



LMOP Webinar

Electricity Options for Remote
Location or Low Landfill Gas Flow

December 6, 2023

Welcome and Agenda

AGENDA

Biogas Utilization, Electrification, and Decarbonization of Landfills

Adam Wright, CEO, Vespene Energy

Brett Arnold, Head of Business Development, Vespene Energy

Powering Methane Abatement

Isaac Garaway, CTO, Qnergy

Questions and Answers

Wrap Up

Mention of any company, association, or product in this presentation is for information purposes only and does not constitute a recommendation of any such company, association, or product, either express or implied, by the EPA.

Biogas Utilization, Electrification, and Decarbonization of Landfills

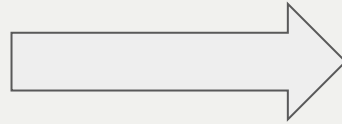
Biogas Utilization, Electrification, and Decarbonization of Landfills

HISTORICALLY, ONLY THREE WAYS TO UTILIZE LANDFILL GAS

01 Refine to RNG

- Gold standard, high margin, but...

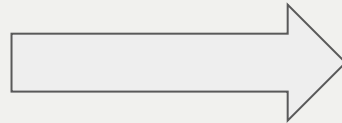
- Infrastructure and capital intensive
- Heavy power requirements
- Requires new pipeline construction or virtual pipelining
- Typically requires higher flows (>800 scfm)



02 Sell Electricity to Grid

- Lower capital requirements, but...

- Historically low margin
- Long interconnect timelines
- Some sites lack 3-phase power



03 Direct-Use Case

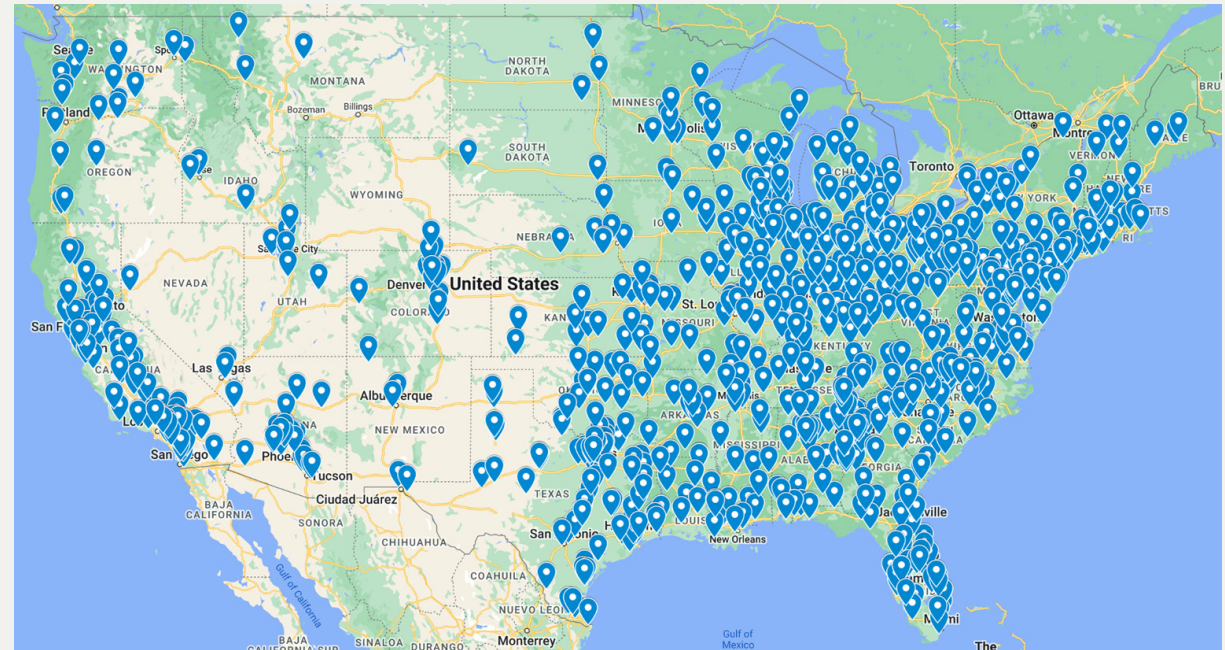
- Also, lower capital requirements, but...

- Low ROI
- Peaked at 125 projects in 2009

OPPORTUNITIES AT SMALL LANDFILLS

- **NSPS-Regulated Sites:** Small landfills collecting and flaring gas represent a significant untapped opportunity to tie together baseload distributed generation resources, while currently a major **economic liability** for communities and landfill operators.
- **Non NSPS-Regulated Sites:** Without a financially viable method of mitigation / use, these sites will remain an **environmental liability** until the landfill grows or more stringent regulations come into place.
- Based on EPA data, we estimate there is approximately 2 GW of potential electricity generation that is either being flared or emitted

MOST OF THESE SITES ARE TOO SMALL AND DECENTRALIZED TO BE VALID TARGETS FOR RNG DEVELOPMENT, AND VOLUNTARY CARBON CREDITS ALONE ARE NOT ENOUGH TO FUND MOST PURE DESTRUCTION PROJECTS.



