A TALE OF TWO RECONCILIATIONS: RECENT EXPERIENCES FROM CONDUCTING 'TOP-DOWN' METHANE MEASUREMENT

Accurate measurement of methane is the basis upon which real reductions in emissions can be achieved, by focusing resources where they will have greatest impact. Moreover, accurate reporting is critical if these efforts can be confidently demonstrated.

New frameworks for reported measured methane emissions such as those developed by the Oil and Gas Methane Partnership 2.0 (OGMP2.0) identify different types of measurement [1]. Those used for reporting emissions are colloquially referred to as 'Bottom-Up' and comprise an aggregation of all known sources on a site. Bottom-up measurements satisfy the expectations of OGMP2.0 Level 4 reporting and may include components such as flaring, venting, fired equipment and fugitives. Level 5 of OGMP2.0 reporting introduces an additional step of measurement taken at the site level as a verification that reporting is accurate. Measurements of this kind are colloquially referred to as 'Top-Down'. Comparison of bottom-up and top-down data is often referred to as the process of reconciliation.

OGMP2.0 does not specify 'how' top-down measurements should be performed. However, the framework does require that the top-down method be able to quantify at emission rates commensurate with those reported and both types of measurement must be accompanied with an estimate of uncertainty [2], without which quantitative comparison is not possible. Reconciliation should not be considered a one-off exercise but should be scheduled as a process of continuous improvement where the fit between reported and verification measurements should improve with each reporting cycle.

In this paper we present recent measurements taken in preparation for Level 5 reporting conducted at two complex oil and gas sites. Both measurements utilise the same methane spectrometer mounted on different types of drones.

Site 1 is a large offshore facility producing both oil and gas. It is located approximately 60 nautical miles offshore. Known emissions from the site comprise incomplete combustion from flaring, engine slip from gas turbine power generation and fugitive emissions. Emissions vary, but are typically <25 kg/hour as estimated with current reporting methodology. At current levels of production and reporting methodology, methane intensity (emissions relative to marketed gas) is ~0.2%.

Site 2 is an onshore gas and oil processing facility. All hydrocarbons are imported and exported by pipeline. Known emissions from the site comprise incomplete combustion from flaring, engine slip from gas turbine power generation and compressors, other fired equipment (e.g. oil heaters), fugitives emissions and discontinuous process vents. Emissions vary but are typically <100 kg/hour. At current levels of throughput and reporting methodology, methane intensity is ~0.02%.

Both sites are typical of their kind, sufficiently large and of distinct design and operation that for Level 5 reporting and reconciliation they can be each treated as a population of one - where they contribute material emissions relative to the operator portfolio and could be reasonably expected to be reconciled individually and not form part of a population-based study.

Methods

Reported Emissions

Reconciliation requires time specific data for the reported emissions that can be compared to the precise time and date of the top-down survey. Production related emissions including those from flares, turbines and heaters were obtained from gas flow rate figures retrieved from the data historian (Pi) for the corresponding hour at which top-down measurements were taking place, using the mean average of one-minute increments. Uncertainty in gas flow was taken from the calibration certificates of the flow meters. Conversion to methane emission rates used United Kingdom EEMS emission factors [3]. For calculated fugitive emissions the annualised estimate was converted into an hourly emission rate. No uncertainty was assigned to emission factors. The combined uncertainty was estimated in accordance with the GUM [4].

Top-Down Measurements – methane sensor

Top-down measurements were conducted using a SeekIR methane sensor which operates on the principle of tuneable diode laser absorption spectroscopy (TDLAS) [5]. In-flight limits of detection of the sensor are 150 ppbv and 40ppbv against atmospheric background levels of methane for the closed cavity (fixed-wing sensor) and open cavity (quadcopter sensor), respectively. The method of methane emissions quantitation is based upon the application of a mass balance equation using methane concentration, wind, and location data, resulting in an accurate and deterministic estimate of the mass flow rate of methane for the area of interest. The limit of quantitation and uncertainty of both methods have been determined through controlled release experimentation [6]. Emissions of >1kg/h are quantifiable with a relative uncertainty of 16% (32% at the 95% confidence interval k=2).

