CARB's Oil and Gas Methane Regulation
2018 Annual LDAR Summary

October 2020

California Air Resources Board

A. Key Findings

- During the first year of implementation of CARB's Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities[1] (Oil and Gas Methane Regulation), the leak detection and repair (LDAR) surveys resulted in a 29% reduction in emissions from components subject to the regulation (e.g., valves, flanges, and connectors).
- Total emission reductions were estimated to be ~5,400 metric tons methane, or ~140,000 metric tons CO_2e.[2]
- Less than 1% of the unique components surveyed were found leaking at or above the regulatory threshold of 10,000 ppmv.
- Approximately 20% of the leaks accounted for 50% of the emissions.
- The natural gas transmission sector had the largest ratio of leaks to components surveyed (2.09%), but the smallest number of components surveyed. The crude oil production sector had the largest number of components surveyed, but the smallest ratio of leaks to components surveyed (0.36%).
- Leaks were most commonly identified from connectors and valves, while open-ended lines had the highest estimated leak rates on average.

B. Background

As an early action measure to achieve the emission reductions required by the California Global Warming Solutions Act (AB 32), CARB adopted the Oil and Gas Methane Regulation to reduce methane emissions from oil and gas production, processing, storage, and transmission compressor stations. CARB's Oil and Gas Methane Regulation was adopted by the Board on March 23, 2017 and went into effect on January 1, 2018. Section 95669 requires owners/operators of oil and natural gas facilities[3] to conduct quarterly LDAR surveys to monitor components for leaks and repair detected leaks within a specified time frame. Quarterly LDAR inspections began on January 1, 2018, and operators are required to submit annual LDAR reports to CARB by July 1 of each calendar year.[4] The following information must be included in operators' annual LDAR reports:

1. Total number of components inspected
2. Total number of leaks identified per leak threshold category (10,000 to 49,999 ppmv, and 50,000 ppmv or greater)[5]
3. For each leak:
    a. Inspection date

[1] California Code of Regulations, Title 17, Division 3, Chapter 1, Subchapter 10 Climate Change, Article 4. Subarticle 13: Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities.
[2] CO_2e was calculated throughout the report using the 100-year global warming potential (GWP) of methane of 25.
[3] Including oil and gas production, processing, and storage; natural gas gathering and boosting stations; natural gas underground storage; and natural gas transmission compressor stations.
[4] The deadline for 2018 reporting was extended from July 1, 2019 to August 30, 2019 to allow for the Oil and Gas Methane Regulation module of the web-based reporting tool, Cal e-GGRT, to come online.
[5] After January 1, 2020, operators will also be required to report leaks ranging from 1,000 to 9,999 ppmv.

b. US EPA Method 21 instrument used
c. US EPA Method 21 instrument calibration date
d. Component type
e. Equipment ID for the equipment the leaking component is on, if applicable
f. Initial leak concentration
g. Repair date
h. Concentration after repair

This Annual LDAR Summary is based on data received from 69 operators who submitted 309 annual reports for LDAR activities that occurred during 2018.

The LDAR requirements in CARB's Oil and Gas Methane Regulation do not apply to all components in California; there are two key exemptions. First, components that are subject to local air district LDAR requirements that were in place prior to January 1, 2018 are exempt from LDAR requirements in CARB's Oil and Gas Methane Regulation because the regulation was intended to cover components that were not already subject to district LDAR requirements.[6] Second, components handling crude oil with an API gravity less than 20 are not subject to LDAR requirements due to their very low emissions levels relative to other components found in gas or other liquid service (less than 2% of all emissions from components subject to CARB's regulation).[7,8,9] Figure 1 shows the fraction of oil and gas components in California that are subject to CARB's regulation, are subject to local air district rules,[10] or handle heavy oil and are exempt from LDAR requirements.[11]

[6] Oil and Gas Methane Regulation, Section 95669(b)(1).
[7] Oil and Gas Methane Regulation, Section 95669(b)(2).
[8] ISOR, p. 55. https://ww3.arb.ca.gov/regact/2016/oilandgas2016/oilgasisor.pdf.
[9] 15-Day Notice Attachment 2. https://ww3.arb.ca.gov/regact/2016/oilandgas2016/oilgasatt2.pdf.
[10] There are eight local air districts with LDAR requirements for oil and gas facilities, including Bay Area Air Quality Management District (AQMD), Monterey Bay Air Resources District (ARD), San Joaquin Valley Air Pollution Control District (APCD), San Luis Obispo County APCD, Santa Barbara County APCD, South Coast AQMD, Ventura County APCD, and Yolo-Solano AQMD.
[11] Heavy oil is defined differently in different district rules, e.g., by API gravity, by flash point, by vapor pressure, or by evaporation percentage. For the purposes of Figure 1, heavy oil was defined as < 20 API gravity.

