Session 1: Methane and Landfills

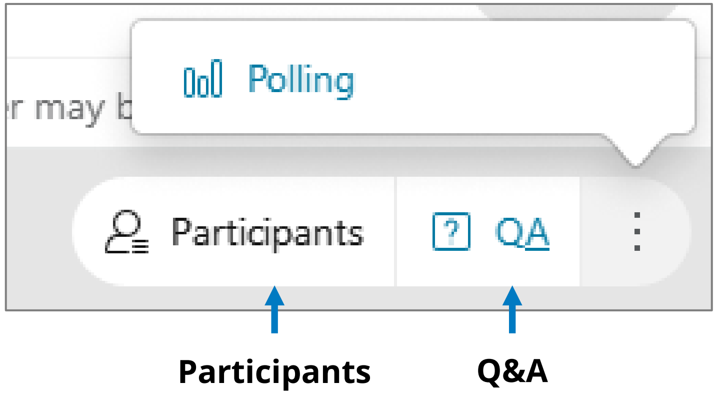
Training on Best Practices for Landfill and Organic Waste Management

October 28, 2024

Webinar Panels

- We will use two panels
  - Participants and Question & Answer (Q&A)
  - Use the arrow to expand or collapse the panels

- Adding Panels
  - If some panels don't appear, select the desired panels in the lower right corner



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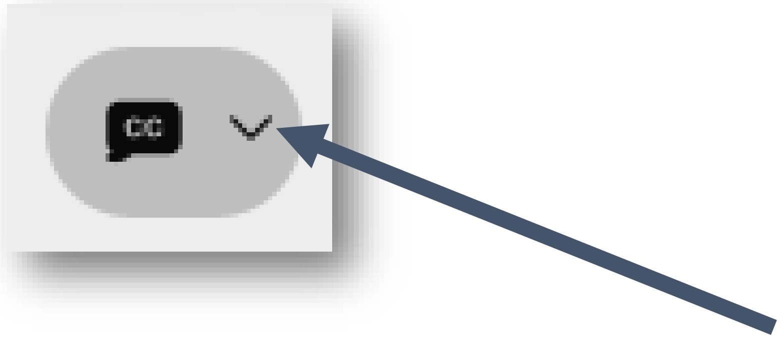

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- Please enter your questions in the Q&A box at any time during the training. These questions will be answered during the open discussion
- To ask a question:
    - Select “All Panelists” from the drop-down menu
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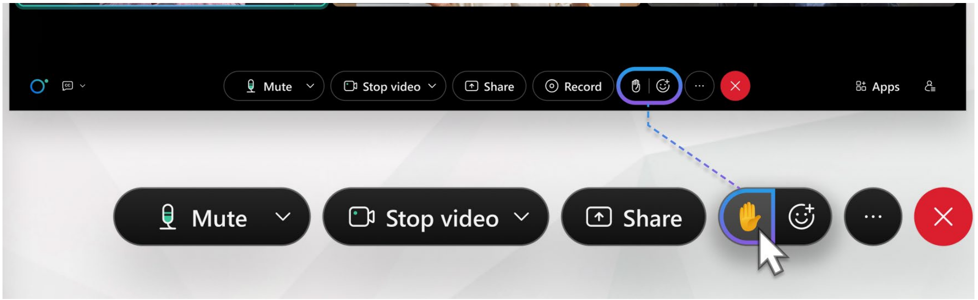

Speakers

Patrick CoatarPeter
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Dana Blumberg (moderator)
Vice President
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James Law
Vice President and Senior Geotechnical Engineer
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Bob Dick
Senior Vice President
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Global Methane Initiative (GMI)

- International public-private partnership focused on advancing:
  - Cost-effective, near-term methane abatement
  - Recovery and use of methane as a valuable energy source
- Provides in-kind technical support to deploy methane mitigation and methane-to-energy projects around the world
- Supports methane mitigation in three key sectors:
  - **Biogas (municipal solid waste, agriculture, wastewater)**
  - Coal mines
  - Oil & gas

Global Methane Initiative

- 49 Partner Countries
- 100s of Project Network members
- Alliances with international organizations focused on methane recovery and use

GMI Partner Countries represent approximately 75% of methane emissions from human activities.

