Cogen without Gas Scrubbing(?)

A Stirling Engine Designed for the 21st Century

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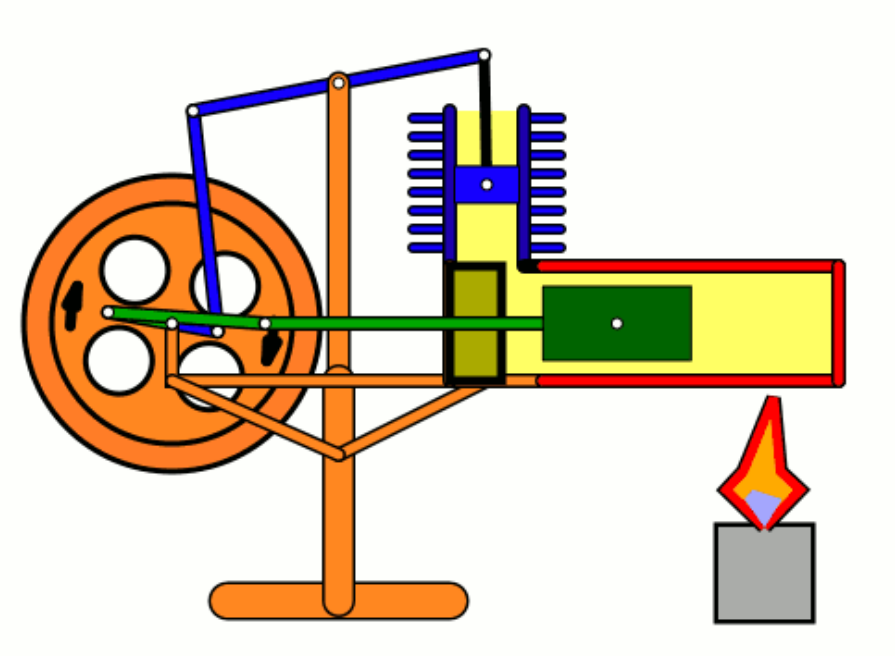
The Challenge

Can modern Stirling Engines make cogeneration viable at smaller Water Resource Recovery Facilities (WRRFs) by reducing maintenance demands and gas scrubbing requirements?

What is a Stirling Engine and Why Use One?

The Stirling engine is an external combustion heat engine that operates from cyclic redistribution of a working gas between heated and cooled portions of a mechanical engine.



"In theory, the Stirling cycle engine can be the most efficient device for converting heat into mechanical work... In fact, with regeneration, the efficiency of the Stirling cycle equals that of the Carnot cycle, the most of efficient of all ideal thermodynamic cycles."

