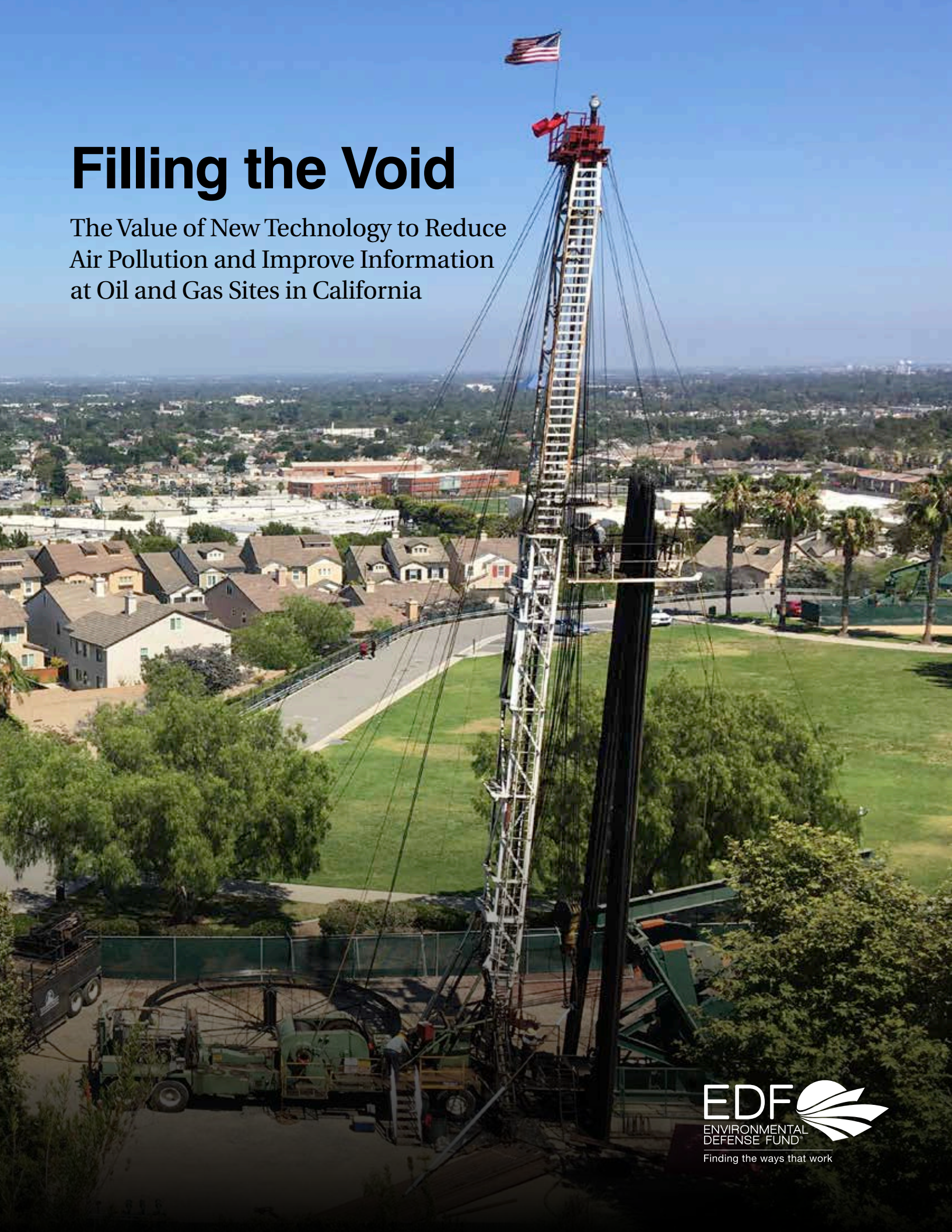
Filling the Void

The Value of New Technology to Reduce Air Pollution and Improve Information at Oil and Gas Sites in California



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Cover photo: Oil production operation near Signal Hill, CA. (EDF photo)

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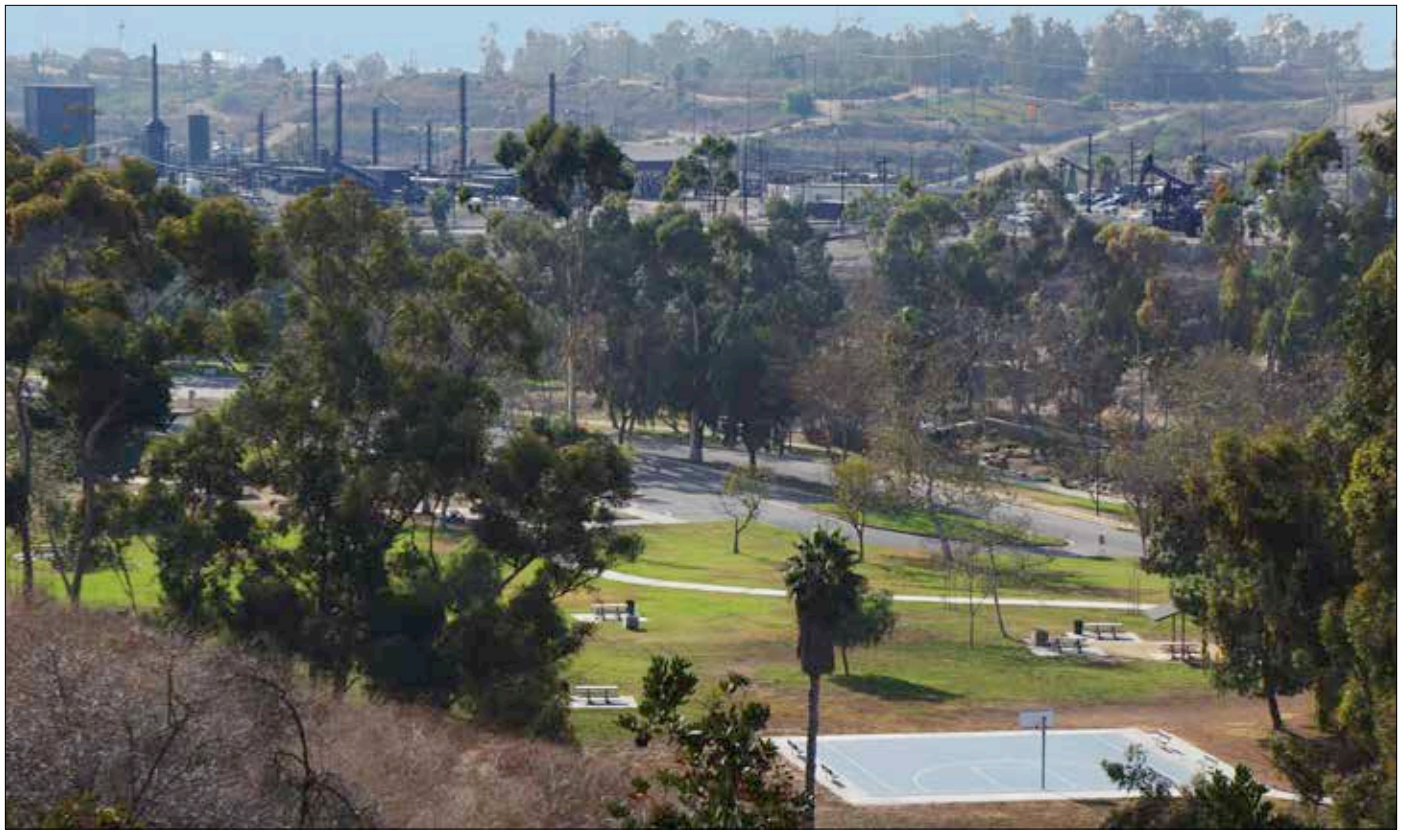

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Inglewood oil field production operation adjacent to the Kenneth Hahn State Recreation Area, Los Angeles, CA.

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Acronyms and abbreviations

BAAQMD Bay Area Air Quality Management District

BTEX The class of compounds that includes benzene, toluene, ethylbenzene and xylene

CalEPA California Environmental Protection Agency

CAPCOA California Air Pollution Control Officers Association

CARB California Air Resources Board

CCST California Council on Science and Technology

CEC California Energy Commission

CPUC California Public Utilities Commission

DOGGR Division of Oil, Gas, and Geothermal Resources

EDF Environmental Defense Fund

EPCRA Emergency Planning and Community Right-to-Know Act

GHG Greenhouse gas

HAP Hazardous air pollutant

MBARD Monterey Bay Air Resources District

NASA National Aeronautics and Space Administration

NMOC Non-methane organic compound

OEHHA California Office of Environmental Health Hazard Assessment

OSHA Occupational Safety and Health Administration

PM Particulate matter

PG&E Pacific Gas and Electric

ROG Reactive organic gas

SBCAPCD Santa Barbara County Air Pollution Control District

SCAQMD South Coast Air Quality Management District

SoCalGas Southern California Gas Company

SJVAPCD San Joaquin Valley Air Pollution Control District

TAC Toxic air contaminant

TRI Toxic Release Inventory

U.S. EPA United States Environmental Protection Agency

VCAPCD Ventura County Air Pollution Control District

VOC Volatile organic compound

Overview

California is the third largest oil producing state in the United States, producing slightly more than oil-rich Alaska. Some of the nation's highest-producing oil and gas fields rest in California's Central Valley region, while the nation's largest urban oil field sits underneath California's largest metropolis: Los Angeles. As a result of over 100 years of oil and gas development, almost one million Californians—many of whom are from underserved and already environmentally burdened communities—live within a half-mile of an oil and gas facility. Tens of thousands of Californians live much closer -some immediately adjacent to active operating equipment.

Very few regulations currently require pollution monitoring at any of California's approximately 54,000 operating oil and gas production wells. Consequently, monitoring is rarely performed.

Public health studies examining the impact of oil and gas operations on nearby communities have demonstrated a link between site-level emissions and an increasing number of public health concerns. However, even though California has a long history of air quality monitoring, real-time data on oil and gas site emissions—data that would potentially drive reductions in pollution—remains practically non-existent.

Very few regulations currently require pollution monitoring at California's approximately 54,000 operating oil and gas production wells.

While high costs have historically hindered widespread deployments of pollution monitoring technology, recent efforts and technological breakthroughs have increased the affordability and reliability of monitors to the point that continuous, real-time monitoring can more readily be deployed. As the monitoring field rapidly advances, further price declines will allow more extensive use. As facility operators, the government and communities make increasing use of monitoring technology, reductions in human exposure risk, improved management of the state's valuable mineral resources and improved health of populations near points of emissions are likely to follow.

This report recommends the implementation of new, robust monitoring standards and deployments at, and near, oil and gas facilities, coupled with public health and community engagement policies that focus on data collection, transparency, and analysis—all made possible by advancements in real-time monitoring technology. Implementing these recommendations can generate data with important geographic and temporal resolution and aid in conducting health-risk and exposure assessments, which can improve regulatory decision making. Importantly, these monitoring recommendations are not a replacement for policies that establish appropriate buffer distances between industrial operations and people living in close proximity, but they can provide data to substantiate the efficacy of, and improve, the science on buffer distances. These recommendations fit into emerging efforts brought about by recent state legislation to better monitor oil and gas sites located in close proximity to California families.

CHAPTER 1

Extended summary

1.1 California oil production and its proximity to people

California is the third-largest oil producing state in the country, with about 53,700 actively producing onshore and offshore oil and gas wells. Its most productive regions are the southern Central Valley and greater Los Angeles area, though coastal regions between Monterey and Santa Barbara, as well as the northern parts of the Central Valley, are also very active. Although extraction, processing and transport of oil and gas can entail high costs for companies, the economic value of the state's crude oil production, even at modern prices, is approximately $9.3 billion dollars per year, and the value of natural gas is $450 million per year.

According to the nationally reputable DrillingInfo database, in Los Angeles County alone, there are 3,511 oil and gas wells in active production, while in Kern County, there are 42,318. Across the state, these wells tap into hundreds of underground deposits, such as the Inglewood Oil Field in the Los Angeles region (the largest urban oil field in the nation) the Midway-Sunset Field in the Central Valley (California's most productive oil field), and the Rio Vista Gas Field in the Sacramento Valley. While production centers at these sites typically use traditional pumping equipment like derricks or rigs, they also often contain processing and handling equipment like tanks, compressors, heaters and dehydrators, piping and other pieces of machinery. Each of these pieces of equipment is integral to the production business, and many contain sources of emissions of methane, volatile organic compounds (VOCs) and other pollutants that can impact the public health and environment if they are not maintained to strict quality standards.

▶ ***Chapter 2 discusses in depth California's oil and gas history.***

1.2 Oil and gas operations pose a threat to public and environmental health

While oil and gas operations yield valuable energy resources, they can also emit harmful pollutants if facilities leak, vent or otherwise release materials into the environment. These pollutants include VOCs and toxic chemicals that can impact the health of local communities and degrade regional air quality, and greenhouse gases (GHGs) such as methane (CH_4) that contribute to global climate change.

Over the past few decades, an increasing number of health concerns have been linked to exposure to oil and gas operation releases, and the distance a person is from those releases has been found, at times, to correlate to degraded health. Emerging research shows that diseases such as asthma, emphysema and even cancer can be associated with a significant exposure to pollutants emitted from oil and gas production, such as VOCs and toxic chemicals like benzene.

Across the state, close to one million people, many of whom are low-income and people of color, live within a half-mile of oil and gas facilities. Scores of Californians are even closer: In certain areas, houses, businesses and public recreational facilities are located less than 100 feet

away from active sites. This proximity creates special risks and concerns that must be addressed to ensure the public health and welfare of all Californians is protected.

In addition to pollution that impacts people directly, oil and gas pollution can also contribute to climate change and the accumulation of ground-level ozone, otherwise known as smog. These conditions can also accompany odors, noises, truck traffic, insect proliferation, water pollution and excess light pollution that occur when sites are not operated up to industry standards or regulations. Together, this cumulative pollution presents a unique and augmented risk of impact to some of California's most underserved communities while also contributing to regional risks that arise because of factors like continued non-attainment with federal air quality standards.

▶***Chapter 3 discusses in depth the types of pollutants and impacts associated with oil and gas pollution as well as the correlation between human proximity to oil and gas infrastructure and exposure risk.***

1.3 New monitoring technology drives pollution reduction

California regulatory agencies, academic institutions and some major emitters have been monitoring pollution for decades. However, most government-controlled monitoring has tended to focus on regional ambient concentrations in order to assess compliance with air quality standards. Furthermore, site monitoring has been conducted or required as part of legal settlements, major environmental release events or to perform research, but those efforts have been limited in duration. This approach has left local communities and agencies without information on real-time pollution discharges from neighborhood sources.

More recently, community-based monitoring and environmental enforcement efforts have gained significant traction, though the large number of sites and pollutants of concern, along with limitations on community resources, make these approaches impractical for measuring and limiting exposure in every community across the state.

Empirical and anecdotal evidence show that the use of emissions monitoring technology coupled with transparent data analysis and visualization of emissions from oil and gas sites can

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Children playing at a house immediately adjacent to an active oil and gas operation in Los Angeles County.

reduce pollutant exposure risk and overall rates of pollution discharge. Use of monitoring technology and the data it provides to facility operators, the government and communities can encourage more efficient and cleaner operations, foster greater transparency between oil and gas companies and their neighbors, and generate the data necessary for government officials to better draft and enforce evidence-based environmental regulations. At their core, pollution monitoring and data analysis empower entities to effectively and transparently communicate the need for tighter operations and regulations while providing public health officials with the data necessary to better evaluate exposures and community risks. It is important to note that continuous monitoring is not a replacement for policies that establish minimum buffer distances between industrial operations and people that live in close proximity; rather, public data can help communities better advocate for policies, such as buffer zones, which can help reduce exposure to pollution and noise disturbances from operations and mitigate their effects on the health of families.

▶ ***Chapter 4 discusses monitoring efforts across the state and evaluates how improvements in monitoring, data analysis and data visualization can yield reductions in pollutant exposure risks.***

1.4 Past monitoring has been insufficient, but the tide is turning

Historically, although there have been many regulations written and adopted to control emissions from oil and gas sites, there have been few, if any, continuous monitoring requirements for production facilities. However, new 2017 requirements that cover California's natural gas storage facilities provide a model for regulatory action and evidence of the coming wave of affordable, accessible technology.

▶ ***Chapter 5 reviews state and local regulations for oil and gas pollution control and the historical insufficiency of monitoring efforts. This chapter also discusses the beginnings of a few model regulatory approaches to monitoring and the industry response to them.***

1.5 Pollution monitoring technology is cheaper and more accessible than ever

Similar to the advancements witnessed in computers and telephones over the last decade, oil and gas pollution monitoring technology has made incredible progress and continues to evolve rapidly. Consequently, although monitoring technology has been available for many years, the increased supply of monitors and data analysis methods, as well as the evolution of new technologies, has expanded the number of sites where these technologies can be deployed cost-effectively. These breakthroughs now make it possible to monitor local, facility-level pollutants at lower costs, granting access to new data that opens up novel solutions to reducing the potential for pollutant exposure. Additionally, new technology and equipment are entering the market regularly, providing a near-continuous stream of solutions to deploy lower-cost and more precise monitors on a regular basis.

▶ ***Chapter 6 discusses the growth of monitoring solutions and opportunity for technology deployment at oil and gas sites. It builds upon a technical report written by Ramboll Environ assessing existing and emerging monitoring technologies.***

1.6 Recommendations for bridging the data divide

This report provides a survey of the impacts of oil and gas pollution on nearby communities and demonstrates the benefits of monitoring technology, data analysis, and data visualization. From

this assessment, it is evident that more monitoring and associated data analysis are needed to reduce and prevent the health, environmental and equity burdens aggravated by oil and gas pollution. Monitoring technology presents a great opportunity to improve public health, facility operations, and company-resident-government relationships.

