Lesson Objectives

- Understand high-Btu, medium-Btu, electric power, and other landfill gas (LFG) products.
- Learn about evaluating potential LFG markets.
- Learn about the determination of the appropriate process for each potential market.
- Learn about a comparative analyses of market options.

Determining Process Requirements

Market determines process
- High Btu
- Medium Btu
- Electric power generation
- Other markets

LFG Assets

- Landfill gas is a local, renewable energy resource
- Landfill gas is generated continuously, it provides a reliable fuel
- Range of energy applications includes power generation and direct use.
- Energy (CH₄ = 55.5 MJ/kg)
  - High Btu - pipeline quality gas
  - Medium Btu - direct sale industrial fuel
  - On-site electric generation
  - CNG/LNG
  - Leachate Evaporation

LFG Assets

- The heating value of raw LFG usually runs from 27.8-30.5 MJ/kg.
- The maximum heating value attained for pipeline-quality methane from LFG is about 55 MJ/kg.

LFG Assets

The primary utilization modes:
- High Btu (approximately 55 MJ/kg) pipeline quality gas for sale to utility companies.
  - requires extensive processing to remove virtually all constituents from the LFG except methane.
- Medium Btu for sale to industrial consumers
  - requires minimal processing, mainly dehydration.
9. LFG Energy Recovery (English)

**LFG Assets**

The primary utilization modes cont.:
- On-site electrical generation (Some gas clean up may be required)
  - internal combustion engine,
  - gas turbine, or
  - steam turbine generator.
- Leachate evaporation
- Compressed natural gas (CNG) or Liquefied Natural Gas (LNG).

**Utilization Options**

- High Btu (pipeline quality) gas
- Medium Btu (industrial fuel) gas
- Electric power generation
- Condensate and leachate evaporation
- Vehicle fuel (CNG)
- Chemical feed stock
- Carbon Dioxide recovery

**LFG Processing**

- Corrosion control
- Water control
- Heating value
- Environmental regulations

**High-Btu (Pipeline Quality) Gas**

- Residual vinyl chloride and other contaminants in the product gas can cause concern.

**High-Btu (Pipeline Quality) Gas**

- High-Btu gas requires extensive processing to remove moisture, trace components, and carbon dioxide.
- There are LFG collection limitations because most processes cannot remove nitrogen and oxygen from LFG.
- From 10% to 40% of the Joules available may be lost in the process.

**Medium-Btu (Industrial Fuel) Gas**

- Relatively little gas processing is required.
- Moisture removal and Compression are most common.
- Removing heavier trace hydrocarbons and contaminants may be required
- The final product is nearly half methane and half carbon dioxide, and has a typical heating value of 500 to 550 Btu/scf.
- Uses: Fuel for furnaces, boilers, or other large full time gas users.
Electric Power Generation

- The most common of the energy applications is on-site electrical generation.
- Can use LFG with very little processing
- Engine types include: reciprocating gas engine, gas turbine, or as boiler fuel for a steam turbine.

Other uses

- Typically needs tax credits to be profitable.
- Microturbines - Essentially a medium BTU gas application.
- Vehicle Fuel, Compressed Leachate Evaporation
- Natural Gas (CNG) - Processes cannot remove N₂ or O₂
- Vehicle Fuel, Liquid Natural Gas (LNG) - Excess air in the inlet gas make processing more expensive.
- Chemical Feedstock - Limited
- Carbon Dioxide Recovery - Not yet

Evaluating Potential Markets

- Usage volume, pattern and demand
- Quality
- Economics
- Distance and delivery

Economics

Incentives to purchase LFG:

- Reduced energy price
- Air emission requirements (LFG can burn cleaner than oil or coal).
- Better availability if the customer has an interruptible contract.
- LMOP has simple tools to evaluate LFG projects.

Incentives of Using Landfill Gas

- Landfills are largest human-made source of methane
  - 25% generated in 2005
- How do LFG systems improve the environment?
  - 1 million tons of waste in place = 300 cubic feet per minute of LFG which generates 7 million kilowatt hours per year
    - Equal to
      - 8000 cars taken off the road
      - 1100 acres of forests planted
      - 100000barrels of oil not used
- At least 424 operational projects in 42 states (US)
Incentives of Using Landfill Gas

- Environmental control
  - Reduces odors
  - Stops local smog and global climate change
  - Reduces green house gas emissions
  - Emissions offsets from fossil fuels
  - Subsurface gas migration Control
- Money
  - Renewable energy source
  - One of the most cost competitive renewable energy sources
  - Sell your below the line stock
  - Federal finance incentives

Builds Communities
- Uses local energy source
- Job creation
- Improved economic development near the landfill
- Involves community planning and partnerships.
- Ex: the Ecology Club at Pattonville High School in Maryland Heights, Missouri, came up with the idea to use gas from the nearby landfill to heat their school. The school paid $175,000 to run a 3,600-foot pipeline between the landfill and the school's two basement boilers. In turn, the landfill owner donated the methane to the school as a way of "giving back to the community." The school anticipates that it will save $40,000 a year, and recapture its investment within five years.

