Appendix D

Impact of survey frequency on emissions mitigation at oil and gas sites

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Methane mitigation at oil and gas production sites is strongly influenced by optical gas imaging (OGI) based leak detection and repair (LDAR) survey frequency. In this analysis, we simulate emissions mitigation achieved under annual, semi-annual, and quarterly LDAR surveys using OGI-based technologies at natural gas production well sites. The simulations are performed using the Fugitive Emissions Abatement Simulation Toolkit, FEAST, developed at Stanford [1]. FEAST is a dynamic simulation tool that models the evolution of leaks over time at natural gas facilities. It takes as input parameters data on model well-site specifications (e.g., component counts), leak detection technology, survey protocol, and cost-estimates. As done in EPA's own analysis of the OOOOa rule [2], the simulation is run for 8 years with capital cost distributed evenly at 7% interest rate. Using this model, we can estimate emissions mitigation under different policy scenarios, emissions profiles, and technologies used to detect methane leaks [3]. In order to make meaningful comparisons to U.S. EPA's regulatory analysis, all model assumptions used here are identical to those found in the Technical Support Documents from the OOOOa rule [4]. This includes details of the model gas well-site, component counts, baseline emissions, cost of OGI-based LDAR surveys, and repair cost. The main difference between EPA assumptions and this model are two-fold:

1. Although average per-site emissions are set to EPA baseline emissions of 5 metric tons per year (5.5 short tons per year), component-level leaks are populated from publicly available peer-reviewed research data (see [5, 6, 7]). Notably, EPA's baseline per-site emissions are likely significantly underestimated, as they are based on emissions inventories that are 38% lower than estimates for oil and gas sector methane emissions in the latest peer-reviewed analysis. [8]
2. The effectiveness of OGI-based LDAR surveys in detecting methane emissions is modeled as a cumulative normal distribution based on empirical field data collected at the Methane Emissions Testing and Evaluation Center (METEC) at Fort Collins, CO [9]. In other words, OGI leak detection was based on testing a camera operator with a series of single-blind controlled releases at METEC.

Figure 1 shows the emissions mitigation percentage achieved at natural gas well sites using OGI-based LDAR surveys at annual, semi-annual, and quarterly survey frequencies.

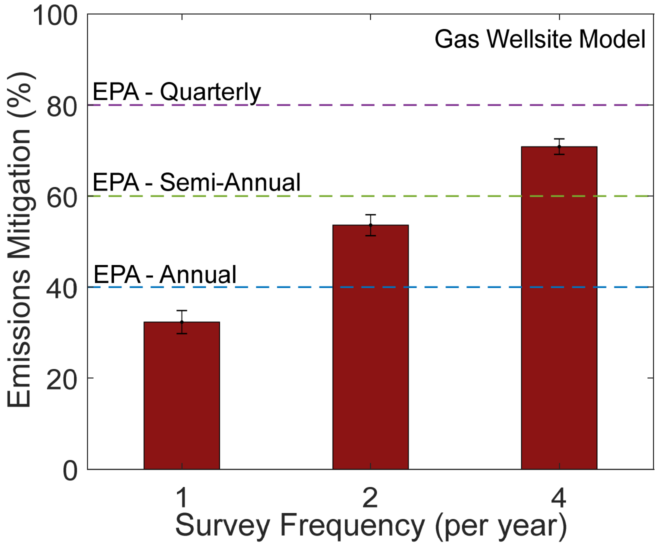

Figure 1: Emissions mitigation at natural gas well sites using OGI-based LDAR at annual (1/year), semi-annual (2/year), and quarterly (4/year) LDAR surveys. The dotted lines at 40%, 60%, and 80%, show the EPA-assumed mitigation effectiveness of OGI-based LDAR surveys at annual, semi-annual, and quarterly survey frequencies.

A few important insights can be noted:

1. Emissions mitigation substantially increases from about 32% at annual OGI survey frequency to about 54% at semi-annual OGI survey frequency—showing that semiannual LDAR reduces about 2/3 more emissions than annual LDAR. These percentages are in the range of those used by EPA, and support the reasonableness of EPA's estimates.
2. While the emissions mitigation percentages achieved at annual, semi-annual, or quarterly OGI-based LDAR surveys are slightly lower under our model than EPA estimates, actual emissions reductions achieved at each of these frequencies are likely higher than EPA estimates, because EPA-estimated per-site baseline emissions are likely significantly lower than actual per-site emissions, as discussed above. The variances in emissions mitigation percentage estimates between our model's estimates and EPA's estimates arises because our OGI-based detection technology model is empirically derived from realistic measurements at the METEC test site in Fort Collins, CO – the camera performance is more conservative in the real-world compared to EPA assumptions.

