U.S. Environmental Protection Agency
Municipal Solid Waste Landfill Technology Workshop
Research Triangle Park, North Carolina

October 29-30, 2024

OVERVIEW

The US Environmental Protection Agency (USEPA) Municipal Solid Waste (MSW) Landfill Technology Workshop was held on October 29 -30, 2024, at EPA's Campus in Research Triangle Park (RTP), North Carolina. In recent years, investment in novel sensing technology for the location and remediation of methane leaks in the landfill sector has grown exponentially with the help of significant funding from the private and public sectors, including research conducted by academic institutions. The workshop was designed to highlight the state of these advancing technologies including their ability to detect and quantify methane and to discuss if/how these technologies might fit into a regulatory framework.

ATTENDANCE

Workshop attendance was available by invitation only. Invitees included representatives from industry (technology developers), regulating agencies, researchers, regulated communities and other stakeholders. Roughly 170 invitees preregistered for the workshop, of which 131 people (or 77%) attended. Final attendance breakdown is as follows: industry representative (46%), government representatives (31%) and other groups (23%), e.g., nonprofit, environmental groups, and academia representatives. Less than 1% of attendees were private citizens.

See **Appendix A** for a complete list of attendees.

AGENDA

This 2-day workshop focused on the development of (and benefits associated with) advanced methane monitoring technologies as applied to landfill monitoring. The workshop agenda was structured to include both individual presentations, panel discussions, and informal questions and answers (Q&A) sessions.

See **Appendix B** for the final agenda.

SUMMARY NOTES

Day 1, October 29, 2024

Opening / Welcome Remarks

Mr. Steffan Johnson opened the workshop to deliver a few logistical remarks. Following logistical remarks, Mr. Johnson introduced the Keynote speaker, Tomás Carbonell, Deputy Assistant Administrator for Stationary Sources, Office of Air and Radiation, U.S. Environmental Protection Agency.

Mr. Tomás Carbonell welcomed and thanked attendees for participating in the workshop. Mr. Carbonell discussed the importance of addressing methane from landfills; underscoring the point that despite the progress over the years in controlling methane emissions from landfills, emissions

from landfills remain the third largest source of methane in the United States (roughly 17%). Mr. Carbonell noted that for the current Administration, reducing methane emissions has been a top policy priority; largely due to its greenhouse gas (GHG) potency and subsequent impact on global warming – i.e., responsible for roughly 1/3 of global warming we are currently observing. Rapid reductions of methane present an important opportunity to reduce the rate of climate change in the future.

Mr. Carbonell spoke on the purpose of the workshop – to bring together impacted stakeholders, e.g., vendors, experts, etc., to learn from one another about new and emerging technologies and work practices that can be deployed that can help reduce methane emissions from landfills. Mr. Carbonell touched on how landfills is a space where new technology is rapidly expanding, and it is important that there is a clear understanding of the types of technologies (particularly in monitoring and detection) that are now available, the validity of those technologies, and how they are working together with improved landfill operations.

Mr. Carbonell noted that the EPA intends to be mindful of information presented/discussed at this workshop – to determine if/how technologies and practices can be incorporated in a number of upcoming landfill rulemakings being prepared under the Clean Air Act (CAA) Section 111. As these rulemakings are being prepared, the EPA is looking at ways to update/strengthen and streamline existing policies.

Mr. Carbonell underscored the point that the EPA has been conducting additional outreach efforts, in addition to this workshop, that include but are not limited to, meeting individually with various stakeholders (e.g., landfill industry representatives and environmental groups). The EPA has also prepared several White Papers that cover various aspects of landfill technologies, management practices, and emission reduction opportunities. Mr. Carbonell added that the EPA is taking comment on these White Papers over the next 60 days. (Note: White Papers are available via the non-regulatory docket, Regulations.gov, under docket ID EPA-HQ-OAR-2024-0453)

Mr. Carbonell concluded his remarks with an overview of the workshop agenda.

Session 1: Setting the Stage
Landfill Challenges and Update on Recent Research and Findings – USEPA, Office of Research and Development (ORD) (Eben Thoma & Susan Thorneloe)

The EPA Office of Research and Development (ORD) representatives Mr. Eben Thoma and Ms. Susan Thorneloe presented on next generation emission measurement (NGEM) tools. They provided an overview of ORD framing thoughts on landfill NGEM, noting that there are 16 fundamental classes of techniques identified, each providing a different type of landfill methane emissions information/data.

Additionally, Mr. Thoma and Ms. Thorneloe spoke on ORD thoughts pertaining to landfill methane source types, noting that landfills have both intrinsic emissions (expected emissions that can be controlled but not eliminated) and fugitive sources of emissions, such as issues with gas extraction systems. While intrinsic sources are critical, it was explained that addressing those is more of a

long-term goal. In the short-term, ORD priorities center around using NGEM to understand and reduce fugitive emissions. It was mentioned that different landfill areas (e.g., the work face area) are dominated by certain source types (intrinsic and/or fugitive), and as such, ORD considers a number of factors when considering NGEM for landfill applications. To provide a better understanding of source types, several images/examples were presented (e.g., point source emissions observed by satellite), along with real-word measurement data (collected from aircraft and satellites).

Emerging satellite forms were discussed. It was noted that ORD's first look satellite landfill measurements was part of a 2023 NASA evaluation of GHGSat, which generated 97 observations of 13 landfills nationwide. Since then, two additional satellite technologies have emerged – Carbon Mapper Sat and MethaneSAT. A few examples of satellite imagery were shown, along with a multi-tiered method comparison (at EPA's South Wake Landfill Testbed where 21 GHGSat observations have been made and 6 multi-unit sensor stations have been installed, to date). A brief overview of ORD methane point sensor trials was presented, and a description of two types of draft Other Test Methods (OTMs) for airborne flux surface emission measurement were mentioned – aircraft form (or OTM-58) and unmanned aerial vehicles (UAV) form.

Next, presenters touched on handheld methane tunable diode lasers (TDLs), which ORD refers to as manual column sensor emission assessment (MCSEA). It is worth noting that TDLs are column sensors, and variations of this technology are used on UAVs and offer a clear value for landfill fugitive emissions. Emerging sensor forms, including QLM's LiDAR were defined, along with four types of UAV-based landfill measurements – e.g., UAV ground surface emission measurement. It was argued that a controlled release standard for mass emissions rate should be established, if UAVs and other hands-off sensing approaches are developed so that they can inspect surfaces and well penetrations. Presenters touched on three types of time-resolved gas collection and control system (GCCS) data (aggregated, partitioned, and individual well collection).

Presenters concluded remarks by identifying nearly half-a-dozen STAR Awardees and offering final thoughts on a path forward as it relates to NGEM approaches for landfill applications.

Questions & Answers (Q&A)

Following the presentation, the floor was opened to attendees to ask the presenters any questions and/or present any individual comments. While some general questions and comments were provided, technical questions primarily focused on the intent/functionality of OTM-58, specifically if it is intended for periodic surface emissions monitoring, and desired tiered approaches (simple verse multi-tiered). ORD presenters recapped the intent of OTM-58a and b, and made mention of their expectation to complete first, OTM-58a – the kilometer scale aircraft-enabled approach, and stated their belief that an ideal tiered approach would focus on techniques/technologies that are more scalable.

Specific Questions, Comments, and Responses

General Logistic Question

Question: Will the presentation be made available to attendees?

Answer: Yes. Workshop materials will be made available to the public through the EPA Docket. (Note: This non-regulatory docket can be found at Regulations.gov under docket ID EPA-HQ-OAR-2024-0453)

Collaboration Efforts
Comment: The Environmental Research & Education Foundation (EREF) should be considered as a primary stakeholder/company to collaborate with.
Answer: Agree. EREF has done a lot of work, which has allowed the EPA to better look at differences in technologies.

Draft Other Test Method 58
Question: Is draft OTM-58a meant to be used for periodic surface emission monitoring?
Answer: The draft form of OTM-58 has two different parts. OTM-58a is the kilometer scale aircraft-based flux surface approach – which is a whole facility emissions measurement approach. This approach has been mostly demonstrated by ChampionX Scientific Aviation. The other part of OTM-58 (OTM-58b) is the sub-kilometer scale approach – this is an UAV enabled point sensor flux surface approach for quantification. Presently, the EPA has not worked much on the point sensor leak detection approach. It is believed that OTM-58a, kilometer scale aircraft-enabled approach, would be the first OTM to be completed.
Answer: It is also worth noting that the OTM process, in comparison to other methods, focuses largely on feedback prior to publishing.

Simple vs. Multi-tiered Approach
Question: What is your ideal tiered approach?
Answer: Emerging satellite forms are developing rapidly, and that is a tool that is going to be helpful. With additional information at the ground level, for example, ground-level meteorological conditions that could help with quantification from satellite forms, and/or with a better understanding of what is happening with gas collection/operational data, we (EPA) can get more out of satellite measurements. This would be an example of a simple multi-tiered approach. You can factor in other technologies, ranging from continuous monitoring of the working area with point sensors to UAV-enabled systems, to pinpoint areas of concern. An ideal multi-tiered approach might focus on techniques/technologies that are more future scalable – e.g., research techniques.

Method Development – *USEPA, Office of Air Quality Planning and Standards, Measurement Technology Group (Dave Nash*)

Mr. Dave Nash presented on method development in support of an MSW landfill rulemaking. He opened his remarks with an overview of the promulgation process for test methods (TMs) or reference methods and described the differences between TMs and OTMs, which are test methods that have not been subject to the rulemaking process. Mr. Nash highlighted some benefits and usefulness of OTMs, including noting that data collected under OTMs can be used by the EPA to revise and improve rules and also identified the advantage of using OTMs as a path to reference method development. Mr. Nash concluded by noting that the best approach to the upcoming rule revision will be the ability/necessity to layer multiple monitoring technologies/approaches.

Questions & Answers (Q&A)

Following the presentation, the floor was opened to attendees to ask the presenter any questions and/or present any individual comments. Questions asked primarily focused on the process of developing an OTM and how an OTM prepared under landfill regulations would differ from those prepared under the more recent oil and gas rulemakings. The EPA noted that the promulgation process for an OTM involves multiple steps, including the development of a draft, a request for public comments/feedback, and implementation. The EPA explained that the biggest difference between landfill OTMs and oil and gas OTMs is that oil and gas OTMs have been established longer and have been better tested.

Specific Questions, Comments, and Responses

Promulgation of Test Methods

Question: Can you walk us through (provide more detail on) the promulgation process for test methods?

Answer: At large, the process includes collecting data to be used for testing, followed by getting in touch (and collaborating) with state representatives to begin to write the reference method(s). Once drafted, the proposed method undergoes the proposal process, which encompasses the development of a preamble, drafting of rule language, and its proposal, which typically involves a comment period.

Answer: It is also worth noting that there are two entry points for specifying a testing procedure. Each procedure is typically based on a specific piece of equipment or measurement technique. So, you can write an OTM using a particular approach, around particular equipment, and anyone is capable using the method as long as the appropriate Data Quality Indicators (DQI) are included and are consistent with data quality.

Landfill OTMs vs. Oil and Natural Gas OTMs

Question: Can you clarify the difference between OTM's required for monitoring landfill methane emissions verse OTM's required under oil and natural gas (ONG) standards (e.g., OOOOb)?

Answer: The largest difference is that OTMs used under ONG standards are more established.