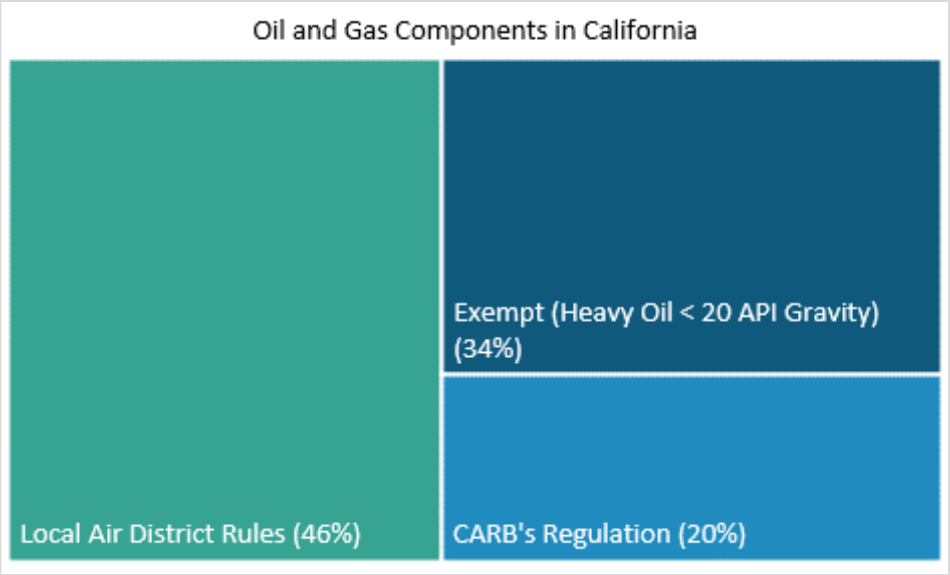

Figure 1: Breakdown of oil and gas components in California. Size of box corresponds to the percent of components in each category (shown in parentheses) based on data from CARB's 2007 oil and gas industry survey and the Oil and Gas Methane Regulation rulemaking.[12,13]

C. Summary of LDAR Data

CARB received 2018 LDAR reports from 69 operators for inspections at 309 facilities. During 2018 LDAR surveys, 1,970,710 unique components were surveyed[14] and 11,359 leaks were identified as greater than or equal to 10,000 ppmv (meaning that the ratio of leaks to components surveyed was 0.58%). Of the leaks found as part of the inspections, 11,288 were repaired or replaced, 37 were critical components[15] and were repaired at the next scheduled shutdown or within 12 months, whichever was sooner, and 34 were delays of repair at the time of reporting and were repaired or replaced within 30 calendar days from the allowed repair time period or by the anticipated repair date stated in the operator's approved delay of repair request. Delays of repairs are requested by operators who need to order specific parts or equipment to repair the leaking component. CARB staff tracks the delay of repair requests to confirm that repairs are completed according to the allowed timeline.[16]

CARB staff reviewed the data in the 2018 annual reports and found no widespread issues with operators' reported data. Issues encountered include conflicting inspection dates, conflicting repair dates, and incorrect initial or repaired leak concentrations. All discrepancies were

[12] ARB. (2013). Oil and Gas Survey. ARB 2007 Oil and Gas Industry Survey Results, Final Report, revised in October 2013.
[13] See footnote 9.
[14] Component surveys were repeated quarterly for a total of ~7.8 million component inspections.
[15] A critical component would require the shutdown of a critical process unit if that component was shutdown.
[16] The 71 critical component and delay of repair leaks were included in this report in Tables 1 and 2 and Figures 2 and 3, but not in estimates of emission reductions because those calculations require a concentration after repair.

corrected by CARB staff after following up with operators. During 2018, 0.67% of the reported leaks had potential errors identified that required CARB staff to follow up with operators and make necessary corrections. Of the facilities that reported LDAR data, 7.8% had discrepancies between the number of leaks recorded in the annual LDAR reports' two reporting tables, and 5.2% of all reported quarterly inspections listed incorrect inspection dates (i.e., dates were not in 2018). The validity of the data presented in this report is dependent on the accuracy of the data reported by operators. CARB acknowledges that there are potential limitations with data being self-reported; however, CARB staff conducted rigorous quality control checks to ensure the highest level of data integrity possible. Over time, as operators gain experience with the regulation, CARB staff anticipates a reduction in the prevalence of issues encountered during the first year of reporting.

