RNG DEOXO ROUNDTABLE

May 2024

INTRODUCTION

When a group of experts from engineering, operations, and business development get together to discuss biogas-to-RNG, you can expect things to get both lively and nerdy fast. In this roundtable discussion, EcoVapor (a DNOW Company) experts, talk about deoxygenation, aka “deoxo,” solutions in biogas-to-RNG applications. .

THE PANEL

Hans Mueller
Vice President, EcoVapor

Joe Hedges
Director of Sales, EcoVapor

Marcus Knox
RNG Product Manager, EcoVapor

Q: Why is O2 a problem in natural gas from both geologic and biogas sources?

JH: It really comes down to meeting the gas quality specifications of the midstream pipeline operators who transport the gas and the utilities who buy and deliver RNG to their customers. If the gas doesn’t meet pipeline specifications, the midstream company can’t take it.

MK: Joe is right. Raw biogas and landfill gas typically contains a variety of contaminants that must be removed before it can be upgraded and sold as RNG. Those contaminants range from oxygen, CO_2, siloxanes, hydrogen sulfide, water and more. The particular problem with oxygen for midstream companies is that it greatly accelerates galvanic cell corrosion rates and can inherently create its own corrosion. If you think about corrosion in terms of mils per year, even tiny amounts of oxygen can accelerate the corrosion rate by a factor of several years. That’s why pipelines restrict overall water and oxygen content.

HM: And it’s a systemic problem. Oxygen contamination impacts the entire biogas-to-RNG value chain. Pipeline networks feed into gas processing plants and if the gas exceeds pipeline spec for oxygen, it can negatively impact amine treaters, rendering them ineffective and resulting in significant damage. That in turn results in upsets, downtime, and potentially significant additional costs.

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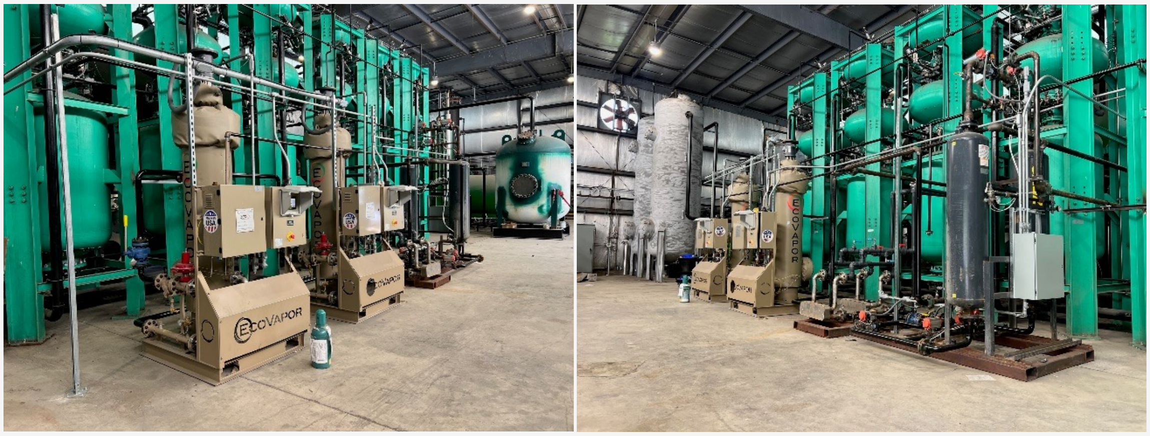
Q: What if you don't treat oxygen to pipeline specification?

HM: If you don't treat the oxygen down to pipeline spec, the only allowable alternative is to flare it, which in turn generates additional CO_2 and ozone-causing emissions, and it is a waste of a valuable natural resource. Biogas is one of the only, if not the only, carbon-negative sources of natural gas production and flaring it contradicts its sustainability benefits and negatively impacts economics. Ultimately, the goal is to meet pipeline spec and sell gas instead of flaring it.



Pictured above: Two ZerO2 deoxo units installed and operational at a landfill gas to RNG facility. Combined, they handle over 500 scfm of biogas and keep oxygen below the customer specification of 200 ppm Oxygen.

Q: How does oxygen enter the biogas process to begin with, and can it be prevented?

JH: Yeah, good question and it can enter the process a few different ways. In agricultural biogas operations, air, which of course contains oxygen, is injected into the upgrading process to help treat H_2S, which also presents a safety threat to people and infrastructure. Since digesters in agricultural biogas operations rely on anaerobic processes, meaning without air, oxygen must be injected back into the raw gas stream so H_2S treating technologies that rely on aerobic processes can treat and/or remove it. So, you're solving one problem, but creating another.

