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Drone Study of Methane Emission Rates from Natural Gas Facilities

International Emissions Inventory Conference
Sept. 28, 2023
Seattle, WA

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Purpose of the Study

- To measure methane emissions rates from Engines, Dehydrators, and Tanks at Natural Gas facilities.
- To compare the measured methane emission rates to available methane emission factors used in calculating annual methane emissions.
- To evaluate the level of agreement between measured emission rates and available emission factors.

Scope of Study

- 15 NG facilities agreed to participate in the study.
  - Facilities located in eight different counties
  - 13 different operators between the 15 facilities
- Facilities were surveyed once per quarter for four consecutive quarters starting in May of 2021.
- Surveys were scheduled in advance.
- Surveys took approximately 1-2 hours per site.

Conducting a survey

- Scientific Aviation was contracted by the Department to fly the drone, analyze the collected data, and calculate a methane emission rate.
- Drone was operated by licensed pilot at all times during the survey.
- Flight path of drone was determined by wind direction, location of equipment at the site, other obstacles (trees, power lines) around perimeter of the site.

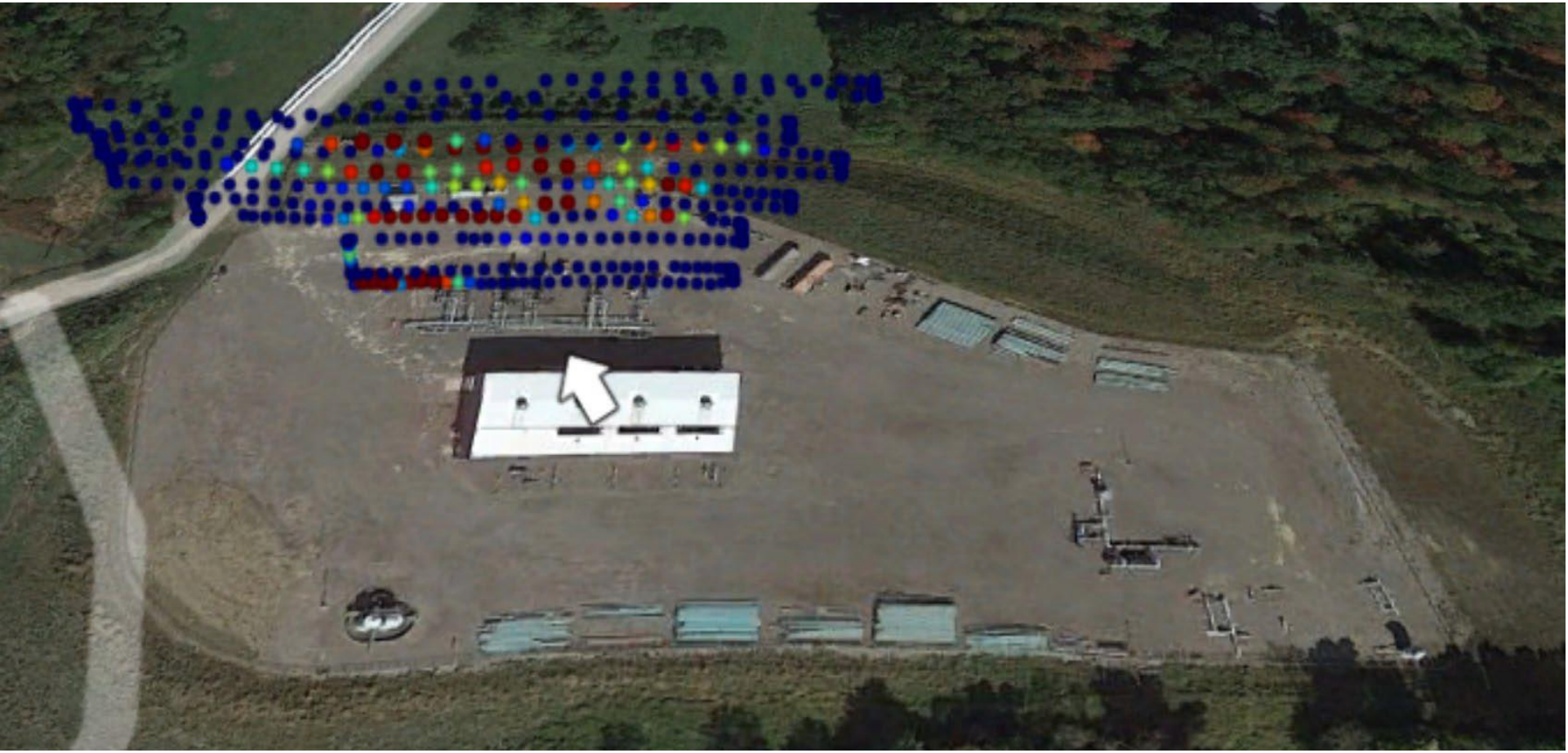
DJI Matrice 600 Pro

Example Site

Drone Flight Path

- Drone would fly down-wind of equipment it was surveying.
- First pass would be approximately 10 feet high and as wide as needed to capture the entire plume.
- Each pass went up by approximately 10 ft increments until no more methane was being detected.

