The Status of Aerobic Bioreactor Landfills in the US

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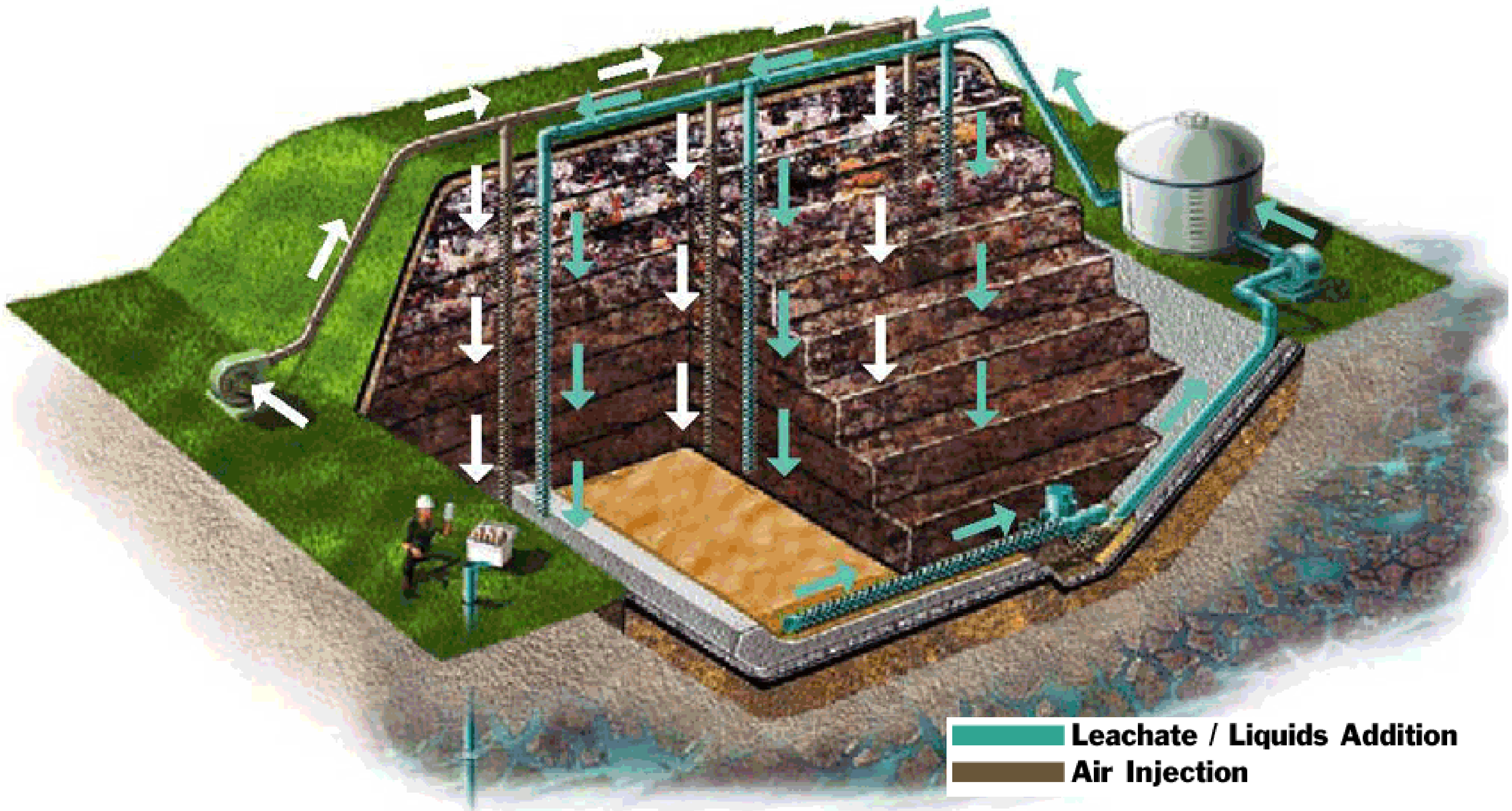
Objectives

- Provide an overview of aerobic landfilling in the US
  - History
  - Case studies
  - Challenges
  - Future of aerobic landfilling

Aerobic Landfills



Source: www.wastemanagement.com

History of Aerobic Landfills

- First study conducted in 1960's (Merz and Stone)
  - Purpose: To develop and evaluate new technologies to improve or accelerate the handling of the Nation's solid waste
  - Operated test cells evaluating air and liquid addition for 4-years
  - Aerobic cells exhibited high temperatures (up to 90°C), smoke, odor problems, and occasional fires
  - Waste moisture content was low, always less than 50% (by weight), often around 40%
  - The aerobic cell settled almost 50% more than the anaerobic
- Fear of fires prevented further research

History of Aerobic Landfills

- Stessel and Murphy revisited aerobic landfills in 1990's
  - Purpose: To make landfills more economically sound, environmentally friendly, and sustainable (landfill mining)
  - More degradation in aerobic cells
  - Waste moisture content remained around 75%
  - No temperature concerns
- Several laboratory and field-scale studies resulted
  - Baker Place Road Landfill (GA)
  - Live Oak Landfill (GA)
  - Langley Landfill (SC)

Aerobic Landfill Patents

- In October 1996, a patent was granted for improvements to landfill mining (US Patent No. 5564862)
- American Technologies, Inc. (US Patent No. 6,024,513) for aerobic systems
- Environmental Control Systems (US Patent No. 5,888,022) for aerobic systems
- Waste Management, Inc. holds a patent for a sequential aerobic/anaerobic system in which aerobic and anaerobic conditions are cycled (US Patent No. 6,283,676)

