LMOP Webinar

Landfill Gas Treatment Technologies

November 16, 2021

LANDFILL METHANE OUTREACH PROGRAM

Welcome and Agenda

Agenda
Nitrogen Rejection via Membrane Technology Gregory Myrick, Technical Manager, Air Liquide Biogas Systems Engineering and Andrew Zikeli, RNG Technical Manager, Air Liquide Biogas Solutions Americas
Case Study: Mixed Metal Oxy-hydroxide Media for Removal of H_2S from Landfill Gas Gary Monks, Director of Product Development, Guild Associates
Questions and Answers
Wrap Up

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LANDFILL METHANE OUTREACH PROGRAM

Nitrogen Rejection via Membrane Technology

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LMOP Webinar • November 16th, 2021

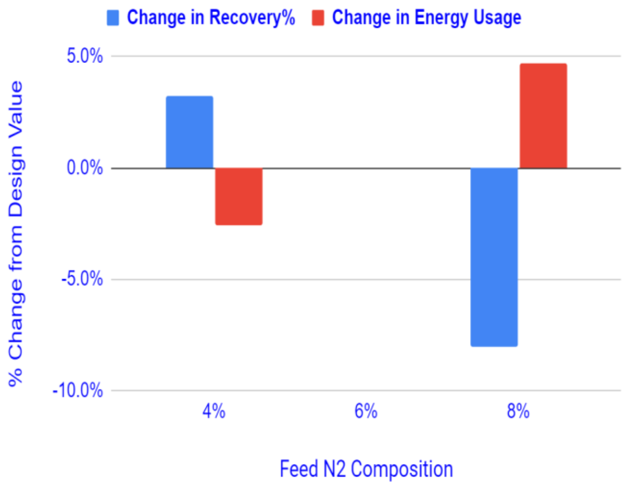
GLOBAL MARKETS & TECHNOLOGIES

Gregory Myrick, Technical Manager of AL Biogas Systems Engineering
Andrew Zikeli, RNG Technical Manager

Contents

Nitrogen Source

The source of Nitrogen in Landfills



- **Nitrogen is introduced into the system by pulling vacuum on the wellfield**
- **N_2 feed from a landfill can range from:[1]**
  - <6% = under stressed
  - 6-12% = normal
  - 16-20% = excessive, migration control
  - 20+% = overstressed
- **N_2 is extremely difficult to separate from CH_4 due to the molecules being nearly identical in size**
  - "[It is] more cost effective to minimize nitrogen entry into the wellfield than to remove nitrogen in the [high BTU upgrading] plant" [2]
  - For membranes: CH_4 recovery and energy usage is a direct function of the feed N_2 composition
- **Composition sensitivity study for Membrane based NRU**
  - System designed for 6% N_2 in the feed gas (~10% N_2 to the Nitrogen Removal Unit)
  - Higher recovery and less energy usage if wellfield N_2 can be managed to 4%