MAP OF US LANDFILLS WITH UN-UTILIZED OR UNDER-UTILIZED GAS RESOURCES AND FLOW RATES >100 SCFM

(SOURCE: EPA LANDFILL METHANE OUTREACH PROGRAM DATABASE)

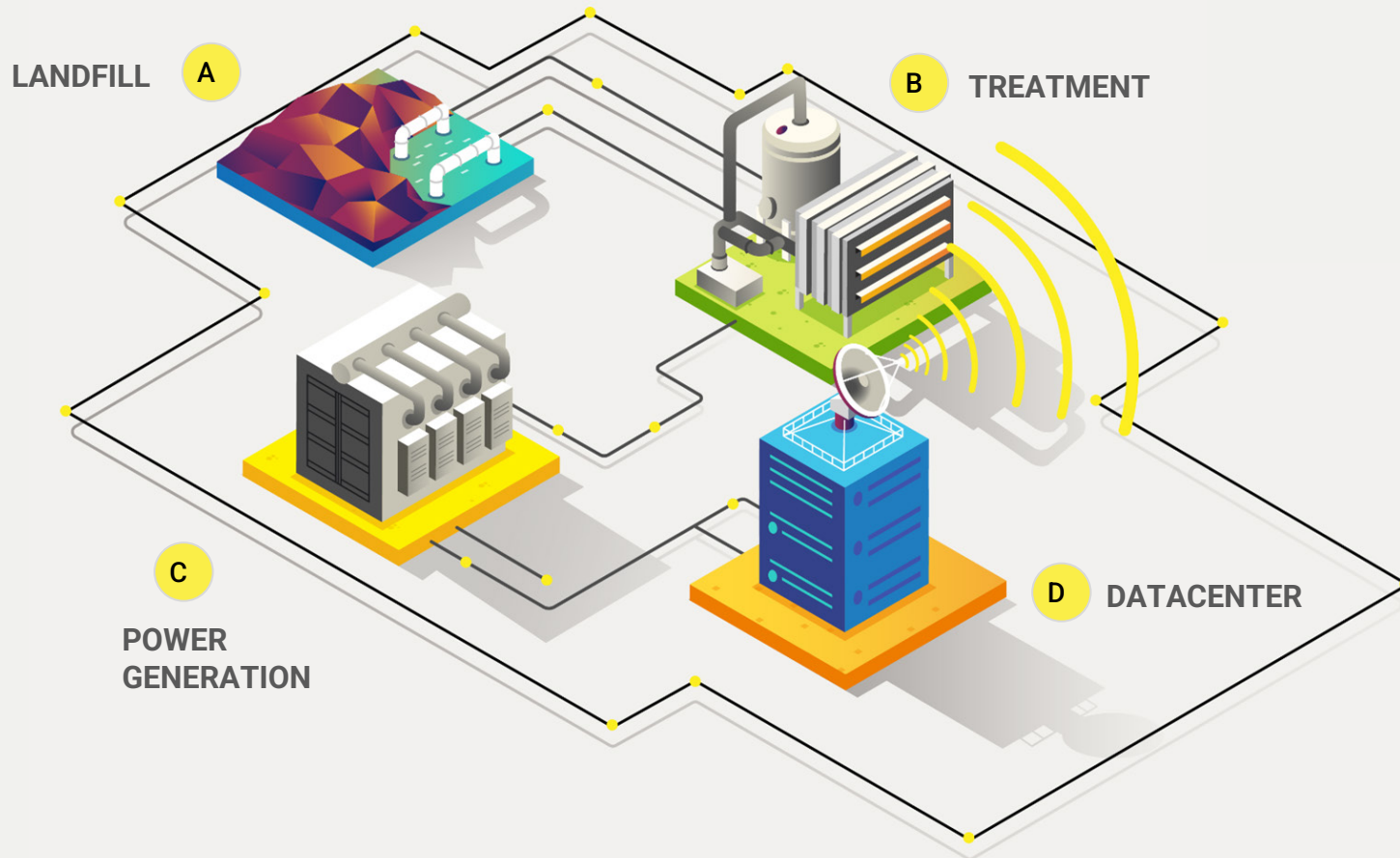
VESPENE PROVIDES A SOLUTION

Vespene Energy's Self-Sustaining Microgrids combine the high economic returns of RNG with the lower cost and scalability of electricity projects, allowing small landfills to profitably contribute to the renewable energy transition.

WITHOUT REQUIRING A GRID INTERCONNECT

PHASE 1: THE CORE OF A SELF-SUSTAINING MICROGRID

Vespene's Self-Sustaining Microgrid is a turbine or engine-based LFG energy project co-located with a modular datacenter. In this way, we bring the user of the energy to the site, rather than exporting the energy to the user. **The only export from the site is data, not electrons or molecules, and data can be transferred via satellite or other wireless internet option.**