Industry Panel – Research and Experiences with New Technologies *(Moderated by Bryan Staley, President & CEO, Environmental Research & Education Foundation)*

Mr. Bryan Staley opened the session with a brief introduction of the below-mentioned panel members. He touched on each organization's sustainability targets and described the proportion of waste management emissions by sector (landfill, fleet, and other sectors); landfill accounting for the majority of emissions (>80%).

Panel Members:

- Mike Thomson, GFL Environmental
- Amy Banister, Waste Management
- Niki Wuestenberg, Republic Services
- Dr. Dave Risk, St. Francis Xavier University

Mr. Mike Thomson identified areas of research and described experiences with new technologies, including, for example, five focus areas for GFL's next generation and sustainability value initiatives. Of which, he discussed in more detail the following focus area: Fugitive Emissions and Energy Resources Management and provided present/real-word examples of supporting technology – such as SnifferDRONE™, as well as Andium devices, which provide landfill access and operator expertise. Mr. Thomson concluded his remarks with an overview of challenges – e.g., organizing Next Generation data with conventional information, and areas of opportunities identified – e.g., building a track record to show progress.

Ms. Amy Banister presented on Waste Management (WM) emissions measurements and analytics, specifically WM's find, fix, and management approach. Covering three main topics: collect more gas; reduce GHG emissions; and minimize observations. To open, Ms. Banister identified goals or the intent of landfill emissions measurements – to, for example, – identify the physical location of emission sources to facilitate remediation and understand root causes; determine the mass emission rate to compare to model and inventory values and gauge emissions mitigation actions; and to compare methods with whole landfill measurements to understand what combination of approaches is accurate and scalable. Ms. Banister highlighted a number of measurement and technology evaluation approaches – continuous (fixed sensors), monthly (satellite observations), and quarterly (surface emission monitoring (SEM) and flux measurements), and provide real-word emission rate data/examples. One recommendation noted was a need to standardize emission rates from satellites. Ms. Banister ended remarks with a summary of WM's lessons learned (pulled from WM's Landfill Methane Measurement Study).

Ms. Niki Wuestenberg presented on emission quantification and identification evaluation. She first discussed the finding of the landfill gas methane technology pilot study – a 2-week study, covering years 2022 through 2024, which intended to evaluate methane sensor testing capabilities to determine threshold and emission rates for data integrity (satellites, planes, drones, and stationary devices). Ms. Wuestenberg touched on a few quantification challenges (e.g., detection limits vary by technology) and takeaways – e.g., difficult to assume yearly emissions with snapshots. Additionally, she provided an overview of 2023 drone leak detection efforts and described the benefits of installing gas collection systems. Ms. Wuestenberg concluded her remarks by identifying the next steps for supporting existing/emerging technology – collecting additional data to better understand landfill emissions.

Dr. Dave Risk presented on applied university research with new technologies. He opened with a broad overview of the work already done to learn more about the waste industry – e.g., conducting a source-apportionment study comprised of 12 landfills. Dr. Risk described the pros and cons of regulating SEM – e.g., easy to conduct but coverage is fractional. He also described available quantification opportunities (e.g., rate based) and the importance of understanding possible errors associated with SEM alternatives. Additionally, Dr. Risk briefly described his regulatory experience in Orange County and offered some recommendations and regulatory considerations related to measurements. He discussed the findings of a landfill controlled methane release study, sponsored by EREF, which evaluated 16 commercial and technologies still in the research and development phase for the ability to detect and quantify emissions from point and non-point

releases. Dr. Risk concluded with remarks describing the path forward – combining operations with policy and research.

Questions & Answers (Q&A)

Following the presentations and just prior to the start of the Q&A segment of this session, Mr. Bryan Staley asked panelists to provide their thoughts on (and for attendees to consider) six informational questions related to informing emission estimates and supporting method development, including, "How to weigh episodic (construction, maintenance) events?" Each panelist provided a brief statement/thought on one or more of the questions posed.

Ms. Niki Wuestenberg underscored (from the perspective of Republic Services) the importance of establishing a path forward, adding that the focus should remain on the find and fix approach to reduce methane emissions, but continued support of other emerging technologies is still needed.

Ms. Amy Banister reiterated Ms. Wuestenberg's remarks, adding that WM will continue to conduct comparative studies. Ms. Banister reminded that all impacted stakeholders have reduction targets that are not necessarily driven by regulation, but instead by company-set sustainability goals. She agrees that there is still a lot of work to be done with the find and fix approach. In the future, WM intends to use more operational data and try to better understand the learnings; looking at what is actionable and observable. With a final goal of taking this information (operational data and the measurement value) and incorporating it into a comprehensive application.

Mr. Mike Thomson echoed the other panelists, adding that the focus should center around standard methods development to make things more transparent, accurate, precise, and repeatable. Mr. Thomson acknowledged that more tools/techniques need to be used by owners/operators to drive action (in terms of operations and capital), and continued collaboration (between industry and regulators) is needed, along with ongoing operations of the simulation facility. In addition, he stressed the need for more expertise, pointing out that many municipalities depend on consultants to help them run/operate their site(s). It is possible that many people in this room can provide the needed expertise to help complete assessments, answer questions, and address concerns. Lastly, Mr. Thomson noted the importance and need to consider/develop community-based standards.

Following panel thoughts, the floor was officially opened to attendees to ask the panelist any additional questions and/or present any individual comments. Questions varied by commenter. Main topic areas covered included: modernizing equivalency demonstrations, development of emission targets, and the importance of metadata. Panelists generally remarked that demonstrating equivalency can be restrictive and that a comparable approach and/or development of a performance-based standards might be more helpful. Regarding emission targets, while presently developed using modeling, the panelists would like to have rates established using technological or operational data.

Specific Questions, Comments, and Responses

Question: What are the panel's thoughts on modernizing equivalency demonstrations, particularly around find and fix?

Answer: EPA Method 21 requires that you demonstrate equivalency. This requirement can be a barrier to some technologies because they are not surface-based. The question now becomes, "How do we get through that barrier?" to allow other technologies.
Answer: Would prefer something more comparable versus equivalency, because they are two different terms. So, the question is, "How do we get from equivalency to comparable?" so that it can be utilized in regulatory development.
Answer: It is believed, to the extent legislation can be crafted to create a path for technology to meet a performance-based standard/requirement, legislation would be valuable in driving innovation.

Question: How and where were the emission targets presented here crafted? Are they based on modeling or technology data?
Answer: Presently using a bit of modeling, but also trying to use operational data. Moving forward, open to other alternatives if they can provide additional information.
Answer: For capital planning, for example, if you are looking to do a new project or looking to do an expansion project, we are trying to run those scenarios through a model that is equivalent to how we are estimating the emissions – on a quarterly or annual basis – to help track emissions projections. How do we transition from model to measurement? How do we hybrid that system? There is a struggle currently to answer these types of questions. That is why we need to accelerate learning of enhancement technologies to improve emission reduction programs and to better determine emission reduction targets.

Question: Is the SWEIS still relying primarily on the collected gas measured and applying your assumptions of collection efficiency to that, based on various operations?
Answer: Short answer, yes.
Answer: It is a concept of continuous improvement as well as methodology – i.e., looking at how to better be informed.
Answer: It does provide an opportunity to include some efficiencies, if you take certain actions within your landfill to improve, for example, cover type. A feature not necessarily offered by other model systems.
Answer: In short, operational parameters (e.g., cover type) drive the determination of what the collection efficiency is.

Question: What was meant by notion of "needing metadata" to supplement some types of technologies? What would this process/approach look like and how would it be done logistically? Why is metadata important to the Agency?
Answer: Regarding metadata, it comes down to first determining the method; thus, more site-specific information is needed. Part of the process here today is to figure out what those key pieces are.
Answer: Metadata collection presents an opportunity (space) for collaboration. Right now, we know that aerial measurements are taking about 90 days to process, making it difficult to explain how measurements were determined/collected. There is an opportunity here to talk about how to collect data consistently – What we are going to look at? What information should we have on hand to answer questions? To avoid false positives? etc. In the same way an instrument measures methane that's not there, it's a real challenge for an operator to justify why it is not methane. More

specifically, if we start looking at operations data that's not relevant to the emission source, it becomes challenging to explain why it's not relevant in hindsight. There is a real value to knowing what is happening onsite and having explanatory operating parameters to enhance what we are seeing in measurements.
Answer: It is worth noting that little micro weather events can occur at a landfill. Wind is a key factor in how an emission rate is developed. Short of putting hundreds of wind sensors out there, it can be challenging to determine thresholds.
Answer: WM is in the process of trying to develop and implement a more automated system to be able to respond to issues in real-time – i.e., so when WM gets an observation, it is immediately kicked out to the field to get a response back and determine the correct corrective action to take (if needed). We found that closing the loop is the most difficult part of the process. However, WM is focused on building a more robust and comprehensive find and fix system for the company to help meet a 40% reduction and get more natural gas from the collection systems.

Session 2: Ground-Based Approaches

Technology Panel – Ground-Based Leak Detection: Method 21 and Beyond *(Moderated by Jarod Bailey, EPA)*

Mr. Jarod Bailey opened the session with a brief introduction of the each of the panel members listed below. The format of this session was to have presentations made by all panel members followed by a Q&A session for all of the panelists.

Panel Members:

- Jarod Henry, Qube Technologies
- Felix Hoehne, Sensirion
- Ali Lashgari, Project Canary
- Ben Silton, Trellisense

Presentation: Application of Continuous Monitoring to Landfill SEM. Presented by Jarett Henry, Qube Technologies.

Jarrett Henry began his presentation by noting that there are three elements in continuous monitoring (CM) systems, including hardware, analytics, and a dashboard. Qube deploys CM systems in landfill applications by placing multiple monitors on the surface of the landfill in a gridded pattern. The data from the monitors is then processed through Qube's algorithms, and the information is provided to operators in real time through Qube's online dashboard. He noted that CM offers advantages over periodic monitoring, such as providing the ability to alert operators instantly when leaks are detected, providing coverage of the entire landfill surface, assisting with odor detection and mitigation, and providing insights about the impacts of operational practices. He mentioned that to deal with the slopes and terrain of landfills, the monitors have special stands so they can be on steep and uneven terrain, and each monitor has its own anemometer to capture local wind effects. He also mentioned that they are currently working to identify the optimal monitor coverage density. Going forward, Qube would like to see an alternative compliance protocol that does not punish more frequent monitoring and data collection, and an example of a regulatory pathway for alternative technology approval is that of the EPA's NSPS OOOOb alternative test method (ATM) program.

Presentation: Nubo Sphere, High Performance Continuous Monitoring Platform for Landfills. Presented by Felix Hoehne, Sensirion Connected Solutions.

Mr. Felix Hoehne started his presentation by stating that Nubo Sphere brings laboratory performance to the field through the use of its ground-based photoacoustic laser-spectroscopy methane sensor. The sensor is small and lightweight, accurate and stable, and has a high response time. The sensor's mean limit of detection is about 0.3 parts per million (ppm), and the 3-sigma limit of detection is 0.9 ppm; the sensor's typcial 3-sigma accuracy is 0.5 ppm plus 10% of the measured value; and the sensor's cross sensistivity to other gases is low, with a maximum error of 1% due to ethane in the typical composition of natural gas. They are currently testing Nubo Sphere at the ORD landfill campaign, with controlled release testing and remote landfill monitoring being complete, and fenceline landfill monitoring is ongoing. They have found a very good correlation between Nubo Sphere and a Licor reference device in the controlled release testing. Their next steps are to develop leak detection and repair (LDAR) and emissions quantification analytics in a fenceline setting. Compared to EPA Method 21, this method has a significantly faster detection time and improved estimate of total emissions. The method has a robust wind speed operating window of 1 meter per second (m/s) to over 10 m/s. Key challenges to this method are dealing with hilly topography and distinguishing between area sources and point sources.