Overview of Session

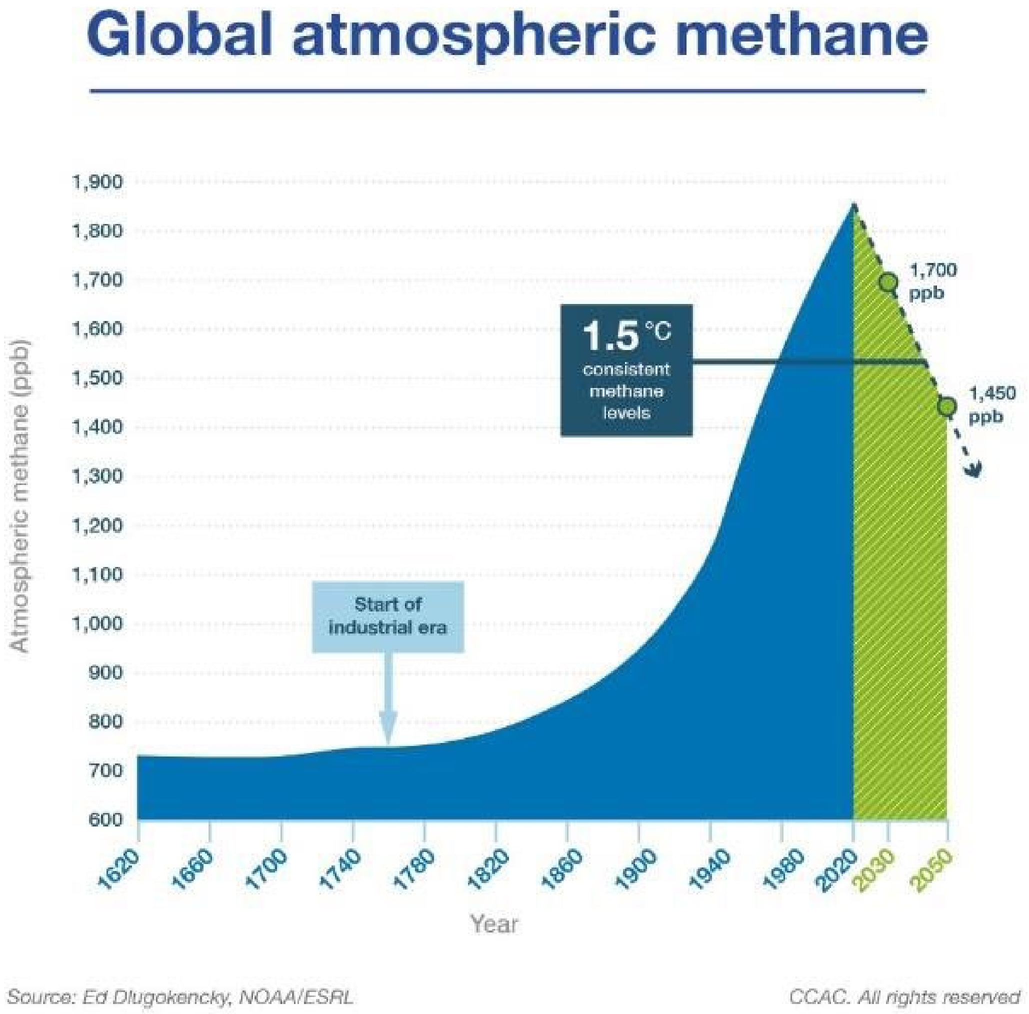
- Methane and Landfill Gas (LFG)
- Dumpsite and Dumpsite closure
- Landfills and Landfill Gas Systems
  - Landfill Gas Collection System
  - Landfill Gas Modeling
  - Landfill Gas to Energy
  - Best Practices for Landfills and Landfill Gas Operations and Maintenance (O&M)
  - Economics of Landfill Gas Collection Systems
  - Case Studies
- Tools and Resources

Methane and Landfill Gas (LFG)

Presenter: Patrick CoatarPeter

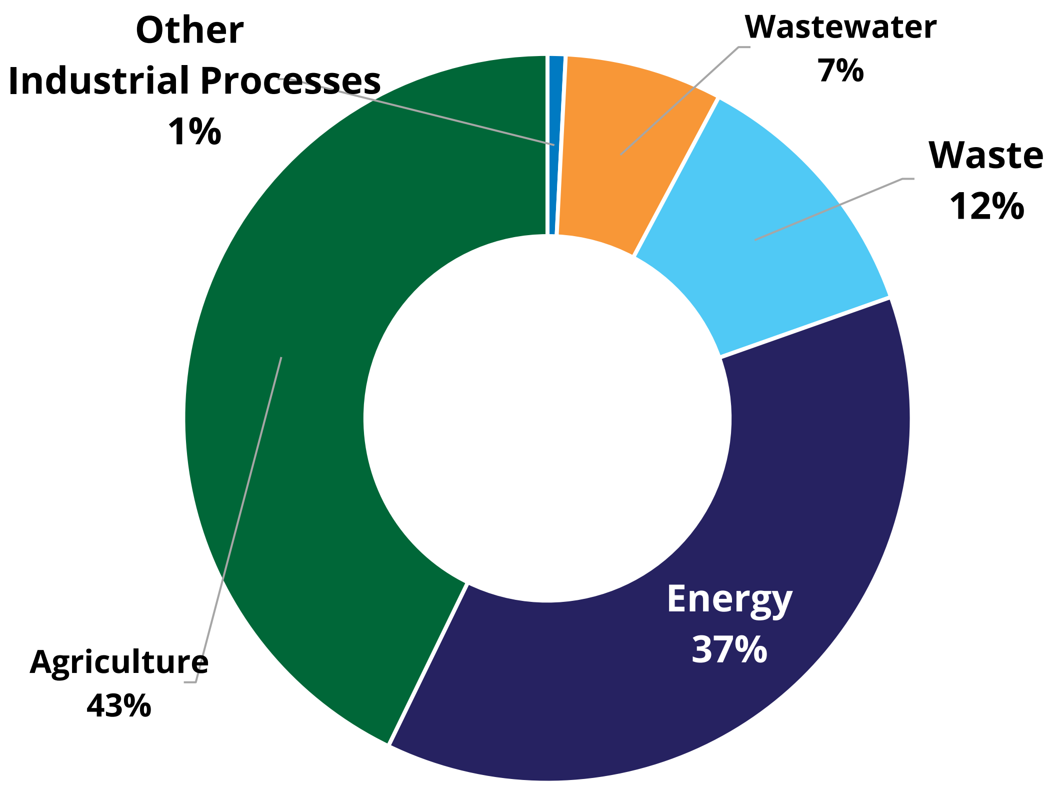
Introduction to Methane

- **Powerful greenhouse gas (GHG).** One ton of methane can trap more than 28 times the amount of heat as one ton of carbon dioxide over a 100-year period
- **Precursor to tropospheric ozone (smog)**, an air pollutant and GHG
- **Short-lived climate pollutant** with an atmospheric lifetime of ~12 years
- **Opportunity for fast climate action**
  - Cutting methane now delivers substantial, immediate climate benefits



Methane Emissions from Waste Sector

- Waste sector is the **third largest source** of global methane emissions.
- In the waste sector, methane is produced due to the decomposition of organic (biodegradable) materials in landfills and dumpsites.
- **Landfill Gas (LFG)** is the gas produced in the landfills. Composition of LFG is approximately 50-55% methane and 45-50% carbon dioxide, with trace non-methane organic compounds.