B.
GAS CONDITIONING

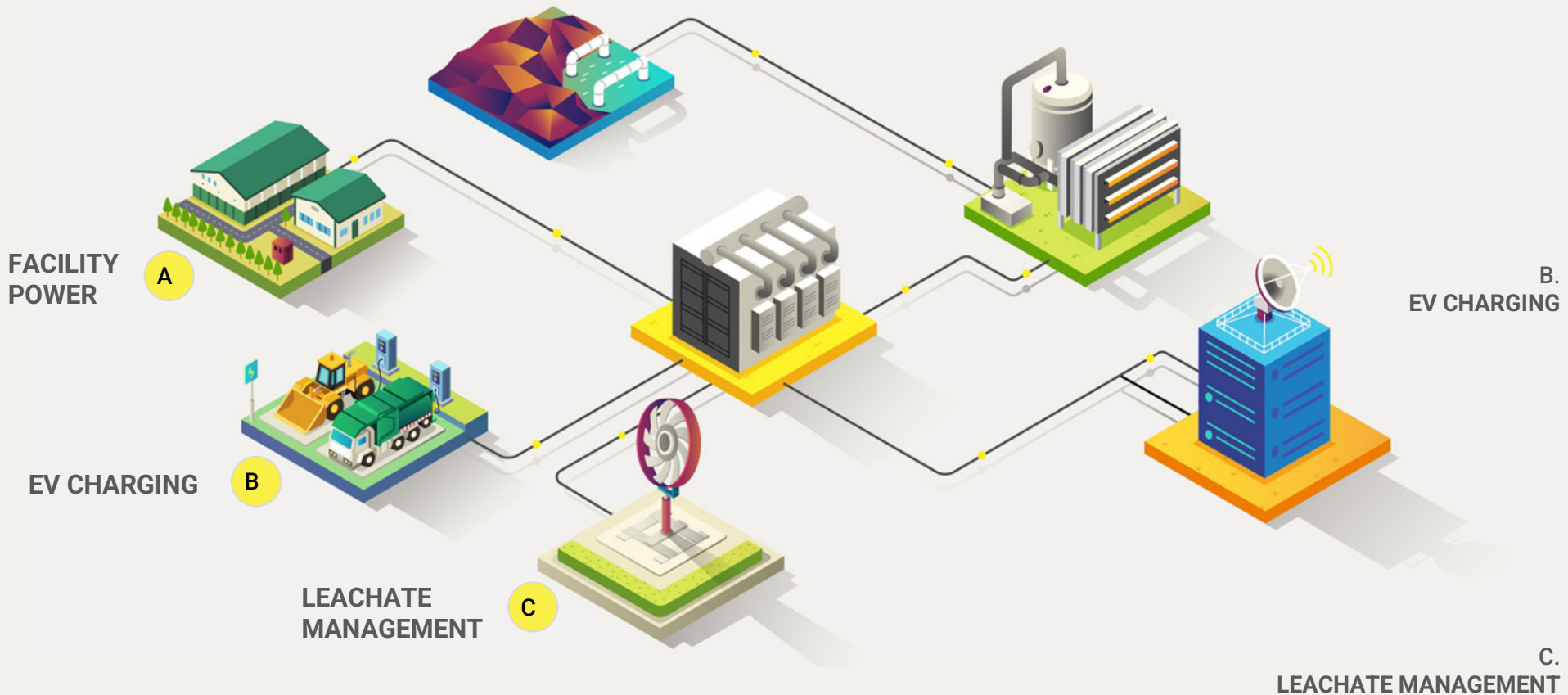
C.
CLEAN GENERATION

D.
CONTAINERIZED
DATACENTER



PHASE 2: ENABLING ONSITE USES

Vespene Self-Sustaining Microgrids balance site loads with **fully interruptible datacenters which enable reliable off-grid energy for leachate management, EV charging, facility power, and other variable site loads.** This ensures that 100% of the electricity is always put to beneficial use and monetized, allowing the generation assets to run continuously.



