

9. LFG Energy Recovery (English)



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.

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Determining Process Requirements

Market determines process

- High Btu
- Medium Btu
- Electric power generation
- Other markets

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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 ($\text{CH}_4 = 55.5 \text{ MJ/kg}$)
 - High Btu - pipeline quality gas
 - Medium Btu - direct sale industrial fuel
 - On-site electric generation
 - CNG/LNG
 - Leachate Evaporation

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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.

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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.

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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).


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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


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LFG Processing

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


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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.


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High-Btu (Pipeline Quality) Gas

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

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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.

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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.

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Methane to Markets

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 N_2 or O_2
- Vehicle Fuel, Liquid Natural Gas (LNG) - Excess air in the inlet gas make processing more expensive.
- Chemical Feedstock - Limited
- Carbon Dioxide Recovery - Not yet

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Methane to Markets

Evaluating Potential Markets

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

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Methane to Markets

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.

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Methane to Markets

Evaluating Potential Markets

- Need a good estimate of LFG available. Without this, success is questionable.
- Evaluate the gas source.
- Determine user requirements.
 - Usage volume (maximum & minimum)
 - Review a copy of purchase records over the past year, if possible.
 - An ideal customer would use the entire LFG output around the clock.
 - Establish gas quality requirements. More processing = less BTU's available to sell.
- Evaluate and compare processes, costs, methane and recovery.

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Methane to Markets

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)

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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

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Incentives of Using Landfill Gas

- 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.

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Case Studies

Landfill Gas Projects in China

Nanjing, Anshan, Maanshan

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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

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Project Goal....

- Develop an action plan to promote wide spread LFG project replication
- Promote change in China to help them develop and implement environmental laws to protect air, soil and groundwater from landfill contamination
- 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

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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)

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NANJING LANDFILL

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Methane to Markets

Nanjing Project Approach

- Electrical generation – German Engines



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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

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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)

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Estimated Project Finances

Term of Loan (yrs)	10	15	20
Loan Price per Kw	\$9,000	0.637	
Maintenance Cost per Kw/yr	\$9,000	0.164 RMB	
Capital Cost per kW future generator	\$1,200,000	10,240 RMB	
Construction rate %	95	100	100
Assumed Exchange Rate RMB/US\$	8.25	193	224

Year	Capital Cost for equip and LF improvements (Investment)	Generation (Kwh/yr)	Maintenance Cost/yr	Gross Income/yr	Net Income/yr	Capital Improvement in \$	Annual Income	Ratio of Capital and annual income
2004	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2005	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2006	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2007	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2008	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2009	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2010	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2011	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2012	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2013	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2014	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2015	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2016	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2017	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2018	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2019	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2020	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2021	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2022	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2023	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2024	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0
2025	\$1,582,500	1200	\$108,000	\$1,307,100	\$927,000	\$0	\$927,000	\$0

Capital cost includes initial LFG system installation
Assumes capital is spent 1 year before equipment operation
O&M costs include engine and LFG system Maintenance
Assumes no salvage value of equipment
No LFG boiler use for this project, actual gas generation rates are unknown
RR are before taxes

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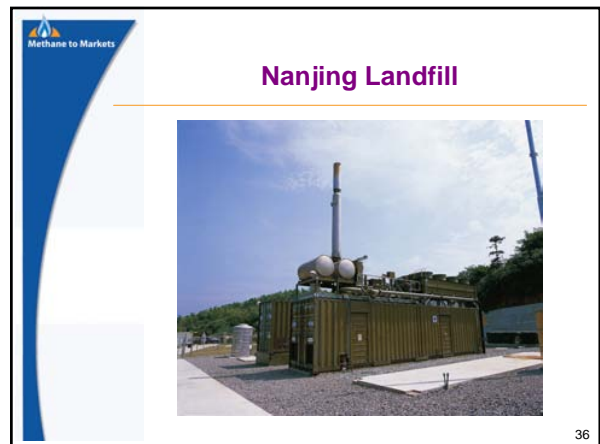
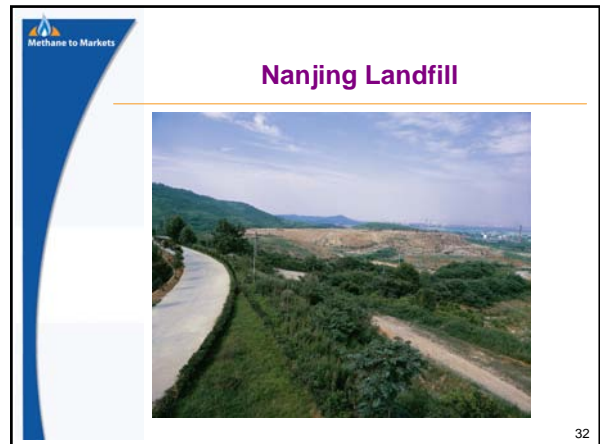
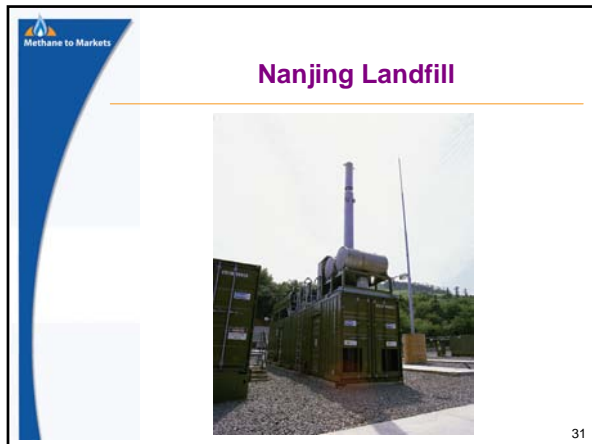
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Nanjing Project Disadvantages

- Higher price for electricity

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9. LFG Energy Recovery (English)

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Nanjing Landfill Gas Treatment



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Nanjing Landfill



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Nanjing Landfill



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Nanjing Landfill Chiller



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MAANSHAN LANDFILL Hospital Waste Incinerator Project

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Maanshan Project Approach

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




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9. LFG Energy Recovery (English)

Benefits of the Approach

- Learning opportunity for Local Engineers and Contractors
- Very simple gas processing.