Presentation: Continuous Monitoring of Landfill Methane – Complexities & Applications. Presented by Ali Lashgari, Project Canary.

Ali Lashgari first presented the applications of CM, stating that they can cover emissions from the working face of a landfill, can help differentiate between leaks and allowable emissions, and can detect emissions at night. Complexities of CM for landfills compared to upstream oil and gas applications are that landfills are large areas with complex terrain that have a combination of point and diffuse sources, and emissions are weather dependent. He noted that research is being conducted to better understand the different sources of uncertainties related to measurement and quantification, to investigate the optimum CM sensor density and placement, to understand local dispersion patterns, and to account for topographical complexities. He noted that controlled release studies with different measurement technologies are being undertaken to better understand measurement uncertainties and the impact of reduced sensor counts. From the Advancing Development of Emissions Detection (ADED) 2024 controlled release studies, reduced sensor count was found to mainly affect localization and time-to-detection, while site-level emissions estimates remain accurate.

Presentation: Quantifying Methane Emissions with Optical Sensors. Presented by Ben Silton, Trellisense.

Ben Silton began by outlining what his presentation would cover and then moved into explaning why emissions quantification is difficult. He noted that emissions quantification takes time and space and provided examples of companies with sensors that are designed to operate at different scales, from directly at the asset, to entire regions of the earth, and also those that provide snapshots in time to those that monitor continuously. He remarked that Trellisense offers continuous montoring at the small-to-large site scale with low costs compared to others offering similar capabilities. Their "Argos Retro" sensors rotate, beaming a non-visible light to multiple reflectors to create multiple lines of sight though an area of concern, capturing path-integrated GHG concentration data. Their

"Argos Solar" sensors are triangulated spectrometers that use the sun as a light source to detect and monitor GHGs and have a solar auto tracker to follow the sun's path. The known position of the sun allows plume localization, and a mesh array of sensors allows for quantification of GHGs over large areas. These sensors can only operate in the daytime, but they can cover a larger area than the "Argus Retro." Both sensor types have an estimated detection limit of 20 parts per billion (ppb). Trellisense offers a subscription structure where customers own the data and Trellisense owns and maintains the sensors, with pricing depending on the site and data complexity.

Specific Questions, Comments, and Responses for the Panel

Question: What is the range of methane detection for your technology?
Answer: Jarett Henry stated that it is 0.1 kilograms per hour (kg/hr) for Qube Technologies; Felix Hoehne stated that it is 1 kg/hr for Nubo Sphere; Ali Lashgari said it is around 0.5 kg/hr for Project Canary; and Ben Silton stated that it is about 0.4 kg/hr for Trellisense.

Question: What is the scalability and cost of your technology?
Answer: Felix Hoehne stated that Nubo Sphere has focused on scalability, and their technology has already been deployed. He expects the costs to go down, driven by the number of sensors needed for all the sites in oil and gas operations. Ali Lashgari responded that Project Canary needs to work on streamlining their technology to make it scalable. He stated that they want to be able to ingest data from many sensors to get a picture of all the emissions at a site. Ben Silton noted that Trellisense technology is priced based on site size and complexity, but it should only cost in the five-figure range. He noted that when considering the different technologies, it is important to include the costs of ownership, such as the costs for calibrations and downtime. Jarett Henry responded that his presentation included estimated costs for each category of technologies.

Question: How do you address time periods where there is pooling but there is not a leak?
Answer: Ali Lashgari replied that they determine this based on site history and by establishing a background. He added that they are still learning about their system from the tests they are currently conducting. Jarettt Henry noted that it depends on whether you're trying to use data to find and fix a leak or if you are trying to quantify emissions. He noted that for some technologies, when there is low wind speed, the trust in the data goes down for a find-and-fix application. Ben Silton added that it is helpful to have optical technologies for this situation, since they are not dependent on the wind. Felix Hoehne remarked that it is important to know what the technologies is good for, including the coverage and operating window.

Question: For technology that is aiming a beam of light to a reflector up to 500 meters away, how is shifting ground accounted for?
Answer: Mr. Silton responded that Trellisense has developed an auto-alignment feature to ensure the light hits the reflector.

Question: While calibration is not needed for these sensors, how long do the systems take to set up? Is there an application for a short-term monitoring campaign?
Answer: Felix Hoehne stated that the Nubo Sphere technology is designed for a long-term monitoring situation and would not be economical in the short-term. Ali Lashgari remarked that for Project

Canary, a few weeks of wind data is needed before the emissions data would be ready to use, so it would likely not be a short-term monitoring solution. Jaret Henry stated that for Qube Technologies, approximately two weeks of data would be needed to make sure the system is providing accurate data. Ben Silton added that for Trellisense, a few weeks of data are needed to ensure the system is working properly. They
usually do use their technology over a short time period following this initial setup time. All of the panelists indicated that the setup or installation of their technologies was quick, with less than a day needed.

Question: Are there lessons about wind variability that already exist from oil and gas applications or from landfills?
Answer: Ali Lashgari responded that they have published data about the effects of wind. Felix Hoehne noted that wind effects can be site-specific. Jarett Henry replied that yes, they have learned about the effects of wind from previous applications.

Technology Panel – Gas Collection and Well Tuning *(Moderated by Jarod Bailey, EPA)*

Mr. Jarod Bailey opened the session with a brief introduction of each of the panel members listed below. Like the previous technology panel, the format of this session was to have presentations made by all panel members followed by a question-and-answer session for all of the panelists.

Panel Members:

- Melinda Sims, LoCi Controls
- Phil Carrillo, SCS Engineers
- Alan Vidal, EcoTech
- Gregory Chrin, Apis Innovation

Presentation: Real-Time Measurement and Control of Methane. Presented by Melinda Sims, LoCi Controls.

Melinda Sims started off her presentation by highlighting LoCi's sensor technology called "WellWatcher," which provides real-time gas collection system data. Their systems measure emissions along with ambient weather conditions in real time, and the information is provided to operators via a platform that can also control valves in the gas collection system to reduce emissions. Over 10 projects, they have seen average increased methane capture of 17%, with emissions reductions of 78,600 metric tons CO_2e (carbon dioxide equivalent). From their work, they have seen that more recently landfilled waste produces more methane, including the areas under daily cover and intermediate cover. In addition, they have found that emissions are tightly tied to operations, and by better managing operations, including automatic tuning, emissions can be reduced. Ms. Sims stated that any future regulatory structures must encourage data collection, as currently there is a perception that having more data will put landfills at a compliance and reporting risk. In addition, she stated that GHG reporting mod-els should encourage gas collection.

Presentation: SCS RMC Automated Wellheads. Presented by Phil Carillo, SCS Engineers.

Phil Carillo first pointed out the common challenges with traditional wellheads monitoring, including that it is labor intensive, data collection is inconsistent, the frequency is limited, there is inefficiency in scaling operations, and there is a delayed response to issues. With SCS RMC automated wellheads, operators have continuous remote monitoring and control through a user-friendly interface, which allows them to enhance operational efficiency. The costs of their technology depends on site conditions and the conditions the operator wishes to monitor. Their process involves conducting an initial site assessment and feasibility study, installation of the automated wellheads, integration with existing landfill gas management systems, and personnel training of the new system.

Presentation: Portable Open Path Laser Methane Detection for Increased Efficiency, Site Coverage, and Safety. Presented by Alan Vidal, EcoTech.

Mr. Alan Vidal provided information on the Gazoscan product, which is a handheld methane detection device that uses tunable diode laser absorption spectroscopy (TDLAS). It has a range of up to 100 meters and is paried through Bluetooth to a mobile phone app. The device works by having a laser diode emit light that is refected and received by a detector in the device. The device can be used in the field to scan for area or point source emissions. The data can be used to quickly identify areas of potential well placement, insufficient vacuum at a well, conver integrity issues, and gas collection system integrity issues. Best practices for use include scanning in a W-shaped pattern and collecting data when wind speeds are low. It is capable of covering complicated terrain, such as slopes, slick areas, and areas with obstacles. Compared to traditional EPA Method 21 surface emissions monitoring, this surface emissions monitoring method reduces time and walking distace by up to 95%, based on walking path density and local requirements, and provides over a 4,000% increase in coverage area.

Presentation: Apis Innovation: Automated Landfill Gas Collection. Presented by Gregory Chrin, Apis Innovation.

Gregory Chrin remarked that the mission of Apis Innovation is to provide landfills with technology solutions that help maximize gas collection system efficiency and up-time. Mr. Chrin noted that 78 landfills are actively using Apis technology in the U.S. and Canada. They offer a “smartWell,“ to maximize the percentage of time that each gas well is optimally tuned, a “headerMonitor,“ to minimize the time to detect and correct problems in the field, and a cloud-based platform to display the data. The “smartWell“ takes measurements every 1-3 hours and makes a valve adjustment, as needed, with each measurement, although users can also remotely adjust valves themselves and request on-demand measurements. The “headerMonitor“ is a flow measurement device that also takes measurements every 1-3 hours using solar power, or it can be hardwired to provide data every 10 minutes. This monitor integrates with third-party sensors and control systems. Automated gas well and remote measurement systems improve landfill gas capture efficiency, and are reliable, cost-effective, and user-friendly. Mr. Chrin remarked that some operators fear that added data could increase compliance risks, and any future regulations should incentivize gas capture and avoid discouraging technology adoption and the collection of additional data.

Specific Questions, Comments, and Responses for the Panel

Question: How do you adjust the automated systems to collect more gas? What is needed to install the automated systems?
Answer: Melinda Sims responded that for LoCi Controls for well tuning, the customer adjusts the parameters based on their desires for higher quality of gas or for higher flow of gas. For leak detection, there are various levels the systems can be set to for indication of a leak. She also indicated that existing wellheads and header monitors are pretty easily changed out for automated ones. Phil Carillo replied that for leak detection, the cheapest way to check for leaks is through hand-held devices. Melinda Sims also added that it may be easier to measure how much gas is being collected versus measuring for leaks.

Question: For the Gazoscan, does the system do data logging and data visualization?
Answer: Alan Vidal replied that the data log is external, and the device takes readings every 3-5 seconds.

Question: The technologies discussed during this panel are well established. Of the installations of the technologies, how many or what percentage are for renewable natural gas (RNG) and for LFG-to-electricity?
Answer: Melinda Sims stated that for their business model, their technology is geared toward increasing the amount of gas collected, for any end-use. Phil Carillo noted that for their business model, the goal was to produce a product that could reduce costs for remotely located landfills. Alan Vidal and Gregory Chrin both indicated that their technologies are mostly used at RNG sites because they are trying to help optimize those operations.

Question: Several of these technologies use solar panels. Are there battery backups or off days?
Answer: Phil Carillo responded that solar and battery prices have come down in recent years, and they hold up to extreme temperatures. He added that the panels last 22 years, the batteries last 10 years, and they can power the sensors for 4-10 days without sun. Melinda Sims stated that one of their instruments has gone 30 days without sun, and it takes measurements every hour.