Global Methane Emissions By Sector

Source: U.S. EPA's Global Non-CO2 Emissions Database

Dumpsites and Dumpsite Closure

Presenter: James Law

Dumpsites

- Wastes widely spread, uncovered and no daily cover
- Uncontrolled methane emissions
- Slope failure and instability issues
- Leachate not managed
- Open fires caused by combustible materials

Dumpsites (Continued)

- Lack of security measures, access by waste pickers
- No liner system or clay soil to prevent ground water contamination
- Disease vectors (dogs, birds, other animals) often present; animals seeking food at open dumps
- No compaction contributing to multiple issues e.g., leachate infiltration, slope instability etc.

Dumpsites (Continued)

- Uncontrolled dumpsites hold 40% of the world’s waste and serve 3-4 billion people.
- World’s 50 biggest dumpsites directly affect the daily lives of 64 million people.
- Dumpsites are estimated to generate 8-10% of manmade greenhouse gases by 2025.

Selected Historical Dumpsite Slope Failures

- 2000 – Payatas Dumpsite, Manilla, Philippines; 278 killed; 300 missing
- 2005 – Leuwigajah Dumpsite, Bandung, Indonesia; 143 killed
- 2015 – Hongao C&D Landfill, Shenzen, China; 73 killed; 4 missing
- 2016 - Hrybovychi Landfill, Lviv, Ukraine; 4 killed
- 2017 - Koshe Dump, Addis Ababa, Ethiopia; 113 killed; 80 missing
- 2017 – Meethotamulla Garbage Dump, Sri Lanka; 19 killed
- 2017 – East Delhi Landfill, India; 2 killed
- 2020 – Ermua Landfill, Zaldibar in Basque region of Spain; 2 killed
- 2024 – Kiteezi Landfill, Kampala, Uganda; at least 35 killed; 4 missing

Reasons for Dumpsite Closure

- **Soil Contamination Risks:** Dumpsites pose significant soil contamination risks, threatening agricultural productivity and ecosystem health over time.
- **Water Source Threats:** Leachate from dumpsites can contaminate nearby water sources, endangering drinking water quality and aquatic life.
- **Methane Emissions:** Methane emissions from dumpsites poses threat to global climate and impact local air quality.
- **Regulatory Necessity:** Closure is often essential for compliance with local and national standards, preventing legal repercussions and promoting sustainability.

Dumpsite Closure

- **Definition:** Dumpsite closure refers to the systematic process of decommissioning waste disposal sites, ensuring safety
- **Options for Closing a Dumpsite**
  - Closure by upgrading into a controlled sanitary landfill
  - In-place closure by installing an engineered cap over the waste (requires collecting LFG)
  - Closure by removing waste from the dumpsite

Improvements for Dumpsites During Closure Planning

Health Protection	• Inspect and record incoming waste • Stop all open burning by educating and outreaching programs • Provide security fence to minimize unauthorized people and animals to the dumpsite • Designate work area for scavengers or waste pickers • Apply daily cover
Environmental Impacts	• Compact waste placement in thin lifts. • Provide intermediate soil cover at inactive and side slope areas • Provide temporary leachate management measures • Collect landfill gas at visible locations with gas wells and flare it
Prepare the New System	• Separate recyclable material at sources and divert various waste streams from the site • Manage activities related to collection, transportation and landfilling (e.g., establishing transfer stations, improving collection services, odor management, pest control, etc.)

Technical Considerations for a Closure Plan

- Choose an appropriate Closure Method
- Select a Suitable Cap or Cover System
- Meet Site-Specific Regulatory Requirements
- Choose Leachate and Landfill Gas Management Systems
- Implement Quality Control & Quality Assurance Program

Challenges in Dumpsite Closure

- Lack of coherent policies and coordination
- Limited access to financial instruments and tools
- Limited administrative capacity of waste authorities
- Restricted markets for waste management & recyclables

Post-Closure Care of Closed Dumpsites

- Maintain the cover system through regular inspection and evaluation of its settlement, cap subsidence and erosion, slope instability and vegetation cover conditions.
- Stormwater run-off / run-on drainage controls.
- Operate, monitor and maintain, if any, the leachate management system, landfill gas controls and wells, and groundwater monitoring wells and stream sampling (if any).