Table 1 shows the LDAR survey leak distribution for 2018 broken down by oil and gas sector. The allowed leak threshold for 2018 and 2019 was 10,000 ppmv; on January 1, 2020, it decreased to 1,000 ppmv. Natural gas transmission had the largest ratio of leaks to unique components surveyed (2.09%), but the smallest number of components surveyed. Crude oil production had the largest number of components surveyed, but the smallest ratio of leaks to unique components surveyed (0.36%). Figure 2 shows the number of leaks identified in 2018 by component type; connectors and valves had the most leaks of the component types.

Table 1: Components Found Leaking by Sector in 2018

Sector	Total Count of Components in LDAR Program[17]	Number of Leaks in Each Category[18]		Number of Leaks/ Component Count in LDAR Program (%)
		10,000 to 49,999 ppmv	50,000 ppmv or greater	
Crude Oil Production	1,131,913	2,974 (0.26%)	1,077 (0.10%)	0.36%
Natural Gas Production	346,031	2,337 (0.68%)	0 (0%)	0.68%
Natural Gas Storage	392,329	1,940 (0.49%)	931 (0.24%)	0.73%
Natural Gas Transmission	100,437	1,138 (1.13%)	962 (0.96%)	2.09%
Total	1,970,710	8,389 (0.43%)	2,970 (0.15%)	0.58%

[17] These counts include the physical number of components that were surveyed four times throughout the year.
[18] A component could have been found to be leaking during a quarterly inspection and been repaired or replaced within the required time period, but may have been measured as leaking again during a subsequent quarterly inspection, resulting in one component accounting for more than one leak.

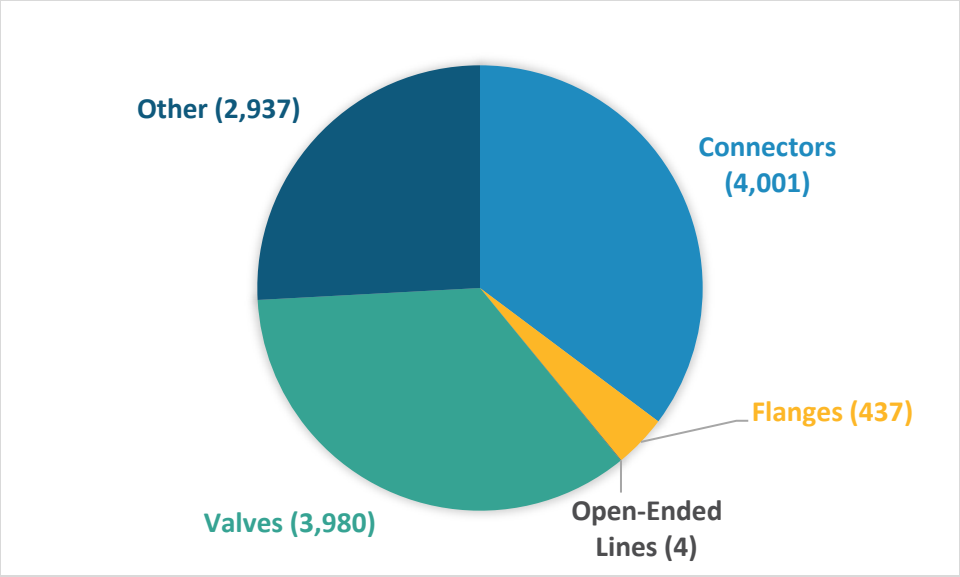

Figure 2: Number of leaks identified in 2018 by component type. The "other" component category includes gas regulators, pressure gauges, pressure relief devices, flow and pressure meter fittings, pneumatic devices, compressor vents, temperature controllers, stuffing boxes, and inactive flare pilots.

CARB staff estimated emissions from the reported leaks using correlation equations developed by Sage.[19] Estimated methane leak rate statistics by component type are shown in Table 2. On average, open-ended lines had the highest leak rates, although they accounted for only four leaks total. The mean leak rate from all components was 0.056 kg CH_4/hr.

Table 2: Methane Leak Rate Statistics by Component Type[20]

	All Components	Connector	Flange	Open-Ended Line	Valve	Other[21]
Min (kg CH_4/hr)	0.008	0.008	0.008	0.093	0.021	0.029
Max (kg CH_4/hr)	1.085	0.178	0.150	0.168	0.864	1.085
Mean (kg CH_4/hr)	0.056	0.020	0.021	0.123	0.070	0.091
Median (kg CH_4/hr)	0.037	0.015	0.018	0.116	0.064	0.096

[19] Air Resources Board IFB No. 13-414: Enhanced Inspection & Maintenance for GHG & VOCs at Upstream Facilities, Sage ATC Environmental Consulting LLC, revised November 2019.
[20] Leak rates were converted from total hydrocarbons assuming a methane composition of 89.2% based on data from the Sage study (see footnote 19).
[21] The max leak rate of 1.085 kg CH_4/hr was on a stuffing box.