Current Field-Scale Aerobic Landfill Projects

- 19 aerobic landfills (1 in Canada)
- Varied motivations for aerobic operation:
  - Remediation of surface water and groundwater impacts (Williamson Co.)
  - Reduction of leachate volume (Williamson Co.)
  - Elimination of methane and other odorous gases (Yolo Co, Donlands Landfill)
  - Rapid stabilization of the waste (Outer Loop, Williamson Co., Marquette)
  - Site redevelopment (Rio Nuevo)
  - Evaluation of design and operating parameters (Live Oak, New River Regional Landfill)

Aerobic Landfill Case Studies

- Williamson County, TN (began in 2000)
  - Retrofit to primarily reduce leachate volume and environmental impact of a pre-RCRA Subtitle D landfill
  - 2.4-ha site, 12 m deep and was constructed with steep side slopes (1.5:1)

  - Vertical well clusters reaching 3, 6, and 9 m at 15 m spacing
  - Air injection averaged 0.8 m^3/min per well.
  - Temperatures were as high as 74^{o}C
  - Settlement reached 5-10% of the overall landfill height over a 5-year period
  - Oxygen uptake, TVS, lignin, cellulose, and biochemical methane potential (BMP), were all reduced

Aerobic Landfill Case Studies

- Tucson, AZ (Rio Nuevo Landfill, began in 2001)
  - Several aerobic landfill tests have been conducted to recover sites occupied by older landfills
  - 0.10-ha pilot test
  - Vertical well injection
  - One-foot settlement in five months
  - Air injection rates varied between 1.4 and 8.5 m^3/min.
  - Injection of air and water was used to control temperature which rapidly increased to 71^{o}C after a few days of operation

Aerobic Landfill Case Studies

- Outer Loop Landfill (Began in 2001)
  - Hybrid Aerobic-Anaerobic Landfill Bioreactor (AALB)
  - Two 2.5-ha test cells were operated in parallel with similarly sized control cells
  - 4.5-m lifts of waste, adding water to increase moisture content, and placing a horizontal perforated piping system for air and liquid injection.

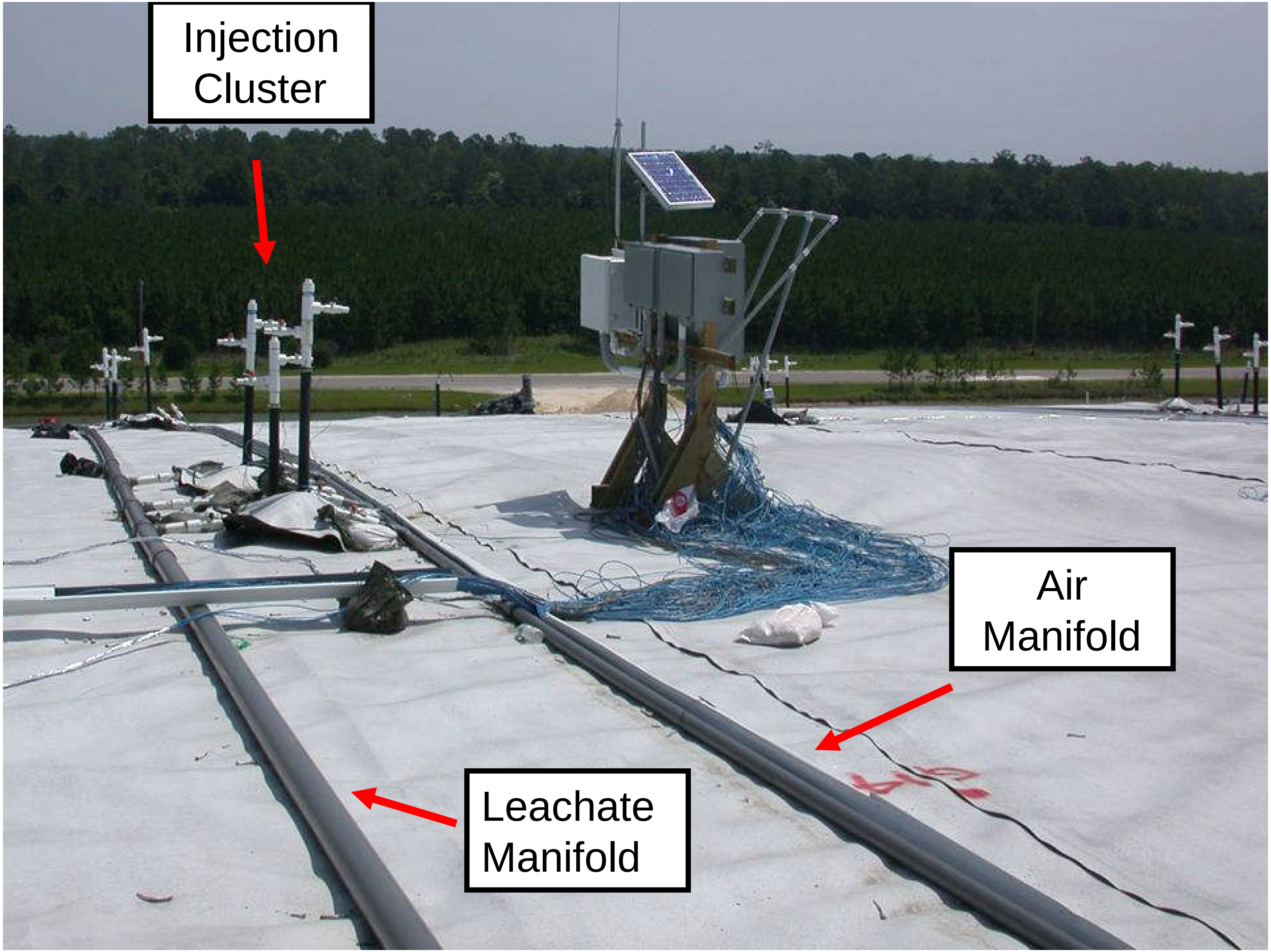
  - By 2005, the cells had reached 21 m in depth
  - Air is injected for a period of 30 to 60 days (60 m^3/min) into each lift to rapidly degrade the waste

