"INOGATE Technical Secretariat & Integrated Programme in support of the Baku Initiative and the Eastern Partnership energy objectives" Project

BUILDING PARTNERSHIPS FOR ENERGY SECURITY

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Training Presentation 1
Introduction to Landfill Gas

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LANDFILL GAS

What is Landfill Gas?

LFG is a natural by-product of decomposition of organic material in municipal solid waste in anaerobic conditions.

- LFG contains about:
- 50% methane (CH₄) and
- 50% carbon dioxide (CO₂).

- LFG also contains:
- Nitrogen N₂,
- Oxygen O₂,
- Ammonia NH₃,
- Carbon monoxide CO and
- NMOC non-methane organic compounds such as benzene and vinyl chloride.

- LFG also contains other non-methane organic compounds and trace amounts of inorganic compounds.
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- Proteins
  - Hydrolysis
  - Acidogenesis
  - Acetogenesis
  - Methanogenesis

- Carbohydrates
  - Intermediates (propionic acid, butyric acid)
  - Acetic Acid

- Fats
  - Fatty Acids
  - Hydrogen
  - Methane
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Fermentative processes:

- \( \text{C}_6\text{H}_{12}\text{O}_6 + 2\text{H}_2\text{O} \rightarrow 2\text{CH}_3\text{COOH} + 4\text{H}_2 + 2\text{CO}_2 \)
- \( \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow \text{CH}_3\text{C}_2\text{H}_4\text{COOH} + 2\text{H}_2 + 2\text{CO}_2 \)
- \( \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{CH}_3\text{CH}_2\text{OH} + 2\text{CO}_2 \)

Hydrogen (\(H_2\))

Carbon dioxide (\(CO_2\))
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Acetogenic processes:

- $\text{CH}_3\text{CH}_2\text{COOH} + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + \text{CO}_2 + 3\text{H}_2$
- $\text{CH}_3\text{C}2\text{H}_4\text{COOH} + 2\text{H}_2\text{O} \rightarrow 2\text{CH}_3\text{COOH} + 2\text{H}_2$
- $\text{CH}_3\text{CH}_2\text{OH} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + 2\text{H}_2$
- $\text{C}_6\text{H}_5\text{COOH} + 6\text{H}_2\text{O} \rightarrow 3\text{CH}_3\text{COOH} + \text{CO}_2 + 3\text{H}_2$

Hydrogen ($H_2$)

Acetic acid ($\text{CH}_3\text{COOH}$)

Carbon dioxide ($\text{CO}_2$)
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Methanogenic processes:
• $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$
• $CH_3COOH \rightarrow CH_4 + CO_2$
• $HCOOH + 3H_2 \rightarrow CH_4 + 2H_2O$
• $CH_3OH + H_2 \rightarrow CH_4 + H_2O$

Carbon dioxide ($CO_2$)

Methane ($CH_4$)

Water ($H_2O$)
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Sulphate-reducing processes:
• $4H_2 + SO_4^{2-} + H^+ \rightarrow HS^- + 4H_2O$
• $CH_3COOH + SO_4^{2-} \rightarrow CO_2 + HS^- + HCO_3^- + H_2O$
• $2CH_3C_2H_4COOH + SO_4^{2-} + H^+ \rightarrow 4CH_3COOH + HS^-$

Hydrogen sulphide (H$_2$S)
What is Landfill Gas?

• Methane in LFG is a potent greenhouse gas, with over 22 times more potent than carbon dioxide.
• Methane in LFG is highly flammable and has explosion risk.
• Although regarded as a hazard, it is a profitable asset.
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Landfill Gas Production

Rate of Landfill Gas Generation

Start of Waste Deposition

Time

20 to 50 years after Waste Deposition
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Landfill Gas Production

![Diagram showing Landfill Gas Production stages](image-url)
Landfill Gas Production

- **Stage 1** – Oxygen contained within the waste is consumed primarily by aerobic microbial activity, results in evolution of mainly carbon dioxide, water and heat. Nitrogen is purged due to the liberation of other gases.

- **Stage 2** – associated with the onset of anaerobic conditions within the waste. Hydrolysis and acetogenic processes take place here. Large chain polymers are broken down to smaller molecules. Short chain organic compounds such as ethanoic acid (acetic acid), ethanoates (acetates), and ethanol are produced, together with ammonia, gaseous carbon dioxide, hydrogen, water and heat. Nitrogen is continued to be purged by hydrogen and carbon dioxide produced here.
Landfill Gas Production

- **Stage 3** – Transitional anaerobic activity where methanogenesis is initiated and gradually accelerates until hydrolysis and acetogenesis rates are balanced. Methanogenic bacteria plays an important role in the anaerobic degradation process. They use ethanoate, hydrogen and carbon dioxide to produce gaseous carbon dioxide and methane.

- **Stage 4** – The rates of hydrolysis / acetogenesis and methanogenesis are in relative equilibrium. This provides steady state conditions during which methane and carbon dioxide are evolved in the ratio of about 3:2. associated with the onset of anaerobic conditions within the waste.
Landfill Gas Production

- **Stage 5** – A period of endogenous respiration during which the organic substrate required for microbial activity becomes limited. At this time, the composition of the interstitial gases within the fill gradually assumes that of atmospheric air.

- In practice, the idealised profiles described by the model are rarely achieved. Varying degrees of phase overlap, phase omission and, even temporary cessation have been reported from the field. In addition, the duration of particular phases and the overall length of time taken for a body of waste to pass through the full degradation sequence varies considerably from one site to another. This reflects the influence of a wide range of factors.
Landfill Gas Utilisation

- In many places, landfill gas is harvested and utilised in different applications due to its high energy capability, as well as to control the potential risk associated with gas migration and emissions.

- The collection system is installed to:
  - Prevent migration – reduce risks
  - Minimise emission – control odour
  - Optimise utilisation (where possible)
Landfill Gas Utilisation

- Typical utilisation of LFG:
  - Power Generation (most popular)
  - Combined Heat and Power
  - Direct use
  - Gas grid as town gas or upgraded to natural gas
  - Flaring
  - Bio-Cover
  - Etc.
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Power generation

GAS ENGINE POWER PLANT (TYPICAL)
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Gas upgrading
Any Questions?

Thank you