A.
FACILITY POWER

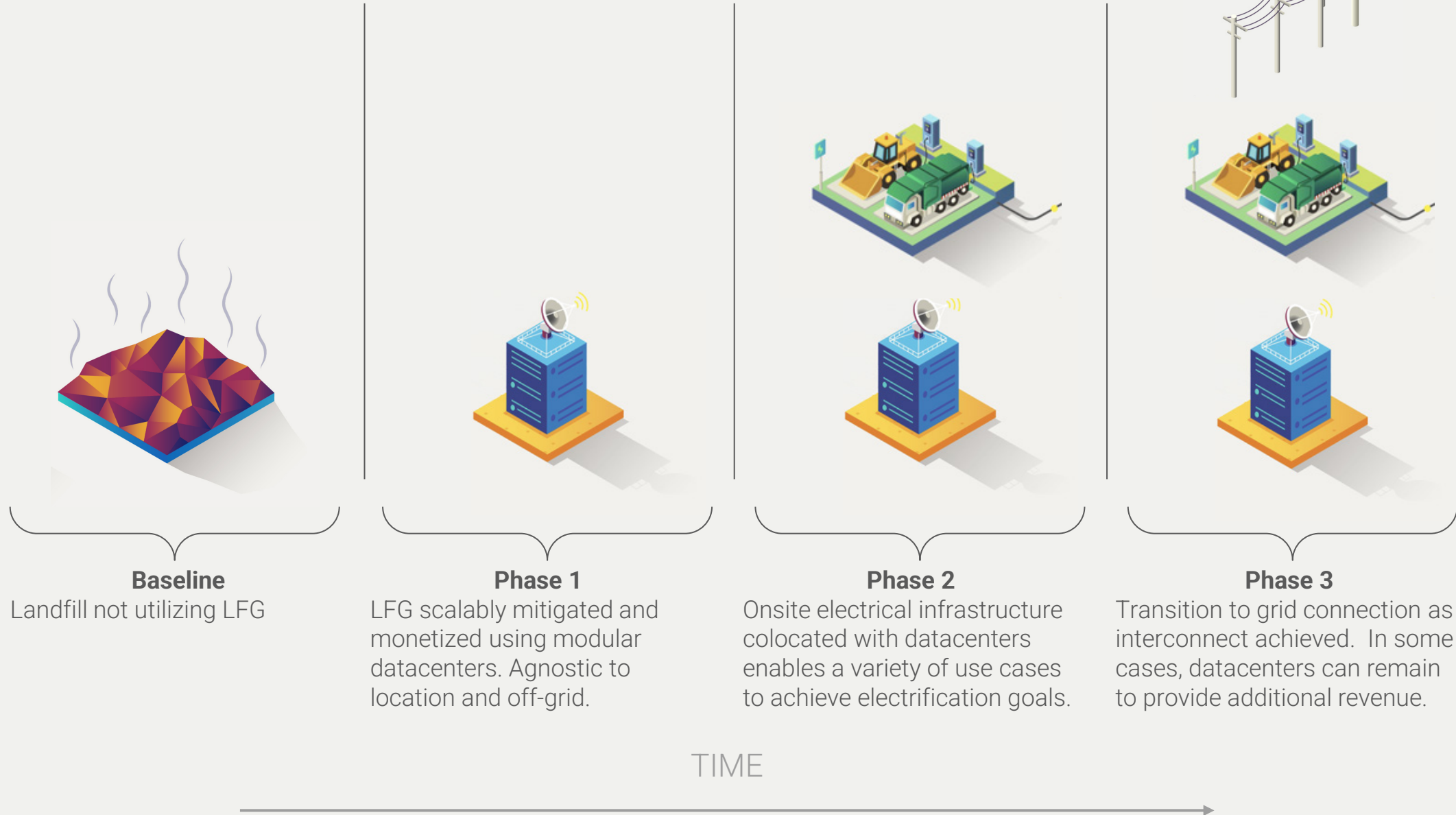


B.
EV CHARGING



C.
LEACHATE MANAGEMENT

EVOLUTION OF SELF-SUSTAINING MICROGRIDS

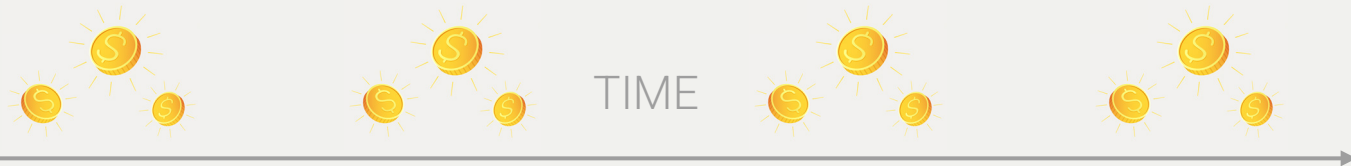
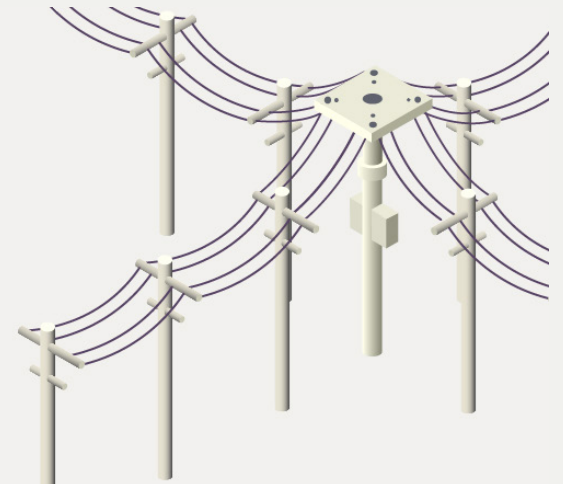


PHASE 3: A BRIDGE TO E-RINs

EPA has accepted a pathway for landfill gas to electricity projects to participate in (RFS) program. Potentially lucrative however interconnect times are very location-**economic returns while interconnections are in process.**



INTERCONNECTION + E-RINS START



KEY BENEFITS

01 GHG Emission Reduction

Economically mitigates methane emissions without regulatory intervention.

02 Modular and Scalable

Minimal site infrastructure requirements. Scales to amount of gas available. Applicable for closed landfills as well as C&D landfills.

03 Health and Safety

Hazardous air pollutants such as VOCs, NO_x, and H₂S are filtered or destroyed during the combustion process.

04 Regional Economic Benefits

Job creation in rural areas. Royalties provide additional revenue for communities. Stimulates adoption of electric vehicles, allows landfills to benefit from government EV incentive programs. Renewable energy for rural electric cooperatives.

05 Reduces Environmental Compliance Costs

Avoids potential future costs related to EPA compliance due to landfill growth or changes to the regulatory landscape.

06 Complementary to Other Projects

Monetize gas during the build-up of a larger project, or the excess gas from an existing project.

REPRESENTATIVE PROJECT SHOWCASE

- Marathon County Landfill in Wisconsin
- 2 MW LFGTE Project Co-Located with Datacenter



MORE SITES IN PIPELINE

Landfill with No GCCS

- Open LF in Midwest
- Venting LFG

Vespene: Install GCCS and build energy project

Landfill with Existing Energy Project

- Closed LF in Midwest
- Existing energy project and interconnection
- Struggling with low price for merchant electricity and looking for solution to keep energy project
- ~600 scfm LFG

Vespene: Repurpose energy project to serve data centers

Landfill with Existing GCCS and Flaring

- Open LF in Midwest
- Flaring 450 scfm LFG
- No existing energy project or interconnection

Vespene: Build energy project

OUR PARTNERS AND PROVIDERS



Thanks from the Vespene Team



Adam Wright
CEO



Joshua Glovin
COO



Aaron Lavee
CGO



Merissa Coello
Environmental Program Manager



Brett Arnold
Business Development Manager

Ready to Talk?

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Powering Methane Abatement

The logo for Qenergy, featuring a stylized 'Q' with a speech bubble tail and the word 'energy' in a sans-serif font.

Qenergy

Powering Methane Abatement

LMOP Webinar
Dr. Isaac Garaway

2023



The Leading Generator for Methane Conversion

Nearly **100%** methane destruction

10 years of maintenance free engine operation

Direct operation on **raw, unrefined methane** from natural gas and landfills

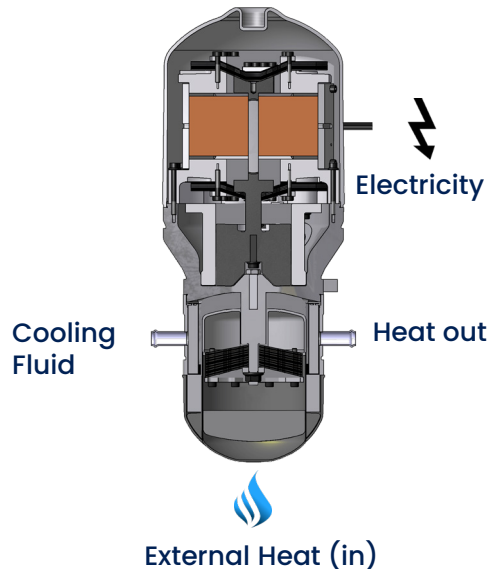
Based on a Proprietary **Linear Engine**
(Free Piston Stirling Engine)