Landfills and Landfill Gas Systems

Presenter: Bob Dick

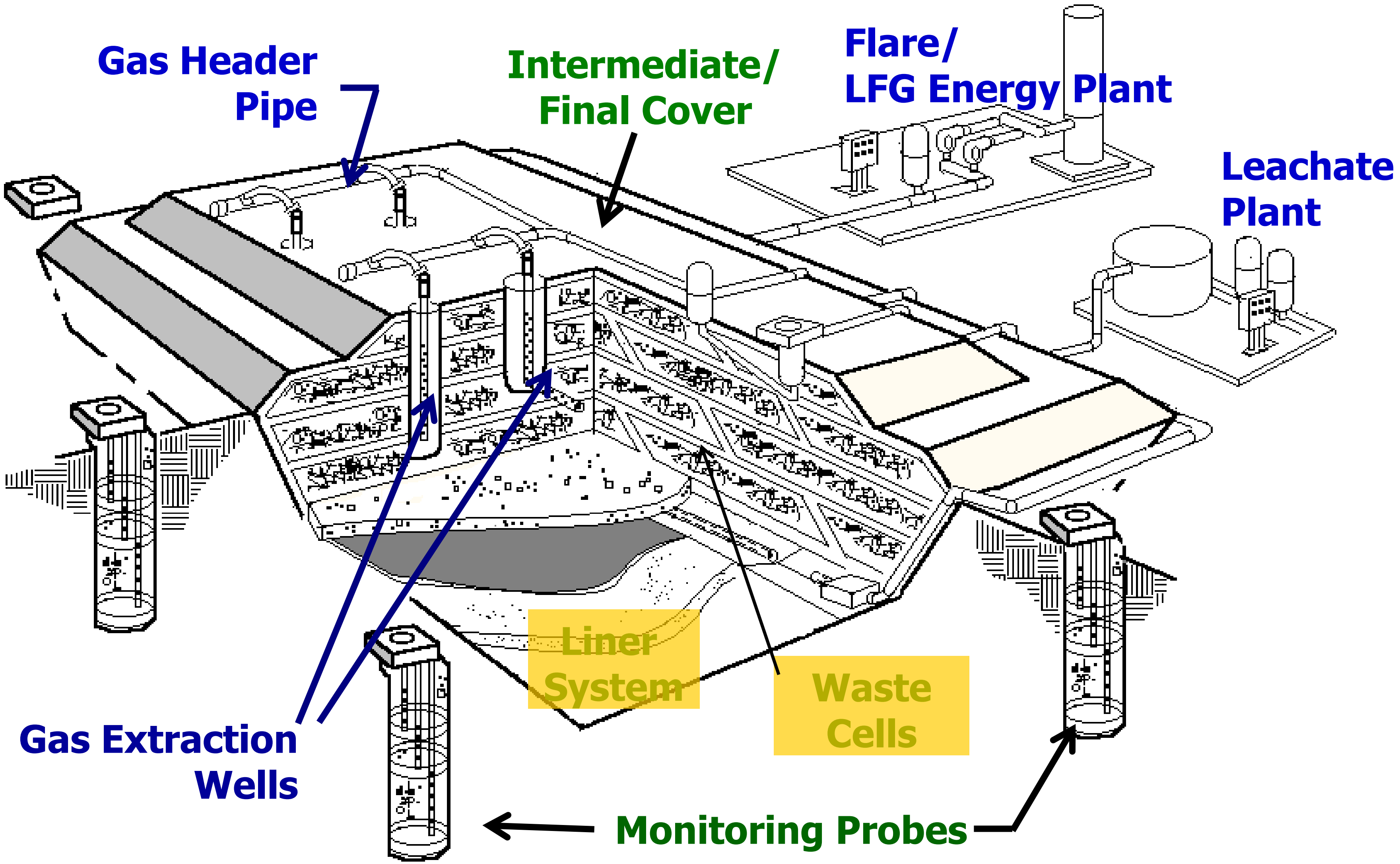
Moving from Dumpsite to Sanitary Landfill

- Before closing dumpsite, a good practice is to build a sanitary landfill.
- U.S. EPA defines sanitary landfilling as an engineered method of disposing solid wastes on land by spreading them in thin layers, compacting them to the smallest practical volume, and covering them with soil each working day in a manner that protects the environment.
- Globally only 8% of solid waste is managed in sanitary landfills.

Key Aspects of a Sanitary Landfill

- Wastes properly placed and covered with daily cover
- LFG collection and management system to reduce methane emissions and offsite migration
- Stable slopes
- Leachate collection and management system
- No open fires
- Security measures to stop disease vectors (i.e., dogs, birds, other animals)
- Liner system to prevent ground water contamination
- Proper compaction of incoming waste

Modern Sanitary Landfill



LFG Energy Project Development

- LFG generated from landfills, can be captured and converted into renewable energy through landfill gas energy projects, reducing methane emissions and producing electricity, heat, or fuel.

Following steps offer guidance for the successful development of a LFG energy project:

- Basics of landfill gas collection systems
- Landfill emissions estimation
- Landfill gas modeling
- Landfill Gas Energy Technology Options
- Economics of Landfill Gas Collection Systems

Landfill Gas Collection System

- **Landfill Gas Collection System (LFGCS):** Captures methane and other gases produced during waste decomposition in landfills usually installed in cells with intermediate/final cover.
  - In U.S., a landfill is required to install LFGCS once the design capacity cross 2.5 million metric ton or the Non-Methane Organic Compound Emissions exceed 34 Mg.
- **Gas Treatment:** Extracted gas may be treated to remove contaminants before utilization or flaring.
- **Energy Recovery:** Enables the conversion of captured landfill gas into renewable energy.
- **Odor and Safety Management:** Controls landfill odors and reduces the risk of explosions by safely managing the buildup of combustible gases within the landfill.

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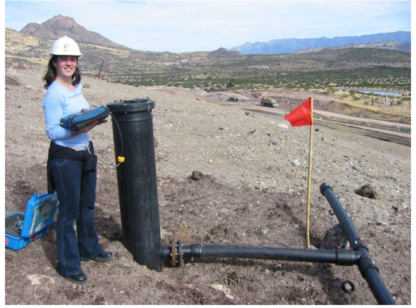
Components of LFG Collection System

- LFG collectors
  - Vertical extraction wells
  - Horizontal collectors/trenches
  - Connection to existing vents, leachate collection system, etc.
- Monitoring wells and equipment
- Network of interconnecting pipes
- Condensate management
- LFG blower/combustion station, including flare, engine, etc.