Question: What are the challenges you have encountered with the use of your technology?
Answer: Phil Carrillo replied that data collection frequency, such as once every 15 minutes or once every hour, needs to be negotiated with the regulators. Gregory Chrin remarked that cost and the fear that having additional data could create a compliance risk are the hurdles to further adoption of the technologies. Melinda Sims noted that she would like to see regulations that would encourage data collection and that would be performance-based.

Question: Is it possible to make money from gas monitoring alone?
Answer: Melinda Sims responded that increasing gas capture provides a clear value proposition. Gregory Chrin remarked that innovation will bring costs down, and then it could be possible to profit just from gas monitoring.

Question: Can your technology be used to monitor methane going offsite?
Answer: Phil Carrillo responded that probes at the fenceline could provide that information.

Day 2, October 30, 2024

Session 3: Aerial Leak Detection and Quantification

Technology Panel – Aerial Methods Part 1 *(Moderated by Jarod Bailey, EPA)*

Mr. Jarod Bailey opened the session with a brief introduction of each of the panel members listed below. The format of this session was to have presentations made by all panel members in Aerial Methods Part 1 and also by all panel members in Aerial Methods Part 2 followed by a Q&A session for all of the panelists in both technology panels.

Panel Members:

- Mike Thorpe, Bridger Photonics
- Oleg Mikhailov, Xplorobot
- David Barron, Sniffer Robotics
- Don Garland, Drones Plus Robotics

Presentation: Gas Mapping LiDAR™ for Landfill Emissions Monitoring. Presented by Mike Thorpe, Bridger Photonics.

After presenting an outline of his presentation, Mike Thorpe explained that Bridger Photonics measures methane through LiDAR (Light Detection and Ranging) that is attached to small, manned aircraft, such as Cessna planes or Bell helicopters. To produce methane maps, they also perform aerial photography and use topographic LiDAR, in addition to methane concentration LiDAR. With their system, they perform methane concentration mapping, which shows emissions source locations and can provide emission rate measurements. To estimate whole landfill emissions, they aggregate individual sources. The surface scan capabilities include a detection sensitivity of 0.5-1.5 kg/hr, emitter localization to within 2 meters, and emission rate estimates for emissions in the rage of less than 0.5 to over 50,000 kg/hr. For landfill applications, they have determined through previous work at landfills that the best conditions for their system include a wind speed generally between 7 and 20 miles per hour (mph), low foliage along scan paths upwind and downwind, and relatively flat topography. They have also noted that large plumes can prevent the detection of smaller emissions sources downwind. In a controlled release study at a landfill, they found that the use of local wind data improved emissions estimates.

Presentation Methane Emissions Quantification Solution for Landfill Applications. Presented by Oleg Mikhailov, Xplorobot.

Oleg Mikhailov began by noting that Xplorobot is a hand-held digital methane emissions detection and quantification technology that does not require thermal contrast between the methane and the background. He also noted that it meets the Department of the Interior 1 gram/hour (g/hr) sensitivity requirement. To date, they have 56 customers for over 800 facilities, have received approval of their technology for methane detection by the State of Colorado and is pending approval by the U.S. EPA. The device includes a TDLAS sensor, global positioning system (GPS), anemometer, thermometer, and visual camera. The data from the device is transferable to a mobile app and the cloud. With the camera, the device is capable of showing leaks that EPA Method 21 and Infrared Optical Gas Imaging (IR OGI) are not able to detect due to wind effects (EPA Method

21) and lack of temperature contrast (IR OGI). Mr. Mikhailov also noted that this hand-held technology is relatively inexpensive compared to other methane detection technologies.

Presentation: Sniffer Robotics: The State of the Art for Landfill Methane Leak Detection. Presented by David Barron, Sniffer Robotics.

David Barron started off by reviewing the advanced methane monitoring technologies used today, which range from handheld to drone for regulatory monitoring and from in-ground sensors to satellites for voluntary monitoring. For Sniffer Robotics, their technology is EPA Method 21 performed with a drone. It uses the same unit of measure (parts per million), samples at ground level, uses nondispersive infrared (NDIR) or closed path closed cavity TDLAS sensors, and uses the same 30-meter serpentine paths required for EPA Method 21. However, this technology uses a drone that carries a sensor just above ground level using a computer to control the path it takes and a laser to ensure the sensor nozzle is just above ground level. Compared to EPA Method 21, this technology can improve the spatial resolution of the sensing while taking less time to complete a survey and allowing for measurements over complicated terrain. The optimal operating conditions for this technology include less than 18 mph winds, temperatures in the range of 14°F to 104°F, and no precipitation.

Presentation: Solutions for Detecting and Measuring Methane Emissions in Landfill Environments. Presented by Don Garland, Drones Plus Robotics.

Don Garland began by mentioning that there are several types of aerial sensors, including TDLAS and OGI cameras, and methods of aerial sensor deployment, such as drones, robots, and aircraft. Drones Plus Robotics provides the sensor deployment technology, typically drones, with the appropriate sensor to meet customers' needs. Mr. Garland noted that different customer desires can determine which sensor technology should be used, such as TDLAS, which is wind-independent, if wind is a major factor. Other technologies, such as sniffers are ground-based, which may be needed to pinpoint leaks. He also noted that to keep costs down, operators should consider outsourcing for continuous methane monitoring, as the hardware investment is relatively small related to the overall costs.

Technology Panel – Aerial Methods Part 2 *(Moderated by Jarod Bailey, EPA)*

Mr. Jarod Bailey opened the session with a brief introduction of each of the panel members listed below.

The format of this session was to have presentations made by all panel members in Aerial Methods Part 2 followed by a Q&A session for all of the panelists in both aerial method technology panels.

Panel Members:

- Seaver Hall, Firmatek
- Peter Barber, SeekOps
- Douglas Baer, ABB
- Nhut Ho, Human Automation Teaming Solutions (HATS) Inc.

Presentation: UAV Based Open Optical Path Sensing – TDLAS. Presented by Seaver Hall, Firmatek.

Seaver Hall started off his presentation by stating that Firmatek's approach is to use drones to collect geo-spatial data using TDLAS to provide insight for managing landfill operations. They first began using TDLAS in 2021, tested their data collection methodology throughout 2022, and began offering their leak detection service in 2023. He explained how TDLAS works and noted that it is a proven technology that has been used for over 60 years. Compared to EPA Method 21, TDLAS provides column-integrated measurements of concentration over a distance, whereas EPA Method 21 provides point-specific measurements at the surface. Currently there is no standardized protocol for using TDLAS as a method of compliance with the landfill NSPS in place of EPA Method 21. The operational limitations for drones with TDLAS are that wind speeds need to be under 30 mph and that snow cover could interfere with the readings. The operational benefits are that 400 acres can be covered in 8 hours, it can provide total site coverage vs. walkable areas, and it provides the ability to see the effects of high release rates vs. low release rates. He noted that at landfills, they have seen leaks not only from the gas system infrastructure, but many are from areas of erosion or weak cover material.

Presentation: Quantifying & Locating Methane Emissions Using Autonomous UAVs. Presented by Peter Barber, SeekOps.

At the beginning of his presentation, Peter Barber discussed the benefits of RNG, including improved local air quality and reduced GHG potential, noting that landfill RNG projects have been increasing since 2005. He also noted that beginning in 2018, the number of agricultural digester projects have greatly increased each year. Through its surveys, SeekOps has identified methane emissions from RNG projects that exceed the emissions identified at traditional oil and gas sites. SeekOps uses drone-mounted TDLAS sensors to detect emissions, with a detection limit of 0.02 kg/hr, and their emission rate estimates compare within 2% of actual. The drones can fly over the whole landfill or just one sector, such as the working face. With their technology, leaks and emissions can be identified, and landfill operators can also use the information to identify areas of optimal wellhead placement.

Presentation: Advanced Mobile Leak Detection Solutions. Presented by Douglas Baer, ABB

Douglas Baer opened his presentation by listing the benefits and advantages of ABB's natural gas leak detection system. Some of these include that their options find large, small, and hidden leaks, the customer owns and controls all data, and it provides for more efficient surveying, which allows for a fast return on investment. The ABB system uses off-axis (OA) integrated cavity output spectroscopy (ICOS) laser technology rather than a conventional TDLAS laser system, which provides for increased sensitivity, ruggedness, and range, with an effective path length of 1-100 km. Their HoverGuard™ system uses this OA ICOS on a drone, which also includes GPS, a sonic anemometer, leak detection software, and a modem to share the data in real time. The system has a high sensitivity of less than 1 ppb, can operate in temperatures ranging from 32 to 120, and has a fast response time of 3-5 hertz (Hz).

Presentation: Operational Automation for Methane Monitoring with Human Autonomy Teaming. Presented by Nhut Ho, Human Automation Teaming Solutions (HATS).

Specific Questions, Comments, and Responses for the Aerial Methods Panels

Question: How do you handle sites with obstacles, such as bald eagles?
Answer: Nhut Ho responded that they prepare for that in the planning stage by identifying known and potential obstacles beforehand and through cooperation with the operator and the local enforcement agency before deployment.

Question: In one presentation, twice as many leaks were observed as those from oil and gas opera-tions. Were those leaks from RNG operations or from the landfill too?
Answer: Peter Barber replied that the leaks were from both RNG operations and the landfill sites themselves.

Question: What are the advantages of your technology?
Answer: Seaver Hall responded that the Firmatek technology is more versatile than walking, as required by EPA Method 21, and is also safer. David Barron replied that landfill gas is best detected at ground level, and Sniffer Robotics provides ground level sensing in a manner that is like EPA Method 21 but that offers greater coverage and is faster. Mike Thorpe stated that imagery is very valuable, which is something Bridger Photonics provides. Doug Baer remarked that drones, such as those offered through ABB's service, have the advantage of providing total site emissions, whereas manual surveys are best for pinpointing discrete emissions sources. Mike Thorpe added that manned aircraft do not require interaction with the facility, which allows for greater ease of taking measurements whenever conditions are best for it.

Question: What is the data processing time and the "find & fix" timelines for your technology?
Answer: Oleg Mikhailov replied that with Xplorobot, leak detection is immediate, but a longer time frame is needed to gather other data to estimate total site emissions. Mike Thorpe replied that for Bridger Photonics, data processing occurs at the same time as the scan, but they perform QA after the scan, so the data sharing is not instantaneous but is quickly provided to the client. David Barron stated that data sharing is immediate for Sniffer Robotics. Peter Barber responded that for SeekOps, qualitative data, such as whether there is a leak or not, is provided faster to the client than quantitative data regarding emissions and emission rates. Nhut Ho said that HATS could make all data available in real time, but they need a system that can accommodate the sharing of so much data. Seaver Hall stated that many companies have learned how to handle big data now. He added that Firmatek has a live camera with their system, so someone could find and fix a leak immediately. Doug Baer said that for ABB, data is shared in near-real time through the cloud.

Question: Some of these technologies are in the building stage. How long will it be before they could be used on a large scale?
Answer: Peter Barber replied that SeekOps builds their sensor in-house, and that is currently the limiting factor for them to be ready to deploy on a larger scale. However, he noted that they are speeding that process up by using a contract manufacturer. Seaver Hall responded that the Firmatek technology is pretty scalable, and they have pilots and equipment ready to go. However, he did note that changes in policies at the company that makes the commonly used drones, DJI,

may become a problem that they will need to determine how to overcome. Oleg Mikhailov said that any person can use the Xplorobot sensor and could do so very quickly. David Barron stated that Sniffer Robotics has a partner program, and they are currently not trying to grow their business. Doug Baer replied that the ABB systems are commercial and ready to go. Nhut Ho responded that their HATS technology can be plugged into any drone. He added that a lot has to do with how often the operator wants to survey their operations and whether they can stack technologies to meet their needs. The operator should have an understanding of what their needs are and the technologies available for them. Nick Swanson noted that if the EPA were to require monitoring, companies would have years to scale up their operations, just due to the time it takes to go through the rulemaking process.