Aerobic Landfill Case Studies

- Outer Loop Landfill (Continued)
  - Temperature was used to control airflow; requiring a cutoff of air with an increase of 7^{o}C in 24 hours or upon reaching 71^{o}C
  - However, a maximum temperature of 38.8^{o}C has been reported to date
  - Preliminary reports show enhanced waste degradation for the AALB as compared to the control anaerobic cells measured by a decrease in cellulose to lignin ratios and Biochemical Methane Potential
  - Density has increased by 14-27%

Aerobic Landfill Case Studies

- New River Regional Landfill (began in 2002)
  - 4-ha bioreactor demonstration cell
  - 134, 5-cm diameter vertical injection well clusters (6, 12, and 18 m deep)
  - Exposed geomembrane cover
  - Air injection has been practiced periodically since 2003


Injection Cluster
Air Manifold
Leachate Manifold

Blowers at NRRL

2- 750 scfm
blowers

Aerobic Landfill Case Studies

- New River Regional Landfill (Continued)
  - Air at flow rates of 1-1.4 m^3/min were observed to impact monitoring wells 15-17 m away
  - Oxygen content was consistently less than 3% in these wells
  - Temperatures increased from 50^o to almost 77^{o}C over a period of approximately 20 days, 4 m away from the injection point and at a depth of 4.5 m
  - Carbon monoxide (CO) was observed during air injection; however there was no reason to believe that a fire existed. The presence of CO was attributed to biological oxidation processes
  - Air permeabilities were between 1.6×10^{-13} and 3.2×10^{-11} m^2 and decreased with depth. Permeabilities declined by a factor of five following injection of liquid

Other Aerobic Landfill Projects

Yolo County Landfill (CA)

Three-Rivers Landfill (SC)

Black Warrior Landfill (AL)

Air Injection Blower System

ECS
ENVIRONMENTAL CONTROL SYSTEMS, INC.

Current Field-Scale Aerobic Landfill Projects

- Overall results suggest:
  - More rapid waste decay than found in anaerobic bioreactors
  - High temperatures observed can result in pathogen destruction
  - Reduction in leachate contaminants and volumes
  - Reduction in methane emissions
  - Enhanced airspace recovery
  - Additional liquid beyond that required for anaerobic bioreactors must be added for reactions to occur

Advantages

- Enhanced waste degradation
- Mitigated odor and methane emissions
- Increased settlement/airspace recovery
- Reduced leachate management liability and costs
- Removal of anaerobically recalcitrant compounds (i.e. ammonia-nitrogen)
- Reduced environmental risk

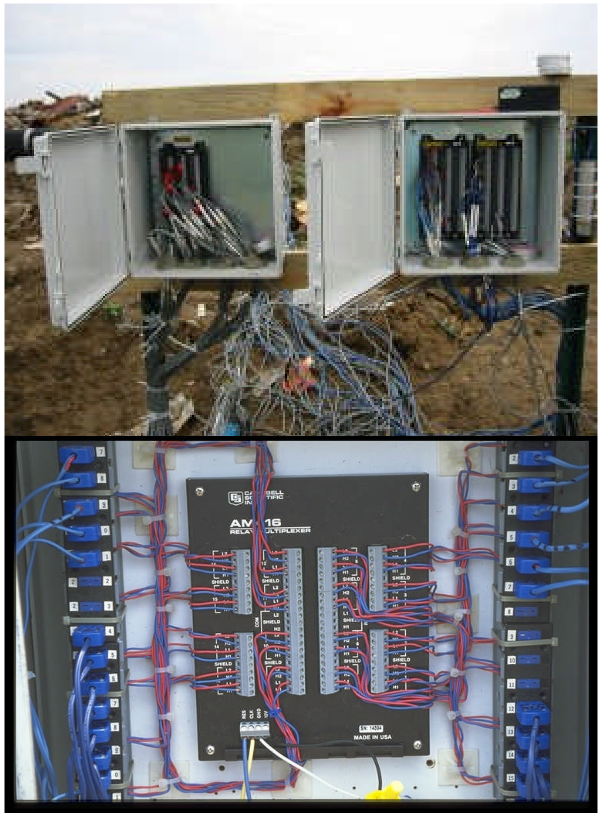
Recovery of Composted Materials

Reduction of Leachate Volume

- Approximately 50% of leachate evaporates
- Potentially lower management costs

Challenges Associated with Aerobic Operation

- As compared to other bioreactor landfills, aerobic bioreactor operation can be more challenging
- Need more control and monitoring
  - Operate at different moisture application rates
  - Due to rapidly decaying waste, liquid movement within the waste varies continually
  - Waste decay occurs via different biological pathways and kinetics
  - Heat transfer and liquid control are more critical