Figure 3 shows the cumulative leak emission distribution from 2018, which demonstrates that ~20% of leaks accounted for 50% of estimated emissions from leaking components. This demonstrates that a relatively small number of sources contributed to a significant portion of the emissions, as has been demonstrated in previous studies of oil and gas facilities.[22,23]

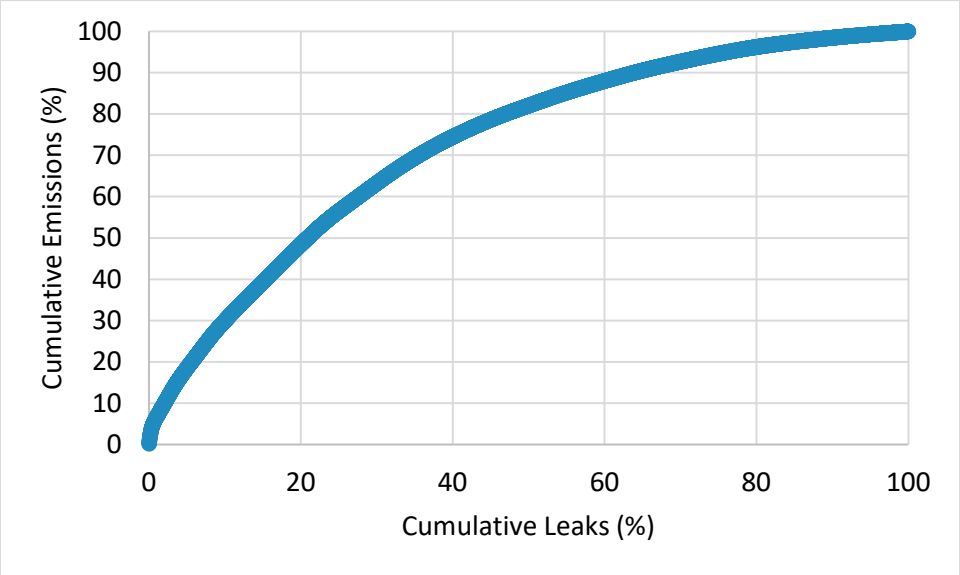

Figure 3: Fraction of cumulative emissions versus cumulative leaks based on LDAR data for 2018.

Emission reductions were estimated by assuming that a leak would have continued unabated for a year without the LDAR program. Total emission reductions from the 2018 LDAR surveys were estimated to be ~5,400 metric tons methane, or ~140,000 metric tons CO_2e.[24] CARB staff also estimated baseline 2018 emissions from all components subject to the regulation in order to evaluate the percent emission reductions from 2018 LDAR surveys. Operators are not required to report concentration data for components measured to be below the leak threshold (10,000 ppmv); therefore, emissions from these "non-leaking" components were estimated by assuming a leak rate equal to the average post-repair leak rate of all leaking components. Similar to emission reductions, baseline emissions from leaks were estimated by assuming that leaks would have persisted for a year without the LDAR program. The combined total baseline emissions from leaking and "non-leaking" components subject to quarterly LDAR surveys for CARB's Oil and Gas Methane Regulation during 2018 was estimated to be ~19,000

[22] Allen, D. (2016). Emissions from oil and gas operations in the United States and their air quality implications. *Journal of the Air & Waste Management Association*, 66:6, 549-575. DOI: 10.1080/10962247.2016.1171263.
[23] Brandt et al. 2016. Methane Leaks from Natural Gas Systems Follow Extreme Distributions. *Environmental Science & Technology*, 50:22, 12512-12520. DOI: 10.1021/acs.est.6b04303.
[24] ~390,000 metric tons CO_2e using the 20-year GWP of methane of 72.

metric tons methane,[25,26] or ~480,000 metric tons CO_2e.[27] Based on those calculations, 2018 LDAR surveys resulted in a 29% reduction in emissions from components subject to the regulation.

Leak data broken down by local air district and owner/operator are shown in Appendix A. Figures A-1 and A-3 show emission reductions from each sector (crude oil production, natural gas production, natural gas transmission, and natural gas storage), and Figures A-2 and A-4 show the ratios of leaks to components surveyed for each sector.[28] San Joaquin Valley Air Pollution Control District (APCD) had the highest emission reductions, with the majority coming from the crude oil production sector (Figure A-1). For all the local air districts with natural gas transmission facilities, the transmission sector had the highest ratios of leaks to components surveyed of the four sectors (Figure A-2). The owner/operator with the highest emission reductions was California Resources Corporation, followed by Pacific Gas and Electric (PG&E) and Southern California Gas Company (SoCalGas) (Figure A-3). The owners/operators with the highest ratios of leaks to components surveyed were SoCalGas, PG&E, and Longbow; similar to the local air district data, natural gas transmission had relatively high leak ratios compared to the other sectors (Figure A-4).