Question: What kind of standard from the EPA would help your company?
Answer: Peter Barber replied that it would be good to have a task force or work group to work on that. He added that there should also be waste industry feedback. Nhut Ho responded that safety is critical, so there should be thought on how it could be better than what there is now with manual EPA Method 21 monitoring. There should be thought to financial feasibility and the robustness of any solution. David Barron stated that some of this is happening now, but it needs to be formalized. There should be formalization of the cascade of localization. Oleg Mikhailov stated that there should be a system for reporting and also for the actions needed after detection of a leak. Mike Thorpe said that there needs to be an OTM, and until there is one, it will be hard for companies to make capital expenditures to scale up. Seaver Hall noted that multiple options will work, but a standard should allow for an operator to choose what works best for their site. Nhut Ho added that there needs to be an allowance or requirement for training on the system used, and there should also be thought given about technology and artificial intelligence replacing people. David Barron adjoined that well field optimization would be a factor.

Question: Do you see breadcrumbing being included in a regulation? If so, how dense would the trails be, and how would that density be decided upon?
Answer: David Barron replied that, in some regards, that isn't known yet. They are currently studying the effects of density and the ability to detect leaks with their own technology. Doug Baer replied that the technology companies can show the averages they have gotten and the breadcrumbing trail used to get those values. Seaver Hall responded that it depends on what is integrated in the data, such as wind. He opined that it will require testing to determine optimal densities for the different technologies. David Barron added that speciation will also need to be specific to landfills rather than to oil and gas operations.

Question: What protocols do you think are needed for controlled release testing?
Answer: Mike Thorpe replied that it depends on whether you are trying to identify leaks or trying to quantify emissions. Doug Baer stated that transparency in the data is needed, there needs to be the ability to show both the raw data, and the algorithms used. Oleg Mikhailov replied that from a leak fixing standpoint, there should be a controlled release procedure that focuses on location identification, which would likely have detection accuracy criteria in the controlled release protocol.

Technology Panel – Aerial Methods (Aircrafts and Satellites) *(Moderated by Jarod Bailey, EPA)*

Mr. Jarod Bailey opened the session with a brief introduction of each of the panel members listed below.

The format of this session was to have presentations made by all panel members followed by a Q&A for all of the panelists.

Panel Members:

- Tia Scarpelli, Carbon Mapper
- Marianne Girard, GHGSat
- Harshil Kamdar, Insight M
- Michael Marsland, Pergam Technical Services

Presentation: The Role of Imaging Spectroscopy for Monitoring Methane from US Landfills. Presented by Tia Scarpelli, Carbon Mapper.

To begin her presentation, Tia Scarpelli stated that Carbon Mapper uses imaging spectroscopy in satellites to observe large methane and CO_2 sources. She noted that imaging spectrometers are designed to identify point sources over a large region. Carbon Mapper produces an emissions estimate for each plume identified, and imagery is used to attribute those emissions to a source. Ideal conditions for identifying emissions with Carbon Mapper include minimal cloud cover, windspeeds of 1 to 8 meters per second (m/s), imaging performed at mid-day, and a homogenous land surface that is not too bright or dark. Common sources of landfill methane emissions observed by Carbon Mapper include gas control and destruction equipment, collection system leaks, cover penetrations, and the landfill work face. They have also found that landfill super-emitters tend to be more persistent than oil and gas super-emitters, and they can last for weeks to years. In addition, their observations have shown that the landfill work face accounts for over 75% of emissions. In controlled release studies, Carbon Mapper data has been shown to correlate well with actual emissions. Stakeholders have used Carbon Mapper observations to identify problem areas for follow-up with surface emissions monitoring.

Presentation: Landfill Methane Emissions Monitoring with GHGSat's Constellation. Presented by Marianne Girard, GHGSat.

Marianne Girard began by remarking that GHGSat's satellite constellation currently includes 12 satellites in orbit that measure methane, and 17 more are going to be put in orbit in 2025. They have a spatial resolution of 25 meters and a detection threshold of about 100 kg/hr. In a controlled release study, their satellites had a 50% probability of detection at 100 kg/hr and a 90% probability of detection at 155 kg/hr. The limitations of the sensors are that the measurements need to be taken during the day, wind speed can affect detection, and cloud cover and haze can prevent good readings. They also have aircraft sensors that are designed to measure emissions at the structure level for localized emissions monitoring campaigns. Their aircraft sensors have a detection threshold of under 10 kg/hr and provide a spatial resolution of under 1 meter. In a controlled release study, their aircraft sensors had a 50% probability of detection at 5 kg/hr and a 90% probability of detection at 7 kg/hr. The information from either the satellite or aircraft sensors can be used to understand where

most emissions come from to prioritize actions, to track emissions over time, and to identify emissions from unexpected locations.

Presentation: Airborne View of Landfill Methane Emissions. Presented by Harshil Kamdar, Insight M.

Harshil Kamdar first presented a timeline of Insight M's operational history, showing that the company was founded in 2014 as "Kairos Aerospace," with commercial flights starting in 2017 to detect methane from oil and gas operations, and had a name change in 2024 to "Insight M." Insight M operates LeakSurveyor™, which combines an imaging spectrometer, and an optical camera deployed on fixed-wing aircraft. It has a detection sensitivity between 10 and 100 kg/hr, with methane imagery resolution down to 3 feet, and optical imagery resolution down to 8.5 inches. Operational constraints include meeting the necessary field conditions, such as not having wind speeds, having the sun angle in a certain range, having no precipitation, and little cloud cover. However, higher-altitude sensing can cover complex terrain easily and scan landfills quickly, allowing for frequently repeated surveys.

Presentation: Aerometrix Greenhouse Gas Detection Services and Technologies. Presented by Michael Marsland, Pergam Technical Services.

After briefly reviewing what his presentation would cover, Michael Marsland provided information on Aerometrix. He stated that the company was founded in 2019, with the goal of improving gas survey methods by integrating new drone technologies. In addition to performing many oil and gas operations surveys, over the past two years, they have surveyed over 20 landfills in Canada and the U.S. using both drone-mounted point source sensors and path-integrated TDLAS, like the Pergam LaserFalcon. Their drones fly 5 to 30 meters above ground level, following serpentine grids with spacing between 7.5 and 50 meters, depending on the area of the landfill and customer interests. Their LaserScan system uses parts per million-meter readings to detect the amount of methane in the plume within the path of the laser. Their in-house data processing and analysis software, Gas Map, then provides the data in a map format to show the location of leaks. gas Map can also perform methane quantification using Flux Curtains, and it estimates emissions with the mass balance method. Compared to EPA Method 21, the path-integrated methodology is more efficient, provides greater coverage, and allows for emissions quantification.

Specific Questions, Comments, and Responses for the Aerial Methods (Aircrafts and Satellites) Panel

Question: How do you convert units?
Answer: Marianne Girard responded that they get the mass and then convert to flux using wind speed data. She noted that they provide their clients with mass and concentration data. Harshil Kamdar replied that for converting to CO_2-e units, that is a different type of conversion. They use guidance from the Intergovernmental Panel on Climate Change (IPCC) to make that conversion. Michael Marsland responded that they use mass and drone anemometer data to make the conversion.

Question: Does your method get mass of methane for an event?

Answer: Harshil Kamdar replied that what these methods provide is an instantaneous snapshot in time, and the duration of any emissions event is not known, but they can put a minimum bound on it based on plume length.

Question: How are private algorithms hindering the sharing of data?
Answer: Marianne Girard responded that GHGSat's source rate calculation is available to the public. Harshil Kamdar said his company provides the same information. Tia Scarpelli remarked that Carbon Mapper's methodologies are publicly available.

Question: What wind detection products would you like to have?
Answer: Harshil Kamdar replied that high-resolution rapid refresh (HRRR) data is good to have. Marianne Girard pointed out that they want accuracy and better resolution of data, but they also want to have the data fast. She noted that some of the best sources of wind data take a few data to get online. Due to the time delay of getting HRRR data, GHGSat uses "Open Weather," since they can get the data faster. Tia Scarpelli mentioned that Carbon Mapper uses HRRR data. She added that it would be very helpful if the uncertainty of the wind data was provided so users could determine which data points may not be useful to use.

Question: Are drones getting good readings when there is tree cover?
Answer: Michael Marsland responded that yes, the drones get good data for any land area except deep water. However, if there is a reflective surface, such as a dense tree canopy, the readings would be at the top of that reflective surface.

Question: How much of your process is automated?
Answer: Marianne Girard responded that much of GHGSat's process is automated because there is so much data gathered, but they do manual QA checks. Tia Scarpelli remarked that Carbon Mapper has similar QA/QC checks, but they also identify plumes and perform source attribution manually. They are moving toward automation for both the plume identification and source attribution steps. Harshil Kamdar replied that they also do manual QA/QC. Michael Marsland responded that for Aerometrix, the data collection is a combination of manual performance and automation, and the data processing is mainly automated.

Question: Are there any scalability issues for your system?
Answer: Tia Scarpelli replied that they have taken note of where their bottlenecks are, which right now is the last step of the QA process. Marianne Girard echoed this for GHGSat and stated that they are working to automate every manual step. Harshil Kamdar echoed this for Insight M, but noted that they have not yet hit an amount of business in which they are limited to scaling up by manual steps. Michael Marsland replied that for drones, they currently can't eliminate the need for a drone operator to be onsite. However, drone-in-a-box technologies will help with this in the future.

Question: Since these systems offer snapshots in time of methane emissions, have you done any analysis on the frequency of surveys needed to reduce emissions?
Answer: Tia Scarpelli answered that Carbon Mapper until recently was only doing airborne surveys, which were campaign-based and needed funding for every campaign. She noted it would be helpful in determining this if there was more data sharing in the industry. Marianne Girard noted that it is difficult to estimate emissions in the long-term based on snapshots.

Question: Have you changed your algorithms based on the data collected over time?
Answer: Tia Scarpelli replied that yes, they have changed their algorithm several times, and they are trying to move to "versioning" so they can apply the updates to historical data. The changes in the algorithm have mainly reduced uncertainty and have generally been small adjustments. Marianne Girard responded that GHGSat has calibrated their system based on controlled release study data.

Discussion on Regulation of Municipal Solid Waste Landfills, *USEPA, Office of Air Quality Planning and Standards, Natural Resources Group (Moderated by Nick Swanson)*

Mr. Nick Swanson opened the session by briefly introducing each of the below-mentioned panel members. Unlike previous panel discussion, this session did not include individual presentations, but rather promoted an open-dialog between panel members and the audience.