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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)

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Value of Gas Burned

ANNUAL REVENUE, MAANSHAN ENERGY RECOVERY PLANT	
Fee Calculation	
Number of Beds	1100
Average Occupancy	30%
Charge per day for medical waste disposal per bed	1 RMB
Annual income	120450 RMB
Exchange Rate RMB/ US\$	8.2
Annual Income in US\$	\$14,689.02 US\$/Yr
Alternate Fee Calculation based on the Value of LFG Burned	
Landfill Gas Burned Per Day	1200 nM3/day
Percent methane in LFG	62%
Methane Gas Value RMB/Cu M	2.7 RMB/Cu M
Value of LFG Burned Per Year	733212 RMB/Yr
Value of LFG Burned Per Year	\$89,416.10 US\$/Yr
Estimated LFG Available	6000 nM3/day
Operating hours per day	3 Hours

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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

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Maanshan Landfill



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Maanshan Landfill



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

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Anshan Project Approach

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

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Two small photographs: the left one shows a wide view of a landfill site, and the right one shows a gas processing facility with a tall tower and storage tanks.

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Benefits of the Approach

- Significant learning opportunity for local engineers and contractors
- New and possibly marketable process
- Highly visible project because of its uniqueness

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Methane to Markets

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)

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Anshan Project Disadvantages

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

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Estimated Project Finances

Year	Capital Cost for plant and LP investments, Cu M\$M	Cu M Methane Production per year	Maintenance Cost/yr	Gross Income/yr	Net Income/yr	Capital Income/yr	Annual Income	Sum of Annual Income
2006	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$825,000
2007	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$1,650,000
2008	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$2,475,000
2009	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$3,300,000
2010	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$4,125,000
2011	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$4,950,000
2012	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$5,775,000
2013	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$6,600,000
2014	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$7,425,000
2015	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$8,250,000
2016	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$9,075,000
2017	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$9,900,000
2018	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$10,725,000
2019	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$11,550,000
2020	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$12,375,000
2021	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$13,200,000
2022	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$14,025,000
2023	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$14,850,000
2024	\$2,500,000	248	\$150,000	\$975,000	\$825,000	\$0	\$825,000	\$15,675,000

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Anshan Landfill



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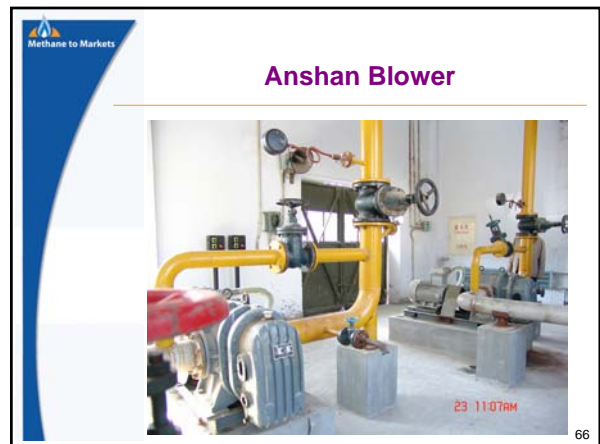
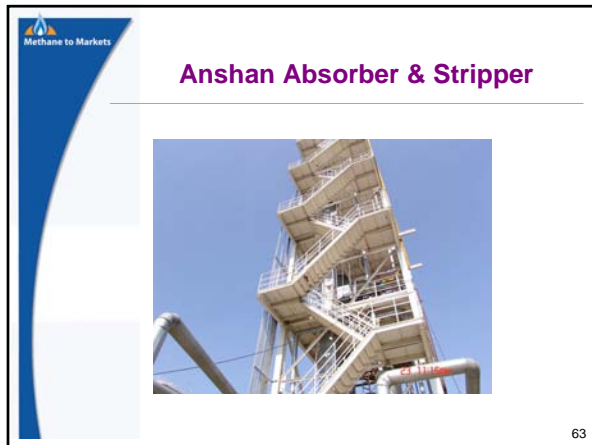
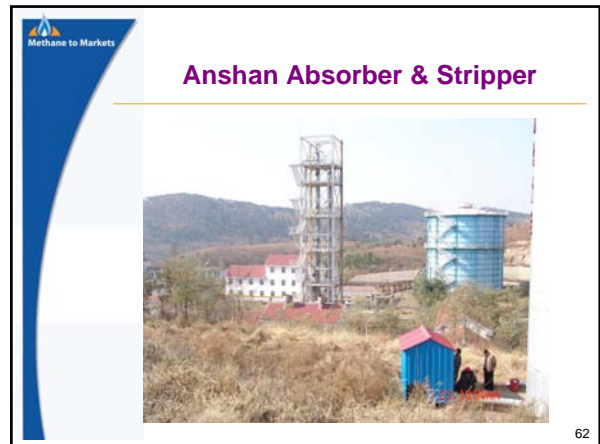
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Anshan Landfill Well Drilling



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9. LFG Energy Recovery (English)

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Anshan Gas Dehydration



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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.

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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 wide spread LFG project replication
- Renewable Energy Law

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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

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Methane to Markets

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

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Recommendations

- Set up a national resource data base 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

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