▶***Chapter 7 details a series of 11 recommendations to help meet the needs of communities and the environment related to monitoring. These recommendations include:***

- *Develop new rules by local Air Pollution Control Districts (APCDs) to incorporate stationary or mobile monitoring at oil and gas production facilities.*
- *Reassess current oil and gas regulations at the state agency level to incorporate real-time stationary or mobile monitoring at oil and gas production facilities.*
- *Develop and distribute resources for communities to launch community-based monitoring, data analysis and data visualization projects centered on oil and gas production facilities.*
- *Recognizing that regulatory enactments take time, state and local agencies should independently deploy government-managed, real-time stationary and mobile monitoring systems at key oil and gas production facilities that operate in close proximity to sensitive receptors and which have been reported to produce impacts on nearby residents, prioritizing communities located within and near the top 25% of the CalEnviroScreen 3.0.*
- *Ensure implementation of new legislation in California (AB 617) includes provisions for real-time stationary and mobile monitoring of oil and gas production operations located in close proximity to underserved communities.*
- *Modify local zoning laws, codes, and land-use permitting practices to incorporate real time monitoring at new and modified oil and gas facilities prior to commencement of operation, while also incorporating real-time monitoring conditions on annual reauthorizations of existing active operations, prioritized by their proximity to people.*
- *Establish findings by city and county planning and public health departments related to the hazards of unmonitored oil and gas production sites located near people.*
- *Increase interagency and community collaboration to develop coordinated systems for monitoring, data analysis and visualization, and sharing of best practices on company, community and regulatory approaches.*
- *Follow Los Angeles County's lead and survey all oil and gas wells in the state of California.*
- *Ensure the South Coast Air Quality Management District (SCAQMD) Air Quality Sensor Performance Evaluation Center supports the development, testing and certification of monitors for pollutants regularly emitted by oil and gas sites.*
- *Engage with oil and gas operators as well as technology providers with real world experience employing advanced monitoring strategies.*

CHAPTER 2

A brief history of oil and gas development in California

Historical accounts indicate that the first travelers to California witnessed natural oil seeps along the gold rush–era routes as early as 1849. Following the discovery of oil in Pennsylvania in 1859, prospectors began immigrating toward the West Coast in increasing numbers, searching for oil and gas deposits that could be extracted and refined. In 1876, California's first commercial oil well was put into production in Pico Canyon, just north of modern Los Angeles. As additional prospectors scoured the land for oil, they made significant discoveries across the region, including in Ventura (1885), Kern County (1890), Los Angeles (1892) and offshore in Santa Barbara (1895). By the early 1900s, oil discoveries occurred regularly across the state, with several major fields in the Central Valley discovered in between 1910 and 1920 and additional major fields in Huntington Beach and Signal Hill/Long Beach discovered in the 1920s.[1]

Due to the natural abundance of California's oil and gas deposits, along with the savvy work of oil-drilling pioneers, the state led the nation in oil production from as early as 1903 and remained on top for several decades. During that time, the large amounts of oil being processed led to a surplus of natural gas availability—natural gas is often generated as a byproduct of the oil extraction and refining process. However, there was no market for that gas in the early 1900s, so much of it was released into the atmosphere. In response to the widespread venting of excess natural gas in the 1920s, the state formed the Division of Oil, Gas, and Geothermal Resources (DOGGR) to limit wasteful practices.[2]

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Oil production near Norwalk, CA, 1946.

U.S. LIBRARY OF CONGRESS

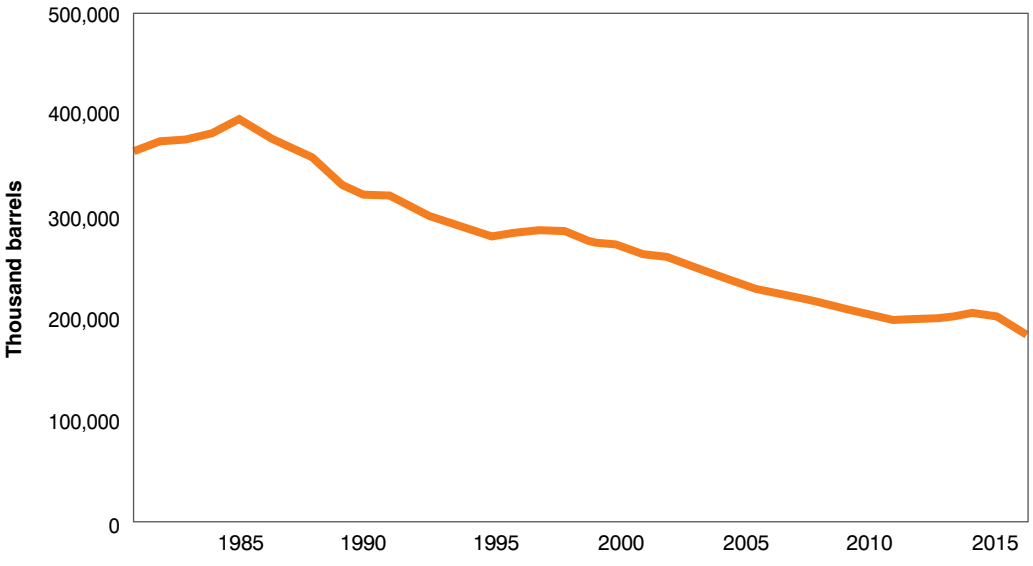
The Arab Oil Embargo prompted the United States to search for domestic production sources, like the Elk Hills Oil Field in California's Central Valley, 1973.

As a result of the Great Depression and the long-term depressed oil prices that followed, the decades of the 1930s and 1940s saw oil and gas production increase at a slower rate than it had in the early years of the state's oil boom. By the 1960s, however, California's oil production was flourishing, and it received another jolt when the federal government opened up the Elk Hills oil field near Bakersfield in 1976 (see photo, above).[3]

In 1985, California's oil production reached an all-time high before beginning a long, slow decline due to factors like low oil prices, declining field productivity, low oil quality and higher production, transport, and refining costs *(see Figure 1)*.With new extraction techniques and technologies, the decline curve of California oil production volumes slowed in 2010 as producers began to implement new additives and steaming methods to extract oil and gas that was previously difficult to reach. Despite its decline, oil and gas production remains a major industry for the state.[4]

FIGURE 1

California field production of crude oil, 1980–2015



Source: U.S. Energy Administration

At present, California's Central Valley produces approximately 80% of the state's oil, with Kern County containing nearly 42,300 active wells, according to DrillingInfo.[5] Meanwhile, Los Angeles contains the nation's largest urban oil field—the Inglewood Oil Field—and has nearly 3,500 wells in active production reported in 2015.[6] California as a whole has nearly 53,700 oil and gas wells in active production and is the nation's third-largest producer by volume.[7,8] Across the state, these wells tap into hundreds of underground fields that span large swaths of the state and fall under the oversight of 14 separate air pollution control districts, the California Air Resources Board (CARB) and six DOGGR districts.[9]

Although extracting oil and gas from underground fields, processing it and transporting it to customers entails high costs for companies, the economic value of the state's crude oil production, even at modern prices, is approximately $9.3 billion dollars per year *(see Table 1)*.

In addition to oil, California companies produce vast amounts of natural gas, both from raw natural gas deposits drawn from the state's approximately 1,130 gas wells and as a byproduct of crude oil production. This gas is valued at over $450 million annually *(see Table 2)*.[10]

Looking forward, some analysts project a rebound in U.S. oil drilling and production in upcoming years. According to World Oil, an oil markets analyst firm, and confirmed by the 2016 California Production Report, the state produced roughly one-fifth the amount of oil in 2016 than it did in 2014. However, due to increases in global oil prices, a rebound in drilling at the state's heavy oil fields is expected. Furthermore, since the vast bulk of California's drilling is conducted by just four firms, as bottom line profits increase, so too will California drilling operations. Overall, World Oil expects the state will see drilling (and associated production) increase by about 30%, to 892 wells in 2018.[11]

TABLE 1

Annual oil production by DOGGR District in 2017

DOGGR District	Oil produced (million bbls) 2016[12]	Value of yearly production at $50/bbl[13]
1 Southern CA including Los Angeles	24.5	$1.225 billion
2 Ventura region	8.9	$445 million
3 Coastal region from Santa Barbara to Santa Cruz	12	$600 million
4 Southern portion of Central Valley	134.1	$6.7 billion
5 Northern portion of Central Valley	7	$350 million
6 Northern California	Negligible	Negligible
Total	**186.5 bbls**	**$9.325 billion**

TABLE 2

Dry natural gas and associated gas production in California in 2016

Amount of net gas produced in 2016 (BCF, or billion standard cubic feet) for all DOGGR districts[14]	Economic value at $2.88 per MCF
157.3	**$456 million**

CHAPTER 3

Oil and gas pollution: risks of health and environmental impacts

"There's concrete evidence that folks who live close to the oil field carry a higher carcinogen burden."

–Dr. Khin Gyi
Neurologist

Oil and gas operations can emit several types of air pollutants that affect the health of families living in downwind communities, the climate and regional air quality. Additionally, sites can emit odors, noises, water pollution and excess light pollution. This cumulative pollution presents a unique and augmented risk of impact to communities living both nearby and throughout the region where operations occur.

3.1 Oil and gas operations can emit pollution and toxics that harm human health

Oil and gas extraction requires various industrial processes that involve the use of materials and gases that are hazardous to human health if they are released. Peer-reviewed studies completed in Colorado, Utah, and Pennsylvania indicate higher than average pollution concentrations near oil and gas production activities.[15,16,17] Similarly, California-based studies have consistently found higher than expected concentrations of pollutants[18] that are likely associated with oil and gas production, while other studies have specifically traced some major emissions sources back to the oil and gas industry *(see Table 3)*.[19,20,21] In addition to the process of pumping oil and gas from the ground, several industrial operations—such as storing and transporting materials; stimulating wells for pumping; and separating and purifying the oil, water and natural gas—can

TABLE 3

Oil and gas activity and pathways for release

Oil and gas operation activity that may result in emissions of air pollution	Pathway for pollutant release
• Oil extraction—pumping and extraction • Oil handling in tanks • Oil handling in pipelines • Oil well drilling and workovers • Well stimulation through hydraulic fracturing and acidization • Oil/water separation • Associated gas removal and compression • Raw/dry gas extraction and handling • Wastewater reinjection and discharge	• Pump seals • Tank hatches • Valves, gauges, pipe fittings, site glasses • Pipe repairs resulting in blowdown • Well venting and purposeful gas discharge • Pressure relief devices • Compressors, seals and vents • Level controllers • Gas regulators • Dehydrator vents
• Steam generation for oil pumping	• Combustion exhaust
• Transport and use of chemicals, injection and drilling materials, and oil/gas	• Truck exhaust • Accidental releases

Source: See citations 19, 20 and 21

TABLE 4

Harmful toxins found in California gas leaks

Type	Oil	Gas	Total
Number of methane leaks sampled (out of 211)	17	74	91
Number of sampled leaks with detectable carcinogens	14 (out of 17)	54 (out of 74)	68 (out of 91)
Percentage of sampled leaks with detectable carcinogens	82%	73%	75%
Carcinogens detected	Benzene, dichloroethane, dichloropropane, ethylbenzene, methylene chloride, TCE, vinyl chloride	Benzene, chloroform, dichloroethane, dichloropropane, ethylbenzene, ethylene dibromide, methyl isobutyl ketone, TCE, vinyl chloride	Benzene, chloroform, dichloroethane, dichloropropane, ethylbenzene, ethylene dibromide, methyl isobutyl ketone, methylene chloride, TCE, vinyl chloride
Number of sampled leaks with detectable developmental toxins	11 (out of 17)	61 (out of 74)	72 (out of 91)
Percentage of sampled leaks with detectable developmental toxins	65%	82%	79%
Developmental toxins detected	2-Hexanone, benzene, ethylene dibromide, TCE, toluene	Benzene, carbon disulfide, ethylene dibromide, methyl isobutyl ketone, TCE, toluene	2-Hexanone, benzene, carbon disulfide, ethylene dibromide, methyl isobutyl ketone, TCE, toluene

Source: Sage Environmental, 2015 Gas Leak Audit

cause the release of contaminants. As equipment used to perform such processes ages and its mechanical integrity diminishes, the ability to operate oil and gas sites in an emission-free manner may be compromised if operators are not investing in sufficient levels of maintenance and oversight. Furthermore, pollutants can be released through venting and accidental discharges, or if operators utilize methods that are designed to let oil and gas emissions escape into the atmosphere.[22]

Researchers studying oil and gas operations and emissions in California have found a wide variety of compounds and concentrations of pollutants in air samples taken from leaking equipment at oil and gas sites.

In a 2015 study conducted by Sage Environmental for California Air Resources Board (CARB), a small subset of oil and gas sources across the state were evaluated for methane and other pollutants, and 211 methane leaks were discovered *(see Table 4)*. A small portion of those leaks was then sampled more extensively. For oil facilities, 82% of sampled leaks contained detectable levels of carcinogens, while 65% contained detectable levels of developmental toxins. For gas facilities, 73% of sampled leaks contained detectable levels of carcinogens, while 82% contained detectable levels of developmental toxins.[23,24]

For the subset of Southern California oil production sites found leaking in the Sage Environmental study for CARB, several methane leaks were also found to contain BTEX compounds (carcinogens and developmental compounds), hexane (a non-methane organic compound emitted alongside other ozone forming compounds) and other toxic air contaminants like trichloroethene (TCE) *(see Table 5 and Figure 2, page 15)*.

In another study conducted by the California Council on Science and Technology (CCST) in 2015, it was found that in San Joaquin Valley the oil and gas sector is responsible for significant percentages (30–70%) of some stationary source toxic air contaminants. In particular, oil and gas makes up more than half of emissions from stationary sources for acetaldehyde, benzene, formaldehyde, hexane (a non-methane organic compound [NMOC]), and hydrogen sulfide.[25]

TABLE 5

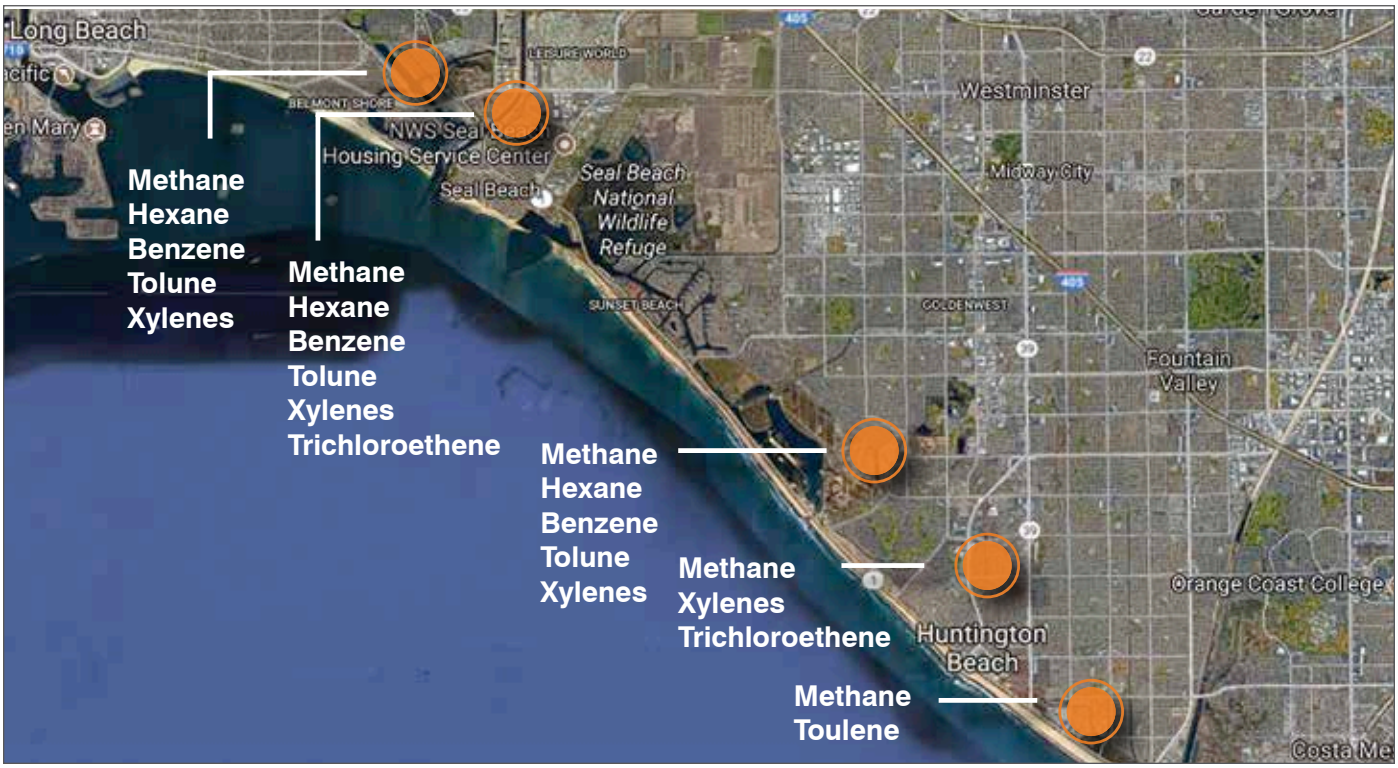
Subset of Southern California oil production site leaks studied in 2015 by Sage Environmental

Equipment description	City and zip code of leak surveyed	Equipment leaking	Subset of pollutants found
Oil handling	Long Beach–90803	Inactive flare pilots	Methane, BTEX, and hexane (NMOC)
Oil production	Long Beach–90803	Gas cap	Methane, BTEX, and hexane (NMOC)
Oil production	Long Beach–90803	Plug valve	Methane, BTEX, and hexane (NMOC)
Oil production	Long Beach–90803	Pipe opening near compressor	Methane, BTEX, and TCE
Oil handling	Huntington Beach–92646	Gas compressor crankcase plug	Methane and BTEX
Oil well with flare	Huntington Beach–92648	Pressure gauge	Methane, BTEX, and hexane (NMOC)
Oil handling	Huntington Beach–92648	Pipe opening near oil well	Methane, BTEX, and TCE