Top-Down measurements

For site 1 offshore measurements, the SeekIR sensor was mounted on a fixed-wing autonomous aircraft. The flight was mobilized directly from shore and required no additional equipment or personnel on the offshore platform.

The fixed wing aircraft was flown at a constant radius from the from the survey center-point and is approximately 250 metres from the site's furthest point. The survey started at the set radius from the asset at the highest sampling altitude. The aircraft descended in a constant radius spiral from the maximum altitude, ~210 meters (700 feet) above ground level (AGL), stepping down at a consistent vertical step of 10 metres to the lowest altitude, around 30 metres (100 ft) AGL. The aircraft was flown at a

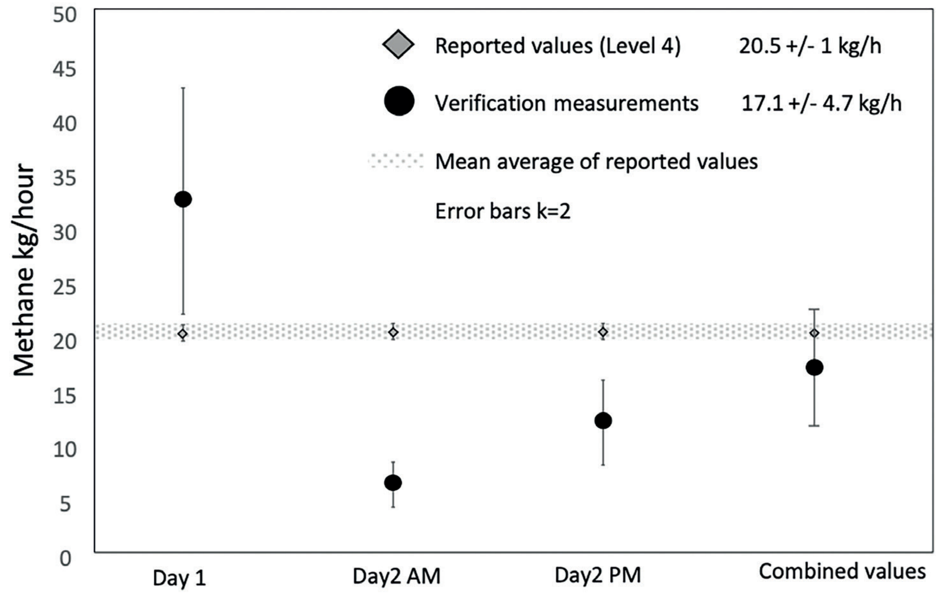

Figure 1: Reconciliation of emissions reported for an offshore site.

constant airspeed of 30 metres per second. Once at the lowest safe altitude, the aircraft ascended at the same altitude step heights flying between the previous laps, creating an vertically interlaced pattern. Further details of the flight management are documented elsewhere [5]. Three repeat flights were conducted over a period of two days, each taking 2 hours to complete, with the on-station measurements taking approximately 40 minutes. Details of the flight protocol have been previously published [7]

For site 2 onshore measurements, the SeekIR sensor was mounted on a DJI M300 quadcopter drone operated by a pilot with visible line of sight. Following an initial site survey, the site was divided into a series of zones, each comprising one or more major equipment groups such as a flare or bank of turbines. Such site division is an adaptation of the concept of functional elements [8] and provides a practical way to manage a site that is too large to be completed within a single flight. Moreover, it allows the sequence of measurements and position of the drone to adapt to changeable weather conditions. The boundaries of each zone were typically defined by access roads. Drones were flown in a raster formation downwind of each equipment group. At no stage was the drone flown directly over equipment. Distance from the equipment to the drone path was typically 50m or less.