Headers and Laterals

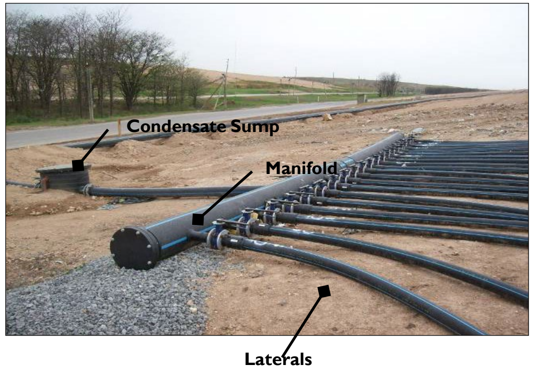
Horizontal Well

Vertical Well



Gas Monitoring Well

Condensate Sump



Flare

Landfill Emissions Estimation

- Direct Measurement: drones/satellites and surface emission monitoring
  - – Only provide concentrations
  - – Difficult to convert concentrations to flow rate
- LFG Modeling
  - – High level of uncertainty
  - – Requires good waste disposal data
  - – Need appropriate models for local conditions

Landfill Gas Modeling

Important factors to consider when assessing LFG

What is LFG Modeling?

- Forecasts gas generation and recovery
- Estimates gas collection system (GCS) efficiency
- Based on past and future waste disposal trends

Importance of LFG Modeling

- Estimates recoverable LFG over time
- Essential for decisions making

LFG Modeling Tools

- **Landfill Gas Emissions Model** (LandGEM)
- **Solid Waste Emissions Estimation Tool** (SWEET)
- **Intergovernmental Panel on Climate Change** (IPCC)
- **Global Methane Initiative Colombia Model** (GMI Colombia Model)

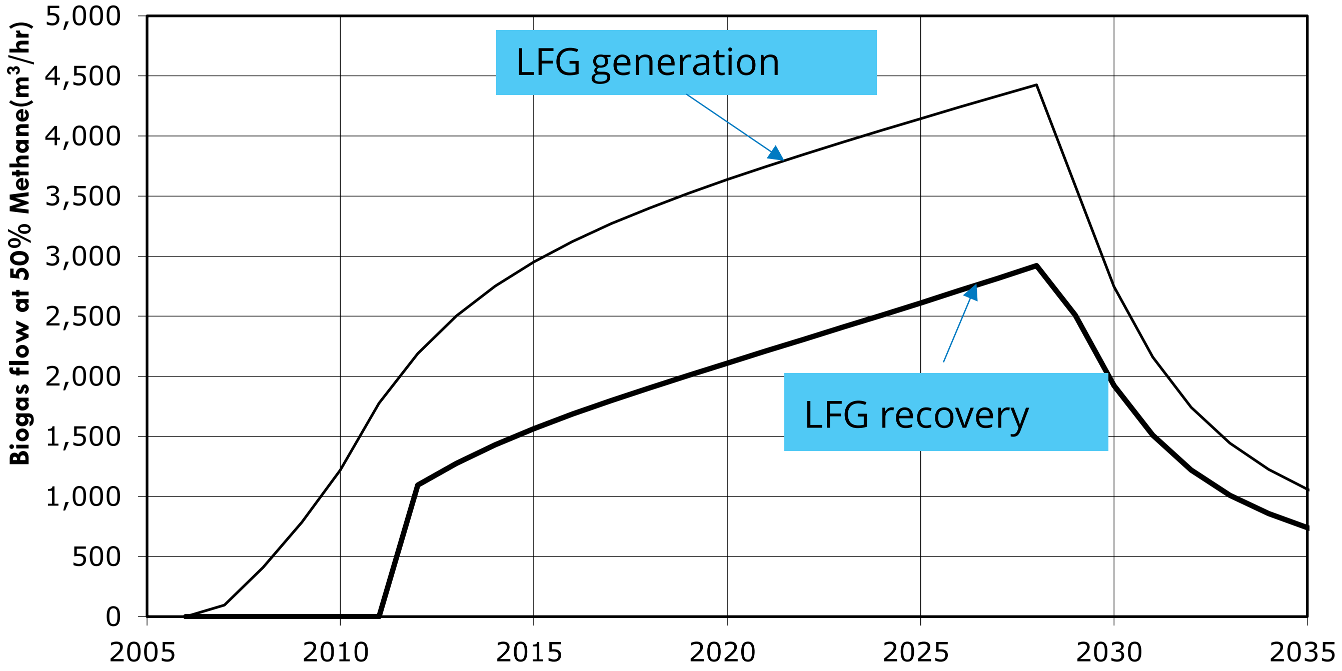
Landfill Gas Modeling

- Landfill gas generation and recovery estimates
  - **LFG recovery is determined by LFG generation and "collection efficiency" – function of:**
    - Collection system design
    - Collection system operation and maintenance
    - Landfill configuration and operations
  - **Factors affecting LFG generation**
    - Waste Composition: Organic-rich waste (e.g., food, paper) leads to higher LFG production.
    - Moisture Content: More moisture accelerates waste decomposition and increases LFG production.
    - Temperature: Higher temperatures promote microbial activity, enhancing gas generation.
  - **Methane generation and recovery estimates for LFG projects**
    - Screening tool for project development
    - Basis for assessing project feasibility

Landfill Gas Modeling

- **LFG Recovery Potential:**
  - 50-85% of generated gas can be collected.
  - Higher collection efficiencies in well-maintained systems with good cover design and optimized well placement.