Source: CARB

FIGURE 2

Harmful pollutants detected at select oil and gas sites in Southern California by Sage Environmental



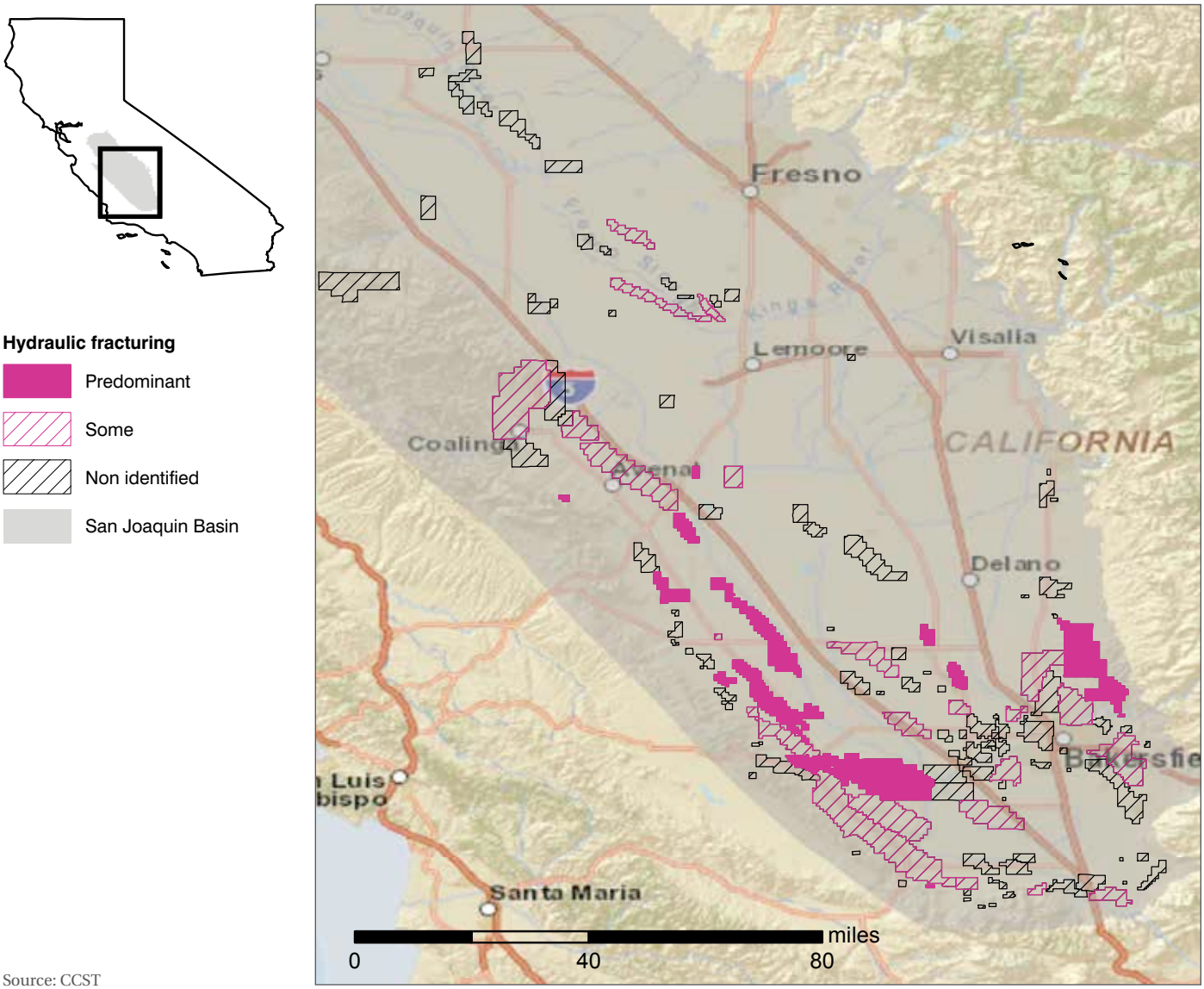
Sources: CARB data overlaid onto Google Maps.

In a separate portion of the same CCST study related to activities involving well stimulation (hydraulic fracturing and acidizing) across the state, nearly 176 of the 320 identified chemicals that are used for well stimulation had known human toxicity values. Furthermore, according to CCST, most well stimulation occurs in reservoirs where oil and gas has been produced for a long time. Thus, according to CCST, communities living on top of fields in Los Angeles and the Central Valley—areas that have been in production for a long time—run a risk of exposure to harmful chemicals, especially if a hydraulic fracture intersects another well (offset well) that can act as a conduit through which emissions can enter the air *(see Figure 3.)*.[26,27] The same study found that well-stimulation activities in areas such as Los Angeles have emitted several known toxic air contaminants (TAC) *(see Table 6, page 17)*.[28]

Although several researchers at CCST have concluded that the total amount of toxic air contaminants emitted from oil and gas operations does not represent a significant portion of the statewide total, they also conclude that the proximity of those emissions to humans, when considered alongside the state's vast transportation and refining infrastructure, is relevant for assessing exposures and developing necessary mitigation measures.[29]

FIGURE 3

Location of hydraulic fracturing operations in the Southern San Joaquin Valley



Source: CCST

TABLE 6

Toxic air contaminants associated with well stimulation activities in the Los Angeles region

TAC species associated in matrix acidizing extracted from South Coast Air Quality Management District dataset

Toxic air contaminant	Average maximum mass injected (kg)	Toxic air contaminant	Average maximum mass injected (kg)
Crystalline silica (quartz)	3546	Isopropoanol	13
Hydrochloric acid	1058	Sulfuric acid ammonium salt (1:2)	7
Phosphonic acid	406	Acrylic polymer	7
Amniotriacetic acid	309	Toluene	4
Xylene	207	1,2,4 trimethylbenzene	2
Hydrofluoric acid	179	Diethylene glycol	1
2-Butoxy ethanol	213	Ethylene glycol	1
Ethylbenzene	63	Naphthalene	1
Methanol	34	Cumene	<1
Thiourea polymer	15		

Source: CCST

TABLE 7

Air pollutants, sources and potential health impacts from oil and gas operations

Air pollutant	Oil and gas source	Health impacts
Benzene	Occurs naturally in oil and gas; leaks during routine operations of natural gas wells, pipelines, compressor stations; also released by diesel-powered equipment.	Leukemia, asthma attacks, lung infections, low birth weight, headaches, vomiting, dizziness.
Diesel emissions	Emitted from generators and trucks associated with oil and gas development. Pumps and compressor stations are often powered by diesel engines.	Asthma attacks, cancer, lung infections, heart disease, premature death.
Formaldehyde	Emitted by compressor stations; created in the atmosphere when oil and gas pollutants, such as benzene, combine with heat and sunlight.	Asthma attacks, cancer.
Methane	The main component of natural gas. Leaks at every point along the natural gas life cycle. Sometimes is ventilated deliberately into the air.	A powerful greenhouse gas that contributes to climate change. Health impacts of climate change include heat illness, asthma attacks, vector-borne infection and disruptions in the global food supply.
Particle pollution	Emitted from generators and trucks used in oil and gas development. Pumps and compressor stations are often powered by diesel engines. Also caused by heavy trucks traffic.	Infant death, asthma attacks, low birth weight, heart attacks, stroke, cancer, premature death.
Silica dust	Sand is used in the process of hydraulic fracturing, or fracking. As sand is transported to well pads and poured into well shafts, silica dust can get into the air.	Cancer, silicosis.
Smog (ground level ozone)	Created when oil and gas pollutants, such as ROGs and NO_x, combine with heat and sunlight in the air.	Asthma attacks, lung infections, impaired lung development.

Source: Center for Environmental Health

In another series of studies conducted by the Clean Water Fund and Earthworks, SUMMA canister air samples and/or infrared cameras detected emissions from several oil and gas facilities located in the Upper Ojai region and the Lost Hills regions of the state. These samples were collected at the source of the emissions or in areas directly downwind from the source of odors or vapors (but not further than 20 feet), including pump jacks and wellheads, pipelines, evaporation pits, processing facilities and storage tanks.[30] Upon performing air sampling in the Upper Ojai and Lost Hills regions, Clean Water Fund and Earthworks revealed the presence of 15 compounds known to have negative effects on human health. Further samples detected the chemical isoprene in excess of recommended exposure limits. The results taken in aggregate led the authors to conclude that communities have been exposed to some oil and gas compounds in excess of health-based standards.[31] The study also included a health survey that found some residents, especially in Lost Hills, had experienced health impacts similar to those that have been linked with oil- and gas-related contaminants.

3.2 Polluting oil and gas operations harm people, especially those in close proximity

Waldo Tobler, a prominent figure in the field of geography, is credited with developing the scientific theory that, while everything is related to everything else, near things are more closely related than distant things.[32] In the field of public health and exposure assessment, this law of proximity applies to the interactions between people and the environment. Put simply, where we live, learn and work directly influence our health experiences, and industrial activities and emissions in close proximity, in particular those upwind of people, can result in highly concentrated population exposures of chemicals and pollutants.[33]

Concerning oil and gas installations, Tobler's Law could not be more relevant. Communities in closest proximity to active operations, particularly those downwind, are likely to experience the strongest interaction with them: whether it be by breathing in a site's air emissions, hearing industrial processes or experiencing other effects. While these people-site interactions are impacted by factors like containment and filtration systems (or lack thereof), meteorological

EDF

Breitburn Oil Field Infrastructure, Los Angeles, CA.

conditions (wind, temperature, etc.), and existing community and health conditions, the basic premise holds true—the closer the proximity, the stronger the likely interaction.

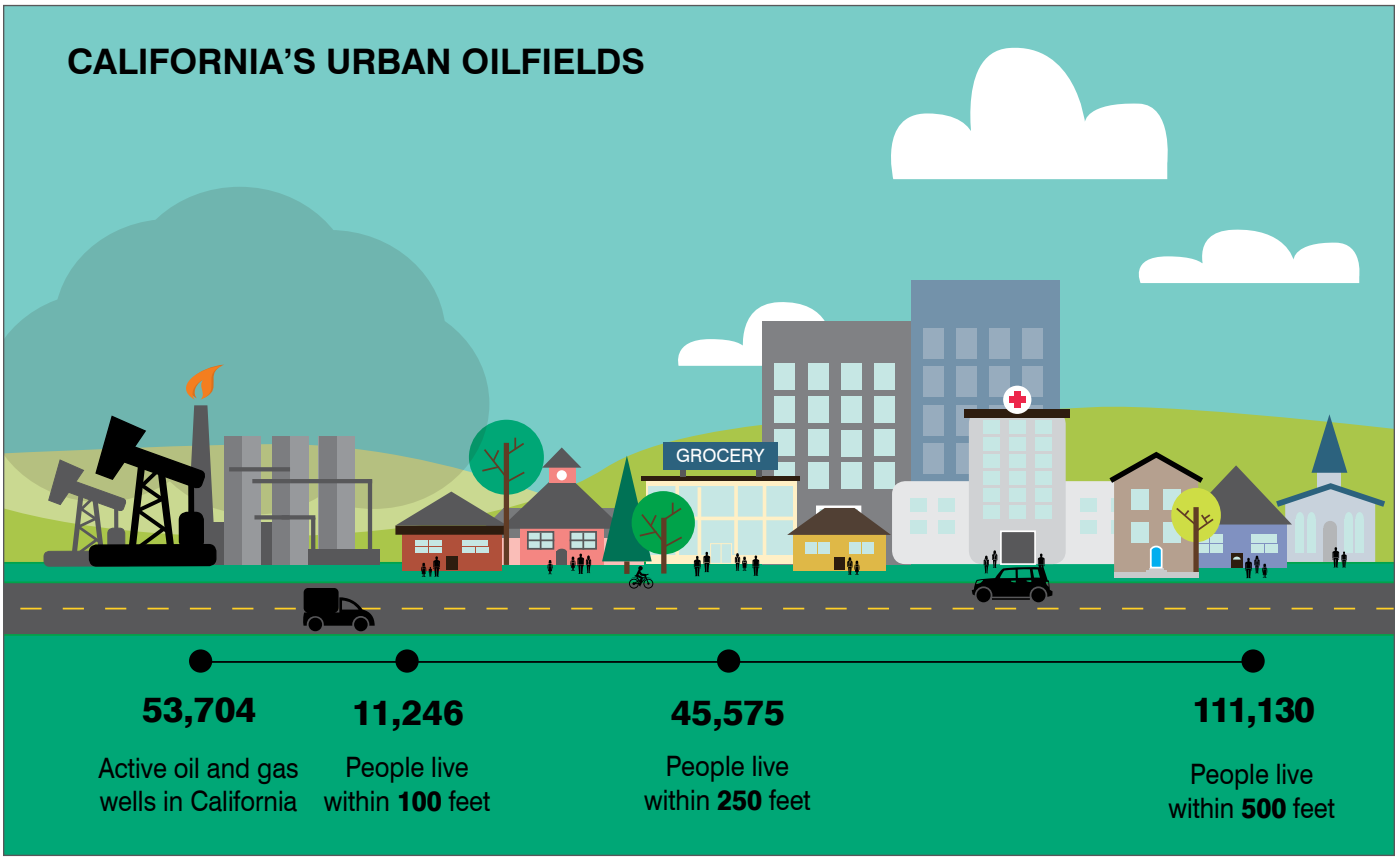
Furthermore, chronic exposure to environmental stressors from oil and gas operations can result in significant damage to health. Underserved communities are especially vulnerable and have a higher risk of health effects due to pollutant exposure. This, in turn, impairs the ability of residents to thrive and prosper.[34] Over time, if oil and gas sites emit pollutants that are diffuse and difficult to contain, such as gases that directly impair the public health, form smog or contribute to global warming, the impact radius can encompass an even larger population.

Over the past few decades, there has been increasing concern over the potential health impacts of oil and gas emissions. Several studies have documented the high levels of volatile organic compounds (VOCs)—including known carcinogens like benzene and xylene, diesel emissions, particulate matter (PM) and silica dust—in the vicinity of oil and gas facilities. Exposure to these pollutants have long been known to cause a variety of adverse health effects in exposed populations, ranging from respiratory diseases like emphysema to heart attacks and cancer.[35] These pollutants are also associated with effects across the entire human life span, affecting fetal growth in the womb and causing asthma attacks that lead to increased ER visits in children. In the elderly, pollutants have been linked to an increased chance of stroke and even death. Studies further indicate that living in close proximity to oil and gas activity presents greater risks to pregnant women and leads to poorer birth outcomes, such as preterm births and congenital heart defects.

In support of these findings, United States Environmental Protection Agency's (U.S. EPA) National Air Toxics Assessment found that populations living further than a half mile from oil

FIGURE 4

Proximity of oil and gas operations to California residences at specified distances



The numbers incorporate distances from active wells only and do not include proximity to other oil and gas operations that have the potential to emit, such as tanks, compressors, dehydrator vents and other oil handling equipment. Source: DrillingInfo and U.S. Census

TABLE 8

Number of people living within specified distances from an actively producing oil and gas well

	Within 100 feet	Within 250 feet	Within 500 feet	Within ½ mile (2640 feet)
All California	11,246	45,575	111,130	890,000
Los Angeles	6,485	25,401	62,327	584,580
Kern County	1,507	6,101	14,710	96,626

The numbers incorporate distances from active wells only and do not include proximity to other oil and gas operations that have the potential to emit, such as tanks, compressors, dehydrator vents and other oil handling equipment. Source: DrillingInfo and U.S. Census

TABLE 9

Number of schools and certified day care facilities within specified distances from an actively producing oil and gas well

	Within 250 feet	Within 500 feet	Within ½ mile (2640 feet)
All California	2	21	378
Los Angeles	2	11	263
Kern County	0	5	42

The numbers incorporate distances from active wells only and do not include proximity to other oil and gas operations that have the potential to emit, such as tanks, compressors, dehydrator vents and other oil handling equipment. Source: DrillingInfo and U.S. Census

and gas sites may surpass U.S. EPA's Level of Concern for developing cancer, so those living closer than a half mile face an especially critical threat.[36] Notwithstanding the emergence of a significant body of research on the health of communities near oil and gas operations, due to the lack of continuous environmental monitoring of air pollutants in communities surrounding these facilities, there has been limited empirical measurement of oil and gas industry air pollution and its health and economic impacts on nearby communities.