Leaders in Free Piston Stirling Engine

A sealed external combustion engine converts unrefined methane to clean energy

LINEAR FREE PISTON STIRLING ENGINE



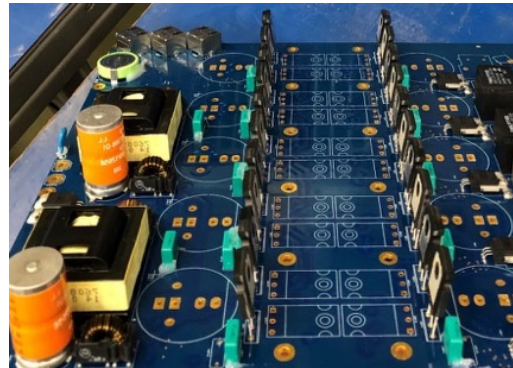
Welded,
hermetically
sealed engine

Proprietary
flexure bearings
= **No rotating
parts, friction,
or lubrication**

Simple design
with only **66
parts**



ELECTRONIC CONTROL



Proprietary firmware and
hardware allow **accurate
engine control** in real time

POWERGEN 5650

No methane slip

Clean -
negligible
CO and NOx

Works with
unrefined
gaseous fuels

Minimal
maintenance
required



Technology Provides Complete Methane Destruction

Two independent third-party evaluations demonstrated that the PowerGen 5650 destroys >99.99% of methane

Technology	Flowrate	Inlet Gas Flow (m ³ /d)	Exhaust Flow (m ³ /d)	Inlet Methane (kg/h)	Outlet Methane (kg/h)	Methane destruction efficiency (%)
PowerGen 5650	Test 1	30.7	43.0	0.817	5.29E-05	99.99
	Test 4	117.2	74.1	3.13	0.000132	100.00
M1.5	Test 1	7.4	6.78	0.194	0.00994	94.86
	Test 3	13.8	9.12	0.366	0.00971	97.30
M5	Test 1	25.1	44.6	0.658	0.0568	91.36
	Test 4	41.4	105.5	1.08	0.131	87.90
6XL	Test 2	65.5	56.3	1.70	0.051	96.95
	Test 5	81.1	53.1	2.02	0.042	97.99
C65	Test 1	223	686.4	5.81	0.00327	99.94
	Test 4	535	1223	14.2	0.000999	99.99
COREMO	Test 4	16.2	18.6	0.421	0.0069	98.37
	Test 4	15.1	22.0	0.394	0.0182	95.34

Source of Table: CanERIC. (2022, October). Scoping Study for a Clean Combustion Technology Showdown. Retrieved from CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT: <http://www.cerinprojects.ca/projects/62b28b967f9ac0318b2c1ae7>

Superior Environmental Performance

Free Piston Stirling is 99% cleaner in air emissions than Internal Combustion Engines