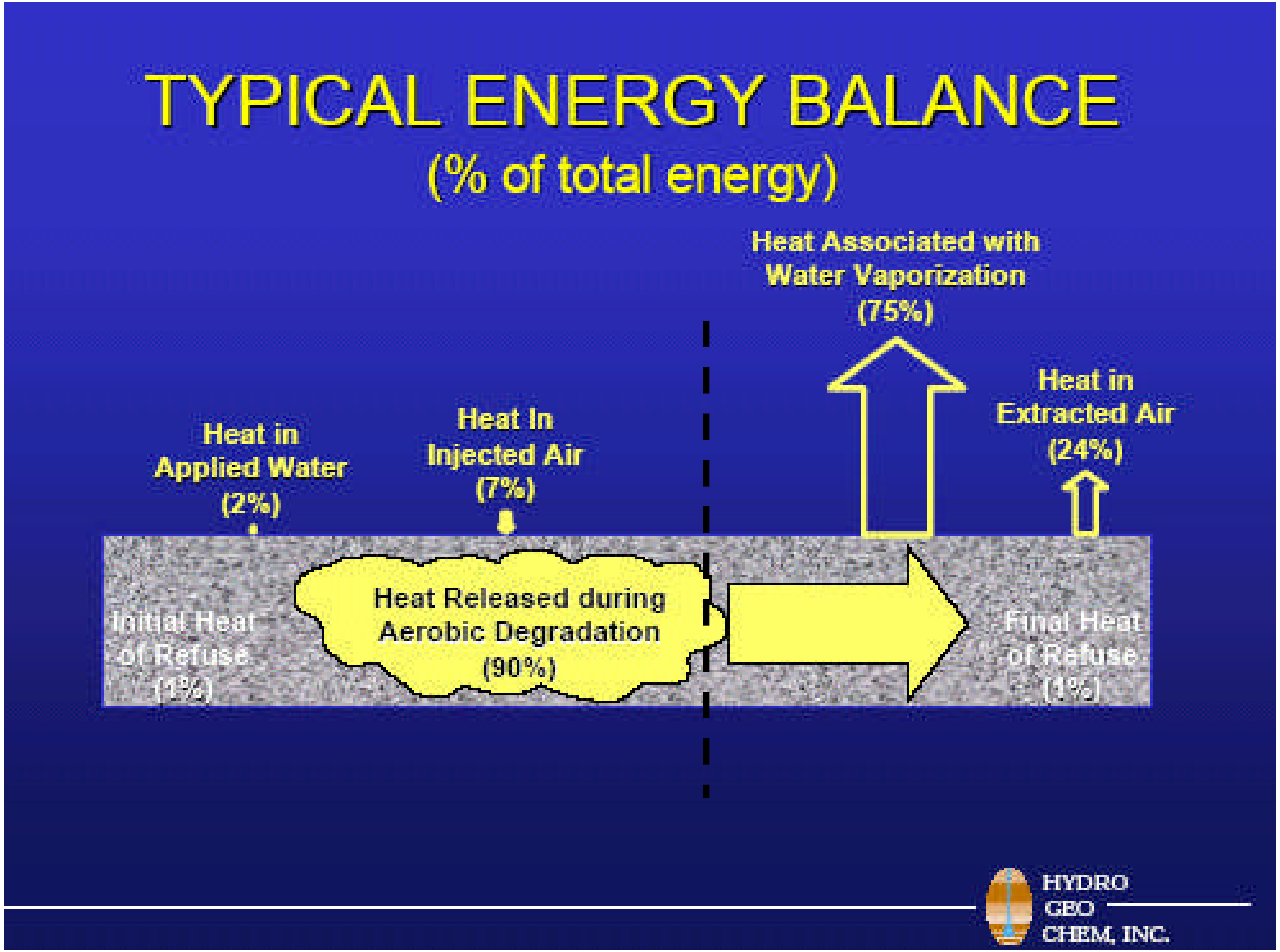
Data Required to Effectively Control the Bioreactor

- Moisture content
- Temperature
- Liquid and air flow patterns
  - Recently, heat and energy information has aided modeling of distribution
- Oxygen transfer rates
  - Determine by operating pumping tests

Heat and Energy Data Needs to Conduct an Energy Balance

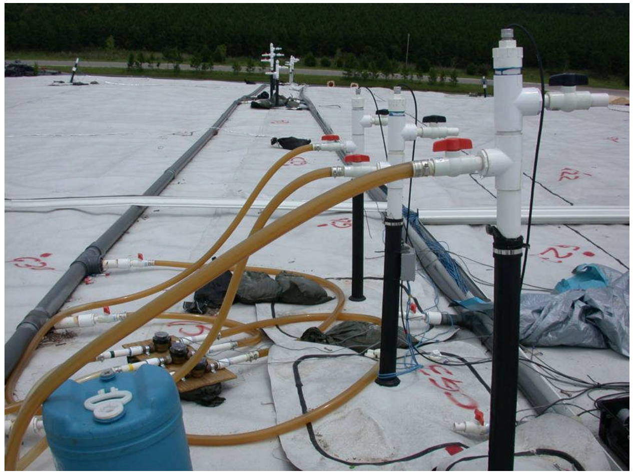
Primary Heat Removal Processes	**Energy Balance**	**Other Observations**

• Vaporization Of Water
• Advective Transport Of Heat In Air Flow
• Thermal Properties Of Wet Air
• Vaporization Of Water
	• Applied Water
	• Heat In:
	    • Injected Air
	    • Extracted Air
	• Heat Associated With Water Vaporization
	• Heat Released During Aerobic Degradation
	• Heat Initial Heat Of Refuse
	• Final Heat Of Refuse
		• Heat Flow, Heat Generation, And Oxygen Transport Are Coupled, Non-Linear Processes
		• Venting well design


TYPICAL ENERGY BALANCE
(% of total energy)
Heat Associated with Water Vaporization (75%)
Heat in Extracted Air (24%)
Heat in Applied Water (2%)
Heat In Injected Air (7%)
Initial Heat of Refuse (1%)
Heat Released during Aerobic Degradation (90%)
Final Heat of Refuse (1%)
HYDRO GEO CHEM, INC.

