

California's Greenhouse Gas Measurement and Monitoring Program

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California's Air Pollution Problem

40 M people
90 people per km²
24 M gasoline cars
1.3 M diesel vehicles
1.4 B km per day
18 M off-road engines
3 large container ports



Geography and meteorology confine air pollutants, so necessary per capita pollution reduction much greater than Atlanta, Houston, New York City, etc.

Despite progress, over 90% of Californians breathe unhealthy air



California's Climate Goals





California's Climate Legislation

- Senate Bill 350 (2015)
 - 50% renewable energy by 2030
 - Double energy efficiency
- Senate Bill 1383 (2016) Requires reductions in SLCPs
 40% reduction from 2013 levels by 2030 for CH₄ and HFCs
 - $\,\circ\,$ 50% reduction from 2013 levels by 2030 for BC
- Assembly Bill 197 (2016)
 - GHG, criteria and toxic emissions to be posted annually, including locations
- Assembly Bill 398 (2017)
 - Extends State's cap and trade program thru 2030
- Assembly Bill 617 (2017)
 - o Identification of communities with disproportionate pollution burden
 - Monitoring and mitigation
- Senate Bill 100 (2018)
 - 100% carbon-free electricity by 2045
- Executive Order B-55-18
 - Carbon Neutrality by 2045



Fifty years ago, a broad cealificant of california leaders united with a common goal, taking action on the severe air pollution that impacted health across our site. The result was the setablishment of the California Air Resources Board and its pioneering actions to address air pollution. With the passage of AB 07, signed by Covernor Brown in July, the Board settred its net half-century committed to ensuring that all California residents, especially those in communities most impacted by air pollution, can breathe clean and behavior and the setter of the se



Progress to Date – Meeting Goals and Decoupling



GHG Emissions GHG Emissions per Capita

GHG Emissions per GDP



418.1 Million Tonnes CO2e

10.5 Tonnes CO₂e per Capita 150 Tonnes CO₂e per Million \$

Measurement Based Climate Research Program Goals

Improve understanding of emissions

- \circ Inform inventories
- Capture spatial and temporal emissions
- Identify high-emitters
- Provide California-specific emission factors
- Study unknown or under-represented sources
- Find opportunities for emission reductions











California Tiered GHG Measurement Program

CO₂, CH₄, N₂O, F-gases, Black Carbon

NASA, NOAA, ARPA-E, EPA, NIST, JPL, LBNL, LLNL, Caltech, Scripps, SATELLITE UCs, CEC, CalRecycle, DOGGR, CDFA AERIAL GROUND LEVEL FIELD STUDIES



COORDINATION

Mt. Wilson Observatory Station Los Angeles County





Super site in Los Angeles



Ideal for tracking long-term trends in urban emissions



Mt Wilson – Methane Source Apportionment





Super site in Los Angeles

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Additional research improved models and inventory



Reference: Gallagher, et al. (2014) Environmental Science & Technology, pp. 1084-1093

- Results from national EPA-based method differed significantly from 2007 Mt. Wilson measurements
- New California-specific emissions inventory is consistent with 2007 Mt. Wilson measurements

Individual Point Source Characterization







Facility Name	Latitude	Longitude 🚽	Air Basin 🗸	Sector	Facility Type 🚽	Date 🗸	CH4 Emission (kg/hr) 🛫	Uncertainty (kg/hr) 📿	Data Status 💡
Zero Waste + San Jose Wastewater + Zanker Landfill	37.4313	-121.9478	San Francisco Bay	Waste Management	Wastewater Treatment	10/05/2017	630.5	139.8	Final
Newby Island Landfill	37.4585	-121.9413	San Francisco Bay	Waste Management	Landfill	10/05/2017	2075.4	586.7	Final
Altamont Landfill	37.7539	-121.6517	San Francisco Bay	Waste Management	Landfill	10/06/2017	2976.8	653.2	Final
Keller Canyon Landfill	38.0039	-121.9365	San Francisco Bay	Waste Management	Landfill	10/06/2017	639.6	208.8	Final
Potrero Hills Landfill	38.2134	-121.9819	San Francisco Bay	Waste Management	Landfill	10/06/2017	2292.2	385.0	Final
Toland Landfill	34.4015	-118.9907	South Central Coast	Waste Management	Landfill	10/16/2017	3200.3	767.2	Final
Sunshine Canyon Landfill	34.3273	-118.5149	South Coast	Waste Management	Landfill	10/16/2017	1434.6	282.8	Final
Chiquita Canyon Landfill	34.4295	-118.6466	South Coast	Waste Management	Landfill	10/17/2017	2153.3	679.2	Final
Simi Valley Landfill	34.2945	-118.7954	South Central Coast	Waste Management	Landfill	10/17/2017	489.4	88.0	Final
Scholl Canyon Landfill	34.1560	-118.1937	South Coast	Waste Management	Landfill	11/09/2017	70.7	15.5	Final
Olinda Alpha Landfill	33.9416	-117.8331	South Coast	Waste Management	Landfill	11/09/2017	1698.6	327.8	Final
BKK West Covina Landfill	34.0364	-117.8995	South Coast	Waste Management	Landfill	11/09/2017	93.0	9.9	Final
Puente Hills Landfill	34.0161	-118.0146	South Coast	Waste Management	Landfill	11/09/2017	360.9	55.3	Final
Foothill Landfill	38.0378	-120.9372	San Joaquin Valley	Waste Management	Landfill	11/18/2017	680.1	146.0	Final
Outrour Bread Lond Bill	20.0724	434 3035	C	14/	1 1.6:11	44/40/2047	504.3	247.0	et a st