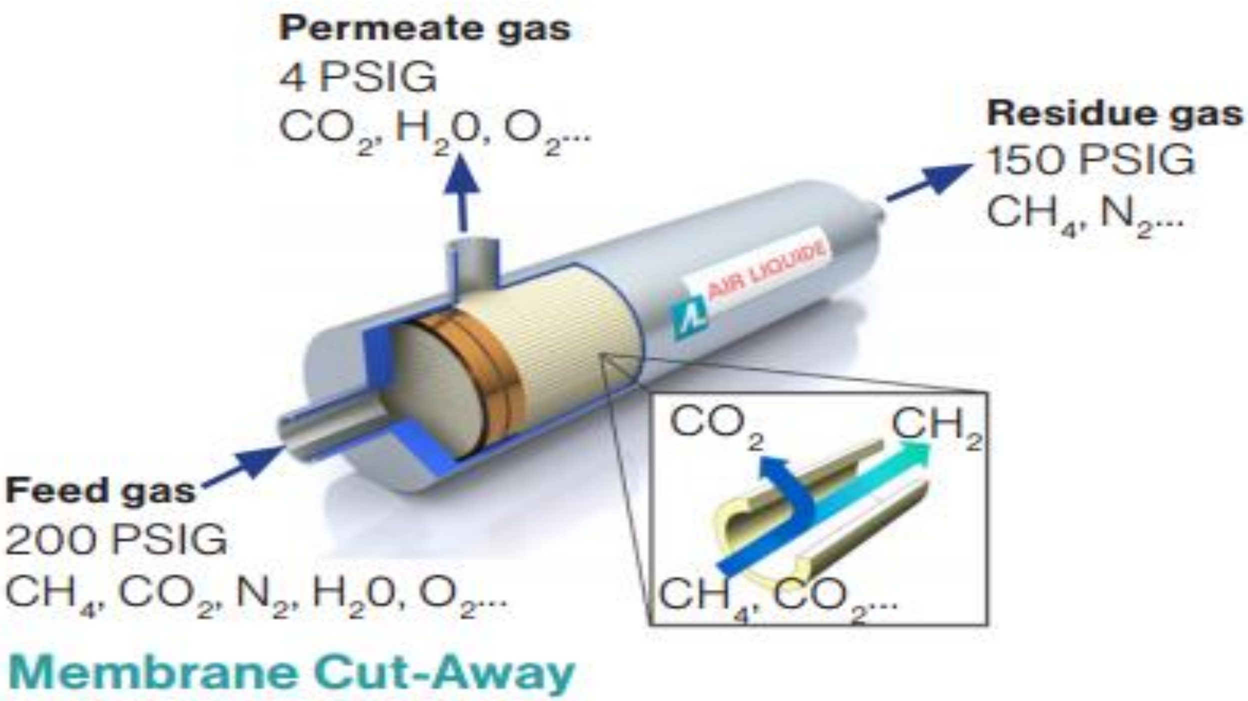
Commercially Available Technologies

Commercially Available Technologies

Type	Feed Pressure	Product Pressure	CH4 Recovery	Benefits	Drawbacks
Kinetic PSA [3]	Moderate (150 – 200 psig)	Moderate (150 – 200 psig)	90%	• High Feed N2 • CO2 co-adsorption	• Adsorption capacity impacted by impurities • Low Recovery
Equilibrium PSA [4]	Moderate (150 – 200 psig)	Low (<25 psig)	96%	• High Feed N2 • Rejects O2	• Adsorption capacity impacted by impurities • Multiple compression stages
Membrane	High (500 psig)	Low (<25 psig)	96+%	• Turndown flexibility • Robust Membranes • No moving parts	• Multiple compression stages • N2/recycle direct correlation
Cryogenic [5]	Moderate (150 – 200 psig)	Low (<25 psig)	96%* *contingent on O2 content	• High flow range • Rejects CO2, O2 & N2	• Impurities freezing potential • Liquid Nitrogen required