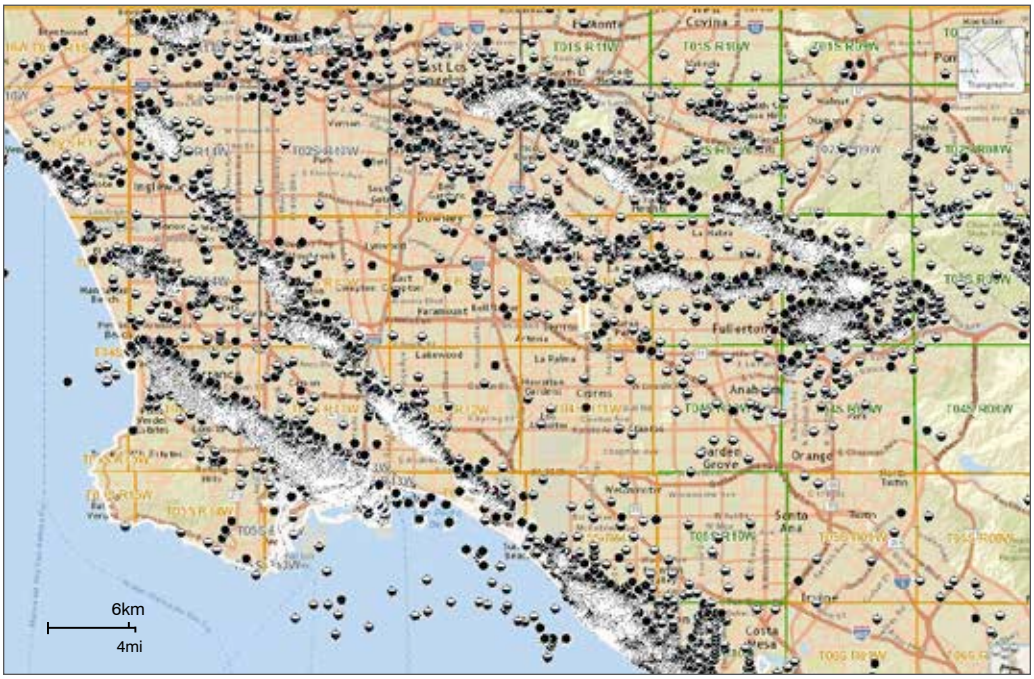
Recent research on the relationship between oil and gas operations and the health of nearby communities is particularly important in California, where close to one million people live, work and play within a half mile of an oil and gas facility.[37] Scores of Californians live even closer to oil production facilities, with thousands living less than 300 feet from such sites.[38] In certain areas of the state, houses, businesses and public recreational facilities are located even closer: less than 100 feet away. It is there that transparent, actionable data is most needed *(see Tables 8 and Table 9 (above) and Figure 4, page 19)*. Measurements of the concentrations of pollutant emissions to which people in those communities are being exposed are critical in determining immediate and long-term risks to children and families.

A closer look at the Los Angeles region clearly illustrates the risk faced by people living in close proximity to oil and gas operations—approximately 584,000 residents live within a half-mile of oil and gas sites, many even closer *(see photo, page 18)*.[39]

The California Division of Oil, Gas, amd Geothermal Resources (DOGGR) Well Finder website, an online tool that allows users to map the location of wells within geographic boundaries, clearly demonstrates the abundance of active oil and gas wells in close proximity to residences and schools in Los Angeles. On this map, each black dot represents an oil or gas well (*see Figure 5 and Figure 6, page 21)*.

FIGURE 5

Known historic and present-day oil and gas sites in a portion of the Los Angeles region



Source: DOGGR Well Finder

FIGURE 6

Known historic and present-day oil and gas sites in a single neighborhood in Harbor City, CA

Source: DOGGR Well Finder

3.3 Oil and gas pollution compounds the problem of exposure to degraded air quality that most affects sensitive populations

Neighborhoods with homes, schools, hospitals, churches and playgrounds that are in close proximity to oil and gas extraction sites are defined as "sensitive land uses" by CARB.[40] These land uses are inhabited by biologically "sensitive populations," including children, the elderly, those with impaired health and pregnant women, that are more vulnerable to the adverse impacts of oil and gas pollution both in the short term and long term.[41,42]

Research has found that newborn babies who were exposed to greater amounts of pollution from natural gas wells during prenatal development experienced higher than average levels of congenital heart defects and preterm birth.[43] In places where air pollution exposure has already impacted the health of certain segments in the population, like Los Angeles and the Central Valley, exposure to oil and gas compounds may become even more serious. Several studies have found that sensitive segments of the population, including those with compromised health due to exposures to pollution of other forms, may be affected in different and greater ways than people with less compromised health.[44]

Additionally, several studies have concluded that exposure to pollution disproportionately impacts low-income communities and communities of color, or environmental justice neighborhoods.[45] The California Environmental Protection Agency (CalEPA) identifies environmental justice neighborhoods as residential populations with high proportions of the poor and unemployed, persons with low educational attainment, a high percentage of non-English speakers, high levels of certain health impacts (low birth-weight, asthma, etc.), and greater exposure to environmental hazards and the attendant health risks as compared to the general population.[46]

Environmental justice communities tend to experience exacerbated health impacts from industrial pollution due to limited financial resources and higher, more proximal exposure to pollution concentrations that cause chronic illness. Chronic illness, in turn, requires a high cost of medicine and medical care, time away from work and increased sick days, which can result in

TABLE 10

Rankings for counties with worst air quality in the United States

				High ozone days in unhealthy ranges 2013–2015						High $PM_{2.5}$ days in unhealthy ranges 2013–2015	
2017 rank	County	State	Total population	Weighted average	Grade	2017 rank	County	State	Total population	Weighted average	Grade
1	San Bernardino	CA	2,128,133	142.3	F	1	Kern	CA	882,176	52.7	F
2	Riverside	CA	2,361,026	122.0	F	2	Fresno	CA	974,861	41.2	F
3	Los Angeles	CA	10,170,292	108.3	F	2	Kings	CA	150,965	41.2	F
4	Kern	CA	882,176	100.5	F	4	Stanislaus	CA	538,388	29.8	F
5	Fresno	CA	974,861	92.8	F	5	Fairbanks	AK	99,631	25.8	F
6	Tulare	CA	459,863	92.5	F	6	Madera	CA	154,998	24.7	F
7	Madera	CA	154,998	46.8	F	7	San Joaquin	CA	726,106	22.8	F
8	Kings	CA	150,965	44.5	F	8	Salt Lake	UT	1,107,314	21.7	F
9	Maricopa	AZ	4,167,947	34.7	F	9	Cache	UT	120,783	20.2	F
10	Uintah	UT	37,928	34.0	F	10	Merced	CA	268,455	19.5	F

Source: 2017 American Lung Association State of the Air Report

lost income, thereby instigating a feedback loop of financial stress and illness. Moreover, poor overall air quality associated with PM and smog pollution combined with exposures from oil and gas operations likely impose a larger cumulative air pollution burden for these communities. One study conducted in Pennsylvania, for example, indicates that populations residing in close proximity to oil and gas activity have almost four times the risk of asthma exacerbation than those that do not.[47]

As demonstrated by the American Lung Association, California still contains a majority of the nation's ten worst regions for PM and smog pollution, most of which are located in Southern California and the Central Valley, and several of which exceed health-based standards set by the U.S. EPA *(see Table 10, page 22)*. Asthma is the number one cause of school absenteeism in Los Angeles, and it is estimated that more than 63,000 children in the Los Angeles Unified School District have asthma.[48] Therefore, communities in close proximity to oil and gas operations may be exposed to air pollutants from those facilities in addition to being subjected to higher cumulative risks associated with degraded air quality and the health impacts stemming therefrom.

3.4 Oil and gas emissions can make regional air quality worse

In addition to the potential emissions of toxic contaminants through pathways like leaky equipment, venting and well completions, oil and gas operations can also release VOCs/NMOCs (non methane organic compounds) and nitrogen oxides (NO_x) that react to form smog and PM.[49] These gases are also known as reactive organic gases (ROGs). In places with degraded air quality, the emission of additional smog and particulate-forming compounds can exacerbate bad air quality and make it even unhealthier for local communities. In one study in the Central Valley, researchers found that increased ROGs in the atmosphere were consistent with fugitive emissions of gases that occurred during storage or processing of associated gas following extraction and methane separation.[50]

Despite the findings that oil and gas operations emit ROGs, the oil and gas industry has generally been considered a minor contributor to smog formation when compared to major emissions sources like cars and other stationary sources in the Central Valley and Southern California. However, Genter et al., (2014) did find that for at least the San Joaquin Valley, oil and gas operations are responsible for 22% of the total VOC emissions and 15% of compounds that react to form smog, which suggests industry emissions contribute more significantly to smog formation than previously believed and that there may be specific differences based on location or region. As California agencies work on the necessary task of incorporating and addressing these emissions within the state implementation plans for non-attainment of air quality standards, robust and transparent data captured from emissions monitors could facilitate the process.

3.5 Oil and gas methane emissions contribute to climate change

Oil and gas pollution not only affects public health—it also increases the threat of environmental harm through climate change because of methane emissions.

Methane—a colorless, odorless, high energy content gas—is the main component of natural gas (comprising approximately 95% of marketed gas) and naturally occurs inside crude oil deposits in varying quantities. As oil is extracted, processed and stored, methane present in the crude oil volatilizes (much like evaporation) off the surface of the oil when the liquid is dropped to atmospheric pressure levels. The volatilizing methane, which is called associated gas because it is associated with oil production, is often captured by company equipment.[51] However, when that gas is allowed to vent, or when the equipment used to collect associated gas or crude oil is not leak tight, the methane enters the atmosphere and contributes to climate change: methane

is a potent greenhouse gas (GHG) over 80 times more powerful by mass than carbon dioxide in affecting short-term climate change.[52]

Aside from oil production, methane is also released during the natural gas production process. Some areas in California have natural deposits of pure natural gas with methane concentrations of 80–99%. Much like in crude oil processing and handling, when excess natural gas is vented or leaks occur, methane can contribute to climate change.

"By emitting just a little bit of methane, mankind is greatly accelerating the rate of climatic change."

–Steven Hamburg
EDF Chief Scientist

In 2017, both the CARB and California Public Utilities Commission (CPUC) took considerable steps to reduce methane leakage from the state's oil and gas infrastructure.[53,54] These regulations require more frequent inspections of oil production equipment (overseen by CARB), natural gas transmission and distribution systems (overseen by CPUC), and natural gas storage sites like Aliso Canyon (overseen by both CARB and CPUC). With the exception of standards for facility monitoring at natural gas storage sites, neither CARB nor CPUC require real-time continuous monitoring of oil and gas operations in California. Expanded information on those standards is included in Chapter 3 of this report.

While it is clear that regulatory agencies in California recognize the hazards of methane emissions and are regulating to reduce them, the science has only recently (within the last five to seven years) determined how much and from which sources methane is emitting. For example, while the statewide inventory for GHG emissions indicates that methane makes up about 9% of total climate pollution, with 20% of those methane emissions attributed to oil and gas operations,recent peer-reviewed literature concludes that the petroleum and natural gas production sectors may emit up to seven times more methane than previously believed.[55,56,57]

Additionally, several studies have concluded that methane concentrations in areas like Los Angeles are higher than expected and reported in the inventory, and that local oil and gas operations are likely contributing a significant portion of that methane through releases from natural gas pipelines, urban distribution systems, and/or production and geologic seeps.[58,59,60]

In addition to investigating the total amount of emissions from oil and gas operations, recent studies have also examined the oil and gas supply chain to determine how and where methane is emitted and evaluate their relative contributions to total methane emissions. Experts generally agree that the bulk of all oil and gas pollution is released by a small subset of equipment suffering abnormal process conditions at any one time, as opposed to all sources emitting the same small amount.[61] This "extreme distribution" or "fat tail" rule signifies that the majority of pollution stems from a minority of the potential sources, called "super-emitters," which may be present in various locations, occurring stochastically, making them more difficult to identify and control. In a recent paper, researchers at Stanford found that, for all measured oil and gas pollution sources (sites or components), the largest 5% of sources contribute approximately 50% of total emissions from each source.[62]

In another study released by CARB in October 2017, using methane detection equipment operated by National Aeronautics and Space Administration (NASA), it was found that just 10% of leakage sites in California may be responsible for 60% of the methane released from individual major sources of emissions.[63] When examining oil and gas production sources of emissions, the CARB study found that, for typical methane sources in Kern Front oil field, common sources include storage tanks, well heads and (potentially) gathering lines. Furthermore, at least one gas processing facility in Elk Hills demonstrated large methane plumes from two of three large compressors on-site.

CASE STUDY

Lloyd Duvernay and Breitburn Operating LP, Gardena, CA

"In the span of about a week it all died," says Lloyd Duvernay, refering to an aggressive and resilient vine that lined the chain-link fence dividing his home from the oil and gas extraction field a mere 43 feet away.[64] The vine's death coincided with an event at the facility that sprayed crude oil high into the air, coating the houses and cars of Lloyd's neighbors.

Lloyd Duvernay, Gardena, CA.

Pointing at the nearby houses, he explains, "They had their roof retiled and their home repainted," but no response was given from Breitburn Energy or any other entity. There was no apology and no media coverage, and ten years later, residents like Lloyd still wonder about the long-term effects of exposure.

This is not the only incident Lloyd and his neighbors have faced since he and his family moved next to the facility 26 years ago. Sometimes, when trucks or large pieces of equipment operate on the site, "the air strongly smells like oil," he says. His backyard also used to flood when it rained, and a smelly concoction of oily, muddy water would seep under his fence. Those rain events, and the four inches of mud and foul smells they would bring, repeatedly ruined his plants and landscaping. Lloyd and his kids needed rubber boots every time they went into the backyard, and even after it stopped raining, the potent odor lingered.

Although soil testing at the time did not confirm toxic levels of contaminants, Lloyd remains concerned about the exposures and their long-term effects, especially for his son Shane, who has battled asthma for most of his life.

Lloyd's neighbor is Breitburn Operating LP, a company that operates several sites in the Breitburn Rosecrans oil field located in the South Central region of Los Angeles, in the city of Gardena *(see Figure 7)*. Since 1989, the oil facility next to his house has been bought and sold several times, but has continuously operated oil derricks, pumps, separators, piping and tanks, according to data from the SCAQMD and DOGGR. Currently, site permits list at least one active and one inactive basic crude oil, gas and water separation system on the site, even though several such pieces of equipment are in plain view.[65] In the surrounding neighborhood, DOGGR records indicate that Breitburn maintains 47 active wells and 17 idle wells. The area around the wells, including Lloyd's block, is zoned for both heavy manufacturing and single-family detached

FIGURE 7

Satellite view of the Breitburn oil production facility and distance to nearby residences

Gardena, CA

Lloyd Duvernay's house is in this figure.

Lloyd demonstrating the dead ivy on the boundary wall separating the Breitburn facility from his front yard.

homes, which allows oil wells to operate next to many homes and blocks from a nearby park and a middle school. A large portion of the area also contains heavy industrial warehouses that move material throughout the week with diesel trucks. The ongoing fumes and noise pollution these facilities bring to the area from active rigs and weekly truck traffic, sometimes continuing late into the night, provide constant disturbances to Lloyd's community. As at most sites across Los Angeles, no air pollution monitoring occurs.

Lloyd observes that while oil and gas development in urban settings is a problem for thousands of people throughout Los Angeles, neighborhoods like his may be getting a worse deal than others. "In some areas of Los Angeles, it seems like both the operators and the government are more responsive…how nice the oil operations look from the street and [how] cleanly operations are run and maintained often depend on what zip code you're in." For example, he explains, in some wealthier areas, "you would never know there is an oil well next door because it's all nicely fenced off with vegetation, and the smell is non-existent."

With little to no response from the company or government agencies, Lloyd and his neighbors are largely uninformed about the operations taking place in the oil field next door, nor do they have any information on the site's emissions or the pollutants to which they could be exposed. As a result, Lloyd wishes the site conducted real-time pollution monitoring. "It would be nice to have some information about the site, and some accountability. Some of the calls I've made to the 24-hour phone number posted at the gate have gone unanswered for days. I'm a good neighbor, but I think they could do a better job." At the same time, Lloyd recognizes he can not ensure the company will conduct monitoring, stating that "most people work hard around here and they don't have time or the money to organize and get that type of information, let alone get a company to become more responsive." Relocating to a neighborhood without the constant worry of an active oil and gas facility operating next door is not a financial option for him.

One thing of which Lloyd is sure, however, is that pollution monitoring, which could notify people like him whether a site was leaking while also alerting site operators to pollution events, would help alleviate some of his concerns. "If I could know what was in the air that certainly would help. I hope the air we've been breathing for years isn't hurting us, but I just don't know, and I'm taking a gamble right now. If there was something that could tell them there was a problem, so it wasn't on me to call, I think that would be a good thing." In explaining what it would take for the company and agencies to treat community residents fairly, Lloyd says, "Respond to the complaints, be compassionate, be sensitive and do the right thing. Remember, it could be your family."

Lloyd Duvernay's neighbor is the Breitburn oil production facility in Gardena.

CHAPTER 4

Monitoring and its relationship to pollution control

"Having better data, such as that produced by comprehensive 24/7 monitoring, would allow for stronger connections to be made between exposures, health behaviors and health outcomes."

–Dr. Paul Robinson
Medical geographer

4.1 Real-time air quality monitoring

California has significant experience with real-time air quality monitoring, but not at the level necessary to determine the effect of site-specific emissions from oil and gas production operations on nearby communities.

4.1.1 Real-time continuous ambient monitoring conducted by state and local government in California

California has one of the most extensive continuous 24-hour-a-day air monitoring networks in the world.[66] With over 250 ambient air monitoring sites across the state and more than 700 monitors, air quality regulatory agencies and some companies have significant experience managing the process of monitor installation, maintenance, and data reporting and analysis. In Southern California, for example, the South Coast Air Quality Management District (SCAQMD) operates 43 real-time continuous monitoring stations throughout Los Angeles and the surrounding three counties.[67] Similar programs for ambient air testing exist in other areas of California, such as Monterey Bay, Ventura County, San Joaquin, the San Francisco Bay Area and Santa Barbara.

Among the fundamental purposes of California's ambient air quality monitoring system are:

- Establishing background levels of air pollutants in the various air basins to determine how much is being added and whether pollution is being transported from one place to another;
- Determining whether pollutant levels meet health-based ambient air quality standards established by the U.S. EPA and measuring the extent of population exposure at the area level;
- Identifying hot-spots (elevated levels of pollution) within a particular geographic area;
- Evaluating whether significant sources (like refineries) or source categories (like transportation) are having a significant impact on ambient air quality; and
- Performing trend analysis and tracking the effectiveness of strategies, programs and regulations developed to achieve needed reductions.

Pollutants monitored at these sites include gases regulated to ensure attainment with air quality standards set by the U.S. EPA and do not include many of the primary gases emitted directly by oil and gas sites, such as methane, benzene, or total volatile organic compounds (VOCs). Furthermore, these monitoring sites are located significant distances away from individual pollution sources. Thus, the existing real-time monitoring equipment operated by local, state and federal agencies is helpful for monitoring regional pollution trends generally, but not suitable for monitoring oil and gas production site pollution specifically.