D. Conclusions

The first year of LDAR surveys for CARB's Oil and Gas Methane Regulation was 2018. In total, the ratio of leaks found with concentrations greater than or equal to 10,000 ppmv to the number of unique components surveyed was 0.58%. The natural gas transmission sector had the largest ratio of leaks to components surveyed (2.09%), but the smallest number of components surveyed. The crude oil production sector had the largest number of components surveyed, but the smallest ratio of leaks to components surveyed (0.36%). Leaks were most commonly identified from connectors and valves, while open-ended lines had the highest estimated leak rates on average. Total emission reductions were estimated to be ~5,400 metric tons methane, or ~140,000 metric tons CO_2e.[29] Based on estimates of total emissions from components subject to the regulation (~19,000 metric tons methane), the LDAR surveys resulted in a 29% reduction in emissions for the first year of program implementation.

[25] Converted from total hydrocarbons assuming a methane composition of 89.2% based on data from the Sage study (see footnote 19).
[26] Leaking and "non-leaking" components accounted for ~5,500 and ~13,600 metric tons methane, respectively.
[27] ~1,400,000 metric tons CO_2e using the 20-year GWP of methane of 72.
[28] The ratio metric in this report should not be compared to the "% of total inspected" metric in Tables 1 and 3 of CARB's Oil and Gas Methane Regulation. Tables 1 and 3 pertain to single inspections of a group of components during district or CARB inspections; the ratios in this report represent four inspections of a group of components during operator inspections. The ratio metric also should not be compared to the loss rate used in the Oil Production Greenhouse gas Emissions Estimator (OPGEE).
[29] ~390,000 metric tons CO_2e using the 20-year GWP of methane of 72.