Membranes 101

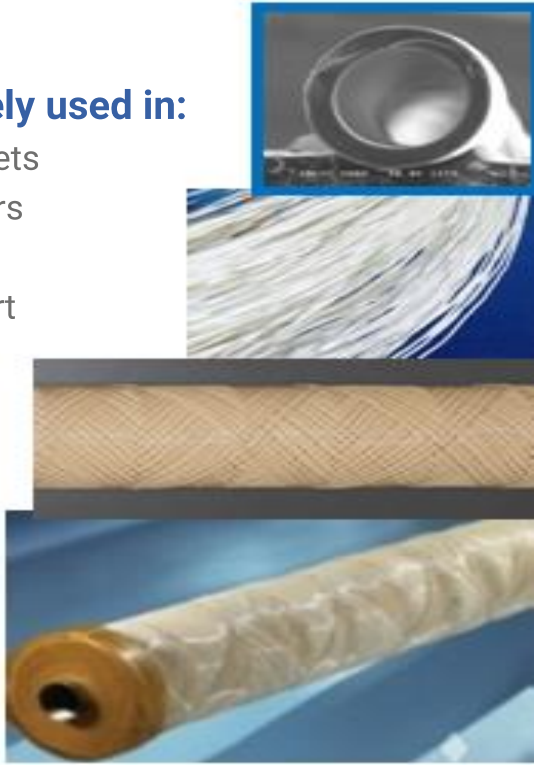
Membrane 101: CO_2 Removal



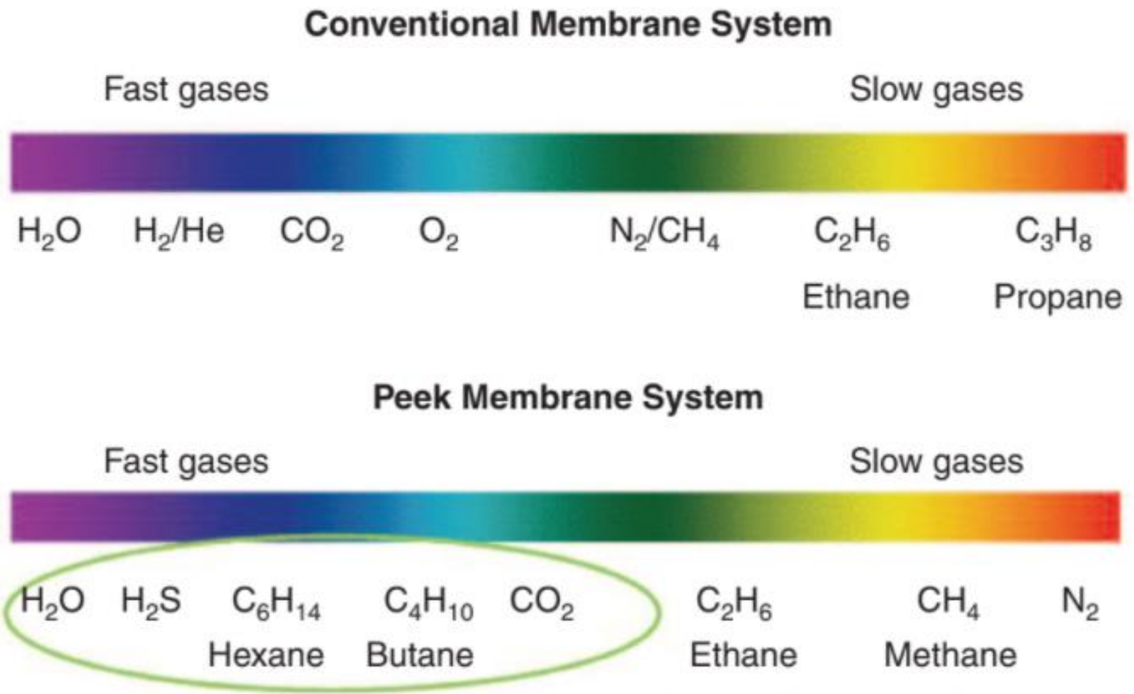
Membrane 101: N_2 Removal

- **Polyether Ether Ketone (PEEK) has best in class thermo-mechanical properties and chemical resistance [6]**
- **PEEK-Sep™ Membrane**
  - Porous PEEK Material
- **Not affected by solvents and chemicals present in natural gas**
  - Allowing the membrane to operate with minimal pretreatment

- **Material is widely used in:**
  - Seals/Gaskets
  - Compressors
  - Bearings
  - Oil Transport