Example Heat Map



Ideal Survey Conditions

- At least 10 passes completed by drone.
- Wind speed between 2 and 10 m/s. Need enough wind to move the plume but too much wind is unsafe for drone flight.
- Deviation of the wind direction less than 45° so the drone can be "downwind" of the equipment being surveyed.
- Be able to isolate plumes from different equipment types


Actual Survey Conditions

- Usually at least 10 passes completed by drone, learning curve for pilot during 2nd round.
- Wind speed between 2 and 10 m/s. Very low wind speeds during second round.
- Deviation of the wind direction less than 45°. The lower wind speeds usually had higher deviations.
- Approximately half of surveys was able to isolate plumes from different equipment types


Post Survey Results Provided

- Estimated CH4 emission rate (lb/hr)
- Estimated CH4 uncertainty rate (lb/hr)
- Number of passes completed by drone during survey
- Avg. wind speed and direction during survey
- Minimum and Maximum altitude of survey
- Deviation of wind speed and direction during survey.

Engine Emission Factors

- Sites involved in this study used a variety of emission factors for calculating estimated annual engine methane emissions:
  - 1.25 lb/mmbtu (AP-42, Table 3.2-1)
  - .001 kg/mmbtu (40 CFR 98 Subpart C, Table C-2)
  - 5.36 g/bhp*hr (Manufacturer's data)
  - 21.7 lb/hr (company stack test)


2021 Methane Emission Estimate Submissions

Site	Engine #	Engine Model	Op. Hrs.	Throughput (MMBTU)	CH4 Emissions (Tons)	EF
A	101	G3516B	8126	72472	0.08	.001 kg/mmbtu
B	101	G3516B	7650	87198	54.50	1.25 lb/mmbtu
C	101	3608LE	7993	142694	111.72	5.36 g/bhp*hr
D	104	3608LE	6965	124465	0.14	.001 kg/mmbtu
E	101	3606	4450	52518	38.48	21.7 lb/hr
F	101	3606	8234	111237	0.12	.001 kg/mmbtu

Site Reporting Results - Engines

- Sites ranged in reported emission rates from combined site engines from .022 to 218.9 lb/hr. (2019-2021 reporting)

- Reporting results provided in tables two and three assume all engines in operation.

Survey Results - Engines

- Sites ranged in measured emission rates from combined site engines from 15.2 to 194.3 lb/hr.
- Sites varied in the number of engines on site from one to twelve, but not all engines were in operation at all times during the surveys.


Reported vs. Measured - Engines

Emission Factor	Reported Engine total emission rate (lb/hr)	Drone Survey Engine total emission rate (lb/hr)
1.25 lb/mmbtu	44.01	18.77
.001 kg/mmbtu	0.25	72.10
.001 kg/mmbtu	0.23	81.43
.001 kg/mmbtu	0.075	58.93
.001 kg/mmbtu	0.022	15.2
5.36 g/bhp*hr	192.68	59.05
21.7 lb/hr	103.8	47.07
.001 kg/mmbtu	0.092	17.1
.001 kg/mmbtu	0.264	41.8
5.36 g/bhp*hr	218.89	83.77
.001 kg/mmbtu	0.25	194.3
1.25 lb/mmbtu	146	33.45
.001 kg/mmbtu	0.22	133.1

Study Results

- Measured emission rates do not match in magnitude some of the reported emission rates.
- Additional surveys necessary to decrease uncertainty in measured values.
- Process very dependent on wind conditions and site geometry. If additional surveys, will need to modify number and location of sites.

Table C-2

Table C-2 to Subpart C of Part 98 - Default CH_4 and N_2O Emission Factors for Various Types of Fuel

Expand Table

Fuel type	Default CH_4 emission factor (kg CH_4/mmBtu)	Default N_2O emission factor (kg N_2O/mmBtu)
Coal and Coke (All fuel types in Table C-1)	1.1×10^{-02}	1.6×10^{-03}
Natural Gas	1.0×10^{-03}	1.0×10^{-04}
Petroleum Products (All fuel types in Table C-1)	3.0×10^{-03}	6.0×10^{-04}
Fuel Gas	3.0×10^{-03}	6.0×10^{-04}
Other Fuels - Solid	3.2×10^{-02}	4.2×10^{-03}
Blast Furnace Gas	2.2×10^{-05}	1.0×10^{-04}
Coke Oven Gas	4.8×10^{-04}	1.0×10^{-04}
Biomass Fuels - Solid (All fuel types in Table C-1, except wood and wood residuals)	3.2×10^{-02}	4.2×10^{-03}
Wood and wood residuals	7.2×10^{-03}	3.6×10^{-03}
Biomass Fuels - Gaseous (All fuel types in Table C-1)	3.2×10^{-03}	6.3×10^{-04}
Biomass Fuels - Liquid (All fuel types in Table C-1)	1.1×10^{-03}	1.1×10^{-04}

Note: Those employing this table are assumed to fall under the IPCC definitions of the "Energy Industry" or "Manufacturing Industries and Construction". In all fuels except for coal the values for these two categories are identical. For coal combustion, those who fall within the IPCC "Energy Industry" category may employ a value of 1g of CH_4/mmBtu.

Information I can get you if you are interested

1. All the Drone Specs
2. Data results from the Dehy's and Tanks
3. Details about the intricacies and limitations of the drone flights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