Challenges Associated with Aerobic Operation

- Distribution and control of air and liquids
  - In aerobic systems, waste settlement is more rapid and pronounced, thus horizontal leachate application may not be appropriate



Injection Lines at NRRL

- Changes in waste characteristics may be beneficial to air distribution, as changes in air flow patterns may maximize the air and liquids coverage area

Challenges Associated with Aerobic Operation

- In-situ monitoring of conditions to ensure that air and liquids follow similar flow patterns
- Determining the amount of air required (the rate of mass transfer of oxygen from the gas phase to the liquid is unknown)

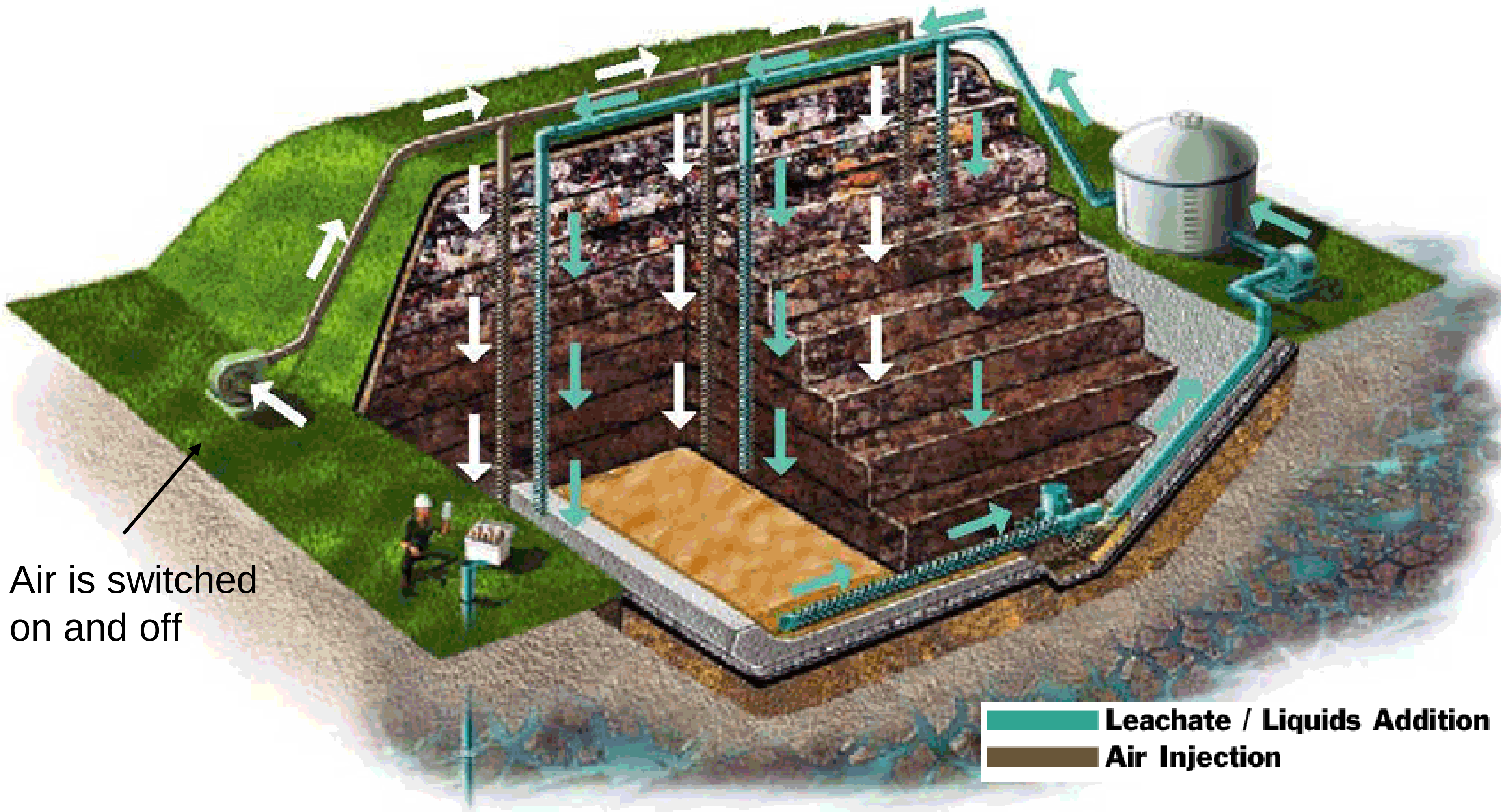
Challenges Associated with Aerobic Operation

- Economics
  - Additional electricity costs
  - Reduced leachate management
  - Reduced methane emissions

Blower System at Williamson County

- Unknown emissions
  - Gaseous (nitrous oxide, volatile organics)
  - Metal migration
  - Collection system clogging (CO_2)