   We have also modeled the effect of environmental conditions and survey protocols on the effectiveness of OGI-based leak detection [10]. While ambient temperature and humidity does affect performance, the biggest impact on leak detection effectiveness comes from two factors: imaging distance and gas composition. We show that that minimum detectable leak rate can increase by almost two orders of magnitude in moving from 5 ft to 50 ft imaging distance [9]. Finally, the presence of higher molecular weight hydrocarbons (ethane, propane) will decrease the minimum detection limit by up to 3 times compared to a pure methane gas.

Table 1: Summary of costs and benefits of OGI-based LDAR regulation at natural gas well sites at annual and semi-annual LDAR survey frequency.

Costs and Benefits	**Annual Survey Frequency**		**Semi-Annual Survey Frequency**	
	This Model	**EPA estimate**	**This Model**	**EPA estimate**
Baseline Emissions (short tons per yer)	5.5	5.5	5.5	5.5
Annual LDAR cost ($/year)	**$ 1045**	**$ 1318**	**$ 1723**	**$ 2285**
Total CH4 mitigation (short tons per year)	2.0	2.2	3.0	3.3
CH4 cost effectiveness ($/ton)	$ 581	$ 600	$ 575	$ 693
Recovery Credits* ($/year)	$ 450	$ 510	$ 684	$ 764
Annual cost with recovery credits ($/year)	$ 595	$ 809	$ 1039	$ 1521
Net Mitigation Cost ($/ton)	**$ 298**	**$ 368**	**$ 346**	**$ 461**

*Recovery credits are based on a natural gas price of $4/Mscf and natural gas is 82.9% methane.

Table 1 gives the summary of costs and benefits of OGI-based LDAR regulation at oil and gas sites. As modeled in the previous section, many of the input assumptions follow EPA guidelines in the technical support document to the NSPS OOOa regulations [4]. This includes OGI survey cost ($600/site/survey), fixed capital costs of compliance, labor costs, and repair costs. Even the price of gas is assumed to be $4/Mscf, following EPA assumptions. Our modeling results show that semi-annual OGI-based LDAR survey results in net mitigation cost of $346/ton, lower than the net mitigation of cost of $368/ton estimated by EPA at **annual** survey frequency**.** Why does semi-annual survey results in a lower net cost in our model compared to EPA's assumptions on annual survey? This is because although the one-time costs and recurring survey costs are identical between our model and EPA analysis, the repair costs are much lower in our model. EPA used the percentage of components found leaking to calculate repair costs.[1] In estimating repair and resurvey costs, EPA assumes that 1.18% of all components are found to be leaking using OGI technology [4]. However, several recent studies suggest different leak rates. The Fort-Worth Air Quality Study surveyed and quantified thousands of leaks at production well sites using both Method-21 and OGI, and showed that only 0.175% of all components were found leaking using OGI. The data in that study also confirm that there is no relationship between site-level emissions and the percent of leaking components [5] [11]. Another recent study in California found only 0.22% of components to be leaking using OGI based surveys [6]. Evidence from speaking with operators also suggest that EPA has over-estimated repair costs,

[1] Notably, while EPA raises concerns about the percentage of leaking components it used in its recent proposal to weaken the LDAR requirements in the OOOOa rule, 83 Fed. Reg. at 52,064, the agency misstates the effect of changing the percentage of leaking components on its analysis in that proposal, because as the agency later acknowledges in its Technical Support Document for the proposal that "since we utilize the average emissions factors [for determining site-level emissions]… the emissions are not affected by any changes in the percent leaking values used" and "the *only* effect the percent leaking has on the cost of control is due to a change in the cost of repairs." U.S. EPA, "Background Technical Support Document for the Proposed Reconsideration of the New Source Performance Standards 40 CFR Part 60, subpart OOOOa" (2018) at p. 63.

which in many cases consists of simple maintenance procedures such as tightening valves or closing thief hatches [3].

The main take-aways from this cost analysis are as follows:

1. OGI-based LDAR has an effectiveness similar to the effectiveness EPA assumed in the 2016 Rule and the 2018 proposal, particularly for semi-annual monitoring.
2. OGI-based LDAR costs are 21% and 25% lower for annual and semi-annual surveys in our model compared to EPA estimates, because of lower repair and resurvey costs. The survey cost and one-time costs for reporting and compliance are identical.
3. The cost-effectiveness of methane mitigation at **semi-annual** survey frequency is $ 575/ton of methane mitigated, lower than the $ 600/ton estimated by EPA for **annual** surveys. These cost-effectiveness numbers are based on EPA's model plant emissions, though, values reflecting field data would likely show better (lower) cost-effectiveness n umbers.

Using economic and model plant parameters from EPA's own analysis but using updated OGI detection effectiveness and leak-size distributions, we show that semi-annual surveys will result in higher emission reductions at lower cost compared to EPA's estimate for annual OGI-based LDAR surveys.

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