4.1.2 Real-time continuous ambient or fenceline monitoring conducted by oil and gas companies as required by regulations or settlements

Sometimes, but not frequently, regional regulatory agencies such as California's Air Pollution Control Districts (APCDs), the U.S. EPA, or local land use agencies require real-time monitoring to evaluate whether the concentration of pollutants from upwind sources exceeds a concentration limit or threshold of concern at the boundary (fenceline) of the facility or determine if pollutants are present in nearby communities. At the facility level, requirements for fenceline monitoring vary by site depending on local air district rules, air quality attainment status for the area in which the facility operates, facility size, and potential to emit. Rarely, though, do smaller facilities—even those with a high potential to emit and easy access to monitors—undergo any continuous monitoring. In fact, this study could find only three examples of a requirement for production site monitoring, all of which occurred after tireless community organizing, years of public outcry and legal action from residents over impacts from nearby facilities.[68,69,70]

Perhaps the best example of fenceline and community air monitoring required by regulation is found at large petroleum refineries in California and other states.[71] Increasingly, through both legislation and local regulation, these facilities must conduct real-time pollutant monitoring *(see Table 11)*.

In September 2017, the California Air Resources Board (CARB) and the California Air Pollution Control Officers Association (CAPCOA) released a report that evaluated the air monitoring capabilities, gaps and potential enhancements for refinery monitoring in California.[72] In this report, the joint agencies found that an improved near-refinery air monitoring network could be

TABLE 11

Continuous air monitoring currently conducted by refineries in California

Refinery name	City	Monitor type	Pollutants
Alon Refinery	Bakersfield	4 ground-level monitors on site	Total hydrocarbons (VOCs), H_2S and NH_3 only
Chevron Richmond Refinery	Richmond	3 community-based semi-permanent monitors	Benzene and several others
		4 ground-level monitors on site	SO_2 and H_2S only
		6-part laser-based fenceline system	Ozone SO_2, H_2S and NH_3 only
Phillips 66 Bay Area	Rodeo	9-part laser-based fenceline system	Total hydrobarbons (VOCs), methane, benzene, SO_2 and H_2S, and several others
		4 ground-level monitors on site	SO_2 and H_2S only
Shell Martinez	Martinez	1-part fixed fenceline system	SO_2 only
		4 ground-level monitors on site	H_2S only
Tesoro	Martinez	4 ground-level monitors on site	SO_2 and H_2S only
Valero	Benicia	3 ground-level monitors on site	SO_2 and H_2S only

Source: CARB, Refinery Air Monitoring Assessment Report

achieved through site-appropriate implementation of: 1) continuous, real-time or near real-time air monitoring inside the refinery, 2) predictive and real-time dispersion modeling of unplanned refinery releases, and, 3) real-time or near real-time community monitoring. These findings align with California legislation recently passed in 2017 (AB 1647–Muratsuchi) that requires Districts to design, develop, install, operate and maintain refinery-related community air monitoring systems; and petroleum refineries to develop, install, operate and maintain fenceline monitoring systems by January 1, 2020.

In addition to supporting the goals of AB 1647, the September 2017 CARB/CAPCOA report supports a proposed rule currently before the SCAQMD, Proposed Rule 1180, which would require refineries in Los Angeles to deploy continuous fenceline and community air monitoring systems.

4.1.3 Real-time continuous ambient monitoring conducted by academic institutions, state agency research divisions and the federal government

In addition to regional monitors operated by state and local governments and required monitors at some large stationary source facilities, some academic institutions, state government agency research divisions and federal government institutions also conduct air monitoring—though less regularly. Examples of such monitoring include:

- The National Aeronautics and Space Administration (NASA) Jet Propulsion Lab at the California Institute of Technology operates a monitoring network of 14 stations for greenhouse gas (GHG) emissions across Los Angeles within the MegaCities Project;[73] and
- The CARB research division conducts air quality and emissions research related to GHG emissions—including methane emissions—through a network of 15 regional monitoring stations across the state.[74]

4.1.4 Real-time continuous facility stack monitoring

In addition to California's network of ambient air monitoring, state and federal law requires some individual facilities to perform monitoring to determine the emissions rates from on-site sources and assess their compliance with air quality standards.[75,76] By law, these facilities must attach monitoring equipment, subject to strict operational requirements, to specific pieces of equipment or smokestacks in order to document continuous compliance as well as exceedances of standards. Furthermore, facilities are commonly required to self-report violations of emissions standards and problems with monitor operation to local agencies.

Typically, however, only facilities over a designated size are required to install real-time pollution monitors, and neither the proximity of potential emissions sources to local populations nor the potential toxicity of the materials handled are considered. Moreover, these monitors only oversee large points of exhaust, and thus fail to identify emissions escaping from other sources, such as wells, tanks and compressors at oil and gas production sites.

4.1.5 Government-run short-duration stationary and mobile monitoring following an environmental release, regulatory violation or to perform research on oil and gas pollution

Although it is neither frequent nor standardized, air quality monitoring sometimes occurs in response to an environmental release event or regulatory violation at an oil and gas site or as a means of conducting a time-limited assessment of air pollution contributions from a particular source or area of sources. In such events, monitoring may occur for a period of time as a real-time continuous operation to analyze emission trends and design sophisticated models. Alternatively, monitoring may be episodic, sporadic or attached to mobile-mounted systems for the purpose of responding to major pollution events or conducting research. Examples pertaining to oil and gas operations include, but are not limited to:

- Chevron Refinery Fire Air Monitoring Study conducted by the Bay Area Air Quality Management District (BAAQMD) (2012)[77]
- ExxonMobil Refinery Fluid Catalytic Cracking Unit (FCCU) Startup Air Monitoring Study conducted by SCAQMD (2015 and 2016)[78]
- Baldwin Hills Community Standards District Air Monitoring Study for the Baldwin Hills Oil Field (2015)[79]
- Aliso Canyon Natural Gas Leak Air Monitoring Study conducted by CARB and SCAQMD (2016 and 2017)[80,81]
- The SCAQMD has conducted air quality testing to quantify gaseous emissions from small point sources in the Southern California Air Basin, including evaluations of oil wells for methane and non-methane organic compounds (NMCs) and benzene compounds[82]
- The California Energy Commission (CEC) has routinely funded air quality and emissions research related to oil and natural gas operations through the Public Interest Energy Research (PIER) program[83]
- The CARB research division, in partnership with other agencies, including NASA, has conducted air quality and emissions research related to methane emissions through a series of select scientific monitoring campaigns, as well as source identification research related to the AB 1496 methane hot spots program to determine the presence of super-emitting sites[84,85,86]
- The CARB rulemaking division has conducted air quality testing at leaks on select oil and gas sites and production operations in preparation for discrete rulemakings[87,88]

4.2 Air monitoring

Air monitoring, including continuous and enhanced mobile monitoring, has increasingly become a community effort.

Independent of government, academic and facility-level monitoring, some community groups, not-for-profit organizations and private companies have launched their own monitoring efforts and networks in California aimed at identifying sources of pollution at the regional and local level. With the emergence of new, lower cost, increasingly accurate sensors, along with the opportunities provided by modern cloud computing, community air monitoring projects and ensuing data analysis have reached increased levels of sophistication. Although most of these projects have focused on monitoring for particulate matter (PM), some projects (albeit few) have also monitored pollutants emitted by oil and gas sites.

Examples of past and ongoing community air quality monitoring projects in California include, but are not limited to:

- Clean Water Fund's Community Air Canister Sampling in Lost Hills[89]
- The West Oakland Environmental Indicators Project: Ground Level Monitoring of Particulate Matter in West Oakland[90]
- The Coalition for Clean Air CLEAR (Community Learning Enhances Air Resources) Program for Particulate Matter Measurements in Los Angeles[91]
- The Coalition For A Safe Environment LACEEN (Los Angeles Community Environmental Enforcement Network) pilot project for monitoring air quality and other environmental conditions in a Wilmington residential community[92]

- Communities for a Better Environment Bucket Brigade[93]
- AirWatch Bay Area, an interactive tool for the frontline communities of the San Francisco Bay Area to explore its air quality[94]
- SafeCast's mobile-based radiation and air quality monitoring program in communities across California in conjunction with international deployment efforts[95]

Historically, due to the high costs of time and resources, along with the complexities of conducting continuous air monitoring, all projects identified that were related to oil and gas production monitoring, such as Clean Water Fund's community-based air canister sampling project in Lost Hills, were time-limited in duration.

4.3 Shortcomings of existing oil and gas production monitoring activity in California

"It'd be a relief to know that all these kids are growing up in a safe neighborhood and their parents don't have to worry about poisons and fumes in the air."

–Lloyd Duvernay
Gardena resident

While California agencies and research institutions already conduct significant air monitoring and emissions studies, current monitoring activity (either real-time or for research purposes) has not traditionally accounted for the full range of pollutants generally released by oil and gas production sites (methane, BTEX, etc.). Where such monitoring has been conducted, it has generally lacked both the scope and specificity necessary to quantify exposures at the neighborhood level. Furthermore, where site-specific and leak-specific monitoring has been done, it generally demonstrates that emissions are significant enough to warrant further evaluation.

When looking at the current landscape of active monitoring systems, several shortcomings are evident with regard to their ability to capture oil and gas production system emissions and potential community exposures resulting therefrom:

- **Lack of data:** Most air quality monitoring systems in operation in California do not measure the pollutants of concern from oil and gas production sites, namely methane, benzene and other VOCs. For that reason, data that can be used in community health protection efforts is lacking. While some monitors are located near the fencelines of the state's largest petroleum refineries (and more are on the way) or attached directly to emitting smokestacks at the largest stationary facilities, no comprehensive community monitoring data for 24-hour real-time assessments specific to oil and gas production exists. Furthermore, of all monitoring deployments studied in California, only one monitor in Santa Barbara appears to have been installed with the intent of aiding detection of emissions from a local oil and gas production operation, though no data is readily available.[96]
- **Scattered data:** In the areas where monitoring is conducted, the monitors are operated by various discrete entities—CARB, local air districts, individual facilities, private companies, community groups and NASA, to name a few. These dispersed efforts scatter data on monitor installations, monitor readings and monitor locations, making it difficult to consolidate and analyze information in a useful manner. While several companies are working to aggregate data and present it on easy-to-understand visualization platforms, such projects are still in development and not yet available for the range of pollutants released from oil and gas sites.
- **Lack of consistent data:** In the areas monitoring is conducted, not all pollutants are monitored, as monitoring requirements vary by locale and research project. Discrepancies in pollutant monitoring requirements and deployments create data gaps that constrain the ability of analysts to identify emissions trends.

4.4 Emissions monitoring and reporting can drive pollution reduction in the oil and gas sector

As documented by Ramboll Environ in an evaluation conducted on behalf of Environmental Defense Fund (EDF) in 2017, there are currently several options available for real-time continuous air sampling, both in point-source measurement devices and open-path lasers at oil and gas production sites located in California.[97] Due to advances in computing and monitoring technology, many of these monitoring devices are lower cost, and they are often as precise as monitoring systems that have been used at major industrial sources. Furthermore, when data from these monitors is aggregated and displayed on transparent and user-friendly data visualization platforms, businesses, government entities and communities groups can better learn about sources of pollution and initiate action.

Substantial evidence from both observational and anecdotal data suggests that a positive correlation—and at times a specific link—exists between the installation and operation of pollution monitors and the reduction of air pollution from monitored sites, especially at sites where monitoring systems are paired with government-led air quality improvement plans and facility-led pollution control and prevention plans.[98,99] Accordingly, it is expected that if monitors were deployed at oil and gas sites in California, pollution reductions and enhanced community protections would follow.

4.4.1 Empirical evidence from existing monitoring programs shows that monitored facilities are more likely to reduce pollution

Several historical examples demonstrate that programs that require monitoring and reporting of environmental pollution, along with reporting of human exposure risk, lead companies to reduce pollution discharge.

- **U.S. EPA Toxics Release Inventory (TRI) Program:** [100] In October of 1986, in response to growing concerns about local preparedness for chemical emergencies and the availability of information on hazardous substances, Congress passed the Emergency Planning and Community Right-to-Know Act (EPCRA). Section 313 of EPCRA created the TRI, which requires companies to report information about toxic chemical releases from their industrial facilities. One of the basic tenets of the TRI program was that by making information about industrial management of toxic chemicals available to the public, the TRI would create a strong incentive for companies to improve environmental performance.[101] According to a U.S. EPA study of TRI and its effect on emissions, TRI facilities conducted over 370,000 source-reduction projects between 1991 and 2012, which resulted in a 9–16% average decrease in facility-level emissions of target chemicals.[102]
- **CARB Air Toxics "Hot Spots" Program:** In 1987, the state legislature passed AB 2588, which requires facilities that release a specified amount of criteria pollutant emissions per year and greater than five tons per year of any Federal Hazardous Air Pollutant (HAP) to report those emissions to the state. According to the 2016 Annual Report on AB 2588, the program has led to significant toxic emissions reductions. Hixson Metal Finishing in Newport Beach, for example, fell under AB 2588 for its excessive hexavalent chromium emissions in 2014. By December 31, 2016 they reduced their cancer risk from 1,502 in a million to 25 in a million, below the program's risk level.[103]
- **CARB GHG Mandatory Reporting and Cap-and-Trade Program:** In 2010, CARB instituted the first-ever California reporting program for GHG emissions at facilities emitting greater than 10,000 metric tons of carbon dioxide–equivalent gases per year, followed by a new regulation requiring reductions of the aggregate level of emissions from facilities emitting greater than 25,000 metric tons of carbon dioxide per year. In response to the program, several facilities reporting emissions close to the 25,000 level for inclusion in the program modified operations so they would fall below the threshold, resulting in lower overall emissions for this class of facility.[104]

4.4.2 Anecdotal data suggests that new requirements for emissions monitoring would reduce pollution from oil and gas production systems

Oil and gas production sites in California are not required to regularly monitor pollutant discharge, despite many sites using hazardous chemicals and having a documented history of noxious odors, sometimes within feet of houses, schools and other sensitive infrastructure.

Research suggests that deploying advanced pollution monitoring systems at oil and gas sites would result in reduced pollution exposure risk for communities in close proximity and reduced emissions of pollutants that have an adverse effect on regional air quality. Monitoring does this by providing data that can be used by government agencies and affected communities to encourage and compel oil and gas operators to reduce emissions. Monitoring also provides data that can be used by operators to improve site design, maintenance and operations to reduce emissions.

4.4.2.1 Corporate drivers for pollution reduction from oil and gas operations

At a holistic level, oil and gas production sites and operators, like other facilities, maintain a social license to operate, in addition to legal permits and licenses. "Social license to operate" refers to the principle that businesses cannot operate without general acceptance from larger society. This license is not a true physical license but rather a metaphorical one that underlies the interaction between businesses, people and the environment. The principle contends that businesses can endure longer and more profitably when they face less societal backlash because they minimize the time, effort and money needed to defend themselves in the public eye, complete complicated negotiations and defend lawsuits. At its core, continuous emissions data can raise community and governmental awareness of facility pollution and thereby encourage and compel corporations to act responsibly.

In addition to driving better overall corporate behavior, new monitoring systems at oil and gas sites can be designed to evaluate and aggregate emissions in real time—making them capable of quickly alerting operators to process upsets, operational malfunctions and breakdowns, and emissions sources. Consequently, companies can respond to problems faster or before they turn into larger, more expansive dilemmas, minimizing the harm those leaks inflict upon environmental and public health. Some oil and gas operators, like Chevron, have used such an approach to manage equipment unrelated to emissions for years, demonstrating the value to companies of the overall approach and rationale.[105] Other companies, like Shell and Statoil, have already started testing emissions monitoring systems voluntarily on oil and gas facilities on a limited basis.[106,107]

In addition to alerting facility operators to operational issues and emissions from production sites, emissions monitoring data can identify risks and characteristics that investors use to evaluate operational health, investment risk, and worthiness. Accordingly, new monitoring systems may work to lower overall emissions and potential community exposures through the drive to eliminate investor concerns.[108] Similar to reducing investor risk, businesses would also have an interest in reducing liability risk from both a worker and community exposure standpoint. Monitoring that results in transparent data would push operators to reduce emissions and therefore reduce liability.[109]

Notwithstanding the incentive to attain a better public image and minimize liability, oil and gas operators subject to requirements for real-time monitoring would also be driven to manage pollution to reduce the chance of additional oversight and regulations.

4.4.2.2 Government drivers for pollution reduction from oil and gas operations

Governmental agencies are tasked with protecting the health and welfare of the people, and emissions data can substantiate whether a facility, set of facilities or industry as a whole is injuring the environment or public health above a threshold of significance. Transparent emissions data can therefore substantiate the need for new regulations or improved enforcement that will result in pollution reductions.

Of course, several rules and regulations already restrict pollution from oil and gas operations across California. These restrictions exist for several purposes, including worker health, public health, public safety and climate protection. However, compliance and enforcement of these rules are evaluated sporadically by local air quality management districts, even for communities living in close proximity to sites at which an exposure event has occurred.

Real-time advanced emissions monitoring systems can serve to document compliance with regulations that mandate reductions or pollution control at particular facilities, helping to establish a more level regulatory and health-protection landscape that is less biased to issues of agency resource limitations or socioeconomic conditions. Furthermore, emissions data can be used by regulatory agencies to enforce requirements on facilities that are operating outside of established laws and regulations and provide communities opportunities to petition agencies for further action.

"We've had gas emissions, oil emissions, in the air that have permeated into our homes... because I'm so close to the oil fields, I'm very concerned as a resident and as a mother."

–Deborah Weinrauch
Culver City resident

4.4.2.3 Community drivers for pollution reduction from oil and gas operations

People living near gas wells and facilities, as well as workers at related job sites, may be exposed to multiple toxic substances both on an acute (short-term, high-exposure) and chronic (long-term, low-exposure) basis.[110] As discussed above, the health concerns that typically pervade these communities include asthma, exacerbated forms of previously-existing respiratory illnesses and chronic illnesses including lung cancer, chronic obstructive pulmonary disease and others.