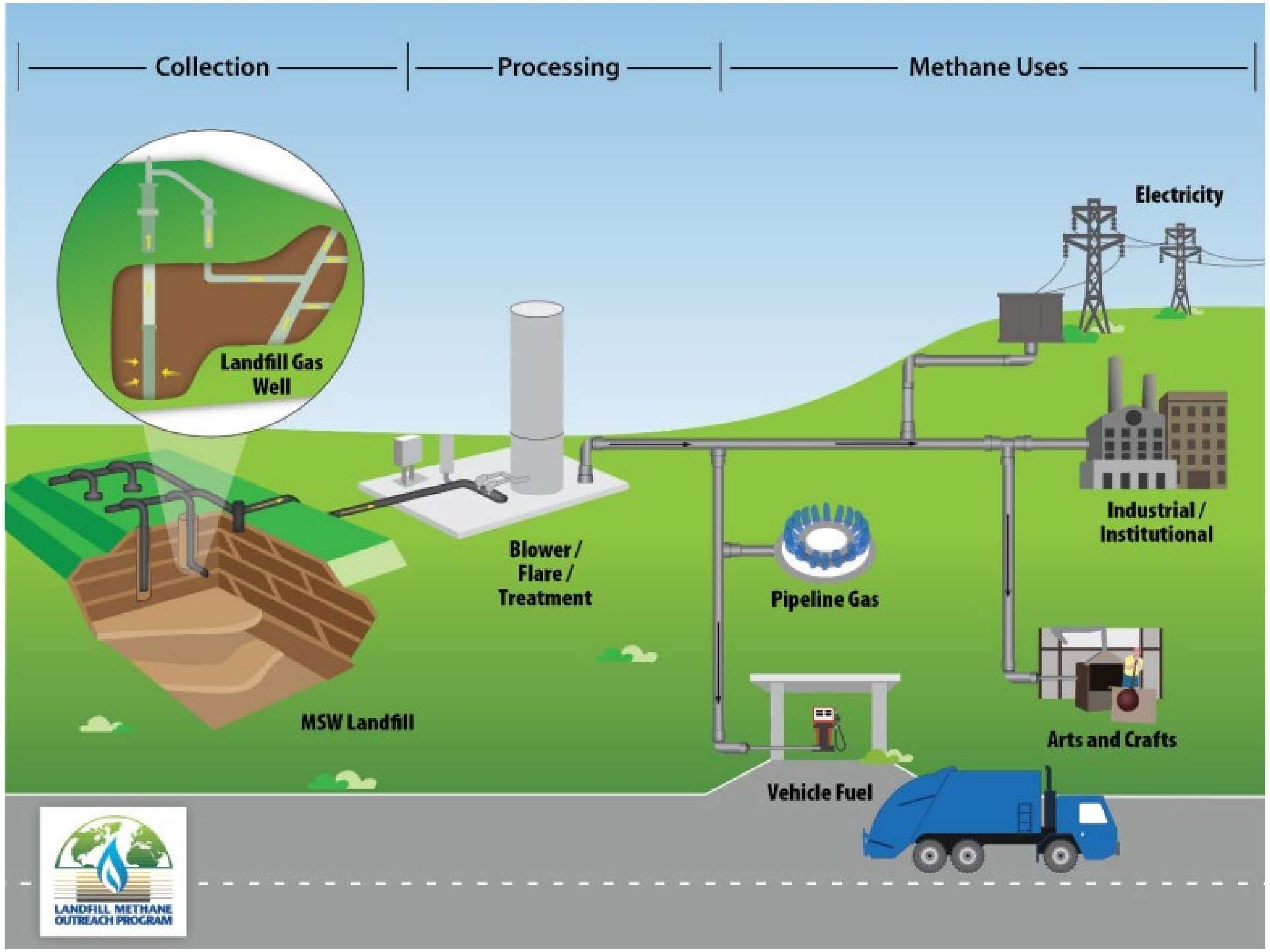
LFG Generation Estimate from a Landfill Site in U.S.



Landfill Gas Energy Technology Options

- **Medium BTU fuel (Direct Gas Utilization):** Used directly or with little treatment for commercial, institutional, and industrial use to supply water heaters, furnaces, aggregate dryers and greenhouses. Typically contains 50% methane.
  - **Leachate Evaporation:** Landfill gas is used as fuel for the evaporation of leachate, thus reducing treatment costs.
- **Renewable Natural Gas (RNG):** Landfill gas can be converted into RNG which can be injected into the existing natural gas grid. RNG can also be processed into compressed natural gas (CNG) or liquefied natural gas (LNG) for use as a cleaner alternative to gasoline and diesel in vehicles.
- **Electricity:** Landfill gas is used as fuel for internal combustion engines, fuel cells and turbines for the generation of energy to be sent to the grid.

LFG Energy Project Phases and Methane Uses



LFG Energy Project Benefits

- Destroys methane and other organic compounds in LFG while producing renewable energy
- Offsets use of nonrenewable resources
- Potential benefits for the landfill;
  - Another source of income
  - Improved landfill operations
- Potential benefits for the end user
  - Reduces fuel costs
  - Use of renewable resources
  - Supports the strategy of being a “green” and/or sustainable company
- Local economic development

Direct Gas Utilization

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- **Boilers**
- **Direct thermal applications**
  - Kilns
  - Furnaces
- **Innovative applications**
  - Greenhouses
  - Infrared heaters
  - Pottery kilns
  - Leachate evaporation
- **Advantages**
  - Simple technology
  - End user benefits from reliable low-cost fuel
- **Disadvantages**
  - Need a near by energy user
  - Requires pipeline right-of-way

Renewable Natural Gas Upgrade

- **Technology**
  - Gas is purified from 50% to 97- 99% methane
  - Removal of carbon dioxide is primary step
  - ~ 9 percent of currently operating LFG energy projects in the U.S. are creating RNG
- **Advantages**
  - Inject treated product into natural gas pipeline
  - Can be used as vehicle fuel
- **Disadvantages**
  - Must meet strict standards of natural gas pipeline
  - Costly technology
  - Economical for large scale only