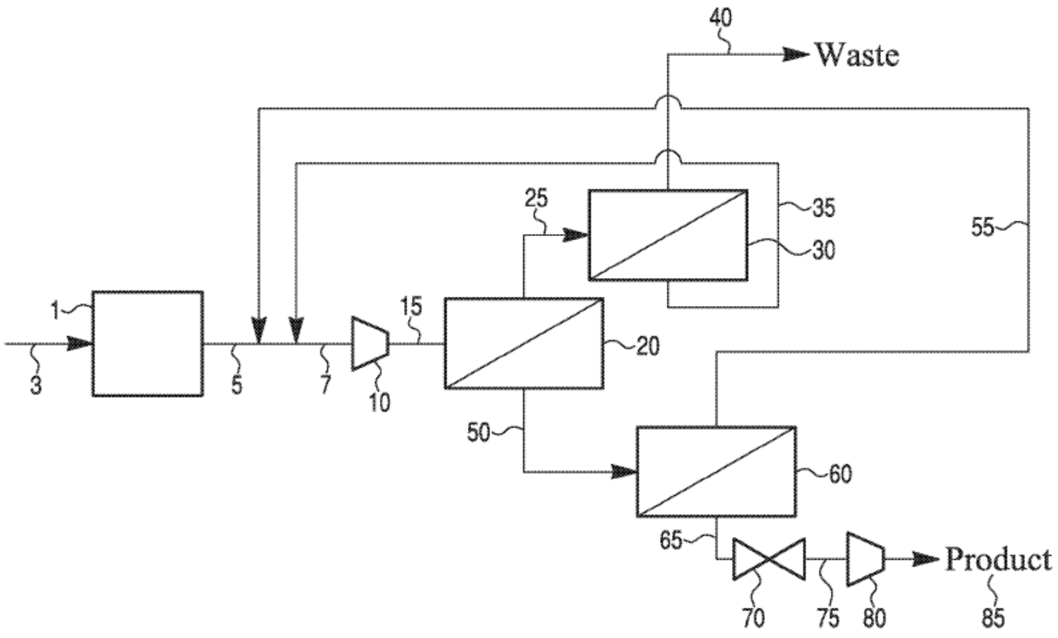
Membrane 101: Comparison



Nitrogen Rejection Unit (NRU) Process Overview

Membrane NRU Process Overview

- **Technology developed and patented by**
  - US Patent – 10,780,392 [7]
- **Scope**
  - Single stage compression (screw or
  - Membrane skid
  - Multi-stage compression for produc
- **Process**
  - 3 = Raw Feed from source
  - 1 = CO2 Removal step
  - 10 = NRU feed compression
    - With recycle streams 35+55
  - 15 = Temperature control
  - 40 = High pressure waste [40% CH_4/60
  - 65 = Low pressure product [96+% CH_4]
    - 70 = Purity Control
  - 80 = Product compression to pipeline requirements



Applications

Operational Applications

- **Two biogas upgrading plants operating since April 2019**
- **Arlington, TX**
  - ABC Innovation of the Year in 2019 [8]
  - 4000 SCFM feed (scalable to 5100 SCFM)
  - 4-6% N_2 in the feed
  - 10% N_2 to the NRU
  - 95+% CH_4 Recovery
- **Horicon, WI (pictured)**
  - 2600+ SCFM feed (scalable to 3100 SCFM)
  - 4-8% N_2 in the feed
  - 9-13% N_2 to the NRU
  - 96% CH_4 Recovery
- **1 facility in operation on Natural Gas feed since October 2020**
- **4 additional facilities in development**

AMERICAN BIOGAS COUNCIL

Acknowledgements and Sources

Acknowledgements and Sources

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Thank You!

gregory.myrick@airliquide.com
andrew.zikeli@airliquide.com

Guild Associates, Inc.
5750 Shier-Rings Road
Dublin, OH 43016
Phone: (614) 798-8215
Fax: (614) 798-1972

Case Study: Mixed Metal Oxy-hydroxide Media for Removal of H_2S from Landfill Gas

Gary L. Monks
November 16, 2021

Outline

Topic
H_2S Removal – Overview
Dry Media Performance & OpEx Challenges
New Dry Media Technology
Case Study
Summary

H_2S Removal – Why?

- H_2S removal from LFG is necessary
  - Toxicity
    - NIOSH REL (10-min. ceiling): 10 ppm
  - Odor
    - Odor threshold 0.01-1.5 ppm
  - Equipment protection
    - Corrosion prevention in engines, membranes, etc.
  - Compliance
    - Air permits
    - Pipeline specifications

H_2S Removal – How?

- H_2S removal from LFG is costly
  - Costs of equipment (CapEx) and operation (OpEx)
  - Wide range of process types used, broadly:
    - Biological
    - Wet Chemical
    - Dry Media
  - Process selection is a trade-off, influenced by:
    - Flow / [H_2S] / daily amount of H_2S removed
    - LFG end-use
    - Availability of capital
    - Payback analysis
  - Some upgrading technologies remove H_2S without pre-treatment
    - Post-treatment may still be required

H_2S Removal – How?