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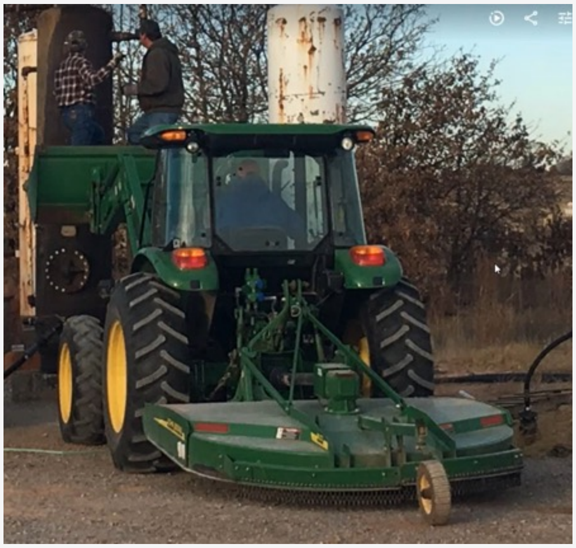
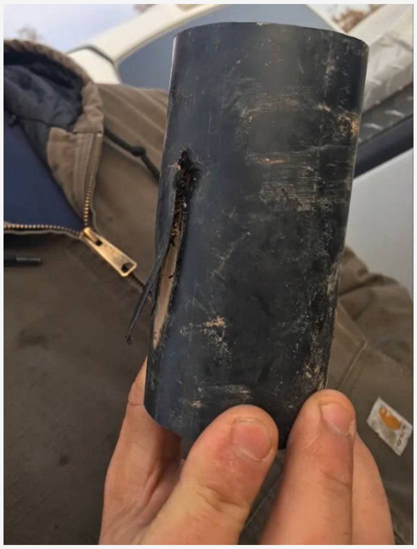
Q: Lawnmowers? Please explain.

MK: Landfill gas operations tend to use PVC pipe laid on the surface to transport gas, and lawnmowers and PVC pipe don't get along! Let me explain. The surface of a landfill is, well, "land," particularly those that have areas for reclamation and areas of active landfill use. Vegetation, including grass, weeds, trees, and other plants must be controlled, which often includes large riding lawnmowers. It is not uncommon for lawnmowers to run over, and slice open a PVC pipe used to transport landfill gas, which in turn sucks air and oxygen back into the landfill. This typically causes a surge in oxygen content that can quickly overwhelm an upgrading system, resulting in flaring.

HM: And, then we're back to flaring biogas, which can generate ozone precursors and of course, wasting a valuable resource. In fact, here's an example of a PVC biogas line damaged by a lawnmower. As soon as it was damaged, the operators saw a significant increase in oxygen content in the landfill gas stream.





Pictured above: Example of how landfill gas streams can be vulnerable to routine landfill maintenance practices. In this case, slicing a biogas line laid on the surface allows air to enter the biogas stream, along with Oxygen.

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Q: Okay, you've convinced me that oxygen contamination in biogas and landfill gas streams is a problem. But, how low do you have to go?

MK: It really depends on the contract between the RNG producer and the pipeline, and what can be negotiated. Every pipeline company has to think about corrosion sources and effective mitigation methods based on their expertise and opportunity costs for their buyer/operator to deal with.

JH: RNG can contain some oxygen, but it depends on the pipeline company. We've encountered pipeline specifications ranging from 2000 ppm down to only 5 ppm. In Michigan, for example, it is common for pipelines to have an oxygen spec at or below 5 ppm. It really depends on the pipeline operator and what they believe is right for their infrastructure and system integrity.

HM: The relevant specification is typically set by the most stringent pipeline in the network the RNG facility is producing into. A local, smaller gas gathering network may have a less restrictive spec, but if it is delivering the gas downstream to a larger interstate pipeline with more stringent standards, then the more restrictive standard is going to prevail. The minimum allowable or tightest specification tends to "swim" upstream.

Q: What technologies and processes are used to remove oxygen from biogas and landfill gas?

HM: Deoxo processes fall into two main categories – prevention and removal. In oil and gas, for example, the primary preventative technique we see is gas blanketing, which maintains positive tank pressure so there is no vacuum to suck air into the system. It can be cost effective in biogas applications depending on the volume of the biogas stream, but it isn't foolproof. Gas blanket applications can be operationally complex and require constant tinkering to maintain reliability and performance. The biggest problem is that gas mixtures are always seeking equilibrium – they try to go where they are not through diffusion. And once the gas finds its way in, it's in.