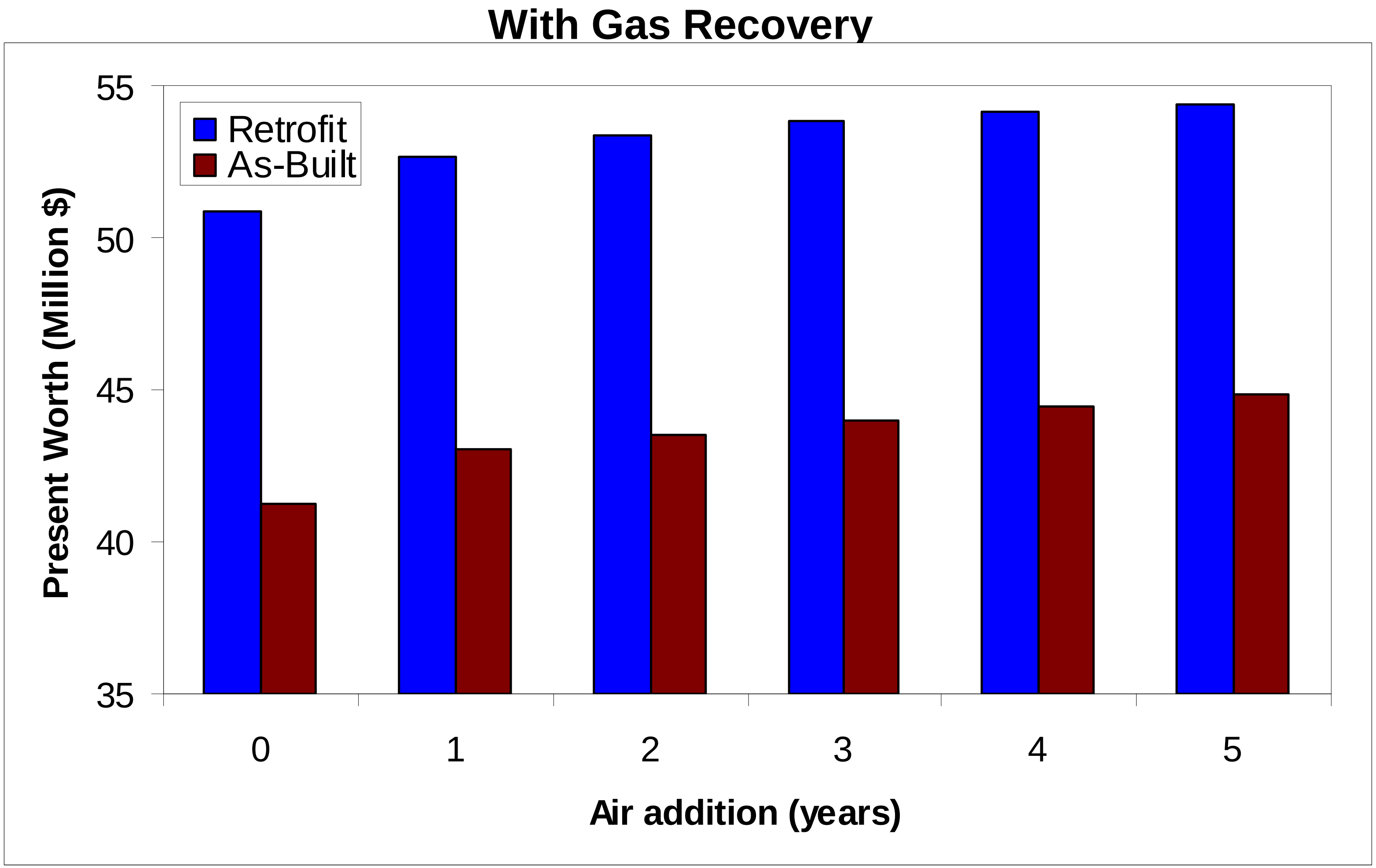
Hybrid Bioreactor Landfills



Air is switched on and off

Source: www.wastemanagement.com

PW Cost of a Hybrid Landfill as a Function of Duration of Air Addition