EPA Panel Members:

- Dave Nash, MTG
- Julius Banks, GHG Reporting Program
- Madjid Delkash, NRG
- Dan Heins, OECA
- Eben Thoma, ORD

Question & Answers (Q&A)

Following introductions, Mr. Swanson opened the floor to questions and comments. The types of questions asked, and comments made varied by attendees. Several attendees spoke on their personal experiences either helping to develop and/or comply with regulations, including with the EPA's ONG rules (OOOOa/OOOOb). Attendees agree that the ONG rulemakings present a learning opportunity, as there are similarities (and differences) between these rules and those intended for landfills. The EPA assured attendees that they intend to collaborate with appropriate parties/offices throughout the rulemaking process to ensure a long-lasting, viable policy. A few attendees spoke about their concerns related to the 500 ppm concentration; with some inquiring about how the EPA determined this value. The EPA explained that the concentration amount was not determined by EPA but adopted and has been a successful indicator for compliance.

Other attendees inquired on the general framework of the landfill rules, asking, "What will it include?" EPA assured attendees that they are, at this time, committed to implementing only the updated NSPS and Emissions Guidelines (EG). Several questions were asked about the use of EPA Method 21 for surface monitoring compliance, specifically if/how EPA intends to incorporate the method into the proposed rules. At least one attendee noted that EPA Method 21 is not specified in the current rules as a leak detection and repair program, but instead a trigger to the installation of a gas collection and control system (GCCS) or as a mechanism to determine how well that system is operating. One attendee asked about the EPA's intent to incorporate wind data collection (at a site-specific level). The EPA explained, as it relates to site-specific monitoring requirements, including regulations pertaining to wind collection, that they do not intend to develop prescriptive regulations, but instead to set broadly applicable regulations that can be evenly applied across the country. At least one attendee asked about using the mass balance approach on a source level

rather than tracking using a whole site mass balance. The EPA underscored the notion that an owner/operator needs to be able to show that the proposed technology adequately demonstrates emissions reductions. Another attendee commented on certain early actions, noting that they are a 'low-hanging fruit' that should be encouraged.

In regard to third-party data collection, at least one attendee asked about whether the EPA intends to ensure that these vendors are providing accurate information/data – e.g., third-party policing? The EPA stressed the importance of having auditable methods that might allow EPA to perform an audit or offer the ability of owners/operators to audit their own contractors.

While there was a general consensus and understanding amongst attendees that landfills are a major contributor to methane emissions, there were some disagreements as to an owner/operator's ability to further reduce emissions and GCCSs' abilities to reduce methane and control odors or other non-methanogenic organic compound released to the atmosphere. Some attendees added to the point noting that the true value (or amount of) methane emissions is largely unknown because there still remains a number of unregulated landfills in operation.

In closing discussions, several attendees inquired about the plans or next steps, post-workshop. The EPA reminded attendees that the rulemaking process for developing the proposed landfill rulemakings will begin shortly, and at this time, the EPA has a commitment (from the current administration) to prepare a proposal by December 2025. The EPA also reminded attendees that a number of White Papers have recently been issued, and the Agency is currently requesting comment on these papers, which cover a particular issue related to a future MSW landfill rulemaking.

<u>Specific Questions, Comments, and Responses</u>

Wind Data Collection and Usage
Question: As it relates to upcoming rulemakings, does the EPA plan to include allowable ways to measure/record wind data, using for example, onsite services or local weather data, or a way to unify how all the collectors are using wind data?
Answer: From a regulatory stance, site-specific data is difficult to develop. As an Agency, we (EPA) are tasked with developing regulations applicable to everyone, and as a result, the more tools that have to be regulated (or site-specific metrics and data) the more the regulation has to be broadly developed (or be generic). So typically, a one-size-fits-all approach cannot be used, because what works in one place may not work well elsewhere. While the Agency is not opposed to developing more site-specific regulations, that type of policy can be difficult to implement and enforce.
Answer: It is worth noting that the reporting program is a regulatory program but is separate from the EPA's Office of Air Quality Planning and Standards (OAQPS). Meaning, the reporting program, while it's regulatory, it is often incorrectly thought of as an inventory. There are a lot of gaps. For instance, as it relates to the reporting threshold – only about 85% of the total GHG emissions in the country is collected. The EPA is not looking to regulate facility-by-facility, but instead develop a set of regulations that can be applied across the country. These regulations also need to work regardless of climate. It is also important to note that some regulated entities within the same sector are regulated under different statutory authorities.

Answer: Site-specific wind can be part of the rulemaking; however, when we are talking about research questions, like "When was the workplace covered?" we need to address issues as a community.
Answer: It is the Agency's belief that rulemakings do not have to be so prescriptive as to say that you need to use a specific technology to measure the data that is submitted. With that said, consultations with relevant regulatory agencies, like ORD, are needed to make sure regulations are based on the latest science.

EPA Method 21 (500 ppm leak detection threshold)
Comment/Question: EPA Method 21 is not specified in the current rules as part of a LDAR program, as it is for other sectors. Instead, EPA Method 21 is used as a mechanism for triggering the installation of a GCCS or a mechanism to determine how well that system is operating. Is the EPA now considering adding a leak detection program for landfills? The EPA has more flexibility going from a no leak detection and repair program to looking holistically at what options there are and determining what the standard actually is without comparing it back to the 500 ppm standard used for other industries.
Answer: EPA Method 21 does not always fit what is needed. We (EPA) are trying to determine the next steps for industry, by looking at how we measure emissions, how we monitor emissions, how we check for leaks, etc. While the EPA is committed to answering these questions, the current rule is complicated. All attempts are being made to make the rules more logical.

Question: What does the 500-ppm concentration mean/indicate?
Answer: The EPA adopted the 500-ppm concentration threshold, because it was shown that sites that emitted below 500 ppm performed well.

Comment: It is worth noting that if 500-ppm is used as a metric for emitters, it will be difficult to support if the bases (or information) used to determine the trigger is largely unknown.
Answer: What make sense is to establish an upper-level threshold and allow sites the flexibility of determining the type of technology used to achieve the limit; however, the question still remains, "How do we get to that number?"
Answer: Furthermore, it's necessary to identify primary challenges – such as ensuring that sites continue to grow and gas collection systems are operating properly (e.g., not damaged). As such, a notification system should be in place to indicate when collection systems are experiencing issues. Another example of a challenge faced by landfill owners/operators includes managing the safety and general operations of the working face area.
Answer: On the whole, the overall integrity of a collection system is important.

Landfill Rulemaking vs. Existing regulations EPA Method 21 (Comparison)
Comment: Following back to EPA Method 21, it was asked earlier whether there could be other methods identified in the future that work better at detecting leaks and monitoring emissions. It is worth noting that many workshop attendees are interested in testing their methods compared to the EPA method – to see how EPA Method 21 compares to other techniques and how vendors compare to one another; how different operators using the same method compare to one another. (Note: Commenter offered an open invitation to next month's-controlled release tests/study was presented to attendees).

Answer: A reminder that EPA Method 21 was developed in the 1980s. As such, it needs to be updated.
Answer: It is worth noting that EPA Method 21 does a direct comparison of concentration, comparison between different measurement methods is a difficult proposition.
Answer: Please note that EPA Method 21 is not a measurement, but a threshold, and not set up well for head-to-head comparisons.

Rulemaking Framework
Question: What will the upcoming rulemaking consist of – NSPS, emissions guidelines, new subparts, etc., and how are you (EPA) going to accommodate competing rules of the NESHAP, for example?
Answer: The EPA is committed to implementing an updated NSPS and Emissions Guidelines. As of today, no other options are being proposed, although they are considering Section 112 regulations. Putting a potential NESHAP aside, if/when new CAA Section 111 requirements are proposed, the newly proposed requirements will supersede any existing requirements. It is worth noting that state requirements may differ slightly.

Landfill Rulemaking vs. ONG Rulemaking (Mass Rate Standard)
Question: Will the mass rate standard (or perhaps the fraction of each gas standard) be similar to the standard proposed in the ONG regulations – meaning will there be an onramp for alternate or advanced technologies, and/or you will be able to, through OTM, find a method that could be used in place of continuous emissions monitors?
Answer: It is worth noting that the hurdle to overcome to have a reference method approved is high. Many workshop attendees are likely at a point where they have collected enough data and can begin developing an OTM. Fortunately, OTMs can be revised.

ONG GHG Reporting Program
Comment: It is worth noting that the EPA has a request for information out that would look at advanced detection and quantification methods for use in GHG Reporting for both ONG standards (OOOOa and OOOOb). Regulated ONG communities are already seeing potential compliance conflicts. As a result, we encourage the Agency to participate in high levels of collaboration between offices.
Answer: EPA panelists reenforced their commitment to working with appropriate parties/offices throughout the rulemaking process.

BSER / Post-Workshop Efforts
Question: How do we move or create a pathway forward for advancing and using technologies without getting bogged down in prescription, post-workshop? Controlled release studies are available, however, "How do we better collaborate to solve the problem?" Recommend (as a call-to-action) that the EPA set a limit (that is collaboratively determined) and allow impacted stakeholders to figure out how to reach/meet the limit.
Answer: Foremost, Section 111 regulations are crafted based on the best system of emission reduction (BSER). These systems are then translated to a standard. It is the standard of performance that site operators/owners must adhere to, not the technology it was based on. In short, since technologies vary, the main requirement for compliance is meeting the standard.

Question: Some argue that the BSER still refers to the active landfill gas collection system. In these cases, how do you measure the performance of that system without inadvertently creating barriers to achieving the standard?
Answer: Determining the correct BSER is difficult to do, particularly for the landfill industry. Arguably, workshops like this one are a good starting point for initiating conversations – since there are a variety of groups represented (environmental, industry, government, etc.). However, the EPA agrees that work beyond this workshop needs to continue amongst impacted groups.
Answer: All attendees are encouraged to reach out to the EPA with any questions or concerns, or technological data and/or setup meetings to begin dialogue.

Mass Balance Approach
Question: Regarding mass balance, what are your thoughts about using a source level exceedance threshold versus a whole site mass balance exceedance threshold? Note that there are ways to conduct mass balance (on whole site) accurately; however, the challenge stems from costs. Conducting mass balance calculations frequently is costly. You could also run into the issue of setting a baseline threshold for landfill sites that vary in size and composition. Source-specific thresholds are arguably more scalable and tested.
Answer: An operator/owner must be responsive – in other words, be able to show that the proposed technology adequately demonstrates emissions reductions, prior to inclusion in regulation.

Alternative Methods
Comment: There was a reminder that it was suggested that the EPA has already permitted groups to set up alternative methods and let companies that can do the monitoring against those standards come in and apply.
Answer: The EPA can push the envelope in alternate methods, but not the actual standard itself. We (EPA) are typically not the ones pushing the technology as regulators, but rather the ones who are following suit.

Methane Recovery Requirements (Early Actions)
Comment: In response to the above 'call-to-action' it was suggested that the emissions across all platforms can be identified the working areas(areas of high sources of emissions). Note that's also part of the landfill that commonly does not regulate capture until 5 years after the base has been installed. Case data has been built encouraging landfills to install early action gas capture equipment – an activity presently not regulated. So, there would be no question about whether an operation was exceeding regulatory requirements.

Overall, it would be a mistake to exclude (or not emphasize) methane recovery requirements, considering the more than 25 years of data and resources available. Thus, it's important to focus on methane recovered as the ultimate validation of additional measurement technology and early action. While there are no oxidation or cover connections, for example, there is a small connection between waste and the atmosphere. As such, recommend using hard methane measurement data when available to build, improve performance standards. Secondly, early actions are a low-hanging fruit; performed in every emissions platform. While, many operators do develop early collection plans, these activities can be quantified. These activities also provide a service to emissions

technologies by identifying the actual hard methane meter to recover and answering questions, like "How does that stack up with your quantification of all the different various methods; focusing on the area today, where we know we have huge emissions?" I think we can quantify it and get some emissions from their platforms and collaboratively share the data. There's no regulatory risk associated with this activity, but instead this activity presents an opportunity to focus on the lowest hanging fruit to enhance methane recovery.