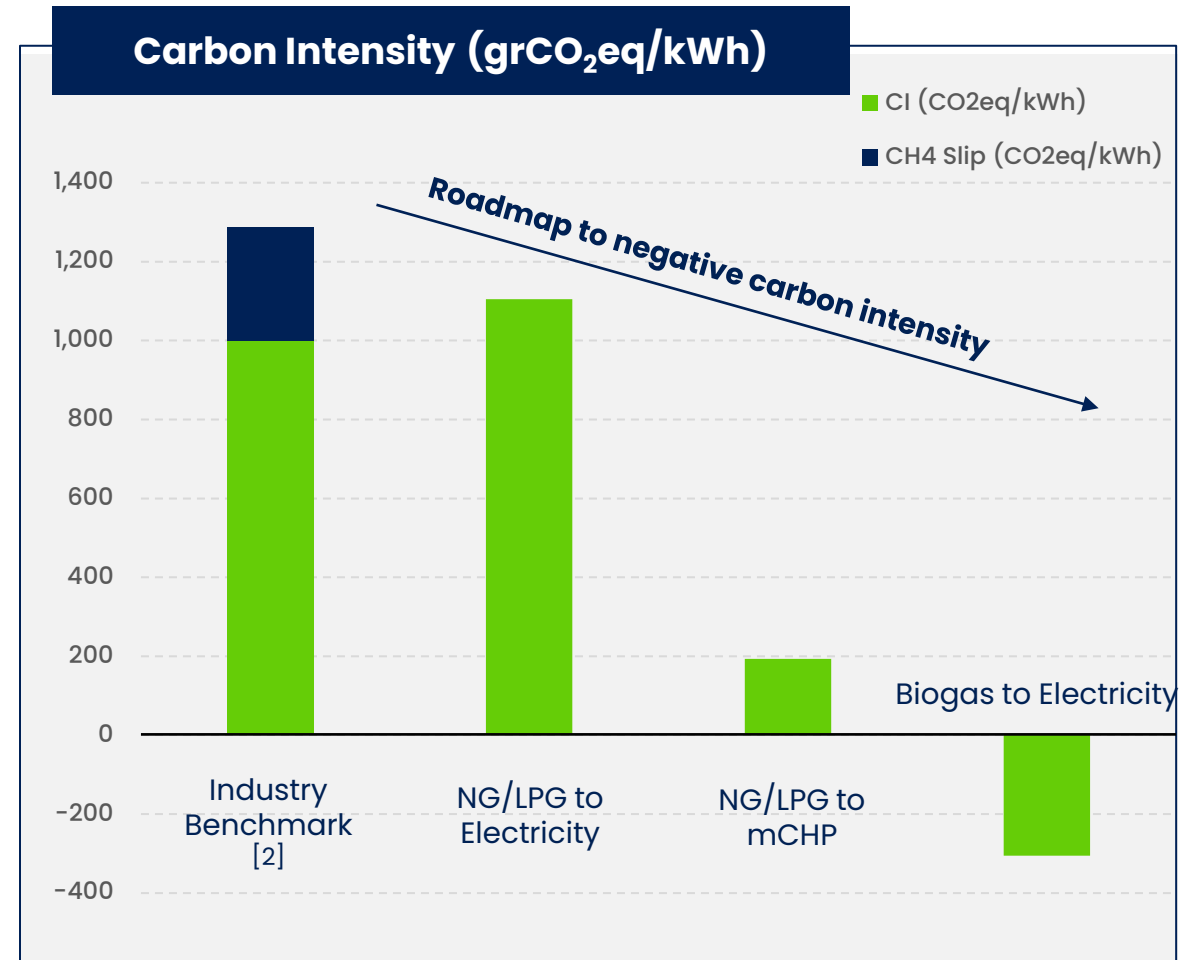


Air Emissions using NG/LPG for electricity

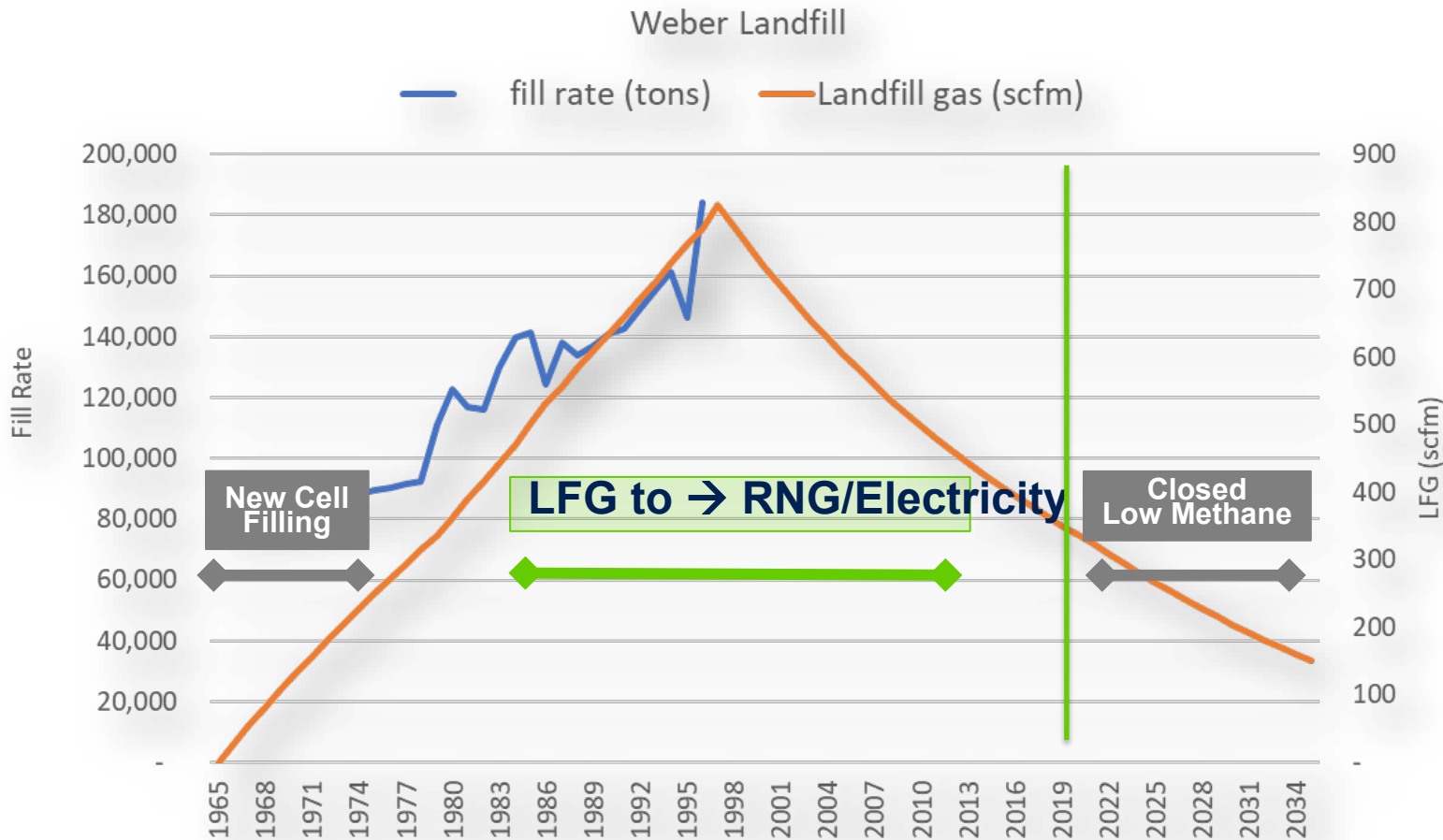
Units: gr/kWh	PowerGen 5650	EPA (1039) [1]	Ratio
NOx	0.066	7.5	99.1%
CO	0.012	8	99.9%
PM	0*	0.4	-

[1] EPA 2014 regulation for non-road compression ignition engines

[2] Spark Ignition Data/Gasoline, natural gas, propane, ethanol etc. data
https://www.epa.gov/sites/default/files/2021-01/small-nonroad-spark-ignition-2011-present.xlsx?VersionId=Q0ZX0ILY_aHsfYcZKphUWBT2hi6rS_0h