Area Source Characterization

Flux Towers

- Landfills
- Dairies







California GHG Monitoring Network

- Network started in 2010
- Current network
 - 7 CARB-managed stations (more coming)
 - Additional collaborated sites
- Measurements
 - \odot Picarro CH₄, CO₂, H₂O
 - \circ LGR N₂O, CO, H₂O
 - BC, F-gases, VOC (Mt. Wilson)
 - PBLH/wind profilers (red circles)
 - Adding real-time GC/MS at selected sites
- CARB data available to research community
 - o <u>https://www.arb.ca.gov/aqmis2/res/aqdselect.php</u>





CARB Inverse Modeling Program





Top down approximately 30-50% > Bottom up in California

Top down inventory comparisons

- Based on geography of emissions ——
- Working on adding VOC observations
- Initiated research to characterize methane emissions at dairies and develop California specific manure management and enteric fermentation emission factors and to develop mitigation options

Next Steps:

Need source apportionment study in the SJV Better understanding of landfill emissions





Using Remote Sensing to find Methane Leaks

Joint CEC – CARB – NASA/JPL Study





Survey area selected to capture majority of methane point sources in California



Figure 3-6. AVIRIS-NG flight boxes for Fall 2016 campaign surveying the energy sector (red), non-energy sector (yellow), and mixture of these categories (orange).





AVIRIS-next gen (2012)



VSWIR-Dyson (2017)



Airborne Visible/Infrared Imaging Spectrometer

Leveraging 30+ years of NASA investments and New Aerospace Paradigm

• Over \$100M in instrument technology, data analysis/algorithms, airborne campaigns

m-mdd)

enhance.

CH



• Tank leaking methane in Kern oil field

- Very high spatial resolution
- Quick data turnaround
- Does not detect diffuse areas sources

Which Sources Emit Highly Concentrated Plumes?



Airborne Surveys Conducted in California

Simulating Satellite Data Using the same instrument on airplanes – allows for pilot studies

Three airborne campaigns that have moved us from research to program dry-run (voluntary)

Research

2016-2017 – California Methane Survey

- Surveyed 272,000 facilities and component, 10% of CA Landmass with multiple revisits.
- A significant fraction of our emissions occur as individual plumes in all sectors

2020 – Evaluation of Mitigation Potential

- Worked with industry prior to 'enroll' their infrastructure.
- More than 60% of found plumes could be mitigated
- Industry voluntarily provided feedback on what was leaking and why

2021 – First Program Dry Run

- Let industry know we were flying but did not 'enroll' volunteers.
- Used internal databases to identify owners of infrastructure with plumes
- Worked closely with regulatory and enforcement staff, local air districts for communication and other actions



Program



Sector:
Emissions:
Mitigated:
Response:

Oil and Gas 97 kgCH4/hr Yes Tank Valve

001_GAO20201109t182655p0000-3



Sector:
Emissions:
Mitigated:
Response:

Utilities 190 kgCH4/hr Yes Solenoid valve on NG compressor

030_GAO20201119t182156p0000-1



Sector:	Waste
Emissions:	1,445 kgCH4/hr
Mitigated:	Yes
Response:	GCCS/Construction

033_GAO20201115t183718p0000-A



Sector: Emissions: Mitigated: Response: Waste 258 kgCH4/hr Yes Crack in cover near pipe connections

061_GAO20201115t201750p0000-A



Examples of Operator Replies



Operator searched area with a FLIR camera and TVA. >50k ppm detected. Source identified as a broken manway hatch on a permitted crude oil storage tank. The manway hatch was re-serviced





After Repair:





Ideal Observational Platform

moving from observation to mitigation – launch in 2023





Ideal Observational Platform

moving from observation to mitigation – launch in 2023

Satellite



Data Center



Data

Pipeline

Results



Lat/Long, rough image Spatial resolution ~30m Results available in 24 hours

> Program Follow up, boots on the ground, mitigation





380 385 390 395 400 405 410

CALIFORNIA AIR RESOURCES BOARI **Developing Sustained Observations** *The Carbon Mapper Consortium*

- Two satellites will be launched in 2023.
- Approximately 8 additional satellites will be launched ~ 2025.
 - All methane data to become public
- Polar Orbit worldwide data
 - Most methane sources that emit highly concentrated plumes can be observed every two weeks



Next Steps

- California will actively incorporate this data in our programs
 - Working on targeting
 - Public portal
 - Plume ticketing system
- Want to work with other jurisdictions to:
 - Expand the use of the data
 - Achieve more mitigation
 - Expand learning (what works, what doesn't, what causes the leaks, develop best practices, etc)
- Need to understand the extent to which these emissions are or are not already accounted for in the inventory

For more information visit: https://ww2.arb.ca.gov/our-work/programs/california-satellite-partnership

Modeling Mitigation Potential

Potential Methane Mitigation



Methane Source Finder







CO₂, CH₄, N₂O, F-gases, Black Carbon



Thank you

QUESTIONS?