ONG Rulemaking Framework (Areas to Consider)
Comment: While there are differences between the ONG and landfill programs; there are a lot of similarities – e.g., the establishment of a BSER, a matrix for other technologies, and an equivalency matrix based on detection thresholds. From a regulatory perspective, another aspect of the ONG rulemaking worth visiting is the alternative test method option.
Answer: The EPA agrees that while there are differences between the ONG rulemaking and this one for landfills, there are several similarities. A reminder that current landfill regulations are being developed using existing (dated) regulations. The rulemaking process is expected to begin soon. Therefore, the EPA encouraged attendees to reach out to the Agency with any ideas they may have around, for example, landfill regulation, matrix matrices, different control technologies, etc.

Comment: As it relates to the ONG matrix, there is an obstacle to developing that matrix. Presently, there is no emission reduction estimation for adding information to the matrix. Meaning, before a matrix can be developed that shows the equivalent emissions reductions, first need to know what the initial reductions anticipated from a EPA Method 21 CMS program actually are.
Answer: As of now, we need to first figure out what that alternative method is. Currently don't not have anything else in place; partly because we don't have alternative test. So, it's an iterative process where we still need your help.

Comment: Over the past few days, we have been talking a lot about emission rates. Emission durations (time aspect) and intermittencies, as done under the ONG rule, should also be considered.

Method Development Support
Comment: Regarding method development and the need to have something that everyone can rely on, it is worth noting that EREP is a funding agency working with the EPA, and we are very interested in funding comparative assessments, methodology developments, data analysis, etc. – anything that can contribute to the discussion.

Comment: In one example of a past rulemaking, (work completed in 2015 on expanding fenceline monitoring) the test methods (Method 325A and Method 325B) were issued without the inclusion of reference method(s). The EPA is urged to consider implementing a similar approach.
Answer: While EPA understands that this approach was successful for the development of Methods 325A/B, it is an approach that Agency litigation team would likely disapprove. In the case of Methods 325A/B, steps were taken that resembled procedures that were already being implemented in Europe, which streamlined the process and enabled the Agency to move forward. In addition to the previous work done in Europe, it is worth noting that the study used to support the proposed methods was conducted in 2008; so, there was more than 10 years of research/support.

While OTMs permit development of stringent rules, when it comes to rule validation time, they are not ready. The EPA would like to promulgate the landfill regulations as soon as legally possible.

Third-party Data Collection
Question: In 2014, Massachusetts rolled out a commercial food waste ban that they were scaling up. Under this ban, they put the onus on the haulers to perform random audits and then send a notice to the supermarket(s), for example, noting "a non-compliant load." Typically, a second infraction would result in a fine. Under this program, very few fines were issued, even though multiple loads of waste were identified as non-compliant. Ensuring certifications as a platform is one thing, but it's another to make sure that landfills are being operated appropriately and with integrity – making sure that you are noticing leaks and properly quantifying, reporting, and rectifying them. A landfill owner/operator should be confident that data received from sensor providers is accurate. With that said, what are the EPA's plans (or options) for ensuring that providers of these methods are being as robust and comprehensive as possible – whether that includes a third-party policing? If there are no options available, what does that say in terms of providing an alternative way of ensuring emissions minimization? Methane collection, rate optimization, or similar?
Answer: EPA staff (OAQPS and EPA enforcement arm) is tasked with developing the actual rule and figuring out what methods are approved. It important to ensure that whatever is approved are auditable methods – e.g., EPA looking to see if things were done right or owners/operators auditing their own contractors. Regardless of the approach taken, the numbers need to make sense and indicate that operations are performing as expected, which is a shortcoming in the current rules.

Rulemaking Development (Systematic Approach)
Comment: We recommend reducing the amount of "noise," meaning that a systematic approach should be developed.

Correlation Between Gas Collection and Control Systems (GCCS) and Emission Reductions
Question: It is generally agreed that the active area (within a landfill) is the largest source of emissions; however, confusion stems from not really understanding the purpose or the question trying to be solved here. Arguably the data does not show/reflect the idea that collecting more methane reduces emissions.
Answer: The premise is that there is a finite amount of methane gas being produced, and if that methane is collected it is not being emitted, thus the amount of methane emissions emitted to the atmosphere is reduced.
Answer: It is worth noting that there are multiple reasons at multiple times to explain what is happening in the working face area, and we (EPA) are committed to better understanding what's contributing to the emissions when seen from above (from the aircraft, satellite, flyover, etc.).

Comment: Impacted stakeholders are highly motivated to collect gas and reduce methane emissions. Yet, we have found that the collection of gas does not necessarily correlate with a reduction in methane emissions. We recommend that additional research be done. An example of trenching was offered as support where a large emission spike occurs but the rest of the gas collection system continues to operate steadily.
Answer: The EPA acknowledged these remarks and confirmed that results/correlations are typically dependent on the method used.

Promulgation Timeline
Question: In regard to the timeline, provided you evaluate all the various new technologies and determine whether it is possible to incorporate them into the regulations or any work practices, what are you envisioning for when these new set of regulations are promulgated?
Answer: Presently have a commitment from the Biden-Harris Administration to do a proposal by December 2025. From this date, it typically takes another few years to finalize and begin implementation.

Landfill Rulemaking Framework
Question (from EPA): The following question was proposed to attendees, "What do you want to see in the rule? What policy parameters?"
Answer: Attendees offered the following responses: 1) A non-prescriptive plan. Compliance can be challenging. More specifically, plans must be approved by regulators; however, some regulators fail to approve plans in a timely manner. 2) Flexibility. It was also pointed out that there might be times where gas cannot be collected. 3) All the issues and areas of concern that have been put in writing, and repeatedly brought to your (EPA's) attention are still valid concerns. 4) In regard to the design plan approval process, it is a significate barrier worth noting - only about 40% of plans are approved, which suggests that alternatives need to be dealt with differently, not through the design plan.

Comment: What is helpful, from a technology perspective, would be to think very early on about validation protocols to test technologies. Aligning testing protocols with the actual rule is extremely helpful, because then, technology vendors are able to go to the same site and test under the same conditions.
Answer: That is a good idea to consider.

Comment: We (EPA) understand the importance of incorporating emerging technologies and as previously mentioned, trying to find some flexibility in the rulemaking to include them. The intent is to establish, for example, a benchmark and as long as the technology meets the benchmark it can be used.

Plan Approval Process
Comment: It is worth noting that there have been instances where we could not do a system expansion until system expansion was required. Meaning, if we chose to change the system without having any regulatory authority to do that, we would have gotten fined by regulators because the design approval process as a whole was not completed. To further complicate things, only after you have a certain number of exceedances and met the timeline can you do a system expansion. What ends up happening, in an effort to avoid a drawn-out approval process, owners/operators deliberately allow exceedances to occur.
Question (from EPA): In an effort to simplify the approval process, the EPA is considering removing requirements like temperature as a compliance factor and asked that attendees share experience planning for fires.
Answer: Landfill owners/operators are really motivated to control and prevent fires.

Landfill Rulemaking (Flexibility and Emerging Technologies)
Question: We have heard a lot about existing/emerging technologies this week. It would be nice to see flexibility, specifically a pathway in the rulemaking to incorporate, for example, the existing technologies discussed during the workshop and those emerging in the future.
Answer: We (EPA) understand the importance of incorporating emerging technologies, and as previously mentioned, trying to find some flexibility in the rulemaking to include them. The intent is to establish a benchmark, and as long as the technology meets the benchmark, it can be used.

Comment: We have heard a lot about a lot of different technologies. It is important to understand the difference between near-term (e.g., pressure from rulemaking) and long-term (research questions). These techniques measure different things and while useful, it is still important to fully understand what's happening onsite. Trenching was mentioned earlier. Landfills are continuous construction projects, and there are emissions that are going to be variable – in the proper context. All of these measurements have a lot of value, but they all they all need different things – e.g., method development. So, regulators need to understand how these tools/technologies work in order to better develop the rulemaking.

Achieving Further Methane Reductions
Question: The EPA has talked about how landfills were the third largest emitter of methane and why additional reductions of methane are necessary. From a landfill perspective, we are highly incentivized to control methane emissions, whether for odor control, energy recovery, general health and safety, etc. Arguably, there are no incentives not to reduce/collect methane emissions at landfills. So, when the question was posed, "What do we want included in the rulemaking?" many owners/operators have moved past compliance with regulations. To what extent/degree do landfill operators/owners need to continue to reduce emissions? Achieving zero emissions is nearly impossible as landfills are inherently designed to emit methane. So, on a compliance level, what is the threshold we are actual trying to achieve? Arguably landfill operators/owners are already maximizing emissions reductions – e.g., controlling well heads and pumping out liquids.
Answer: The EPA's mission is to ultimately protect human health/public and the environment. There have been numerous discussions with impacted groups – environment groups, landfill representatives, the public and surrounding communities, etc. that have expressed a need for (and the ability to make) additional reductions. While landfills are doing a lot to help reduce methane emissions from onsite activities, the consensus is that there is more that can be done.

Unregulated Landfills
Question: From the perspective of ONG, the EPA spent a decade ratcheting down the oil and gas NSPS, but the main emission sources, arguably, were the ones not being regulated underneath the rules because there were no emission guidelines. There is a design capacity cutoff before you're even subject to the rule. Is it that the existing rule with the existing applicability needs to be ratcheted down, or that you need to look at expanding the applicability to landfills who are never going to have to collect the gas? And maybe that's where you (EPA) make a bigger emission reduction impact across the country than just rationing down the rule on those that are already regulated.

Answer: EPA recently prepared White Papers on this topic (i.e., landfills) and would like feedback. (Note: White Papers are available via the non-regulatory docket, Regulations.gov, under docket ID EPA-HQ-OAR-2024-0453)

Comment: It is my understanding that the total amount of methane emissions produced from landfills is largely unknown. In an effort to learn what is actually controllable and what is not, since EPA Method 21 focuses on leak detection, perhaps the new rulemaking could consider addressing emissions from another perspective/activity.

LESSONS LEARNED

To better plan future workshops, the following lessons learned were identified:

- While the 2-day workshop allotted for a number of topics to be covered and technologies to be presented, it is believed that expanding the workshop for an additional day might be beneficial and allow for more opportunities to network.
- Although hosting the workshop at EPA's RTP Campus is a cost-savings measure, the limited space available may create capacity issues/concerns in the future, particularly if attendance for follow-up workshops is expected to exceed the number of attendees for this workshop. In this case, consider hosting the workshop at a separate facility/meeting space offsite.
- As it relates to the agenda format, consider designating time specifically for informal discussions.
- Consider incorporating breakout sessions to allow for more focused discussions/learning.
- In situations where multiple events are occurring at the host site, coordinate breaks – to the extent possible – with other concurrent events to prevent a back-log of lunch orders, for example.
- If future workshops are held at EPA's RTP Campus ensure that proper procedures are in place and make attendees aware (in advance, to the extent possible) of ridesharing/hotel shuttle arrival and drop-off procedures.
- If future workshops are held at EPA's RTP Campus make a determination early-on regarding attendees' ability to access internet (Wi-Fi), and make attendees aware (in advance, to the extent possible), in particular international travelers, any usage restrictions.
- Coordinate international travelers' information in advance. Recommend (in lieu of emailing a separate notification requesting personal information needed for approval), incorporating this request for information as part of the registration process – prompted as a conditional question. This would allow the collection of information at the time of registration.