– CRC Handbook of Mechanical Engineering

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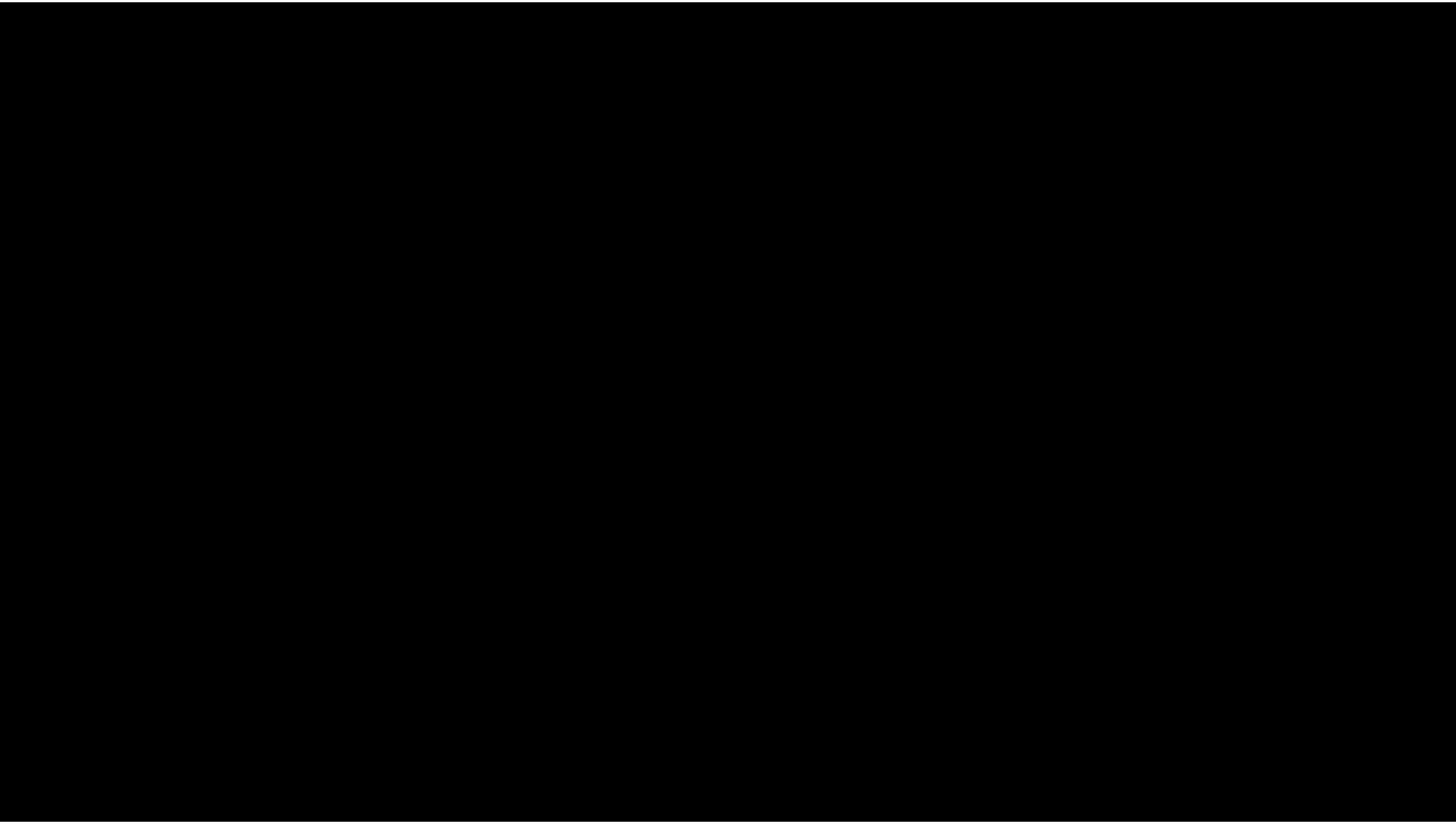
How a Sterling Engine Works



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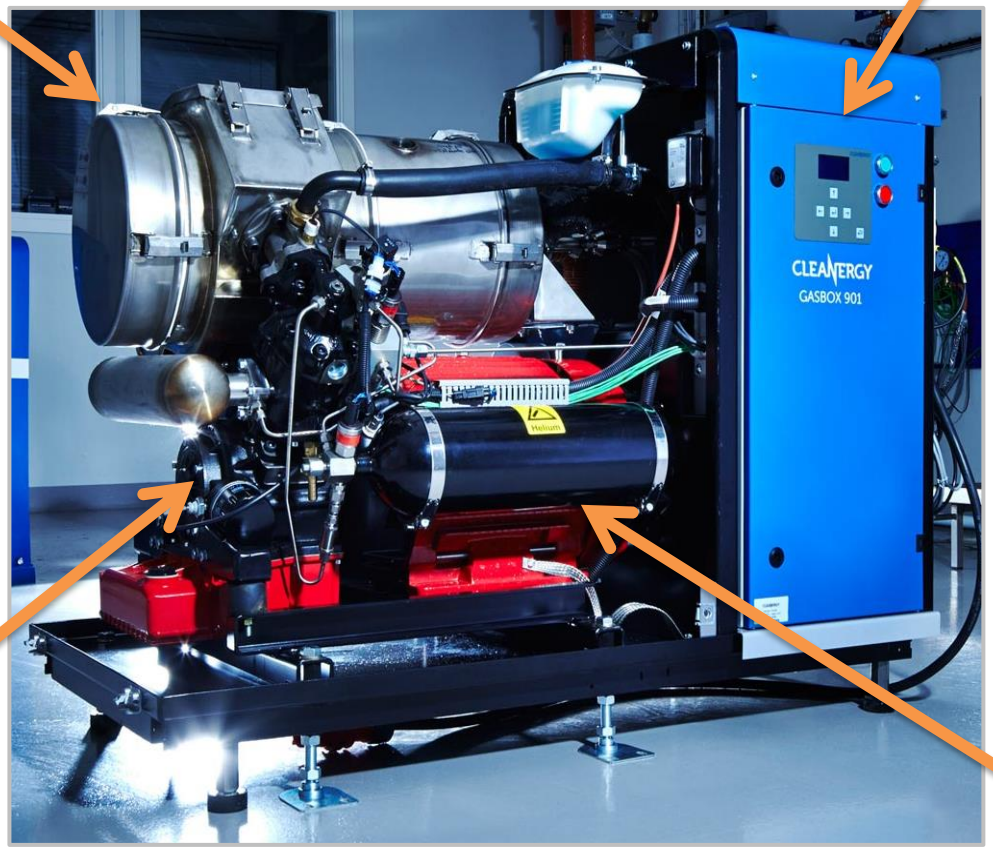
Cleanergy GasBox