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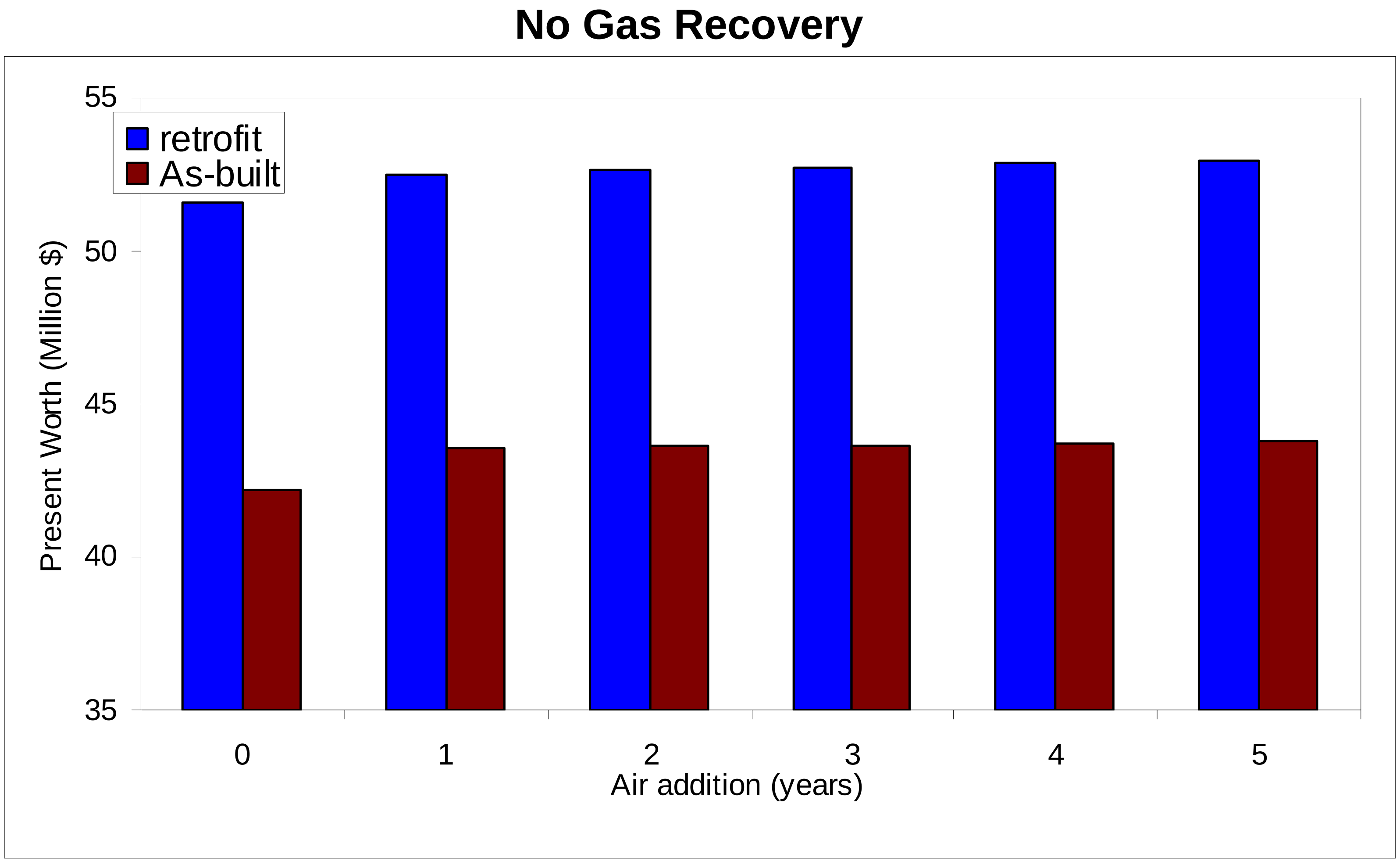
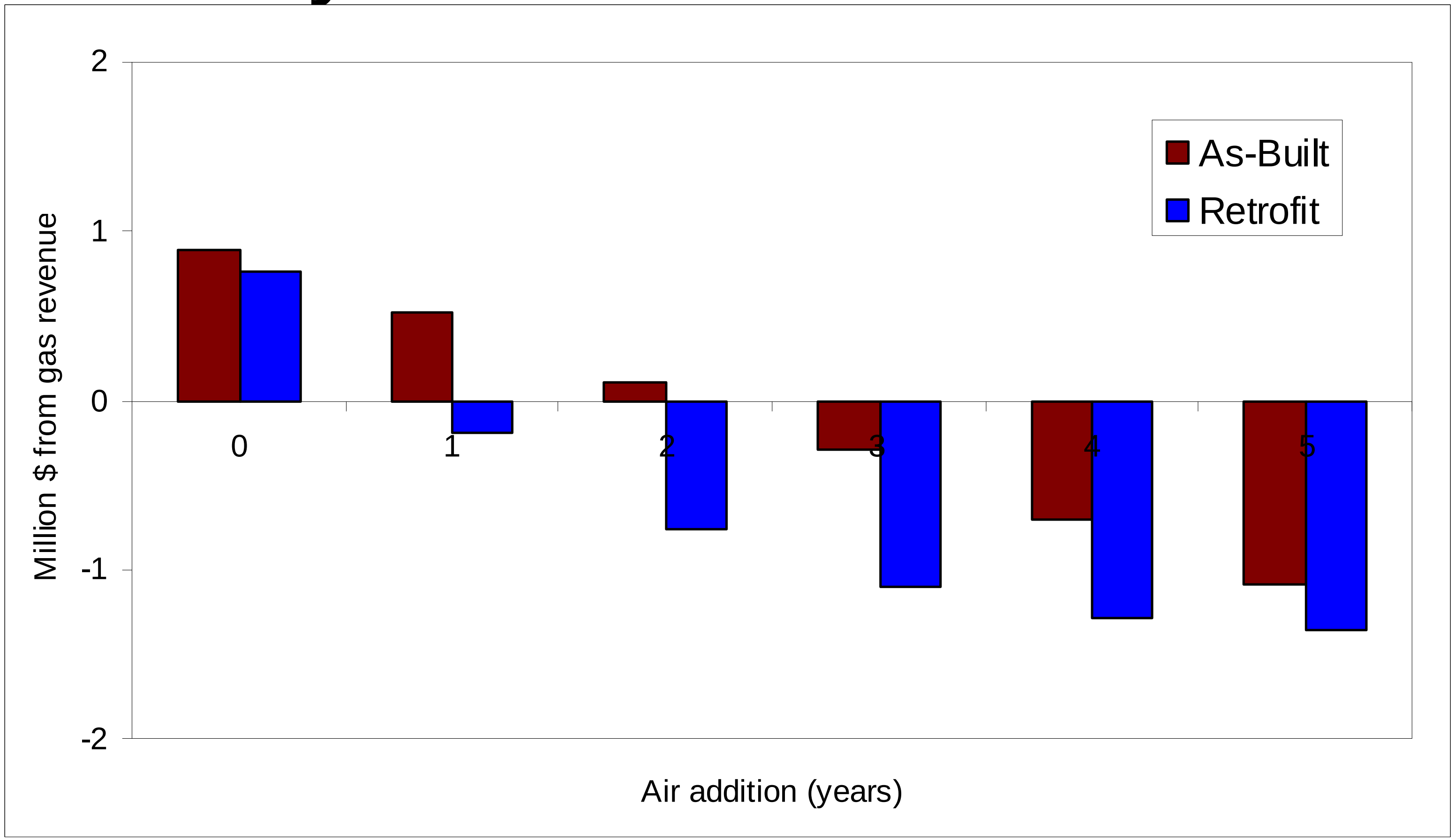
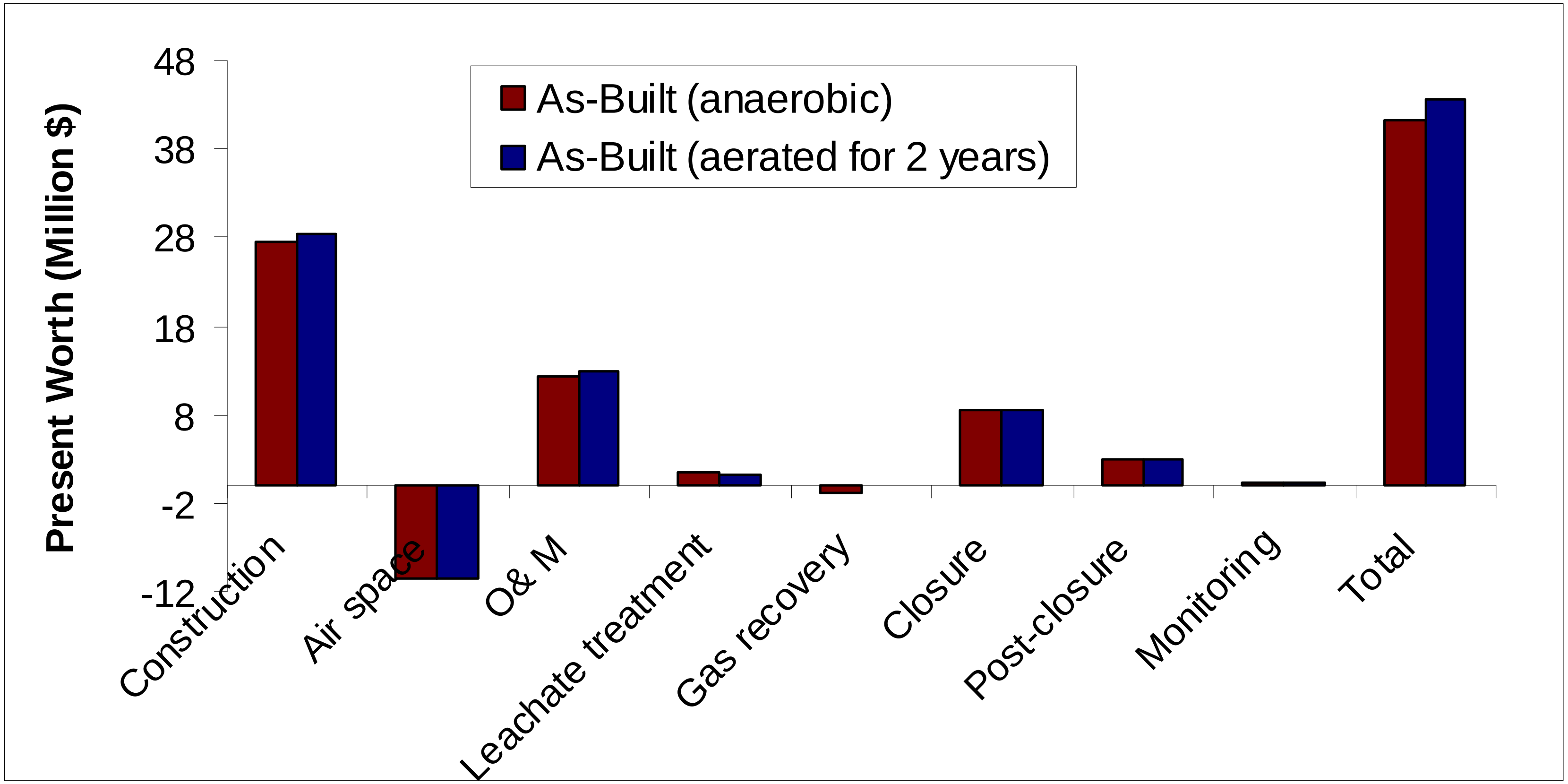