Case Studies
Landfill Gas Projects in China
- Nanjing, Anshan, Maanshan

Project Goal
- Develop three small demonstration projects
- Develop regulations to protect the environment
- Develop policies favorable to landfill gas energy plants
- Set policy or guidelines to overcome institutional hurdles
- Landfill gas collection and recovery will aid in compliance with LFG emission laws and reduce GHG emissions.
- Develop training centers that can be used to educate Nationals

Project Approach
- Develop three different landfill gas to energy technologies
- Electrical generation (Nanjing)
- High KJ gas (methane substitute) for vehicle fuel (Anshan)
- Medium KJ gas for direct burning (Maanshan)
9. LFG Energy Recovery (English)

Nanjing Project Approach
- Electrical generation – German Engines

Benefits of the Approach
- Private developer took much of the financial risks
- Electrical generation is a proven, easily implemented technology
- Prepackaged engine generators simplify installation reduce engineering and construction time.
- Increased power supply

Other Project Benefits
- The landfill gets 5% of the project revenue
- Training Center for educating others The report up to 2000 students so far
- 13 new jobs
- Improved LFG collection (less air and soil emissions)

Estimated Project Finances

Nanjing Project Disadvantages
- Higher price for electricity

Use EPA’s LFG in China Workshops (2008)
9. LFG Energy Recovery (English)

USEPA’s LFG in China Workshops (2008)
9. LFG Energy Recovery (English)

Nanjing Landfill Gas Treatment

Nanjing Landfill

Nanjing Landfill

Nanjing Landfill Chiller

MAANSHAN LANDFILL Hospital Waste Incinerator Project

Maanshan Project Approach
- Medium kJ Fuel
- Developed by local authority
- Novel approach-Built a plant to support LFG Use

USEPA’s LFG in China Workshops (2008)
Benefits of the Approach
- Learning opportunity for Local Engineers and Contractors
- Very simple gas processing.

Other Project Benefits
- The local municipality gets all revenue but also has to absorb all losses
- New jobs
- LFG collection (less LFG emissions to the air, soil, and groundwater)
- Cost savings by burning LFG (see spreadsheet)

Value of Gas Burned

<table>
<thead>
<tr>
<th>Annual Revenue, Maanshan Energy Recovery Plant</th>
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</thead>
<tbody>
<tr>
<td>Fee Calculation</td>
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<tr>
<td>Number of Beds</td>
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<tr>
<td>Average Occupancy</td>
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<tr>
<td>Charge per day for medical waste disposal per bed</td>
</tr>
<tr>
<td>Annual income</td>
</tr>
<tr>
<td>Exchange Rate RMB/ US$</td>
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<tr>
<td>Annual Income in US$</td>
</tr>
</tbody>
</table>

Alternate Fee Calculation based on the Value of LFG Burned
- Landfill Gas Burned Per Day: 1200 nM3/day
- Methane HHV: 62% of Calorific Value
- Value of LFG Burned Per Year: 733212 RMB/Yr
- Value of LFG Burned Per Year: $89,416.10 US$/Yr

Maanshan Project Disadvantages
- Plant was expensive to build
- Revenue is not sufficient to cover the cost of the plant
- Limited daily use of LFG. Plant only operates 2-3 hours per day

Maanshan Landfill
9. LFG Energy Recovery (English)

**Maanshan Landfill**
**Leachate Treatment**

**Maanshan Landfill**

**Maanshan Landfill**

**ANSHAN LANDFILL**
Methyl-diethanolamine (MDEA)
Solvent Removal of Carbon Dioxide?

**Anshan Project Approach**
- High BTU gas
- Developed by local authority
- Technology development with a never before used process

USEPA's LFG in China Workshops (2008)
Benefits of the Approach
- Significant learning opportunity for local engineers and contractors
- New and possibly marketable process
- Highly visible project because of its uniqueness

Other Project Benefits
- The local municipality gets all revenue but also has to absorb all losses
- New jobs
- LFG collection (less LFG emissions to the air, soil, and groundwater)

Anshan Project Disadvantages
- Plant was expensive to build
- Risks caused by new technology development
- Limited use only by landfill fleet vehicles

Estimated Project Finances

<table>
<thead>
<tr>
<th>Year</th>
<th>Capital Improvement</th>
<th>Annual Income</th>
<th>Sum of Capital and Annual Income</th>
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Capital does not include initial LFG system installation
Assumes capital is spent 1 year before equipment operation
Gas Price of 2.7 RMB/Cu M from National Expert
O&M Costs from Project Designer and include labor, replacement, repair, chemicals, coal, etc.
Assumes no salvage value of equipment
No LFG Model was run for this project, actual gas generation rates are unknown
Design LFG flow rate 10,000 cu M / day at 62% methane
Methane Recovery Efficiency 0.96
IRR are before taxes

Anshan Landfill

Anshan Landfill Well Drilling
9. LFG Energy Recovery (English)

Anshan

Anshan Absorber & Stripper

Anshan Absorber & Stripper

Anshan Gas Compressor

Anshan Gas Compressor

Anshan Blower

USEPA’s LFG in China Workshops (2008)
Anshan Gas Dehydration

Project Outcomes
- The three projects are constructed
- Training centers have been developed
- Chinese technical experts have experience with LFG recovery projects
- Laws have been passed to aid in the development of future projects.

Project Outcomes
- Chinese have developed significant skills related to LFG utilization
- Local authorities were able to help overcome institutional hurdles for project development
- Develop an action plan to promote widespread LFG project replication
- Renewable Energy Law

Strategies for Future Development
- Development by Chinese
  - Considerable risk because LFG development in China is in its infancy
  - Competition for capital
  - Could slow the development of multiple LFG projects

Strategies for Future Development
- Development by international LFG to energy firms
  - They have experience that helps reduce risk
  - They have funding available
  - Multiple firms can create competition and improve the benefit to China
  - Multiple developers can simultaneously develop multiple projects allowing significant and rapid LFG project development

Recommendations
- Set up a national resource database for developers, engineers, attorneys, equipment suppliers, etc. Suggest using the USEPA LMOP Model
- Inventory all landfills to determine current tonnage, future tonnage, fill history, and landfilling type (dump vs. sanitary LF)
- Consider regional landfills to consolidate environmental compliance
- If needed, Subsidize LFG Energy with increased prices