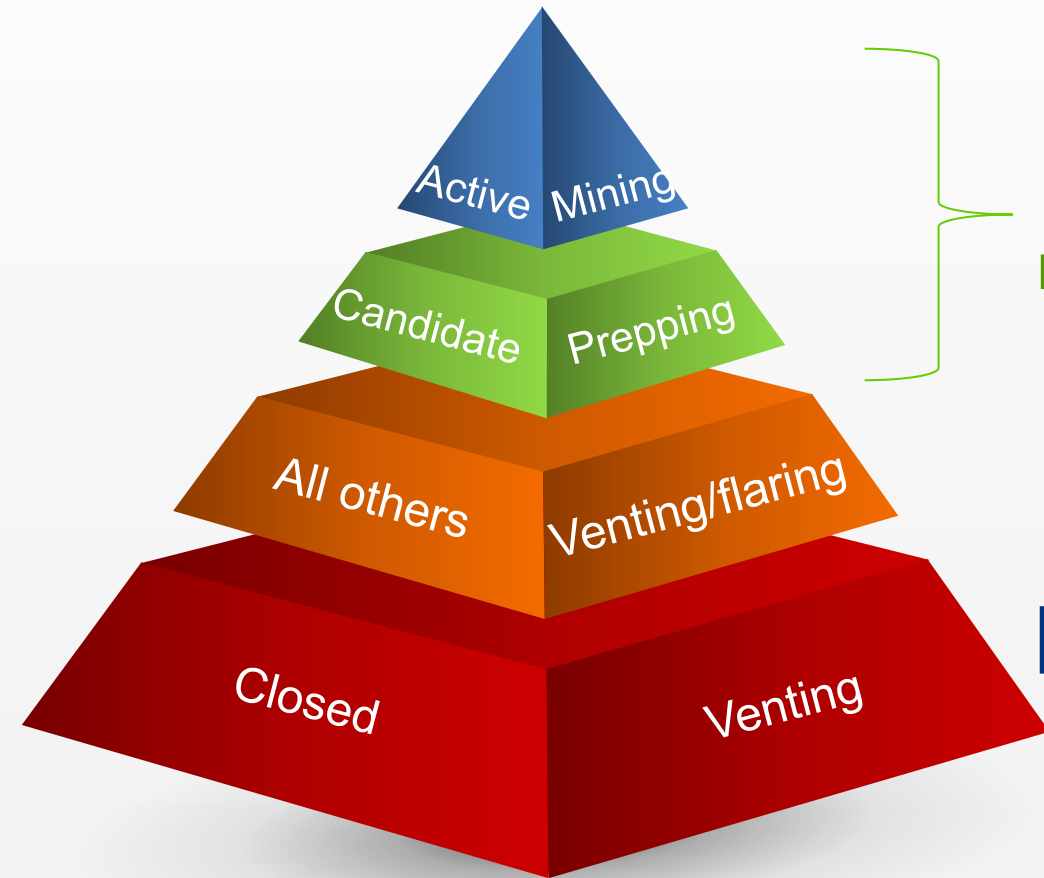


Qnergy Technology Relevance



- Life cycle of a landfill naturally creates two periods of unmitigated methane emission (grey space)
 1. **High levels of Oxygen (O₂)**
 2. **Low levels of Methane (CH₄)**
- These periods represent significant periods of unregulated emissions
- Free Piston Stirling is optimally fit for these two periods

U.S. Landfill Landscape



¹Active ~ 1,300
Closely Monitored
Many have Methane
collection systems

Untapped Resource:

Closed landfills with:

- Low LFG flow (*typically below < 500scfm*)
- Low (%) CH₄ (*typically below < 50%*)

Not realistic candidates for RNG or LFG-to-power.

Represents a **huge source** of Methane emissions that are presently an environmental liability

²Closed > 10,000

State level monitoring
mostly venting/flaring

Source:
1. <https://www.epa.gov/lmop/project-and-landfill-data-state>
2. RMI. *The future of landfills is bright.* Oct 2021

Case Study: Converting Landfill Gas into Electricity

Qnergy makes even closed landfills energy productive



the situation

Maryland Environmental Services (MES) operates a large landfill. The conventional solution is to flare the gas, losing the energy value while methane slippage into the atmosphere still occurs.



the solution

Qnergy installed a PowerGen 5650 onsite to capture and convert the lower-purity methane into useful onsite electricity to power local electrical equipment.



the result

MES offsets grid electricity, acquires backup capabilities for its equipment, and captures voluntary carbon credits.

“

We look forward to seeing replicas of this project on landfills across Maryland.

Dr. Mary Beth Tung, Director of the Maryland Energy Administration



Case Study: Converting Landfill Gas into Electricity

Qnergy uses closed landfill's gas to provide clean power to recreational facility



the situation

A closed Weber County landfill located near a recreational park was still emitting methane into the environment, despite its closure.



the solution

In partnership with Weber County Economic Development, Qnergy installed a PowerGen 5650 to capture and convert landfill gas into useful onsite electricity.



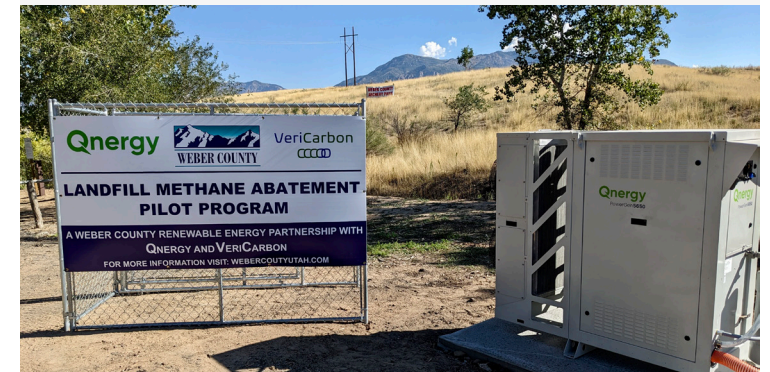
the result

The closed landfill is no longer emitting methane and now produces clean electricity for the park.

“

Our goal is to expand these efforts to the other landfills in the county and throughout the state.