- Process types – costs overview

	Biological	Wet Chemical	Dry Media
CapEx	H	M/H	L
OpEx	L	M/L	H

  - Trade-off analysis generally favors the selection of dry media for landfills with lower gas flows and lower H_2S concentrations, with the drawback of OpEx

Dry Media – Composition

- Conventional dry media types contain:
  - An active component (iron oxide, impregnant, other functional group)
    - Converts the H_2S catalytically to elemental sulfur:

$$H_2S + \frac{1}{2} O_2 \rightarrow H_2O + S$$

  - An inactive component (ceramic, wood or carbon)

Dry Media – Performance

- Media performance is broadly expressed as the **H_2S removal capacity** achieved when media is spent
  - This is when media changeout is required

- Media capacity is typically reported based on **weight**:
  - 6–40%
  - 0.06–0.40 lbs H_2S removed/lb media

- Another key performance measure is the **Changeout Interval** – the time between vessel changeouts

Dry Media – Performance

- The Changeout Interval is directly proportional to media H_2S removal capacity by **volume**
- Performance & OpEx comparisons between media must factor in volume capacity:
  - Volume capacity = Weight capacity x Density
- Capacities by weight of 6-40% translate to capacities by volume of 4-15 lbs H_2S/cu ft

Dry Media – OpEx & Changeouts

- Components of High OpEx
  - Costs of media & freight, changeouts, spent media disposal
    - All are incurred at the same time
- Resources for Media Changeouts
  - Replacement media + freight
  - Operator attention
    - Procurement
    - Planning/Logistics
    - Supervision
  - Equipment Downtime
  - Service Contractor
    - PPE / HSE Protocols
    - Specialist equipment
      - Vacuum trucks, jackhammers
    - Disposal of spent media
      - Testing, documentation

Dry Media – Limitations

- The inactive component (ceramic, wood or carbon):
  - Inherently limits performance
    - Capacity & Changeout Interval
  - Inherently leads to higher changeout costs