Appendix A:
LDAR Data by Local Air District and Owner/Operator

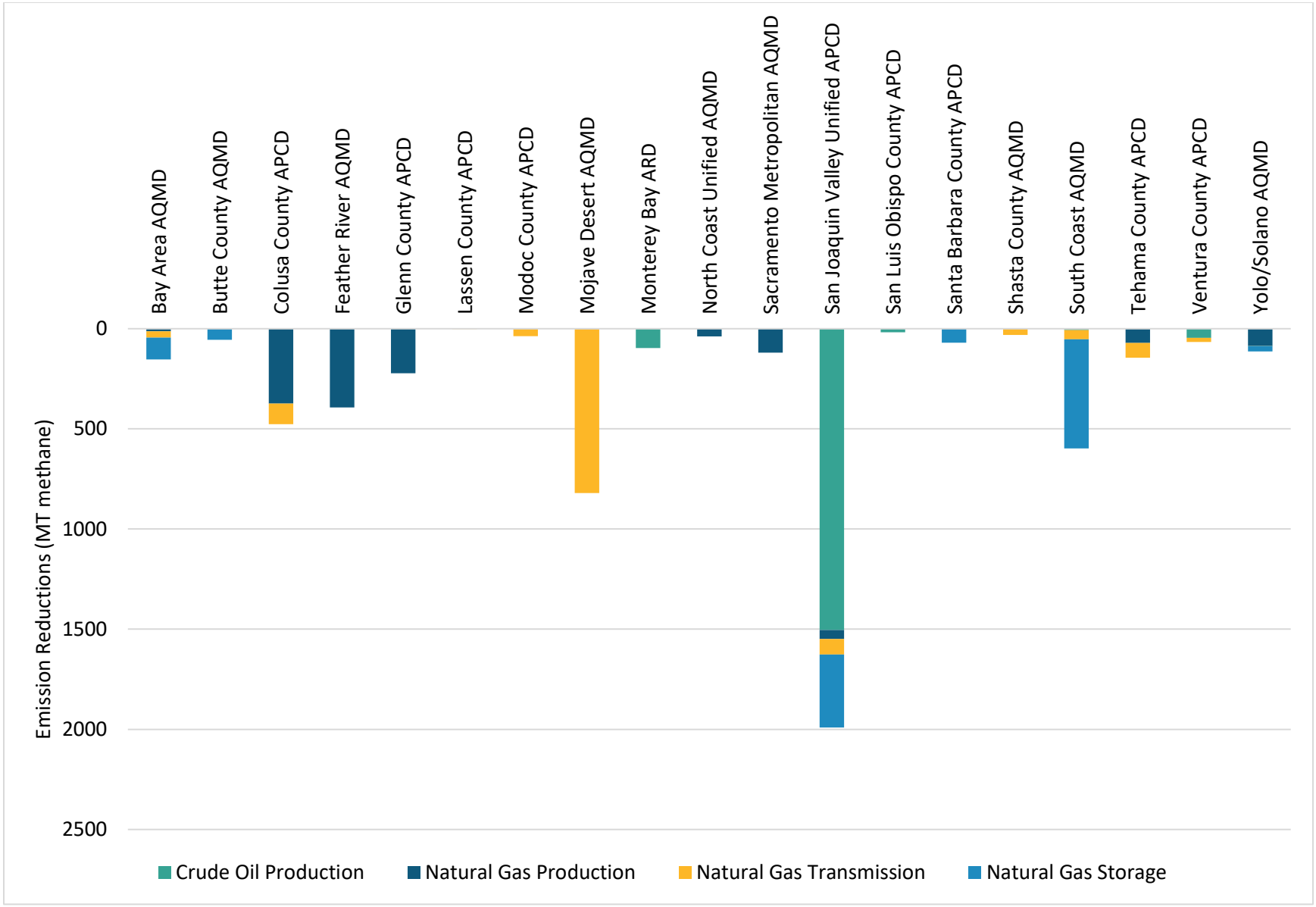

Figure A-1: Emission reductions from each sector by local air district during 2018.