Electricity Generation

- **Most prevalent type of project in the U.S.**
  - ~ 64 percent of currently operational LFG energy projects in the United States generate electricity
- **Sale of Electricity to**
  - Utility
  - Cooperative or industries able to buy directly
  - Nearby large customer
  - On-site use or net metering
- **Average U.S. project size: 4 MW (500 kW - 50 MW)**
- **Advantages**
  - Proven and reliable
  - Option to choose from multiple technologies like turbines, microturbines, internal combustion engine etc.
- **Disadvantages**
  - Capital and operational cost varies based on the technology selected
  - Some technologies like steam and gas turbines require LFG pretreatment

Challenges to LFG projects

- Poor landfill operations (e.g., excessive liquids getting into landfill, inadequate waste compaction)
- Inadequate design and installation from lack of experience the engineer and installer
- Inadequate maintenance, operation and monitoring
- Overestimation of LFG generation for energy projects
- Difficulty in accessing financing especially with insufficient tipping fees
- Unclearly defined contracts with partners and sub-contractors
- Permitting and local financial/buy-in support

Question?

Best Practices for Landfills and Landfill Gas Facilities Operations and Maintenance (O&M)

Presenter: Deji Fawole

Best Practices for Sanitary Landfill O&M

Here is a list of parameters important for Landfill O&M

- Waste acceptance
- Waste placement
- Daily cover
- Leachate management
- Regular inspections
- Erosion control
- Vegetation management
- Access roads
- Condensate management
- Blowers and compressors
- Flare maintenance
- Installation of equipment

Best Practices for Sanitary Landfill O&M

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- **Waste acceptance:** Inspect incoming waste, reject prohibited materials like batteries, motor oil, pesticides etc.
  - **"Good" Waste**
    - Homogeneous
    - Easy to handle
    - Poses little threat to equipment
    - Arrives in collection vehicles from residential and commercial areas
    - Placed on the outside and closer to the surface of the working face
  - **"Bad" Waste**
    - Bulky
    - Difficult to grade or spread
    - Does not compact well
    - Comes from industrial or construction areas
    - Should be placed underneath good waste

Best Practices for Sanitary Landfill O&M

- **Waste placement:** Must be spread in manageable layers and properly compacted. Waste lifts, 120 to 240 cm (4 to 8 feet) thick, is ideal
  - Push waste from the bottom of the slope towards the top
  - Use a bulldozer to enhance the compaction process
  - Maintain a controlled working face
  - Eliminate “Waterfalling” of waste Equipment may need to exert more power

Best Practices for Sanitary Landfill O&M

- **Daily cover:** Apply soil or alternative materials daily to control odors, vectors, and litter
  - Use appropriate materiel
  - Ensure uniform coverage
  - Maintain optimal thickness
  - Remove low permeability materials
  - Avoid excessive cover
  - Adapt for weather conditions

Best Practices for Sanitary Landfill O&M

- **Leachate management:** Collect and treat leachate
- **Regular inspections:** Check for erosion, settlement, and cover integrity
- **Erosion control:** Maintain slopes, repair damage promptly
- **Vegetation management:** Mow regularly, control invasive species
- **Access roads:** Keep clear, repair surfaces to prevent dust and mud tracking

Best Practices for Landfill Gas Facilities O&M

- **Condensate management**
  - LFG collection system should be designed to move condensate to engineered low points
  - Can be disposed by incineration, disposal in sanitary sewer or treating alongside leachate
- **Blowers and compressors**
  - Can be used for flares, engines, or RNG
  - Placement should be near LFG Collection System and considers future expansions
- **Flare**
  - Maintain flare operation for backup
- **Installation of equipment**
  - Construction Quality Assurance (CQA) while installation of gas control system (GCS)
  - Proper documentation

Best Practices for Landfill Gas System Design and Installation

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Most important parameters for LFG collection system design and installation

- **Facility review**
  - Consider landfill geometry, compaction rate, and waste types for efficient LFG system design
  - Consider local climate conditions
- **LFG collector**
  - Focus on capturing gas, controlling gas migration, and minimizing fugitive emissions/odors.
  - Control oxygen content in extracted LFG to protect equipment and minimize operational costs.
- **Lateral and header piping**
  - Consider the placement, materials and size based on specific landfill site

Best Practices for Monitoring Landfill Gas

- **Typical parameters to monitor monthly include:**
  - Vacuum or pressure
  - Methane
  - Oxygen
  - Carbon dioxide
  - Balance gas (nitrogen)
  - Temperature
  - Flow rate
  - Liquid depth in well (once a quarter to once every 6 months depending on weather)

- **Maintain LFG characteristics:**
  - Methane: 46-55%
  - Oxygen: Less than 1%
  - Nitrogen: 2-14%
  - Temperature: Less than 56-60^{O}C

- **Note that each site is different and such ranges may not be possible at all sites**

Economics of Landfill Gas Collection Systems

Presenter: Deji Fawole

Typical Costs of LFG Systems

Cost for Collection and Flaring System (U.S.)		
Cost Component	**Cost**	**Cost Unit**
Gas collection system including wells	$10,000	per acre
Installed cost of knockout, blower, and flare system	$996,000	per system
Annual O&M for collection (excluding energy)	$2,600	per well
Annual O&M for flare (excluding electricity)	$5,100	per flare
Electricity price (depends on type of project)	$0.103	per kWh

Cost for Direct-Use System (U.S.)		
Cost Component	**Cost**	**Cost Unit**
Installed cost of skid-mounted filter, compressor, and dehydration unit	$360(x) + $830,000	$, x = ft^3/min
Installed cost of pipeline to convey gas to project site	$80(x) + $178,000	$, x = ft of pipeline
	$106(x) + $207,000	$, x = ft of pipeline
Annual O&M of filter, compressor, dehydration unit, and pipeline (excluding electricity)	$57,000 * $(x/700)^{0.2}$	$, x = ft^3/min