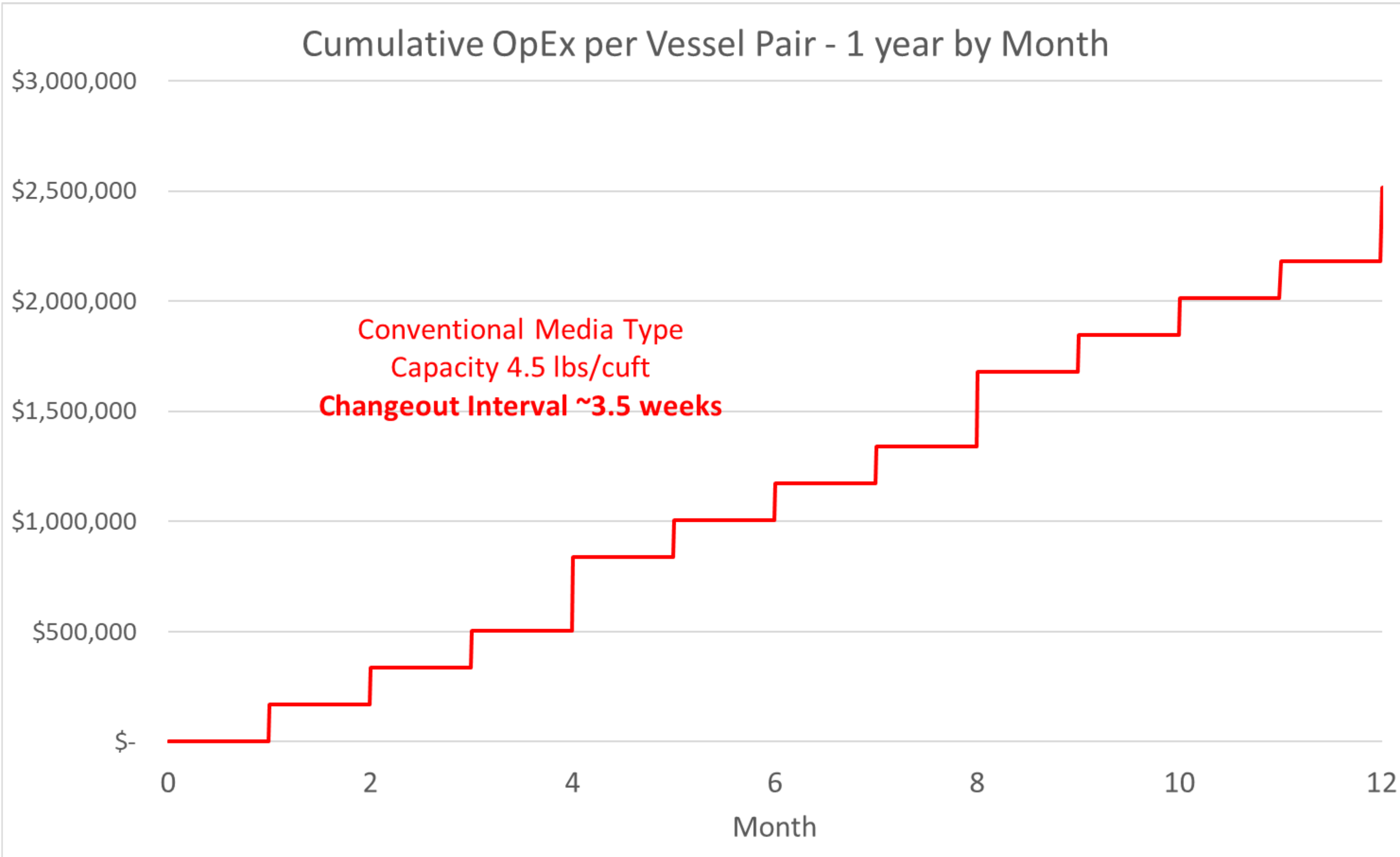
New Dry Media Technology

- Address limitations of conventional media
  - Composition → Performance → OpEx
- Approach
  - Novel precipitation chemistry
  - 100% active component
  - Engineered pore structure
  - Maximized concentration of active sites
  - Optimized H_2S volume capacity
    - Longest Changeout Interval
    - Lowest OpEx
  - Performs in wide range of conditions, including low O_2
- **Solution: Mixed Metal Oxy-hydroxide technology (BSR-050)**