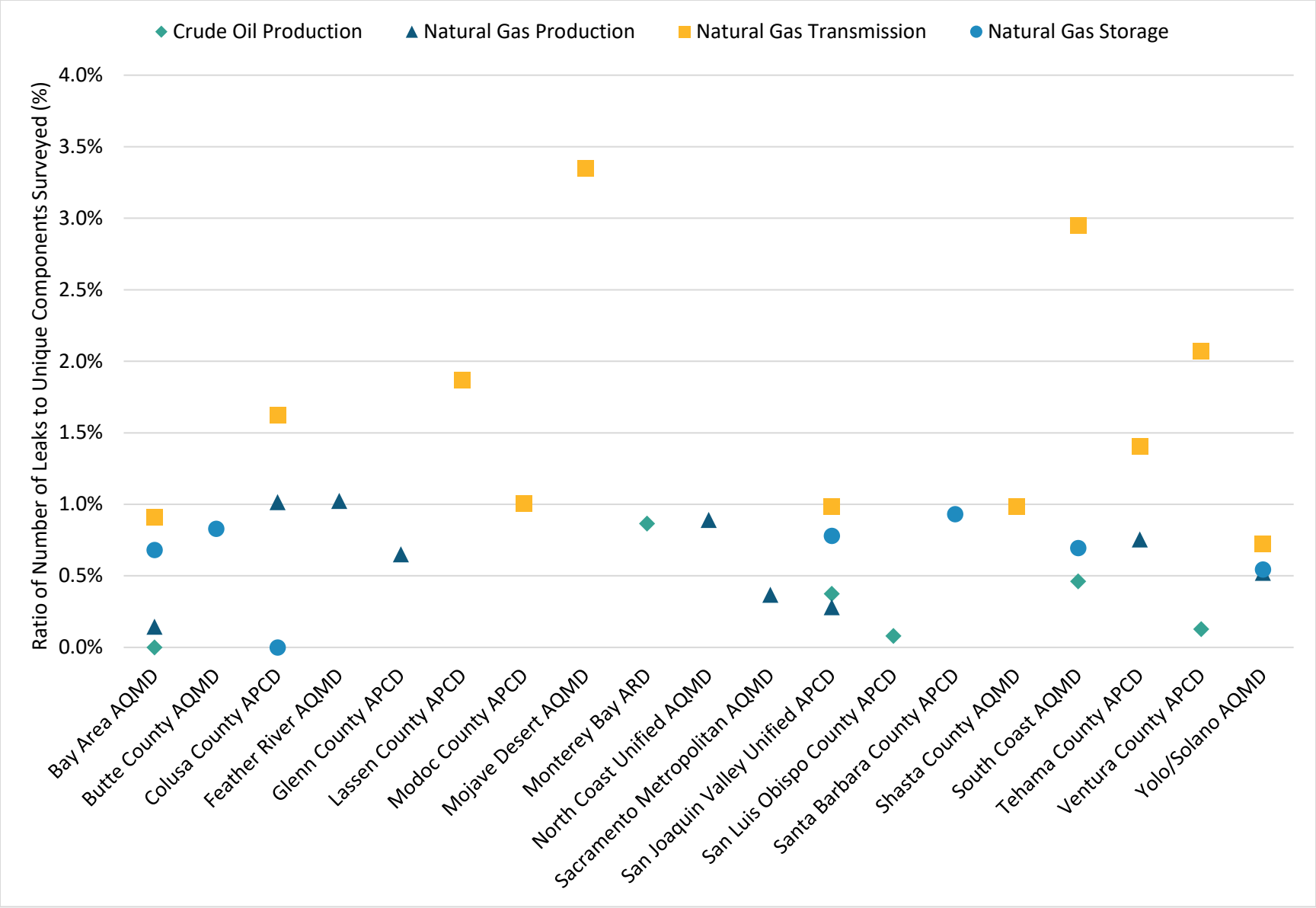

Figure A-2: Ratios of numbers of leaks to numbers of unique components surveyed for each sector by local air district during 2018.

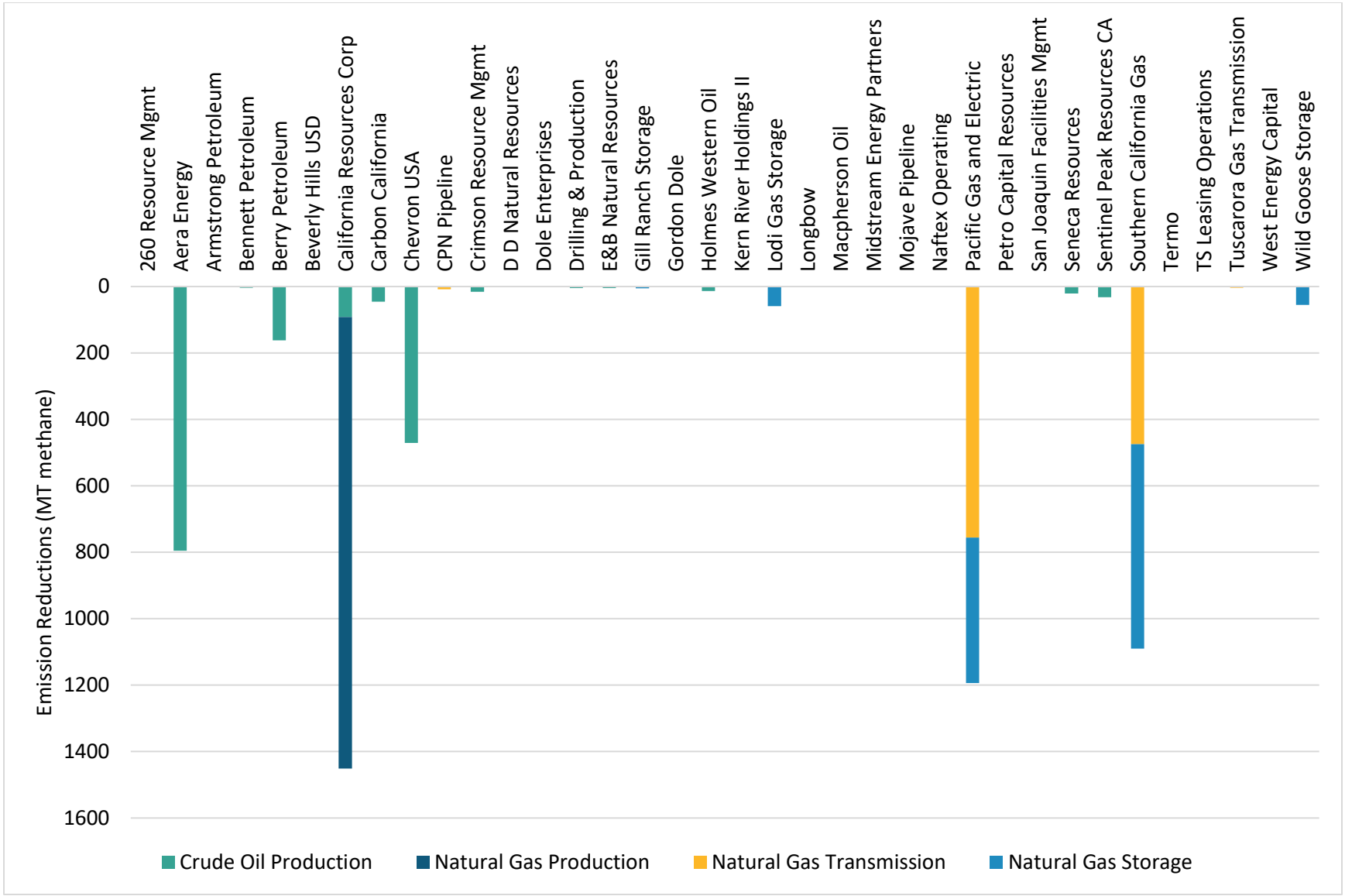

Figure A-3: Emission reductions from each sector by owner/operator during 2018. Of the 69 operators who conducted quarterly LDAR surveys, 33 did not measure any leaks at or above 10,000 ppmv and are therefore not shown here.