Results

Figure 1 show offshore results at Site 1. The average of three top-down measurements is 17.1 ±4.7 kg/h which is indistinguishable from the reported value of 20.5 ± 1.0 kg/h using a k=2 expanded uncertainty. The uncertainty of the individual top-down measurements do not overlap with one another, with the measurement performed on day 1 higher than on day 2.

Figure 2 contrasts pie charts for the reported and measured emissions from Site 2. The reported value (229 kg/h ±10 kg/h k=2) is indistinguishable from the measured value (267 ± 80 kg/h k=2). However, the composite value includes source-level values that contrast significantly. The emissions associated with flaring are larger in the reported value than in the measured (191 kg/h vs. 75 kg/h) which is the opposite to the fired equipment in which measured values were lower in the reported value than encountered in the field (15 kg/h compared to 163 kg/h).

Discussion

For Site 1 the averaged top-down measured results from an offshore location are indistinguishable from those that would be reported for that time. The reported value would therefore be deemed to be reconciled under OGMP2.0 and fulfil the expectations of Level-5. This value cannot be extrapolated to derive an annual emission rate, nor should it be assumed that all emissions from the site are fully understood from one measurement. Further measurements would be required over an extended period to make more definitive statements about long-term accuracy of reporting. The difference in the top-down values over the two-day measurement period is not accounted for by the measurement uncertainty. Either the uncertainty of the top-down method has not been fully derived or there are unknown changes taking place at the site. A review of the minute-by-minute data from the process data, Figure 3, revealed no measurable differences in flow. However, it is possible that there are shifts in the combustion efficiency taking place in the flare or turbines, highlighting the importance of continuous tracking of emissions where feasible. Whatever the cause, it is of note that the total emissions, around 20 kg/h, are small when compared to values reported in other producing environments.

For Site 2, the reported emissions can also be considered to be reconciled as the aggregate values are indistinguishable. However, in examining the source of the emissions it is evident that the reporting is not fully constrained, representing opportunities for reduction. A review of the data at Site 2 identified higher than expected emissions from both a turbine and from a hot oil heater. Further work is required to investigate performance of the fired equipment and either operational changes be made to bring them in line with expected values and/or improvements made to how emissions are measured. Site specific measurement of the flare efficiency would allow values other than an assumed destruction efficiency to be applied to flare gas data. This highlights a key aspect of the OGMP2.0 Levels in that the data should be applied to a process of continuous improvement.

As for Site 1, values cannot be extrapolated to annual emission rates and further measurements are required, but on the currently available data there is no evidence that there is a gross error in the reported emissions and the methane intensity of the site is low. The method of dividing a large site into functional areas and building an aggregate emission value for the purposes of reconciliation is shown to be effective.