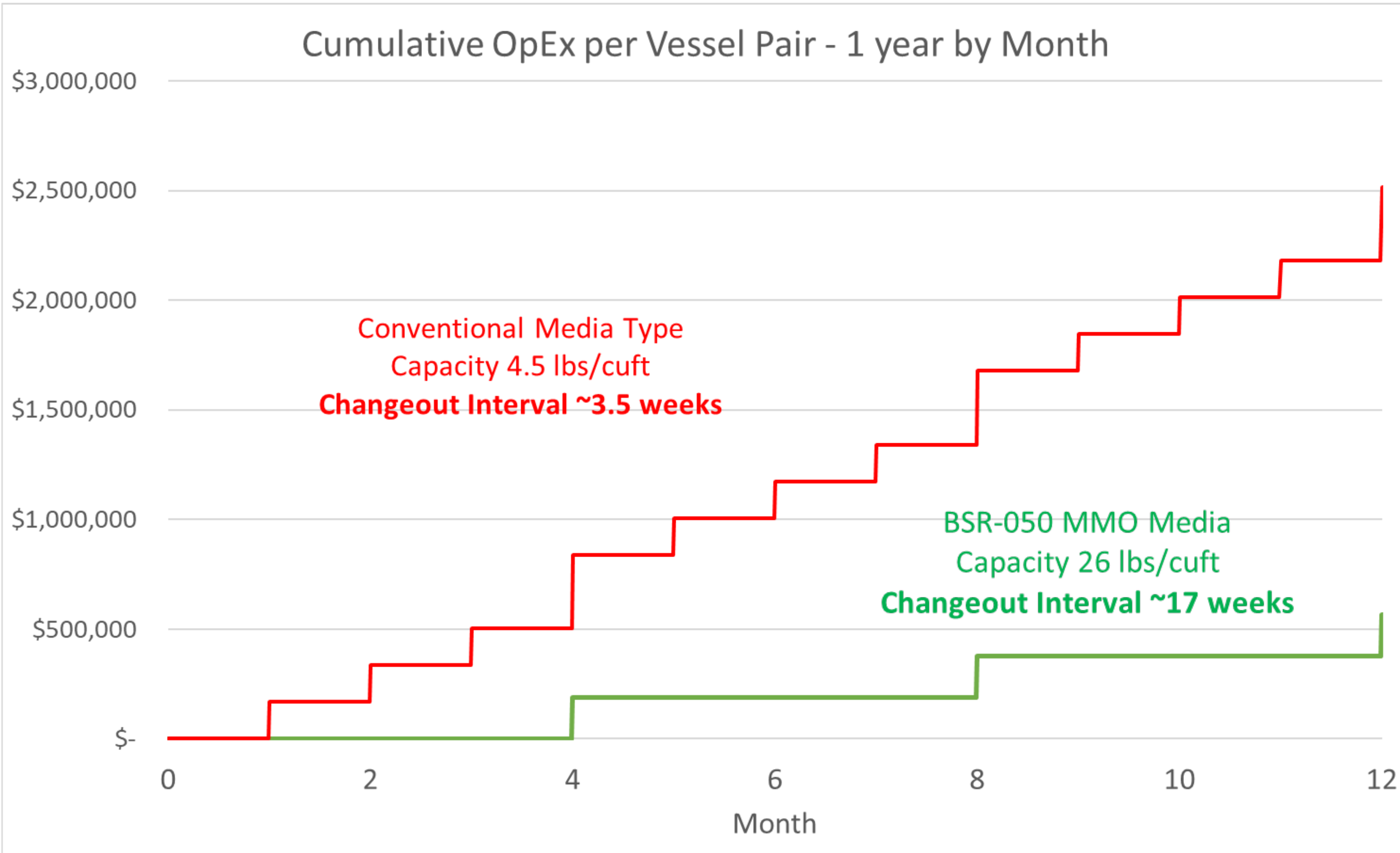
Case Study

- Customer site in TX
  - 800-1,000 ppm H_2S, 0.1% O_2, saturated gas
  - Box-type vessels, Parallel lead-lag configuration (4 vessels)
- Customer was using iron oxide-type media, filling each vessel with 110,000 lbs
  - Changeout interval was typically ~4 weeks (Capacity 6 %wt; 4.5 lbs/cu ft)
  - Spent media bricked, requiring 4-5 days for removal & replacement
- Customer switched to BSR-050, requiring only 33,000 lbs per vessel
  - Changeout interval was extended to ~4 months (Capacity 120 %wt; 26 lbs/cu ft)
  - Spent media was not bricked, 1-2 days for removal & replacement
  - OpEx reduced by 80%
- Due to performance of MMO media, customer introduced stranded gas from additional cells
  - Flow increased from 5,600 scfm to 6,500 scfm
  - Revenue increased

Case Study OpEx Cost Profile



Case Study OpEx Cost Profile



Summary

- H_2S removal from LFG is necessary & costly
- Dry media process type carries the highest OpEx
- Most OpEx costs are incurred around media changeouts
- MMO media technology maximizes changeout interval by maximizing H_2S removal capacity per cu ft
- Case study showed reduction in OpEx by 80%
    - Low O_2 performance
    - Indicates an extension of the boundaries of practical uses for dry media

Guild Associates, Inc.
5750 Shier-Rings Road
Dublin, OH 43016
Phone: (614) 798-8215
Fax: (614) 798-1972

Questions?