JH: Blending a gas stream with high oxygen content with a stream having lower oxygen can also help prevent oxygen levels exceeding the relevant pipeline specification, but the effectiveness of this technique is highly dependent on what gas sources are in proximity. If the low oxygen stream introduces other contaminants, now you must treat for those!

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Pictured above: Four ZerO2 Deoxo units in operation at a Colorado biogas-to-RNG facility using manure sourced from local dairies as a feedstock to meet the pipeline specification for Oxygen content to less than 10 ppm.

Q: What are the removal technologies you mentioned?

MK: Oxygen removal techniques include PSAs, Membranes, Scavengers, and Catalytic processes. Let's run through the pros and cons of each technology. Keep in mind that there are orders of magnitude between these methods, they have specific operational envelopes and if you use them outside of their effective ranges they lose their effectiveness.

First, pressure swing adsorption (PSA) is used to separate certain gas types, or species, from a mixture of gases (typically air) under pressure according to the species' molecular characteristics and affinity for an adsorbent material (media). For bulk gas removal of CO_2 and Nitrogen, the most prevalent gasses in biogas streams that require removal, PSAs are both relatively less expensive than other methods and can be very effective within their operating envelope. That is why they are frequently used in biogas-to-RNG and landfill gas-to-RNG applications.

JH: The problem with PSAs is that they are primarily focused on CO_2 and have only marginal benefit in reducing oxygen levels. They are not specific oxygen removal technology.

MK: If PSAs have any beneficial impact on oxygen, it is a fortunate byproduct, not necessarily a key feature. Another issue is that PSAs have a slipstream and gas can be vented to the atmosphere, recycled or sent to flare. This recycling can occur at the beginning of the process, but now the treating equipment must be upsized to create capacity to re-treat the gas. This is operationally complex and requires compression upstream. Of course, the media must be regenerated and/or replaced periodically, resulting in downtime.

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Q: What about membranes?

MK: Membranes are great for post-contaminant (i.e., Siloxanes, H_2S, and others) bulk gas conditioning and can achieve high levels of methane purity, exceeding 99.5%, mainly by removing CO_2, which is outstanding. Membranes are operationally simple and as I understand them, can last up to 10 years.

HM: But, like PSAs, membranes aren't great at removing oxygen, don't like H_2S, and are not very effective at Nitrogen removal.

JH: And membrane solutions require compression upstream, requiring more energy input to pressurize the stream, adding cost or reducing the amount of RNG for sale.

MK: That's right, and you need more than one membrane. Typically, we see a three-stage membrane arrangement where the first stage separates the stream into CO_2-rich and methane-rich gas streams. The methane-rich stream goes to the second stage, where it is further purified.

The CO_2 stream is sent to a third stage to recover as much methane as possible, and the very pure CO_2 byproduct can be liquified in a liquefaction plant and sold for industrial use. All this sounds good, but membranes do not necessarily directly remove oxygen! If your pipeline transporter has a restrictive oxygen specification, chances are you will still need oxygen removal capacity downstream of the second stage.

Q: Okay, so would you talk to us about scavengers?

MK: No problem. The major benefit of oxygen scavengers is that they are very convenient. When they are used correctly, and I emphasize "correctly," they can remove oxygen in both liquid and gaseous phases. Scavengers are usually less expensive than most catalytic media and can treat down to part per billion, depending on the application, initial amounts of oxygen and so on. The cons relate to safety and operational complexity. Liquid scavengers are asphyxiants and represent an HSE risk from suffocation. Leaks and exposure can present risks to workers. In many applications, the support equipment to regenerate the scavenger media can be complex, costly, and sensitive to contaminants. Also, scavenger media works by trapping the oxygen molecule to another with which it has an affinity, which means the media is consumed in the process and eventually must be replaced and disposed of.

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Q: Can you summarize?

JH: It's important to note that whatever system is used for to manage the produced gas, oxygen removal technology like ours sits downstream of this step in the process.

MK: Yeah, biogas-to-RNG upgrading processes absolutely must have a bulk gas removal system, mainly for CO_2 and Nitrogen, like PSAs, membranes, or some other technology. Although they might remove some oxygen, these bulk treating technologies are not used for oxygen removal specifically.

JH: Right. We don't see PSAs and other bulk removal systems as competitors because they perform a critical step early in the upgrading process, but they don't get the oxygen level down to the pipeline specifications we typically see today. You still need a dedicated deoxo solution.
MK: Exactly, these technologies are like organs in the body. Each one has a role to play, and you need them all for the RNG plant to work.

Q: We're finally at catalytic methods. Tell us about the pros and cons of catalytic deoxo technology.