Although emissions and exposures may be occurring in communities located near oil and gas production sites, the lack of transparent emissions and exposure data keeps community members in the dark about the nature and extent of pollution. In the absence of policies that sufficiently regulate oil and gas pollution near residential areas, access to transparent data on oil and gas emissions and resulting community exposure could offer citizens an opportunity to get involved in new rulemaking processes while pushing agencies to do more to enforce existing source pollution control requirements. Sharing information on real-time facility emissions with the public would not increase responsiveness to major pollution events, but would offer communities a transparent understanding of the pollutant inputs into their local environment. Additionally, public data empowers communities with the tools to better advocate for themselves. Any monitoring programs launched by agencies must engage communities meaningfully throughout every step of the process, from formation to implementation and enforcement.

4.5 Comprehensive data analysis and emissions visualization will assist in pollution awareness and reduction

Two primary goals of air monitoring deployments at oil and gas facilities are better overall operational performance that leads to emissions reduction and greater public confidence in data transparency. To achieve these twin aims, decisions on monitoring system deployments must be based on a foundation of making data accessible to all interested parties, ensuring that data is fully analyzed for trends and observations, and exporting that data onto platforms that allow for meaningful visualization and action.

Perhaps the first step to achieving data accessibility for members of the public is ensuring that neighbors of oil and gas facilities have meaningful opportunities to affect decisions on overall monitoring deployments. While working with community members to help decide the location of monitoring sites, the pollutants being monitored and the data format for analysis may seem irrelevant to community needs, these factors have been shown to play a major role in ensuring the delivery of trustworthy and effective results.

Once data is collected from monitors, the use of tools for publicly displaying, mapping and tracking data is of critical importance, and a monitoring entity can meaningfully display

LOS ANGELES COUNTY

Unmonitored oil production site in the Breitburn - Rosecrans urban oil field, Los Angeles.

its emissions data in a variety of ways. For example, some platforms display multiple streams of real-time, instantaneous data using numeric values or color-coded markers corresponding to monitored locations on a map to denote whether the air quality is acceptable or unhealthy by location as compared to health-based standards.[111,112] Other monitoring tools provide graphs of real-time data so users can identify recent trends or historic detection of measured pollutants.[113] Still other platforms use aggregated data from multiple monitors or mobile sensors to create highly granular yet regional pictures of pollution concentration and potential exposure.[114] In addition to designing a display tool for the data, entities can create report summaries displaying data results for a period of time.

In essence, monitoring data helps the community, businesses and the government make critical decisions, and all parties must have an equal say in how to best deploy monitors and display and analyze resulting data.

CASE STUDY

2017 CARB California Methane Survey

In October of 2017, CARB released interim results from a research study conducted with help from NASA and the CEC that offers the most precise assessment yet of California's largest individual sources of methane pollution—including oil and gas operations.[115] Conducted pursuant to the state's responsibility to identify hotspots of methane pollution as required by 2015 legislation AB 1496 (Thurmond), the "California Methane Survey" found 329 strong plumes of methane emissions, nearly a third of which sourced to oil and gas production, processing and handling—a vast majority of which occurred in Kern County *(see Table 12 and Figure 8)*.[116,117]

TABLE 12

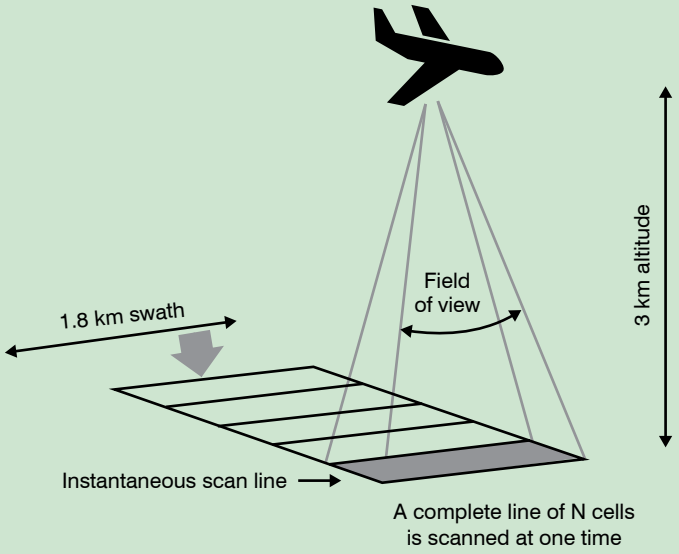
Strong methane plumes from oil and gas sources discovered in the California Methane Survey

Oil and gas production, processing, and handling sources emitting methane (excluding oil refineries)	# of sources found
Oil/gas compressor	2
Oil/gas drill rig	2
Oil/gas gathering lines	10
Oil/gas pumpjack	33
Oil/gas stack	3
Oil/gas tank	19
Oil/gas unknown infrastructure	28
Oil/gas waste lagoon	1
Total	**98**

Although the new study did not find any methane releases that approached the magnitude of the 2015/2016 Aliso Canyon gas leak, which released over 100,000 tons of methane into the air near Los Angeles, it did find that just 10% of sites identified may be responsible for 60% of the methane released from individual sources in California on an ongoing basis. Such findings offer regulators critical information off which to base the design of new monitoring and emissions-reduction programs and evaluate the efficacy of existing programs with the same aim.

FIGURE 8

Diagram of NASA system used to detect methane plumes



In addition to actually discovering strong sources of methane, this study further demonstrates that new monitoring technology is making emissions data more precise and actionable. Whether it be from the airplane-mounted equipment used by NASA in this study, sensors attached to vehicles, mountaintop monitoring stations and satellites, or sensors deployed along facility fencelines, there are many options that exist today for methane detection. This monitoring technology will be crucial to future pollution reduction efforts, such as the implementation of recently passed legislation in California (AB 617 by Garcia) that requires the development of local air quality improvement plans based in part on advanced monitoring data.

CHAPTER 5

Pollution control and monitoring requirements at oil and gas sites

"It is critical to gather accurate data and to monitor sources of pollution so that there can be some kind of relief through technology and regulation."

–Sheila Kuehl
Los Angeles County Supervisor
District 3

California's regulatory environment is sometimes characterized as a complex web of interacting and overlapping requirements that is difficult for businesses and citizens to navigate. It is surprising, then, that oil and gas production—an industry that has continuously operated in some of California's densest communities for over 140 years—has been sporadically regulated with regard to leakage and venting control requirements, and practically unregulated on the issue of regular air quality monitoring.

Fortunately for neighboring communities, major advancements in regulations to control leaks at oil and gas production sites were made in early 2017 by the state government, and those requirements are already being implemented at the regional level. In addition to regulations for leak control, new requirements to continuously monitor for leaks at natural gas storage sites were also enacted in early 2017, and new legislation to require community-level monitoring (though not specific to oil and gas) was passed in the fall of 2017. Those efforts are summarized below and demonstrate the powerful influence that regulation can have on industry behavior and the deployment readiness of both the oil and gas industry and the pollution monitoring industry.

5.1 Current landscape of air quality monitoring and emissions control requirements at California's oil and gas production facilities

Historically, regulatory agencies in California have required or performed monitoring of oil and gas operations only in response to an accident or release event that was well-documented and reported.[118] In many circumstances, even if a leak was found at an oil and gas production site, regulations did not require operators to fix it—even if that leak was occurring in close proximity to people's homes or businesses.

Where leak thresholds have been set, regulatory standards for "permissible" emissions often only take into account what is permissible under Occupational Safety and Health Administration (OSHA) standards for adult on-site workers, who wear protective gear. Therefore, permissible emissions rarely factor in the existing conditions of residents who live nearby without any special protections. In addition, rarely do regulatory standards incorporate conditions for especially sensitive bodies such as children whose small lungs and higher breathing rates make them more susceptible to inhaling a greater amount of toxics at higher frequencies than adults.

Regulations enacted in the past year, however, require facilities to fix leaks they record and operators to inspect sites for emissions at least once every four months. They also require the installation of monitors at major gas storage facilities and draw new attention to the disproportionate pollution burdens of underserved communities. Still, a more robust monitoring framework is needed to protect the health of California's communities living

and working on the fencelines of oil and gas production sites. Without consistent air quality data from sites at all hours of the day, regulators will be unable to protect communities in close proximity to emissions sources and identify trends in oil and gas pollution over time.[119]

5.1.1 California Air Resources Board (CARB) Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities (passed March 2017)

The CARB regulates air pollutants as they relate to public health, including those from oil and gas production, and in March 2017 it passed a comprehensive regulation to reduce the incidence of methane leaks at oil and gas production sites. The rule—the most significant of its kind in the nation—titled "Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities," requires oil and gas production sites to perform quarterly inspections of specified equipment (i.e. well casings, tanks, pipes, compressors, etc.) on-site to search for any leaks and repair the leaks they find that exceed specified sizes.[120]

While the CARB rule marks a considerable step forward for California, leak monitoring at oil and gas production sites located in close proximity to California communities remains only quarterly. Prior to this rule, neither CARB nor local Air Pollution Control Districts (APCDs) required much by way of inspection or maintenance at local production facilities, often specifically exempting them from standards. Now, with quarterly source inspection and repair requirements set to take effect in 2019, basic steps have been taken to reduce possible exposures for California communities. However, the new rules determine compliance with their regulations based on self-reported data, in addition to occasional regulatory audits, whereby operators submit annual attestations to the CARB and local APCDs certifying that leak evaluations have been done.[121] With over 3,500 active production sites in Los Angeles and 42,300 in Kern County alone, neither CARB nor local APCDs likely have the staff or resources to ensure all sites are complying with the standards.

Along with regulations for leak reduction and repair, CARB also oversees a system of mandatory emissions reporting requirements that apply to major oil and gas facilities (alongside other facilities) emitting greater than 10,000 metric tons of carbon dioxide per year.[122] These requirements apply to oil and gas sites with significant emissions generally associated with combustion for the purpose of generating steam and heat to aid in oil extraction. Sites must report aggregate emissions of methane to the state to maintain compliance, and face requirements under the state's cap-and-trade program if these emissions exceed 25,000 metric tons of carbon dioxide per year.[123]

5.1.2 Regional regulations and efforts to reduce emissions at oil and gas facilities by California's APCDs

In response to California's exceptional air quality problems in the latter half of the 1900s and in recognition of the need to develop regional solutions for pollution control, the state formed 35 independent APCDs.[124] These districts perform a number of functions: they adopt rules to limit harmful emissions from commercial and industrial facilities, operate networks of monitors to measure concentrations of pollutants, inspect sources for compliance with local, state and federal regulations, and issue operating permits to facilities.

As far as monitoring emissions from oil and gas production operations and providing communities with real-time, transparent data related to exposure risk, however, these pollution control districts have historically done little—even at sites located in close proximity to communities. Many factors likely contribute to this shortcoming, including the widespread distribution of oil and gas production systems, lack of overall political will, lack of data on the deleterious impacts of oil and gas pollution on communities, high cost of traditional monitoring systems and lack of attention to methane as a pollutant of concern.[125] However, as a result of the new CARB rule for oil and gas systems, as well as efforts to advance the use and deployment of monitoring systems, this may be about to change.

5.1.2.1 South Coast Air Quality Management District (SCAQMD)

In the SCAQMD, the agency regulates oil and gas sites under several rules. In SCAQMD Rule 1148.1, in addition to provisions requiring control of odors at facilities and standards that prohibit purposefully venting emissions to the atmosphere, the rule contains standards related to well cellars, liquids storage, gas handling equipment, abatement devices, well drilling and workovers, and hazardous emissions reporting to local fire agencies.[126] In SCAQMD Rule 1148.2, operators must report the types and amounts of chemicals used in oil and gas well drilling, well completion and well reworks.[127] Additionally, in SCAQMD Rule 1173, similar to statewide rules from the CARB, operators of oil and gas production fields must inspect facilities and fix leaks over a specified size, though such inspections are only required once per year and exemptions apply for equipment in low VOC service.[128]

Furthermore, as discussed above, SCAQMD is presently considering new requirements for monitoring at oil refineries (Proposed Rule 1180) within their jurisdictional reach.

5.1.2.2 Bay Area Air Quality Management District (BAAQMD)

In the BAAQMD, similar to SCAQMD, standards exist related to the control of compounds from natural gas and crude oil production facilities. In BAAQMD Rule 8-37, standards prohibit purposefully venting emissions to the atmosphere, require the repair of specified leaky components and pieces of equipment, mandate the cleanup of liquid spills, and regulate hatched and stuffing boxes.[129] Notably, the BAAQMD requirements in Rule 8-37 specifically exempt leakage from equipment handling pure natural gas and methane, though new statewide rules will likely modify this requirement. Furthermore, even though the BAAQMD regulations require large refineries to perform continuous ambient air quality testing, no real-time monitoring standards exist for oil and gas production facilities.

5.1.2.3 San Joaquin Valley Air Pollution Control District (SJVAPCD)

The SJVAPCD regulates the bulk of oil and gas production in the state due to its large geographic area. Under SJVAPCD Rule 4401, steam-enhanced crude oil operators are required to collect and control volatile organic compound (VOC) emissions from production wells, though operators are only required to thoroughly monitor their equipment emissions once a year. SJVAPCD Rule 4402 sets standards for sumps—surface ponds used to separate crude oil, produced water and solids in oil-producing fields—and requires sumps (though with expansive exceptions) be covered by a material that is impermeable to VOCs. Under SJVAPCD Rule 4407, combustion well vents are required to be connected to either an emissions control device that reduces VOC emissions by 85% or a smokeless flare.[130,131,132] This rule also requires monitoring to ensure compliance, though such monitoring need only be performed on a quarterly basis. SJVAPCD Rules 4408 and 4409 both set additional standards for controlling VOC emissions, with Rule 4408 regulating glycol dehydration systems and Rule 4409 setting leak detection and repair standards for components at light crude oil production facilities, natural gas production facilities and natural gas processing facilities.[133,134] As in other APCDs, no continuous emissions monitoring is required.

5.1.2.4 Monterey Bay Air Resources District (MBARD)

The MBARD issues rules regulating local oil and gas facilities, though its local rules generally allow for greater-sized leaks before repair requirements apply than any of the Districts reviewed and default to federal requirements where applicable. Under MBARD Rule 427, operators of steam drive crude oil production wellheads must reduce VOC emissions by at least 98% by weight and achieve leakage rates specified in the rule.[135] As in other Districts, no emissions monitoring requirements have been identified.

5.1.2.5 Ventura County Air Pollution Control District (VCAPCD)

In Ventura County, the VCAPCD regulates oil and gas sites under rules similar to those of the other districts, though most closely to those of SCAQMD. VCAPCD Rule 71.1 regulates the emissions associated with crude oil and natural gas production, gathering, storage, processing and separation units, VCAPCD Rule 71.4 regulates sumps under similar requirements, and VCAPCD Rule 71.5 restricts emissions from glycol dehydrators.[136,137,138] To control individual leaks, VCAPCD Rule 74.10 requires oil and gas production and processing facility operators to conduct daily observations of all equipment, and quarterly evaluations to look for gas leaks and conduct repairs.[139] As in other APCDs, no continuous emissions monitoring is required.

5.1.2.6 Santa Barbara County Air Pollution Control District (SBCAPCD)

In Santa Barbara County, SBCAPCD regulates emissions from crude oil and natural gas production processes through SBCAPCD Rule 325 and Rule 331.[140,141] Under these standards, like in other air districts, operators must keep certain pieces of equipment leak-free and airtight, and they must inspect equipment for leaks on a quarterly or annual basis, as specified in the rule. Also, as in other Districts, no continuous emissions monitoring is required at oil and gas facilities. According to the SBCAPCD 2017 monitoring plan, the District does operate one local monitoring site at Las Flores Canyon to collect data, including total hydrocarbons near a prominent oil and gas facility, although no data has been located for this site.[142]

5.1.3 California Division of Oil, Gas, and Geothermal Resources (DOGGR)

DOGGR is the statewide regulatory agency that oversees oil and gas well construction, operation, production and extraction activity in California.[143] In general, DOGGR works to prevent the waste of the state's natural resources, including pollution caused by improper or imprudent operation of oil and gas facilities. DOGGR, however, generally regulates only activity with an impact below the surface of the ground, yielding regulatory authority over air emissions to local air pollution control districts and CARB. As a result, DOGGR regulations concerning oil and gas production sites include little to no monitoring requirements.[144]

5.1.4 California Public Utilities Commission (CPUC)

The CPUC is a statewide regulatory agency that regulates the activity of California's natural gas utilities, including the emissions from natural gas transmission, distribution and storage systems. Since 2014, acting under statewide legislation (SB 1371 related to Natural Gas Leak Abatement), the CPUC has worked to create a new series of rules requiring utilities to find, fix and prevent leaks from natural gas pipelines and storage facilities.[145] In June 2017, the CPUC issued new rules for gas utilities that require them to deploy stationary methane detectors for the early detection of leaks, applying the rule to compressor stations, terminals, gas storage facilities, city gates, and specified metering and regulating (M&R) Stations.[146]

While these rules do not require continuous monitoring, nor do they apply to California oil and gas production sites (the CPUC rules apply only to natural gas storage sites), they demonstrate the availability of monitoring systems that can be deployed at sites with incredible speed, as operators have already begun to test and install advanced monitoring systems in response.

5.1.5 Local regulations for public safety

In many cases, local public safety standards have been developed to ensure the public is not placed at unnecessary risk of hazard for fire or explosion stemming from nearby oil and gas production operations. In Los Angeles for example, the County's Department of Public Works has enacted methane mitigation standards that generally require any new buildings to be at least 300 feet from active, abandoned or idle well(s).[147] Furthermore, these standards, like those of other cities

in the area, require specialized monitoring and venting in buildings for the purpose of methane detection and explosion control. Such standards do not require monitoring for the purpose of assessing human health and exposure, however, so they offer little use to such research.