Gary Monks
gmonks@guildassociates.com
614-602-1760
www.guildassociates.com

Questions

Q&A

Wrap Up

Contact Information

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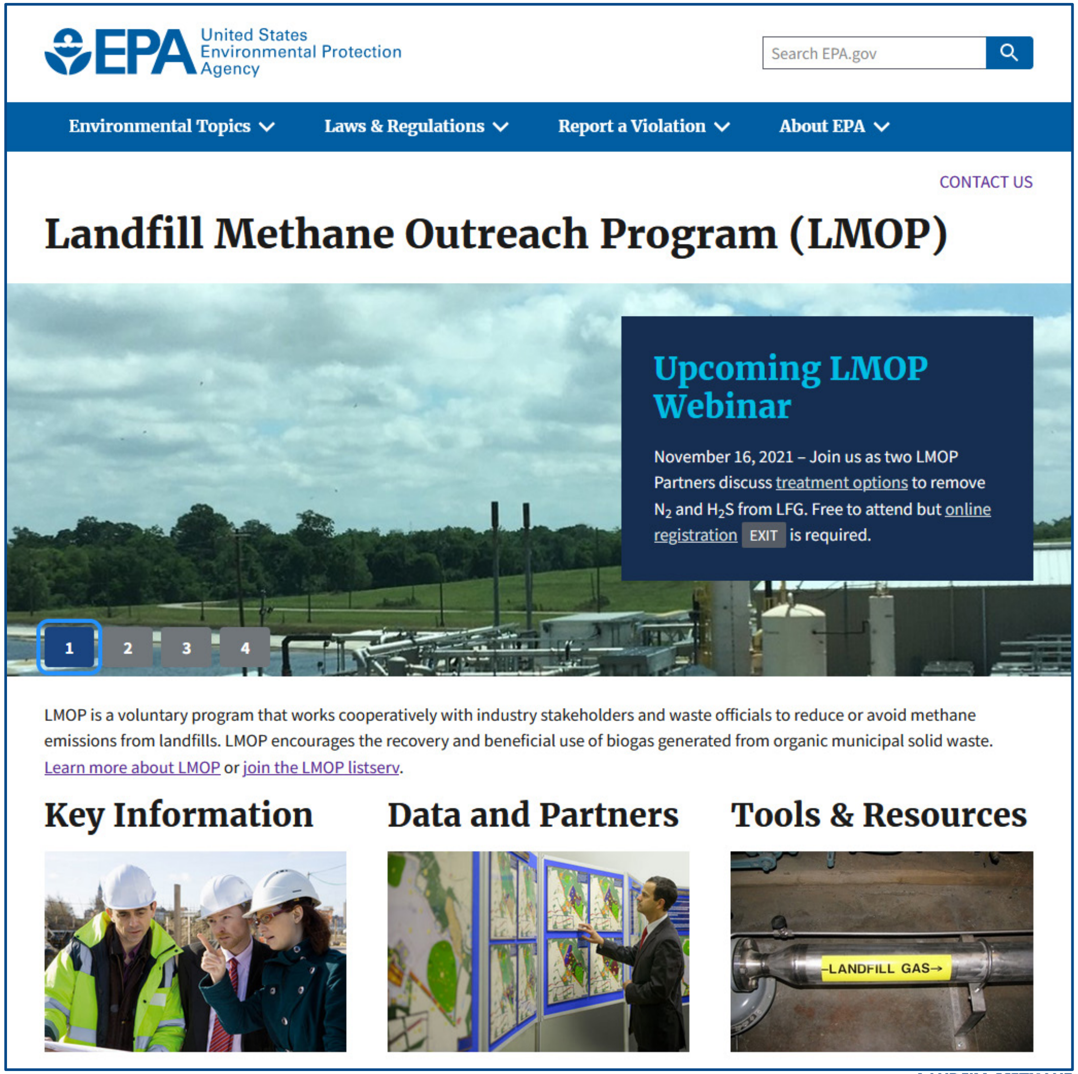
Wrap Up

- The slides and recording from today's webinar will be posted on the LMOP website
- To learn more about LMOP or LFG energy, visit our website at epa.gov/lmop
- Have a webinar idea? Drop us a note with your email in the Q&A box or email lmop@epa.gov



Thank You

Please reach out with any questions or comments

Ellen Meyer
meyer.ellen@epa.gov
(202) 748-7888

Lauren Aepli
aepli.lauren@epa.gov
(202) 343-9423