Appendix A – Final List of Attendees

No.	First Name	Last Name	Company / Organization
1	Nanishka	Albaladejo	SC&A, Inc.
2	Sabrina	Argentieri	USEPA/OECA
3	Dr. Douglas	Baer	ABB Inc.
4	Jarod	Bailey	USEPA
5	James	Baird	LFG Service Partners, Inc.
6	Sarah	Baker	USEPA/OAR/OAQPS/OID/CTPG
7	Nicholas	Balasus	Harvard University
8	Amy	Banister	WM
9	Julius	Banks	USEPA/OAR/OAP/CCD/GGRPB
10	Dr. Peter	Barber	SeekOps
11	David	Barron	Sniffer Robotics
12	Jeffrey	Benya	Michigan EGLE-AQD
13	Katherine	Blauvelt	Industrious Labs
14	Halley	Brantley	WM
15	Sara	Brodzinsky	Environmental Integrity Project (EIP)
16	Tomás	Carbonell	USEPA/OAR
17	Phil	Carrillo	SCS Engineers
18	John	Carter	Eastern Research Group (ERG)
19	Wyatt	Champion	USEPA/ORD
20	Parker	Chilcoat	Firmatek
21	Gregory	Chrin	Apis Innovation, Inc.
22	John	Coequyt	RMI (Rocky Mountain Institute)
23	Eric	Deibel	Virginia DEQ
24	Madjid	Delkash	USEPA
25	Dan	Duncan	Elkins Earthworks, LLC.
26	Charles	Elkins	Elkins Earthworks, LLC.
27	Joe	Fanjoy	ERG
28	Kim	Finlay	Industrious Labs
29	Daniel	Foley	GHGSat
30	Mike	Foran	LFG Service Partners, Inc.
31	Tom	Frankiewicz	RMI (Rocky Mountain Institute)

No.	First Name	Last Name	Company / Organization
32	Sue	Fraser	ECCC
33	Jorge	Garcia-Rocha	Colorado Air Pollution Control Division
34	Eleanor	Garland	RMI (Rocky Mountain Institute)
35	Donald	Garland	Drones Plus Robotics
36	Gerri	Garwood, P.E.	USEPA/OAR/OAQPS/PACS
37	Anne	Germain	National Waste & Recycling Association (NWRA)
38	Jan	Gilbreath	USEPA/OA/OP/ORPM
39	Marianne	Girard	GHGSat
40	Elizabeth	Goodiel	USEPA/OAR/OAP/CCD/GGRPB
41	Roger	Green	WM
42	David	Greene	SCS Engineers
43	Seaver	Hall	Firmatek
44	Hannah	Halliday	USEPA
45	Kareem	Hammoud	U.S. Climate Alliance
46	Kelly	Hanna	Manko, Gold, Katcher & Fox, LLP
47	Daniel	Heins	USEPA/OECA
48	Jarett	Henry	Qube Technologies Inc.
49	Dr. Nhut	Ho	HATS, Inc
50	Felix	Hoehne	Sensirion Connected Solutions AG
51	Maia	Hutt	Southern Environmental Law Center (SELC)
52	Steffan	Johnson	USEPA
53	Dr. Harshil	Kamdar	Insight M
54	Tom	Koutroulis	Orange County (OC) Waste & Recycling
55	Menaka	Kumar	USEPA/ORD
56	Edwin	LaMair	Environmental Defense Fund (EDF)
57	Quinn	Langfitt	California Air Resources Board (CARB)
58	Dr. Ali	Lashgari	Project Canary
59	Richard	Leahy	Harvard Law School
60	Johannes	Loschnigg	GHGSat
61	Ludda	Ludwig	USEPA
62	Megan	MacDonald	USEPA/ORD
63	Karen	Marsh	Lumina Sky Consulting, PLLC
64	Layne	Marshall	USEPA/OAQPS
65	Michael	Marsland	Aerometrix Services Inc. (also representing Pergam)

No.	First Name	Last Name	Company / Organization
66	Carol	McCabe	Manko, Gold, Katcher & Fox, LLP
67	Brian	Merle	Michigan - EGLE
68	Oleg	Mikailov	Xplorobot
69	Eli	Miller	University of Colorado Boulder
70	Chad	Miller	Monitoring Control & Compliance
71	Carlos	Montalvo	Lyten, Inc.
72	Ahra	Nam	Climate Imperative
73	Dave	Nash	USEPA
74	Nicole	Neff	LoCI Controls, Inc.
75	Nick	Nichols	Apis Innovation, Inc.
76	Donna	Nolen-Weathington	USEPA
77	Suyog	Padgaonkar	Climate Imperative
78	Erica	Parker	Californians Against Waste
79	Anthony	Pelletier	GFL Environmental
80	David	Penoyer	Republic Services
81	Dustin	Pickering	QED Environmental Systems, Inc.
82	Drew	Pomerantz	SLB
83	Andrew	Quigley	LoCI Controls, Inc
84	Peter	Quigley	LoCI Controls, Inc.
85	Natalia	Restrepo V.	Commission for Environmental Cooperation (CEC)
86	Dave	Risk	FluxLab, St Francis Xavier University
87	Mel	Russo	SCS Engineers
88	Julian	Sabri	Orange County (OC) Waste & Recycling
89	Joe	Santangelo	GFL Environmental
90	Tia	Scarpelli	Carbon Mapper
91	John	Scheller	IA - Process Automation
92	Darin	Schroeder	Clean Air Task Force (CATF)
93	Eric	Shelley	SLB
94	Andy	Sheppard	SCS Engineers
95	Erin	Sheridan	Michigan - EGLE
96	Ben	Silton	TrelliSense
97	Melinda	Sims	LoCI Controls, Inc
98	Dr. Stephen	Smith	QLM Technology Inc.

No.	First Name	Last Name	Company / Organization
99	Rachael	Spelman	Apis Innovation, Inc.
100	Hari	Srinivasan	Lyten, Inc.
101	Dr. Bryan	Stanley, PE	Environmental Research & Education Foundation (EREF)
102	Lesley	Stobert	SC&A, Inc.
103	Matt	Stutz	Weaver Consultants Group
104	Nick	Swanson	USEPA
105	Tim	Taylor	Colorado Dept. of Public Health & Environment (CDPHE) - Climate Change Program
106	Bill	Tennant	Sniffer Robotics
107	Eben	Thoma	USEPA/ORD
108	Michael	Thomson	GFL Environmental
109	Susan	Thorneloe	USEPA/ORD/CESER
110	Mike	Thorpe	Bridger Photonics, Inc.
111	David	Tieu	Orange County (OC) Waste & Recycling
112	Tony	Tobatto	ABB Inc.
113	Jamie	Tooley	ECOTEC Solutions, Inc.
114	Sherry	Tostenson	Virginia DEQ
115	Haley	Turner	USEPA
116	Luke	Valin	USEPA/ORD
117	Dr. Aaron	van Pelt	QLM Technology Ltd.
118	Paul	Van-Rooy	USEPA
119	Alan	Vidal	ECOTEC Solutions, Inc.
120	Xiaolin	Wang	Harvard University
121	Sherri	White-Williamson	Environmental Justice Community Action Network (EJCAN)
122	Jane	Williams	Sierra Club
123	McKenzie	Wilson	Windfall Bio
124	Rosalie	Winn	Environmental Defense Fund (EDF)
125	Ryan	Wolbert	USEPA
126	Niki	Wuestenberg	Republic Services
127	Daryl	Yao	HATS Inc.
128	Landon	Young	GHGSat
129	Peter	Zalzal	Environmental Defense Fund (EDF)
130	Dr. Yousheng	Zeng, PE	Providence Photonics
131	Jamie	Ziah	USEPA/OAR/OAP/CCD/GGRPB

Appendix B – Final Agenda

Day 1 – October 29, 2024

7:30 am – 8:30 Registration Open. Check-in with security

8:30 – 9:00 Opening Remarks – *Tomás Carbonell, Deputy Assistant Administrator for Stationary Sources, Office of Air and Radiation, U.S. Environmental Protection Agency*

Session 1: Setting the Stage

9:00 – 9:30 Landfill Challenges and Update on Recent Research and Findings – *U.S. Environmental Protection Agency, Office of Research and Development*

9:30 – 10:15 Method Development – *Dave Nash, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Measurement Technology Group*

10:15 – 10:30 Break

10:30 – 12:00 Industry Panel – Research and Experiences with New Technologies – *Moderated by Bryan Staley, President & CEO, Environmental Research & Education Foundation*

Amy Banister, Waste Management
Niki Wuestenberg, Republic Services
Mike Thomson, GFL Environmental
Dave Risk, St. Francis Xavier University

12:00 – 1:00 Lunch Break – Lunch will not be provided, but EPA's campus does have an onsite cafeteria.

Session 2: Ground Based Approaches

1:00 – 2:15 Technology Panel – Ground Based Leak Detection: Method 21 and Beyond

Jarrett Henry, Qube Technologies
Felix Hoehne, Sensirion
Ail Lashgari, Ph.D., Project Canary
Ben Silton, TrelliSense

2:15 – 2:45 Questions for Ground Based Leak Detection Panel, moderated by EPA

2:45 – 3:00 Break

3:00 – 4:15 Technology Panel – Gas Collection and Well Tuning

Melinda Sims, LoCI Controls
Phil Carrillo, SCS Engineers
Alan Vidal, EcoTech
Gregory Chrin, Apis Innovation

4:15 – 4:45 Questions for Gas Collection and Well Tuning Panel, moderated by EPA

4:45 pm Day 1 Closing Remarks – *U.S. Environmental Protection Agency*

Day 2 – October 30, 2024

8:00 am – 8:30 Registration Open. Check-in with security

Session 3: Aerial Leak Detection and Quantification

8:30 – 9:45 Technology Panel – Aerial Methods Part 1

Mike Thorpe, Bridger Photonics
Oleg Mikhailov, Xplorobot
David Barron, Sniffer Robotics
Don Garland, Drones Plus Robotics

9:45 – 10:00 Break

10:00 – 11:15 Technology Panel – Aerial Methods Part 2

Seaver Hall, Firmatek
Peter Barber, SeekOps
Douglas Baer, Ph.D., ABB
Nhut Ho, Ph.D., Human Automation Teaming Solutions (HATS) Inc.

11:15 – 12:15 Questions for both morning panels, moderated by EPA

12:15 – 1:15 Lunch Break – Lunch will not be provided, but EPA's campus does have an onsite cafeteria.

Session 4: Aerial Methods (Aircrafts and Satellites) & Regulation Discussion

1:15 – 2:30 Technology Panel – Aerial Methods – Aircraft and Satellites

Tia Scarpelli, Carbon Mapper
Marianne Girard, GHGSat
Harshil Kamdar, Ph.D., Insight M
Michael Marsland, Pergam Technical Services

2:30 – 3:00 Questions for Aircrafts and Satellite Panel, moderated by EPA

3:00 – 3:15 Break

3:15 – 4:45 Discussion on Regulation of Municipal Solid Waste Landfills, *U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Natural Resources Group*

4:45 pm Adjourning Remarks – *U.S. Environmental Protection Agency*

* All times are in Eastern Time