5.2 New requirements for continuous emissions monitoring at natural gas storage sites

New requirements for continuous emissions monitoring at natural gas storage sites demonstrate a model for regulatory action and evidence of the coming wave of available and accessible technology.

In addition to passing new leak detection (via quarterly inspections) and repair regulations for oil and gas operations in March 2017, as described above, CARB also passed standards requiring the state's 13 natural gas storage sites (but not its oil and gas production or processing sites) to continuously monitor for the presence of gas leaks.[148] These new requirements were a direct response to legislation passed in the wake of the Aliso Canyon gas leak in 2015–2016 in recognition of the insufficiency of voluntary industry monitoring standards to meet the goals of preventing and rapidly detecting emissions from these sites.[149,150]

Provisions of the CARB rule on continuous monitoring at natural gas storage sites

FENCELINE MONITORING

Monitoring conditions upwind and downwind of the facility

Natural gas storage sites, which closely resemble oil and gas production sites, must now install fenceline emissions detection systems that include requirements for facility operators to:

- Develop monitoring plans that contain equipment specifications and procedures for requirements
- Install at least one methane sensor upwind and at least one sensor downwind of the facility
- Continuously measure and record meteorological conditions;
- Establish baseline monitoring conditions using at least 12 months of continuous monitoring data
- Install an audible and visible alarm system that triggers and alerts facility operators any time the downwind sensor(s) detects a reading greater than or equal to four (4) times the downwind sensor(s) baseline or in the event of a sensor failure
- Contact CARB, DOGGR, and the local air district within 24 hours of a confirmed alarm
- Be able to store at least 24 months of continuous instrument data; generate hourly, daily, weekly, monthly, and annual reports; and make data available upon request of CARB Executive Officer
- Begin monitoring within 180 days of ARB approval of the monitoring plan

ON-SITE MONITORING

Continuous monitoring as a replacement for daily leak detection

Natural gas storage sites, which closely resemble oil and gas production sites, must now inspect gas production equipment for leaks daily or install continuous methane monitoring systems. In the event an operator chooses to install a continuous monitoring system, it must meet the following requirements:

- Be equipped with an audible and visible alarm system that alerts facility operators
- Alarm systems shall be triggered any time a leak is detected above specified set points or in the event of a sensor failure
- Alarms must be able to store at least two (2) years of continuous monitoring data
- Alarm systems shall be tested quarterly, calibrated at least annually, and placed back into service within 14 calendar days of a problem being discovered and fixed
- Site operators must maintain records and make them available to the CARB Executive Officer

Under the new regulations, natural gas storage sites and accompanying equipment, which operate much like a series of wells at oil and gas production sites, must meet the above-mentioned requirements.

A common missing thread from regulations of California's oil and gas production sites has been consistent, continuous monitoring requirements. While several regulations at the state and regional level have addressed leak detection through periodic site visits (once per quarter or once per year) equipment repair and operational standards, all lack required constant monitoring on the fenceline or on-site at oil and gas facilities. The CARB regulation of natural gas storage fields, sites which are designed much like production sites, provides a potential regulatory model for new oversight.

PG&E

Acutect continuous methane detection system installed at the Pacific Gas and Electric (PG&E) Los Medanos natural gas storage facility, Concord, CA.

In response to the new CARB regulation, natural gas storage providers in California have started shifting internal policies around storage. Many storage facilities have now either tested or installed monitors to detect leaks in real-time, which gives them the ability to respond even faster to stem emission events that may occur at their sites. For example, the Southern California Gas Company (SoCalGas), operator of the faulty site responsible for the Aliso Canyon leak, has since installed infrared methane monitoring systems at the fenceline of sites as a preventative action.[151] Pacific Gas and Electric (PG&E), owner of multiple gas storage sites in Northern California, is also testing continuous monitoring systems.[152] Central Valley Gas Storage, another of California's natural gas storage providers, has also tested and installed continuous methane monitoring devices on site in response to the new CARB standards.[153]

CHAPTER 6

Overview of emerging technology and advancements

"We are seeing the first wave of lower cost, real time oil and gas pollution monitors right now. Other waves will come and make it even better, faster and cheaper."

–Elias Tobias
Technology Provider
Safety Scan USA

Similar to the advancements witnessed in computers and telephones over the last decade, oil and gas pollution monitoring technology has made significant advancements and continues to evolve rapidly. Consequently, advances in monitoring technologies have (and continue to) increase the number of facilities that could implement cost-effective pollutant detection and concentration monitoring. Some technology both on the market today and in development may also be able to evaluate emissions rates and volumes. These breakthroughs make it possible to assess pollutants at the local facility level, granting access to new streams of data that can aid in reductions and avoidance. Additionally, new technology and equipment are entering the market regularly, providing a near continuous stream of solutions to deploy lower cost and more precise monitors on a regular basis.

In 2017, Ramboll Environ, a globally recognized environmental and health consultancy, conducted a technical assessment of the status of technology on the market today that can perform real-time emissions detection and pollutant concentration evaluation at oil and gas facilities, with a focus on technologies that can detect methane, benzene and/or ozone precursor compounds. This assessment evaluated the commercial availability of such technology as well as factors that could affect the usability and relevance of particular technology applications, such as their ability to detect multiple compounds at once, their cost and their remote capabilities. Ramboll Environ's evaluation displayed its results in a color-coded chart *(see Table 13, page 44)*.

From Ramboll Environ's initial identification of 18 distinct technology applications and review of technology providers, followed by an even deeper assessment of six specific technology application categories, one thing is clear: although monitoring technology has been deployed sporadically and unevenly at oil and gas sites to date, a significant amount of technology is in widespread use in other sectors or commercially available for use now, and can be deployed once initiatives demand it. Furthermore, many of these technologies can be deployed both as real-time, stationary monitoring or mobile monitoring systems that provide episodic emissions detection either on a regularized timetable or in response to an emissions event. The benefit of mobile systems should not be undervalued and should be considered in the development of any present-day pollution monitoring plan.

TABLE 13

Color-coded review of monitoring technology by Ramboll Environ's for EDF

Sensor category	Monitoring technologies	Compound classes	Sampling rate	Simultaneous detection of multiple compounds?	General limit of detection	Remote capability	Cost range in US$	Degree of market penetration
Sample collection	Active sampling	Methane, benzene, non-methane organic compounds (NMOC)	Discrete, time-weighted average	Yes	Methane: < 1 ppm Benzene: < 10 ppb NMOC: < 50 ppb	Yes	Under $1,000 each	Widespread use
	Passive sampling	Methane, benzene, NMOC	Discrete, time-weighted average	Yes	Methane: < 1 ppm Benzene: < 10 ppb NMOC: < 50 ppb	Yes	Under $1,000 each	Widespread use
Open Path Optical/Laser Absorption Spectroscopy	Differential Optical Absorption Spectroscopy (UV-DOAS)	Benzene, NMOC (monocyclic aromatic hydrocarbons)	Continuous	Yes	Benzene: < 10 ppb NMOC (monocyclic aromatic hydrocarbons): < 50 ppb	Yes	$60,000–200,000	Commercially available, limited availability
	Differential Absorption Lidar (DIAL)	Methane, benzene, NMOC	Continuous	No	Methane: < 1 ppm Benzene: < 10 ppb NMOC: < 50 ppb	Mobile-capable but requires an attendant to move the instrument's location	$295,000–445,000	Commercially available, limited availability
	Fourier Transform Infrared Spectroscopy (FTIR)	Methane, benzene, NMOC	Continuous	Yes	Methane: 15–60 ppb Benzene: 30–100 ppb NMOC: 1–100 ppb	Yes	$75,000–120,000	Commercially available
	Tunable Diode Laser (TDL) Spectroscopy	Methane, benzene	Continuous	No	Methane: 0.5–1 ppm Benzene: 10–30 ppb	Yes	$15,000–65,000	Commercially available
	Infrared camera	Methane, benzene, NMOC	Continuous	No	Qualitative detection only, add-on devices allow for emission rate quantification	Yes	$50,000–75,000	Commercially available
	Solar occultation flux	Methane, benzene, NMOC	Continuous	Yes	0.5 kg/hr from 50 m downwind or 0.3 mg/m^2 across a plane	Mobile-capable but requires an attendant to move the instrument's location	New unit is ~ $1,000,000, one-month study is $200,000	None in U.S., only in Sweden

See key, page 46

Sensor category	Monitoring technologies	Compound classes	Sampling rate	Simultaneous detection of multiple compounds?	General limit of detection	Remote capability	Cost range in US$	Degree of market penetration
Extractive (non-open path) optical/ laser absorption spectroscopy	Fourier Transform Infrared Spectroscopy (FTIR)	Methane, benzene, NMOC	Continuous	Yes	Methane: 15–60 ppb Benzene: 30–100 ppb NMOC: 1–100 ppb	Yes	$20,000–50,000	Commercially available
	Non-Dispersive Infrared Sensor (NDIR)	Methane, NMOC	Continuous	No	Methane: 1–500 ppm NMOC: 500–1,000 ppm	Yes	$1,000–10,000	Commercially available
	Tunable Diode Laser (TDL) spectroscopy	Methane, benzene	Continuous	No	Methane: 1–10 ppb Benzene: 10–30 ppb	Yes	$15,000–50,000	Commercially available
	Cavity-enhanced spectroscopy	Methane, benzene	Continuous or semi-continuous	Yes	Methane: 1–10 ppb Benzene: 0.1–30 ppb	Yes	$40,000–150,000	Commercially available
Chromatography	Mass spectrometry	Methane, benzene, NMOC	Semi-continuous	Yes	Methane: < 1 ppm Benzene: < 10 ppb NMOC: < 50 ppb	Yes, if carrier gas included. Handheld units may have higher detection limits than bench-top units	$20,000–60,000	Commercially available
Ionization	Photoionization Detector (PID)	Benzene	Continuous	Yes	Benzene: 2–100 ppb NMOC: 0.05–200 ppm	Yes	$1,000–10,000	Widespread use
	Flame Ionization Detector (FID)	Methane, benzene, NMOC	Continuous	Yes	Methane: 1-10 ppm Benzene: 10–100 ppb NMOC: 50–500 ppb	Yes	$5,000–50,000	Widespread use
Reactive	Pellistor	Methane	Continuous	No	Methane: 100–1,000 ppm	Yes	Under $1,000	Commercially available
	Electrochemical	Methane, total VOC	Continuous	No	Methane: ~ 100 ppm Total VOC: 100–1,000 ppb	Yes	Under $1,000	Commercially available
	Metal oxide semiconductor	Methane, total VOC	Continuous	No	Methane: 10–100 ppm Total VOC: 1–10 ppm	Yes	Under $1,000	Commercially available

See key, page 46

KEY

Cost	Under $1,000	$1,000–$50,000	Over $50,000
Degree of market penetration	Available for purchase in larger quantities multiple vendors	Available but limited quantities/ limited vendors/prototype	Not commercially available, only used in research
Precision/resolution			
Methane	<1 ppm	1–10 ppm	> 10 ppm
BTEX	<10 ppb	10–100 ppb	> 100 ppb
Ozone-precursors	<50 ppb	50–500 ppb	> 500 ppb

Notes to aid interpretation of Table 13 as written by Ramboll Environ

1. Resolution bins are based on typical background concentrations of the pollutants listed.

2. In 2002 the estimated statewide ambient concentration of benzene was approximately 0.6 ppb (~2 µg/m^3) (CARB, 2004). Statewide the annual average benzene concentration has decreased from ~2.5 ppb in 1990 to ~0.5 ppb in 2007 (CARB, 2009). From: https://oehha.ca.gov/media/downloads/crnr/benzenerelsjune2014.pdf

3. Methane background concentrations from: https://www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases

4. TVOC background concentrations were estimated from the following sources: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1247565/

http://lib.ugent.be/fulltxt/RUG01/002/166/567/RUG01-002166567_2014_0001_AC.pdf

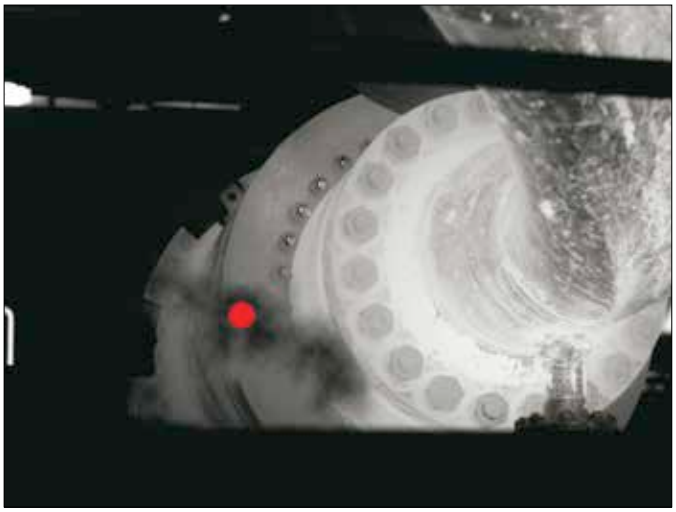
https://www.aiha.org/government-affairs/PositionStatements/VOC%20White%20Paper.pdf

5. Equipment costs represent the capital expense of the equipment, operating costs are not included. Depending on the manufacturer, some costs may be lower than the prices listed if large quantity orders are placed.

6. Costs presented in this table are estimated capital costs of the monitoring technology. In many cases, it is possible that cost per unit could be lower than the range presented in the table if a large order is placed to reduce manufacturing costs. Additional costs are needed for operation and maintenance of monitoring technologies or networks. These costs, not presented in the table, can vary depending on the reliability and robustness of the technology, or the sophistication of operating the technology. Some operation and maintenance costs may fall anywhere between $5,000 and $500,000 annually, depending on the technology and application. Moving forward, advancements in technology and manufacturing practices help will drive down capital costs and advancements in data analytics, cloud computing, and data management strategies will help drive down operating costs.

EDF

Emissions at an oil production site as seen through an infrared optical camera.



FLIR

Methane leak from piping connector as seen through infrared optical camera and with dot added to indicate location of leak.

CHAPTER 7

Recommendations

Air pollution from oil and gas production operations can pose a serious exposure risk to nearby communities, especially to those in close proximity. In some areas of California, reports from residents living mere feet away from oil and gas operations indicate they are frequently impacted by dizziness, nausea, asthma, frequent and spontaneous nose bleeds (especially in children) and noxious odors—symptoms that match the results of studies identifying impacts on people from oil and gas pollution.[154] In other instances, people report increased incidences of certain cancers or related health ailments.[155] At the same time, emissions research conducted by government and community organizations demonstrates that oil and gas operations can,

Recommendations checklist to cut oil and gas pollution through monitoring

- ✓ Develop new local rules by local APCDs to incorporate stationary or mobile monitoring of oil and gas production facilities
- ✓ Reassess state oil and gas regulations to include real-time stationary or mobile monitoring at oil and gas production facilities
- ✓ Develop and distribute resources for communities to launch community-based monitoring projects
- ✓ Utilize public funds to quickly deploy state and local monitoring systems at key oil and gas production facilities
- ✓ Ensure implementation of AB 617 includes provisions for monitoring of oil and gas production
- ✓ Modify local zoning and land-use laws to incorporate monitoring
- ✓ Establish findings by local public health departments about hazards of unmonitored oil and gas sites
- ✓ Increase collaboration between government agencies and communities
- ✓ Follow Los Angeles County's lead and survey all oil and gas wells in the state of California
- ✓ Ensure AQ Spec tests monitors for oil and gas pollutants of concern
- ✓ Engage with oil and gas operators and technology providers, employing advanced monitoring strategies

and in some cases do, emit toxics that may cause these types of ailments. As California's population continues to grow and urban areas become more densely populated, the proximity of active operations to people will likely become an even greater concern.

Given these realities, it is no surprise that residents are demanding to know *what* exactly is being emitted in their neighborhoods and that increasing efforts to monitor oil and gas pollution have arisen in the past few years. Those efforts have been important, but the current regulatory landscape for monitoring at oil and gas production operations in California is still too piecemeal and lacks the ability to deliver continuous and accurate public data on pollutants being emitted from facilities. Meanwhile, air monitoring technology and data analytics have been advancing at lightning speed, while costs continue to decline, rendering the deployment of monitoring technology increasingly accessible, user-friendly and affordable.[156]

These circumstances all shed light on the ease, availability and need for monitoring, and demonstrate that it can—and should—be a part of the solution for reducing the risk that oil and gas production operations pose to our environment and health.

To close the information gaps identified in this report—facilitate reductions of air toxics, smog-forming gases, and climate change agents; advance the public understanding of pollutant releases from oil and gas production sites; arm communities with data in order to better advocate for themselves; and enhance the ability for smart policy making in the future—California regions with oil and gas production should consider these recommendations:

RECOMMENDATION

Develop new local rules by regional Air Pollution Control Districts (APCDs) to incorporate stationary or mobile monitoring of oil and gas production facilities, prioritizing active sites in closest proximity to people and/or in underserved communities.

California's regional APCDs are responsible for the adoption of control regulations for stationary sources within their boundaries, including standards for air contaminants like benzene and volatile organic compounds (VOCs) from oil and gas production sites. As shown through ample evidence that such sites pose a potential risk to human health, the state's APCDs should develop and incorporate requirements for oil and gas pollution monitoring in their rules, in addition to the standards for regular on-site leak detection and repair that currently exist.

In the development of standards for real-time oil and gas monitoring, APCDs should develop mechanisms that draw upon recent improvements in air quality monitoring technology that have led to the ability to capture data with high spatial resolution, low detection limits and with maximized cost effectiveness. Where real-time monitoring is infeasible to capture all desired pollution data because of cost or technological limitations, Districts should evaluate and implement the use of mobile air monitoring systems that are suitable for capturing data upon the occurrence of an emissions release or at regularized, frequent intervals. Furthermore, since enhanced air pollution monitoring systems are likely to yield pollution and exposure reductions, local APCDs should evaluate and perform health impact analyses as part of any new monitoring deployment planning exercise.