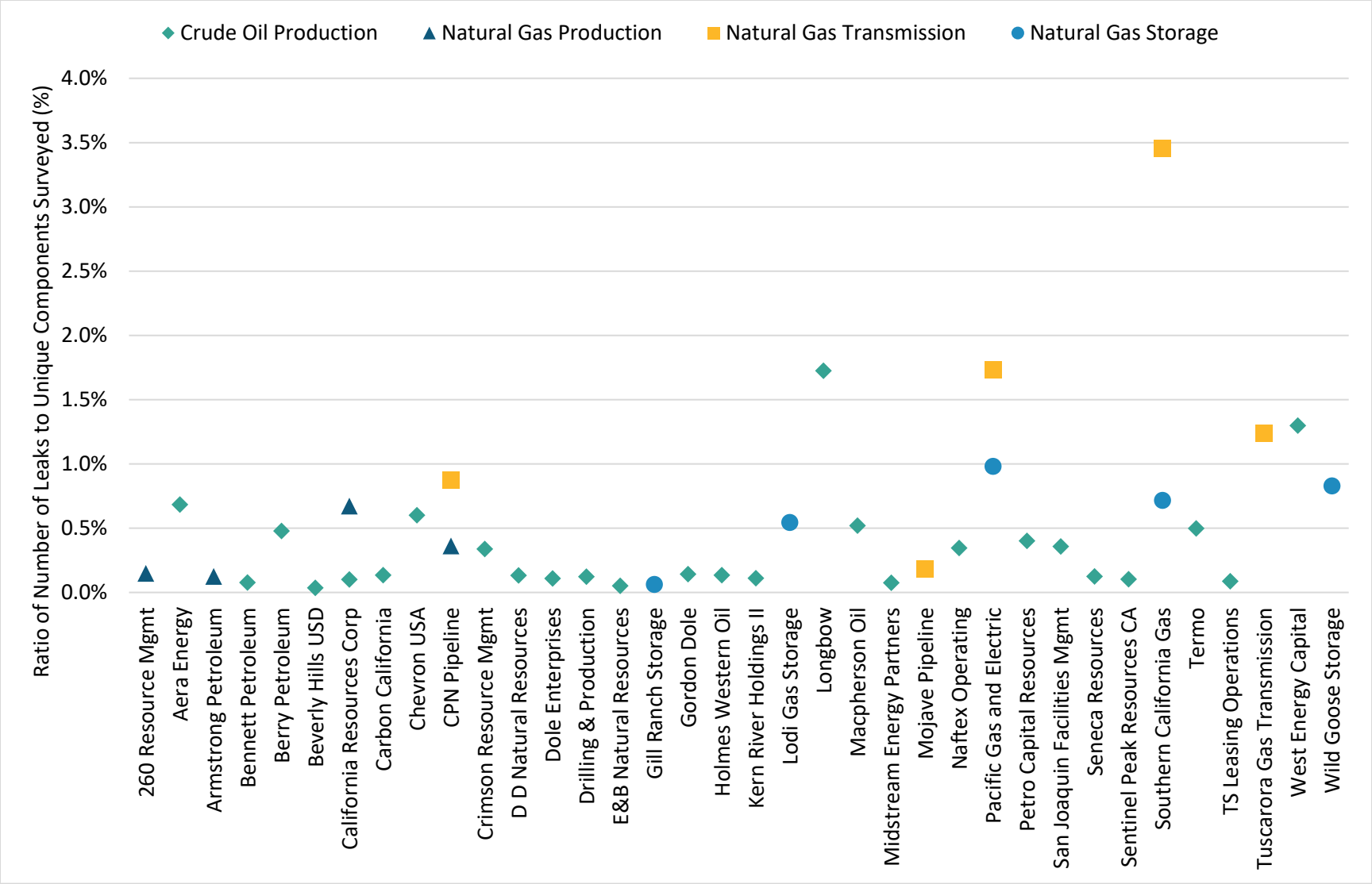

Figure A-4: Ratios of numbers of leaks to numbers of unique components surveyed for each sector by owner/operator during 2018. Of the 69 operators who conducted quarterly LDAR surveys, 33 did not measure any leaks at or above 10,000 ppmv and are therefore not shown here.