Typical Costs of LFG Systems

LFG Electricity Project Costs (U.S. – 2020)			
Technology	**Optimal Project Size Range**	**Typical Capital Costs ($/kW)**	**Typical Annual O&M Costs ($/kW)**
Microturbine	1 MW or less	$3,400	$340
Small internal combustion engine	799 kW or less	$2,900	$320
Large internal combustion engine	800 kW or greater	$2,000	$300
Gas turbine	3 MW or greater	$1,700	$190

Costs of Onsite Small-scale CNG Fueling Station (U.S. – 2020)		
Inlet LFG (scfm)	**Plant Size (GGE/day)**	**Cost ($/GGE)**
50	198	$3.28
150	594	$2.52
300	1,188	$2.18
600	2,377	$1.93

GGE: gasoline gallon equivalents **scfm:** standard cubic feet per minute **$/kW:** dollars per kilowatt

Economics and Financing

Steps involved in LFG collection system projects include:

Quantify capital	Designing and engineering
	Permits and fees
	Site preparation and installation of utilities
	Startup cost and working capital
	Administration costs
Quantify O&M costs	Parts and materials
	Labor
	Utilities
	Taxes
	Financing costs
	Administration

Economics and Financing

- Estimate revenue
  - Grants from government and international bodies
  - Revenue from tipping fees
  - Revenue from energy sales (in case of LFG to energy system)
  - Tax incentives
- Assess economic feasibility
  - Economic performance parameters include
    - Net present value (NPV)
    - Internal rate of return
    - NPV payback period
    - Capital and O&M costs

Economics and Financing

- Compare all economically feasible options and select winners
  - Side by side comparison of all options
  - Conduct sensitivity analysis
  - Risks associated with each option
  - Compare non-price factors
- Assess project financing options
  - Private banks
  - Investors
  - Federal, provincial and local governments
  - International bodies

Case Study

Presenter: Deji Fawole

Ahmedabad, India - Pump Test

- City wanted to estimate the amount of LFG that could be recovered for a LFG Energy Project.
- On behalf of GMI:
  - Developed a work plan for a pump test,
  - Hired a driller, supervised installation,
  - Trained local technician to monitor the test wells and
  - Used a landfill gas model to estimate potential LFG recovery.
- The driller was inexperienced in drilling on a dumpsite and many health and safety issues arouse.
- Data collection also had many technical issues.

Ahmedabad, India

Ahmedabad Pump Test Results

- Drill rig was not sufficient for drilling into waste
- Driller gained experience drilling in waste
- Health and safety issues
  - Workers wearing sandals on top of waste and using heavy equipment
- Excavation was required which compromised the quality of the well
- Pipes and blower had to be guarded from scavenging
- Technician was inexperienced and monitoring had errors

Lessons Learned

- More experienced needed for drilling on a dumpsite but some capacity building took place.
- Conduct health and safety training.
- Better training for technician monitoring.
- Pump test was not accurate for estimating potential LFG recovery.
- LFG recovery assessment better done with model.

Tools and Resources for Facility Operators

Presenter: Bob Dick

Tools for Facility Operators

[Landfill Gas Model (Colombia LFG Model)]

- Excel spreadsheet that uses first order decay model
- Estimates LFG generation and recovery from MSW landfills
- Developed for Colombia but can be used anywhere since Colombia has several representative climates

[Solid Waste Emissions Estimation Tool (SWEET)]

- Excel-based tool that quantifies emissions of methane, black carbon, and other pollutants from sources in the municipal solid waste sector
- Provides emissions and emissions reduction estimates at the project-, source-, and municipality-level
- To be covered in Session 4

Tools for Facility Operators

[Hydrologic Evaluation of Landfill Performance (HELP Model)]

→

- Quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills
- Estimates water balances for landfills
- Models rainfall, runoff, infiltration and other water pathways to estimate how much water builds up above the landfill liner

Resources for Facility Operators

The Best Practices for Solid Waste Management: A Guide for Decision-Makers in Developing Countries

- Focused on medium and large urban centers
- Audience is state and local government authorities (decision makers, policy makers and agency staff)
- Available in multiple languages
- Estimates LFG generation and recovery from MSW landfills
- Developed for Colombia but can be used anywhere since Colombia has several representative climates

ISWA Landfill Operational Guidelines (version 3)

- Written for lower-income and middle-income countries to transition from open dump to sanitary landfill
- Chapters include:
    - Site roads
    - Daily cover
    - Bird, litter, and vector control
    - Operations
    - Leachate control
    - LFG management
    - Biocovers
    - Landfill closure

Resources for Facility Operators

[A Roadmap for Closing Waste Dumpsites: The World's Most Polluted Places]

- Provides guidance to local authority or government on the process and procedures requires to close dumpsites and develop an alternative sound waste management system.
- Content includes guidance on:
    - Governance
    - Financial and economic problems
    - Technical challenges

[ISWA The Impact of Management Choices on Landfill Methane Emissions]

- Goal to compile factual arguments to illustrate and clarify which realistic management choices during landfill operation provide the best options to minimize greenhouse gas (GHG) emissions from landfills over their lifetime.

Questions?

References

- Mavropoulos, A., Cohen, P., Greedy, D., Plimakis, S., Marinheiro, L., Law, J., Loureiro, A., & Timothy Bouldry. (2016). A Roadmap for closing Waste Dumpsites: The World's most Polluted Places (By ISW).
- SCS Engineers & International Solid Waste Association (ISWA). (2020). Estimating waste sector GHG emissions in Tyre Caza, Lebanon, using SWEET.

Thank You!

Please reach out with any questions to: biogastoolkit@epa.gov

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