In support of this recommendation for new requirements for advanced pollution monitoring systems, APCDs should look to a recent 18-month long survey of 557 wells in the unincorporated regions of Los Angeles County by the Los Angeles County Oil and Gas Strike Team. In their report, the Strike Team issued a series of recommendations in the fall of 2017 advising that "fenceline monitoring can be used to identify leaks and unintended or accidental releases at any facility if the same technologies are applied, not just refineries, and could alert communities of potential health and safety issues."[157] This recommendation calls upon local air pollution districts, such as the South Coast Air Quality Management District (SCAQMD), which is currently considering real-time air monitoring requirements at refineries under Rule 1180, to launch a similar rule for monitoring requirements at production sites.

In addition to new rules which apply to all sites, local APCDs should also develop and incorporate conditions within individual new, modified and renewed operating permits that ensure continuous monitoring systems are deployed at oil and gas production sites—with an emphasis on sites with the highest potential to cause exposure to surrounding people.

Of course, while emissions detection and measurement technology is rapidly advancing, there are obstacles to achieving widespread deployment immediately. These limitations, as outlined by Ramboll Environ, include monitor availability, cost, barriers to new technology adoption and others. Accordingly, monitoring deployment timetables in APCD regulations and programs should take issues like availability into account but also recognize the power of technology-forcing regulations and early-stage deployments to bring down costs and pave the way for larger-scale adoption.

As APCDs evaluate options for the inclusion of monitoring in air pollution reduction and prevention plans at oil and gas facilities, recognition must be made that some sites are more likely to impact local communities than others due to factors such as proximity and environmental and socioeconomic conditions. As a result, APCDs should prioritize the implementation of monitoring deployment standards at facilities located in geographic areas within the top 25% of the CalEnviroScreen 3.0 and in close proximity (closer than a half mile, and if necessary within 500 feet) to oil and gas facilities. Furthermore, in the development of such rules and permits, agencies should ensure meaningful and continuous community and public participation to foster effective and appropriate monitoring plan development, implementation and enforcement. If community participation is neglected (which often occurs in government efforts), it is more likely that objectives will not be achieved as intended. Additionally, any local rules developed on the topic should ensure adequate coordination with existing or planned regulations at the state level to avoid duplication and inefficiency. Finally, as part of any regulatory framework developed by a local or state agency, mechanisms for remedial action should be in place in the case of the detection of pollutant concentrations at a level of concern.

RECOMMENDATION

Reassess current oil and gas regulations at the state agency level to include real-time stationary or mobile monitoring at oil and gas production facilities, prioritizing active sites in closest proximity to people and/or in underserved communities.

Current statewide regulations implemented by the California Air Resources Board (CARB) and California Division of Oil, Gas and Geothermal Resources (DOGGR)—both agencies regulating oil and gas production—do not incorporate real-time, continuous stationary monitoring at all oil and gas production sites, nor do they require regularized mobile mounting to capture the same or alternative classes of pollutants. Many of the existing regulations were developed before several of the advancements in monitoring technology emerged, as outlined above and as identified by Ramboll Environ. According to evidence collected following the adoption of the CARB oil and gas methane rule, finalized in early spring of 2017, the deployment of 24/7 monitoring requirements at natural gas storage facilities is already underway, which offers an example for similar regulations that should be in place at oil and gas production sites.

Given the progress in the field of sensor technology and the growing risks that people in proximity to pollution from oil and gas production facilities face, updating current regulations to incorporate the installation of monitors in pollution-prevention and -reduction programs is a logical, necessary and prudent step forward. Incorporating stationary and mobile monitoring in these standards will result in better knowing, measuring and sharing the types of pollutants being emitted into the atmosphere by these operations.

As stated above with regard to the inclusion of monitoring in efforts at APCDs, it must be acknowledged that barriers to immediate widespread deployment of monitors do exist. However, limited deployments of monitors can be made today. We therefore recommend that

CARB and DOGGR prioritize the implementation of monitoring conditions in communities in the top 25% of the CalEnviroScreen 3.0 and in close proximity (closer than a half mile) to oil and gas facilities. The selection of monitors should not necessarily be prescribed by the agency, but rather set forth collaboratively after meaningful engagement with the public and stakeholders. To implement these plans, companies should pay for the installation and data aggregation of monitors, data should be made public and government agents should verify the accuracy of the data collected through regular audits.

RECOMMENDATION

Develop and distribute resources for communities to launch community-based monitoring, data analysis and data visualization projects centered on oil and gas production facilities.

The availability of emissions monitors for oil and gas pollutants like benzene, methane and VOCs indicates that successful community air quality monitoring and enforcement projects can be developed and deployed for oil and gas production facilities in California. Such projects have already been developed for pollutants like particulate matter (PM), though enforcement efforts stemming from such monitoring initiatives are still unclear.

To ensure genuine opportunities exist for effective community participation in developing monitoring projects, resources for long-term project management and data analysis must be made available. This includes resources for training, webinars, grants and other tools that allow organized residents to develop their own monitoring pilots and networks. Examples of successful community air monitoring projects demonstrate that residents need such resources, yet some communities that lack access to technology and funds find themselves with limited ability to deploy monitors and get answers to their questions. While there is no cure-all to address these important issues, we recommend that local air pollution control districts make community participation a necessary feature of any oil and gas monitoring program, while also dedicating resources to communicating with residents, gauging their needs and making monitoring resources available to them.

RECOMMENDATION

Recognizing that regulatory enactments take time, state and local agencies should independently deploy government-managed real-time stationary and mobile monitoring systems at key oil and gas production facilities that operate in close proximity to sensitive receptors and have been reported to produce impacts on nearby residents, prioritizing communities located within, and near, the top 25% of the CalEnviroScreen 3.0.

Deploying real-time fixed monitors is the best way to collect data on the pollution emitted by oil and gas facilities in areas of high concern. As more systems are ordered and installed, more streams of data will be collected, which can then be funneled into advanced modeling and computational software to evaluate exposure risks and neighborhood public health impacts. Furthermore, feedback associated with monitoring installation and deployment can be collected and shared, allowing companies that are developing low-cost monitoring systems to learn from examples and compete for utilization, thereby providing signals for greater technological innovation and cost reduction as companies learn about market demands.

Any oil and gas air monitoring pilots or studies launched by either a state or local agency should seek to prioritize locations in neighborhoods already overburdened with high exposure to many sources of pollution, including oil and gas activity. By addressing these communities first and foremost, efforts will ensure that data is being aggregated and analyzed in the areas of the state that have access to the least amount of information but the greatest need. In identifying sites for early deployment, agencies should work directly with communities so that

the priorities of each monitoring deployment are determined by the communities to whom the agencies seek to provide information. Additionally, communities located in the closest proximity to oil and gas activity—within 500 feet—should be given extra consideration, with even additional consideration for those within 250 feet. Furthermore, early deployment should not be time limited in duration, but instead deployed without designated end dates so as to ensure data capture during all phases of production operation.

One potential option for funding of air quality monitors can be found in the auction proceeds from the California Global Warming Solutions Act of 2006 (AB 32)—the cap-and-trade program. Monitoring requirements for oil and gas facilities, such as those in Colorado, have already been shown to reduce emissions from operations.[158] Under the latest iteration of CARB's Scoping Plan, it was estimated that a 25% reduction in oil and gas emissions would result in $55–$285 million in avoided social costs of carbon and a 1–3 MMTCO2 range of GHG reductions. Another option for funding may arise under the imposition of new fees at the local level, such as those passed by city and county planning agencies.

RECOMMENDATION

Ensure implementation of new legislation in California (AB 617) includes provisions for real-time stationary and mobile monitoring of oil and gas production operations located in close proximity to underserved communities.

Several recently enacted pieces of legislation aim to improve the quality of California's air and reduce the environmental impact of emissions from major stationary sources. These new laws provide pathways and opportunities to incorporate monitoring at oil and gas production sites, as well as for processing and materials used in operations. Probably the most comprehensive law is AB 617, passed in the fall of 2017. State agencies, air districts and interested legislators tasked with implementing AB 617 should work in a coordinated and collaborative manner with each other, affected communities and technology experts to ensure monitoring at oil and gas production sites is considered in the planning and implementation stages of these laws. Agencies should also strive to engage community-based organizations and the designers of pioneering monitoring efforts early and continuously in the development, implementation and enforcement stages. The creation of a community-based and technical advisory committee will ensure that meaningful engagement with communities and rigorous technological understanding underlie the development of air monitoring conditions.

RECOMMENDATION

Modify local zoning laws, codes and land-use processes to incorporate real-time monitoring at new and modified oil and gas facilities prior to commencement of operation, while also incorporating real-time monitoring conditions on annual reauthorizations of existing operations located in close proximity to people.

Agencies charged with regulating and permitting oil and gas operations at the local level should ensure companies provide an air emissions monitoring plan before approving any application that has been submitted to them. In Los Angeles, for example, where much of the nation's urban drilling continues to take place, companies have largely been permitted to operate with little to no requirements for monitoring harmful emissions. In Los Angeles County, oil and gas extraction operations are regulated under Title 22 of the Los Angeles County Code—a regulation that mandates certain standards related to setbacks and other requirements, but is silent on detecting and responding to pollution events through monitoring.[159] Now, as a result of recent efforts by the Los Angeles County Oil and Gas Strike Team, the county's Department of Public Works has recommended the change in zoning code to include requirements for monitoring that can be used to identify leaks and unintended or accidental releases.

A 2015 report on an inventory of Los Angeles County oil and gas wells concluded that 85% of the wells in the County do not require permit-based approvals, and operators may drill "by-right" without oversight by the County.[160] Additionally, the same report found that many companies operate on grandfathered permits that have not been reviewed in decades. By-right drilling in all counties in California that allow facilities to operate without oversight or monitoring should be eliminated, and existing permits should receive thorough reviews. To the extent that permit holders must submit annual information to land-use planning and permitting agencies, those agencies could incorporate installation of monitoring plans and systems as a precondition for acceptance of annual reports—thus avoiding having to physically change local ordinances and zoning laws.

Regardless of the mechanism, monitoring conditions should be applied both to old permits—as a condition of continued operation—and to new and modified operations prior to allowing (re)commencement of operations. Such standards should take into account monitor availability while also prioritizing deployments in communities in close proximity to oil and gas operations and those located within and near the top 25% of the CalEnviroScreen 3.0. Local public works departments (or agents with similar duties) should inspect and analyze monitoring data once these conditions are put into place, and operators should be required to notify administrators of any air emissions release incidents.

RECOMMENDATION

Establish findings by city and county planning and public health departments related to the hazards of unmonitored oil and gas production sites located near sensitive receptors.

Current zoning laws allow for heavy industrial operations, like oil and gas extraction, to take place as close as 30 feet from homes, schools and playgrounds. In some cases, operators are able to drill in residentially zoned areas as long as they apply for conditional-use permits. These poorly zoned areas allow for incompatible land uses that must be addressed by city planning departments. Updating zoning laws to no longer allow homes and heavy manufacturing to occur within feet from each other is a start.

Additionally, given the ample research and peer-reviewed literature on the health impacts of exposure to oil and gas pollution, county and city public health departments in California should engage in formal deliberations to determine whether residences, businesses and schools within specified distances of unmonitored active oil production sites constitute a health hazard and requires action. A recent report released by the California Office of Environmental Health Hazard Assessment (OEHHA) looked at a list of reported chemicals emitted by refineries during the processing of crude oil, including compounds known to be toxic to humans, like benzene.[161] The report found that of the 188 chemicals on the list, 54 chemicals listed under Proposition 65 are carcinogenic, 21 chemicals have developmental effects and 13 chemicals have male or female reproductive effects.[162] A separate CARB report also articulated a need for site-appropriate live modeling based on real-time air monitoring data to accurately predict off-site consequences within minutes of a facility becoming aware of a release.[163]

While the CARB and OEHHA reports focus on processing of fuels, their findings—that releases from major oil and gas facilities have significance to nearby communities, and monitoring systems can help address such impacts—apply to oil and gas production sites as well. When coupled with the ample research results from CARB, the California Council on Science and Technology (CCST), and SCAQMD discussed in this report and combined with observations by local Public Health departments, it is clear that pollutants released in close proximity to people are a public health risk. Health officials should therefore consider protecting fenceline communities by using their power to identify the risks of unmonitored sites and call for action from appropriate regulatory bodies.

It is important to note that in response to public health concerns related to oil and gas production in, and near, communities, several organizations, including both community

organizations and public health departments, have articulated the need and value for appropriate buffer distances between industrial operations and people that live in close proximity to those operations. The installation of continuous monitoring systems should in no way be construed as a replacement for, or stand in the way of, policies that establish such buffer distances. Rather, public data on site-level emissions can help communities better advocate for policies like buffer zones.

RECOMMENDATION

Increase interagency collaboration with communities to develop coordinated systems for monitoring, data analysis and visualization, and sharing of best practices on company, community and regulatory approaches.

In order to effectively establish a statewide monitoring network for all oil and gas production facilities, interagency coordination among relevant state and local agencies, as well as a clear delineation of roles, will be imperative. For example, if a local agency like SCAQMD updates or pursues regulations to include real-time monitoring at some or all production sites, then it should clearly communicate and work with California Air Pollution Control Officers Association (CAPCOA), the local Air Pollution Control Districts, and CARB to implement and socialize those requirements.

Separate from interacting with other government institutions, agencies must engage communities and involve them in all stages of development, implementation and evaluation in order to create a thorough oil and gas monitoring network. This includes agency engagement on research, planning, implementation, education and decision making about the development, funding and evaluation of monitoring policies. Partnering with local leaders and community-based organizations to enhance the effectiveness of education, decision making, policy implementation, and adaptation research and innovation is also key. Similarly, NGO, academic, public health and technology groups should be engaged to ensure that a diverse group of perspectives and areas of expertise are leveraged throughout any rulemaking process on monitoring.

It is important for agencies to foster enabling conditions for frontline communities early, on a continuous basis and via meaningful participation opportunities in the development of new policies and funding decisions. This overarching principle of collaboration and communication applies to all of the recommendations.

RECOMMENDATION

Follow Los Angeles County's lead and survey all oil and gas wells in the state of California.

Following the passage of a motion in 2016, the Los Angeles County Board of Supervisors was directed to convene an oil and gas Strike Team—comprised of the Planning Department, the Public Works Department and the Department of Public Health—to assess the conditions, regulatory compliance, proximity to homes, and potential public health and safety risks associated with existing oil and gas facilities in unincorporated Los Angeles County.[164] The motion led to an 18-month-long effort in which the Strike Team reported its findings to both the Board of Supervisors and to an expert advisory committee—culminating in a set of recommendations for the Board to follow. The analysis from the strike team underscores the need for similar efforts to be undertaken throughout California—even though they may require lengthy action.

The impacts of oil and gas operations on human health are not unique to Los Angeles residents; they are suffered throughout the state. As such, it is advisable for key state and local agencies in California, including county Boards of Supervisors, CARB and DOGGR to similarly convene Strike Teams of their own to conduct thorough analyses of each facility and evaluate its

location and proximity to people. Such a survey would help evaluate the state of current facility operating practices and deliver meaningful information on the public health risks associated with oil and gas operations. Additionally, a survey would help inform which policies and programs are in need of amendment, elimination or creation to ensure better protection of the environment and public health.

RECOMMENDATION

Ensure the SCAQMD Air Quality Sensor Performance Evaluation Center (AQ Spec) supports the development, testing and certification of monitors for pollutants regularly emitted by oil and gas sites.

The SCAQMD's AQ Spec is generally considered a leader in air quality monitoring sensor evaluation. The program is based on independent assessments of the quality, accuracy and capabilities of current sensor technology. However, the AQ Spec program currently focuses on sensors that detect criteria pollutants and particulates, but not those that detect oil and gas pollutants like methane and benzene. We therefore recommend that sensors that detect pollutants associated with oil and gas activity—including methane, the class of BTEX compounds, VOCs generally and reactive organic gases (ROGs)—be added to existing and future AQ Spec projects. To the extent that the AQ Spec program requires additional resources to accomplish this, those resources should be made available on an expedited basis.

RECOMMENDATION

Engage with oil and gas operators and technology providers with real world experience employing advanced monitoring strategies.

As with any new regulatory requirement, it is important for regulatory agencies and policy makers to understand the impact of their decisions on the regulated community. While the public health and associated economic impacts of the status quo system on local communities, as well as the economic benefits associated with avoiding local exposure to toxic air compounds and regional air quality damages, are documented, the overall cost of technology deployment for real-time stationary or episodic mobile monitoring is not yet well known. For example, recent advancements in technology coupled with learnings from limited field deployments at oil and gas sites may have brought down overall costs of deployment. Additionally, given the complexities of some production sites, it is possible that some monitoring deployments may be more infeasible (based on cost or engineering considerations) than others at a particular location.

In order to fully capture the range of issues, costs and benefits associated with real-time and mobile monitoring system deployment at oil and gas sites, state and local regulatory agencies should engage with oil and gas operators who are presently employing advanced monitoring strategies. Similar engagement should occur with monitoring system technology developers who have actually deployed systems in the field. By engaging with people and companies with real world experience, agencies in California can more fully understand the operational and cost considerations of monitoring system deployment in the interest of prioritizing technologies and approaches that achieve health and environmental benefits while also supporting feasible and cost-efficient industry implementation.

One recent example of the effectiveness of this approach occurred at a conference hosted by the SCAQMD in October 2017. At this conference, associated with the agency's AQ Spec, dozens of providers showcased new and emerging technology for real-time emissions detection and measurement, including some for methane emissions.

Notes and citations

With the exception of Steven Hamburg, all quotes in this document were collected during interviews conducted by EDF for the video series titled TechnologyForChange, available at https://www.edf.org/techforchange

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