Stephanie Russell, Weber County Economic Development Director

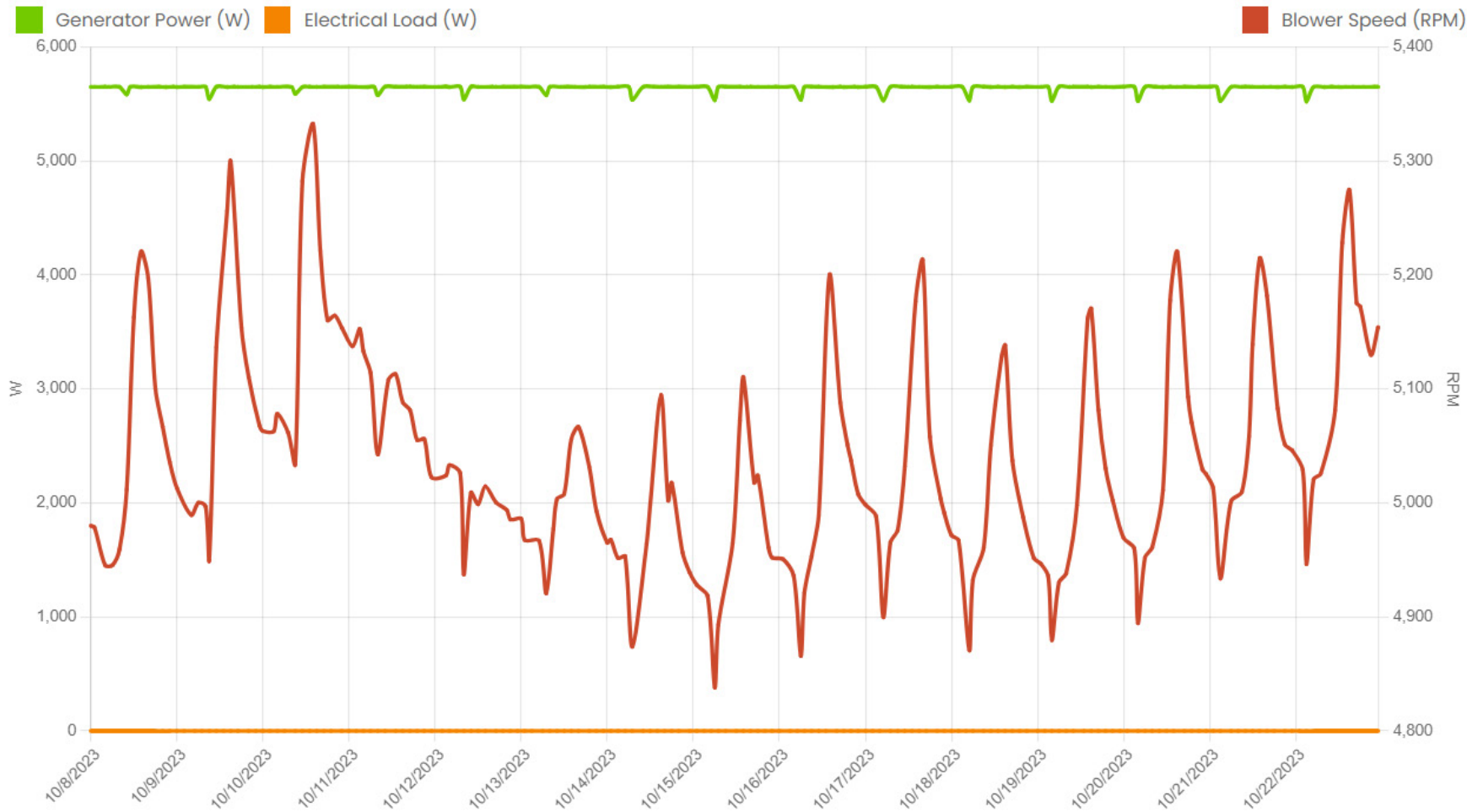


Technology fit

- Free Piston Stirling Engines operate reliably on low grade LFG (> 30% CH₄)
- Integrated internal blower 'pulls' LFG from landfill
- Produces power continuously without any filtration or sweetening of the LFG
- Consumes roughly 6.5 scfm LFG (@ 60% CH₄)



Power Output vs Fuel Energy



→ Power Output

→ Fuel Energy

Significant daily variation (> 10%) in fuel quality does not impact power production rate

Key Advantages

- Stirling technology converts LFG from closed landfills into clean continuous power from an otherwise unusable resource
- Allows landfill owners to realize financial gain from what would otherwise be an environmental liability
- Provides electricity for additional site enhancements in areas that generally do not have access to the local utility grid
- Technology is certified, quiet and proven reliable



Sustainable power



Long operating life



Multiple fuel sources

Thank you

info@qnergy.com | qnergy.com

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Questions

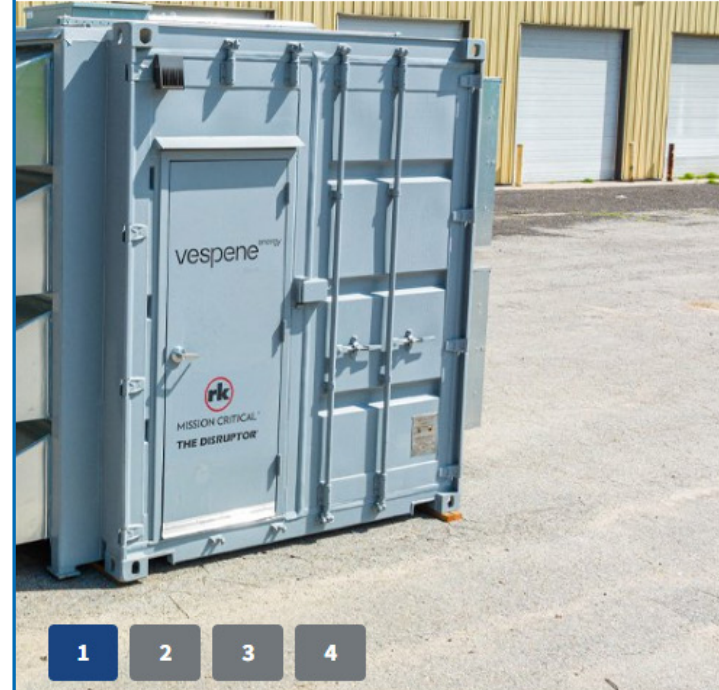
Q&A

Wrap Up

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

Landfill Methane Outreach Program (LMOP)



1 2 3 4

Upcoming LMOP Webinar

December 6, 2023 – Join us as speakers discuss [landfill gas electricity end use options](#) for remote or low-flow landfills. Free to attend but [online registration](#)  is required.

LMOP is a voluntary program that works cooperatively with industry stakeholders and waste officials to reduce or avoid methane emissions from landfills. LMOP encourages the recovery and beneficial use of biogas generated from organic municipal solid waste. [Learn more about LMOP](#) or [join the LMOP listserv](#).

Key Information



Data and Partners



Tools & Resources