HM: I thought you'd never ask! It's no secret our specialty at EcoVapor is catalytic oxygen removal technology. Our catalytic deoxo solutions have proven their worth in the Oil and Gas industry, enabling producers to decontaminate their tank vapor, which is usually the most valuable gas on the well site, of oxygen so it can be sold to the pipeline instead of flared. Oil and Gas producers are subject to at least the same, but often more stringent, pipeline specification issues faced by RNG producers.

Also, catalytic deoxo is operationally simple and reliable because there are no moving parts, and it treats down to non-detectable levels without using media or chemicals. It can meet almost any pipeline spec and can safely reduce oxygen concentration down to the parts per billion (PPB) level. Provided you limit the contaminants, the catalyst doesn't participate in the reaction, so life of unit is very long.

MK: Like any method, however, catalytic deoxo isn't perfect. The catalyst is sensitive to certain contaminants, so we still need to treat H_2S and water upstream of the deoxo unit, just like you would have to with membranes. The catalytic process generates some water, which must be removed with a dehydrator or other technology before it can be sold to the pipeline. And, our ZerO2 units require 480 3-phase power, which is not usually a problem with RNG applications but sometimes can be at remote Oil and Gas production sites.

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JH: That's true, and it is important to keep in mind that not all catalytic deoxo solutions are created equal. At EcoVapor we pride ourselves on the flexibility of our technology and our collaborative approach. ZerO2 units come in different sizes and are modular, so we can scale up quickly to meet changing needs over time as your project grows. Also, we focus on your project needs, not what we like to sell. We can add fans, chillers, and dryers, or leave them out as your situation requires. We package only what you need, which reduces complexity and cost.

Q: What does the future of RNG look like?

JH: RNG has a promising future because biogas and landfill gas operations can provide a reliable stream of clean, carbon-negative energy. Pipelines, however, are getting increasingly restrictive and today it is common to see an oxygen specification of 5 PPM or lower. For gas coming out of a digester, catalytic deoxo is simply the most effective way to get down to that level.

Q: How can people get more information on EcoVapor's deoxo solutions?

JH: You can visit our website at EcoVaporrs.com where you get more information, submit an information request, or call us at 844-663-5273.

Thank you all for sharing your time and expertise with us today.

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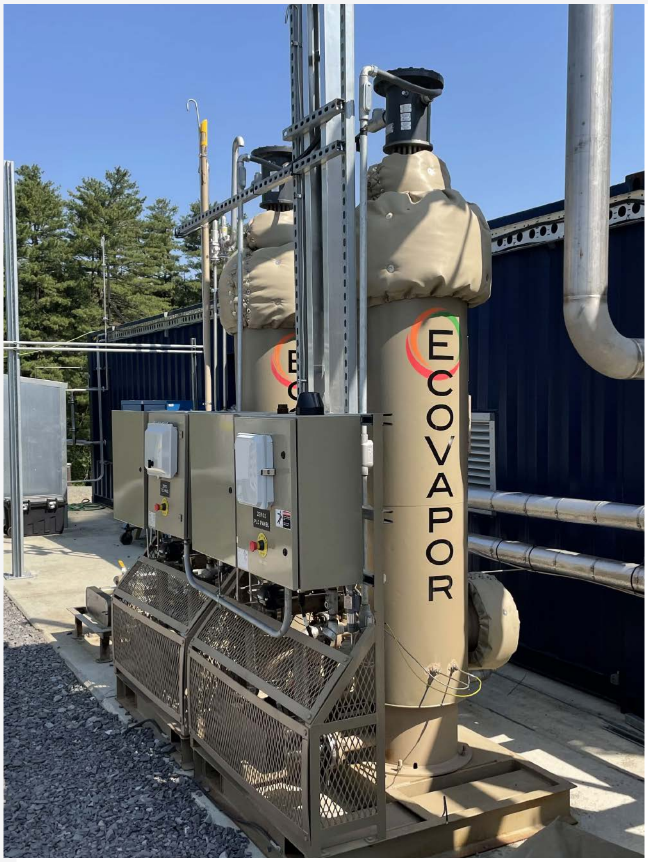

ABOUT ECOVAPOR

EcoVapor, a DNOW company, offers a suite of technology-based solutions for improving the sustainability of gas-powered energy systems by converting waste streams into revenue, which reduces emissions. Our flagship ZerO2™ removes oxygen from biogas ("deoxo"), landfill gas and tank vapors, allowing gas to meet pipeline specification and be sold instead of otherwise being flared. We serve the Oil and Gas and Renewable Natural Gas (RNG) markets.

Contact us today at 1-844-NO-FLARE (844-663-5273) to see if ZerO_2 is right for your agricultural biogas to RNG operation.