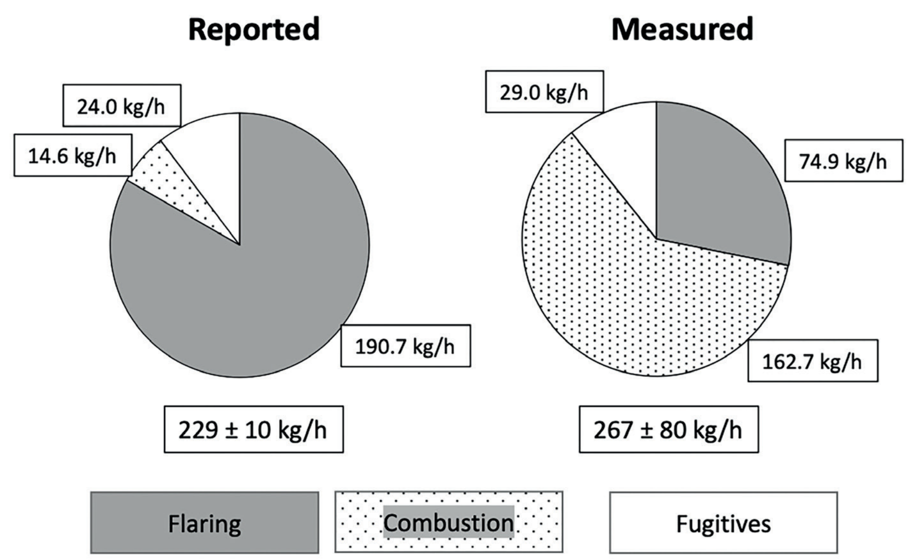

Figure 2: Reported and measured emissions from site 2.

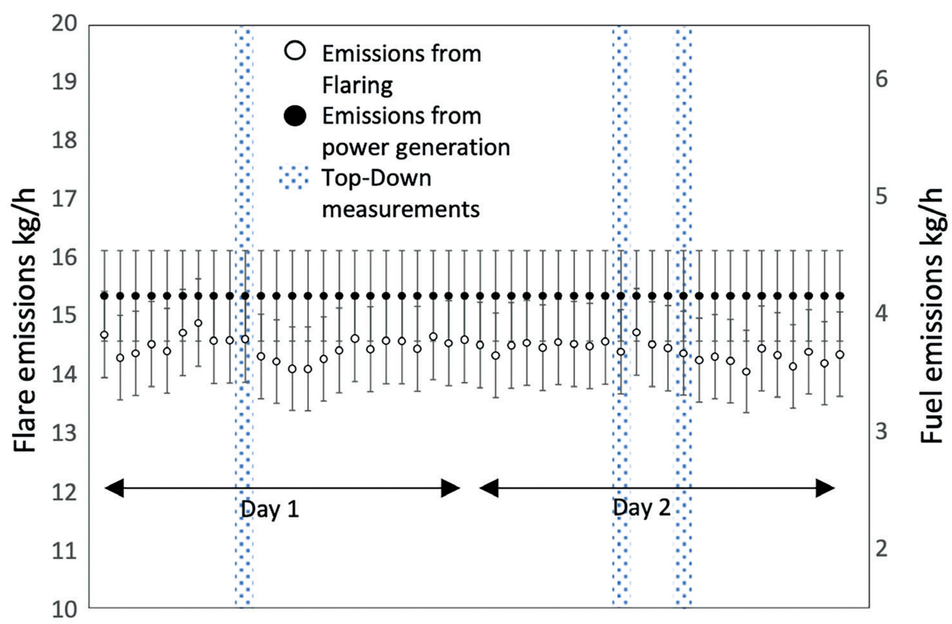

Figure 3: Detailed analysis of process related emissions shows stable conditions over the two days of measurements at Site 1 – shown here in 1-hour increments over 48 hours. Differences in Top-Down values recorded during this period cannot be assigned to changes in the process.

Conclusion

Bottom-up and Top-down data from two contrasting large oil and gas sites has been successfully compared, fulfilling the expectations of OGMP2.0 Level 5. The use of the SeekIR sensor mounted on quad and fixed-wing drones has been shown to be effective. The division of the onshore site into multiple zones has been demonstrated to be a practical way of reconciling data from large footprint sites. Level 5 data has been used to identify ways that reported emissions can be improved and opportunities for emissions reductions identified.

The results highlight the advantages and disadvantages of different methods. The fixed-wing aircraft reduces the need to send personnel offshore, increases independence in the measurements and provides a true moment-in-time assessment of all emissions at a site. Conversely, the rotary drone offers greater special resolution – allowing the source of anomalies to be more readily identified. Together this highlights the need to select the method best suited to the specific site.

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Author Contact Details

Peter Evans, Senior Engineer, BP

- Sunbury on Thames, Middlesex TW167LN, UK • Tel: 01932 760000
- Email: PETER.EVANS@uk.bp.com • **Web: www.bp.com**