Effect of Air Addition on Gas Recovery



Itemized Cost Analysis for an Aerobic Bioreactor



Future of US Aerobic Landfills

- Air injection will more likely be used periodically
  - Initiate biological reactions early in the landfill life
  - Remediate old landfills
  - Polish leachate quality (remove ammonia-nitrogen) and anaerobically recalcitrant waste (air addition at end of landfill life)
  - Hybrid bioreactor landfills with either short term cycling of air injection into the landfill or sequencing of aerobic and anaerobic conditions

Remediation of Old Landfills

- Used in Germany
- Remove anaerobically recalcitrant compounds
- Biologically stabilize waste
- Evaporate leachate

Polish Leachate Quality

- Removal of ammonia-nitrogen
- Add air to a small, older portion of the landfill
- Nitrogen can be removed via nitrification and denitrification processes
- Lab studies indicate relatively quick removals

Removal of Ammonia-Nitrogen

- Apply to smaller areas of the landfill (dedicated treatment zones)
- Oxygen must be present, the higher the faster the rate
  - Low gas-phase oxygen concentrations will result in ammonia removal
- pH should be near neutral
- Temperature can be as high as 45^{o}C; optimal temperature is between 35 and 40^{o}C

Economics of Nitrogen Removal

Leachate Injection Rate (L/day)	Total Process Cost in Present Value ($)	Volume Leachate Treated (gal)	$/gal of Leachate Treated
4,000	75,000	3.86×10^6	0.019
3,000	68,800	2.89×10^6	0.024
1,500	64,700	1.45×10^6	0.045

- Removal occurred in a 200-m^2 area
- Accounts for operation, maintenance and capital costs (blowers and piping)

In comparison with other removal options:

On-site leachate treatment ranges from $0.004 – 0.18/gal
Off-site leachate treatment ranges from $0.06 – 0.40/gal

Future of US Aerobic Landfills

- The USEPA recognizes that aerobic landfills "increase the rate of decomposition, reduce the emissions of harmful and odorous trace gases, and improve the quality of leachate. These advantages are significant in terms of pollution reduction and the reclamation of landfill sites (EPA, 1993)"
- In the preamble to the NESHAP regulation of bioreactor landfills, the USEPA concluded that it expected relatively few bioreactor landfills to be operated aerobically and therefore excluded them from regulation
- EPA does consider aerobic landfilling to be a potential option for reducing methane emissions

Future of US Aerobic Landfills

- It appears that this technology has application in the US, particularly at:
  - Small landfills where methane collection and beneficial use is not economical
  - For rapid remediation of older landfill sites for site redevelopment
  - Where rapid initiation of waste degradation is desirable for airspace recovery
  - Where the potential for aerating smaller areas of the landfill create an economically attractive option for leachate treatment

Future of US Aerobic Landfills

- More research and data collection are necessary to understand the full potential of aerobic landfills

Lab-scale research at UNCC

Questions?