation

Dairy silage, or dairy cow feed, has been identified as a significant source of volatile organic compounds (VOCs) and probably nitrogen oxides ($NO_x$), both of which are ozone precursors, and thus may contribute to the ozone nonattainment of the San Joaquin Valley where 80% of California's 1,700 dairy farms are located. This project quantified VOC emissions from silage management at California dairies and identified mitigation opportunities. Researchers monitored and modeled VOC emissions throughout different phases of silage management. The results indicate that most VOC emissions happen in feed lanes where feed materials are spread rather than from the storage piles. Therefore, mitigation efforts should focus on reducing emissions during feeding activities, not the exposed face of silage piles. The results of this study have been shared with the San Joaquin Valley Air Pollution Control District to assist their mitigation measures and prescribed control strategies. *ARB Contract 11-325*

## Alternative Management Practices to Effectively Mitigate Nitrous Oxide Emissions from Agricultural Soils

Agricultural soils are a major source of the greenhouse gas nitrous oxide ($N_2O$) in California, contributing over 53% of the State's $N_2O$ inventory. Production of $N_2O$ in soil is mainly a microbial process involving nitrification and denitrification which can be affected by environmental factors including soil management practices. This project evaluated four alternative management practices that may reduce $N_2O$ emissions from tomatoes, corn, and lettuce cropping systems: 1) different nitrogen (N) fertilizer types and placements; 2) use of nitrification inhibitors (NIs); 3) subsurface drip irrigation (SDI); and 4) organic management. Overall, the use of NIs, SDI instead of furrow irrigation, and incorporation of N fertilizer into two rather than one band most consistently reduced $N_2O$ emissions. Ammonium N fertilizer produced more $N_2O$ than nitrate N, indicating that nitrification contributed more $N_2O$ than denitrification in the systems tested. The results of this study provided experimental evidence of the effectiveness of alternative soil management practices for mitigating $N_2O$ emissions from California cropping systems. More analyses, however, would be required to assess the economic and other environmental impacts of the management options. *ARB Contract 11-313*

## About the Air Resources Board's Research Program

California's progress on addressing environmental problems is guided by a strong scientific knowledge base. The Air Resources Board sponsors a comprehensive program of research into the causes, effects, and solutions of the air pollution problem, supporting its regulations on cars, trucks, fuels, power plants, and other sources. The research is done under the guidance of ARB's Research Screening Committee and in partnership with the University of California system and other research institutions.