Combustion Chamber

Control Panel



Cylinders & Pistons

Working Gas (Helium)

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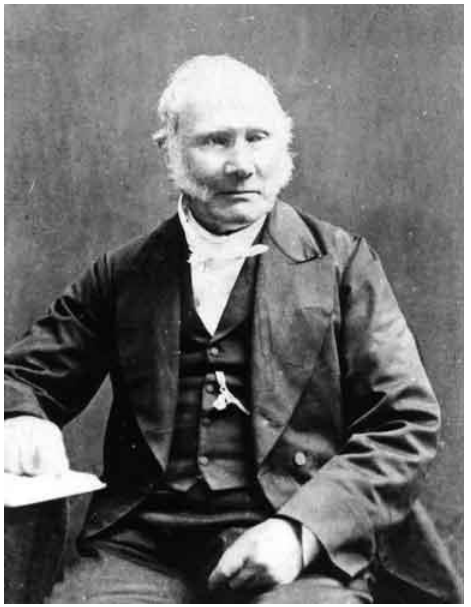
Stirling Engines (a partial history)

- 1816 – “Hot Air” Engine Developed by Robert Stirling
- 2005-2007 - Several Stirling Engine Projects developed at Wastewater Plants including Owl’s Head NY.
- 2007- Stirling engine supplier goes out of business.
- 2008- Cleanergy company founded in Sweden, engines developed and installed in Europe.
- 2015- Cleanergy Stirling Engine installed at a Landfill in Louisiana.
- 2016- Cleanergy Stirling engine installed at Helena, MT WWTP.



Robert Stirling
(Source: Wikipedia)

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Technical Specifications

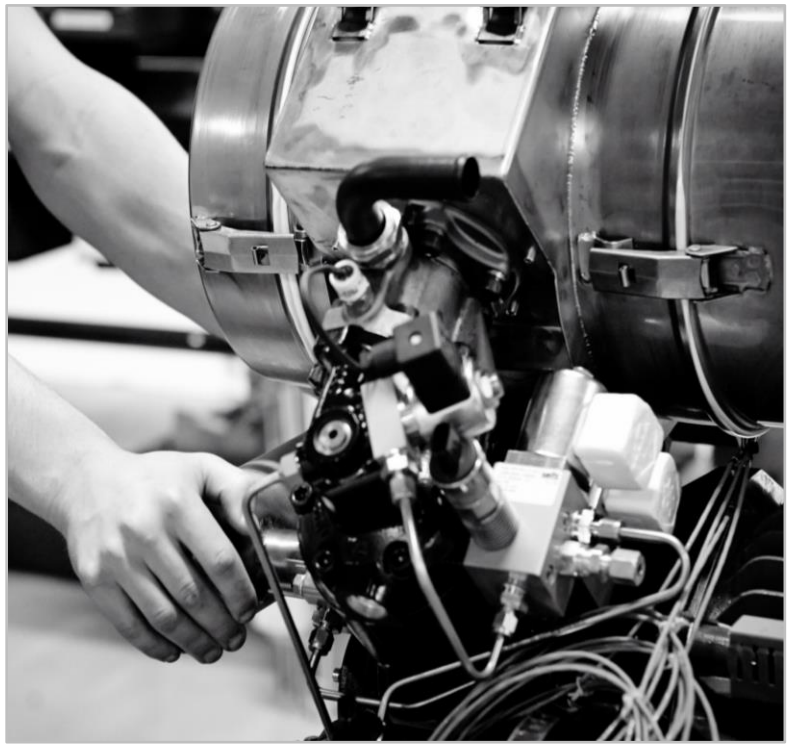
Stirling Engine Type	Alfa
Working gas	Helium
Electrical power	2-9 kW
Thermal power	8-26 kW
Electrical efficiency	25%
Total efficiency	95%
Life expectancy	25 years
% Methane	18-100%
Combustion system	Mild combustion
Combustion control	Lambda
Fuel pressure	4 psi

CHP that is in the reach of small plants

Gas scrubbing cost prohibitive for small plants.

25 year life and 1 year maintenance schedule compared to short life and high O&M.

- Stirling Engines are less sensitive to H_2S and siloxanes.
- Can process biogas with methane content as low as 18%.
- Produces electricity and hot water.



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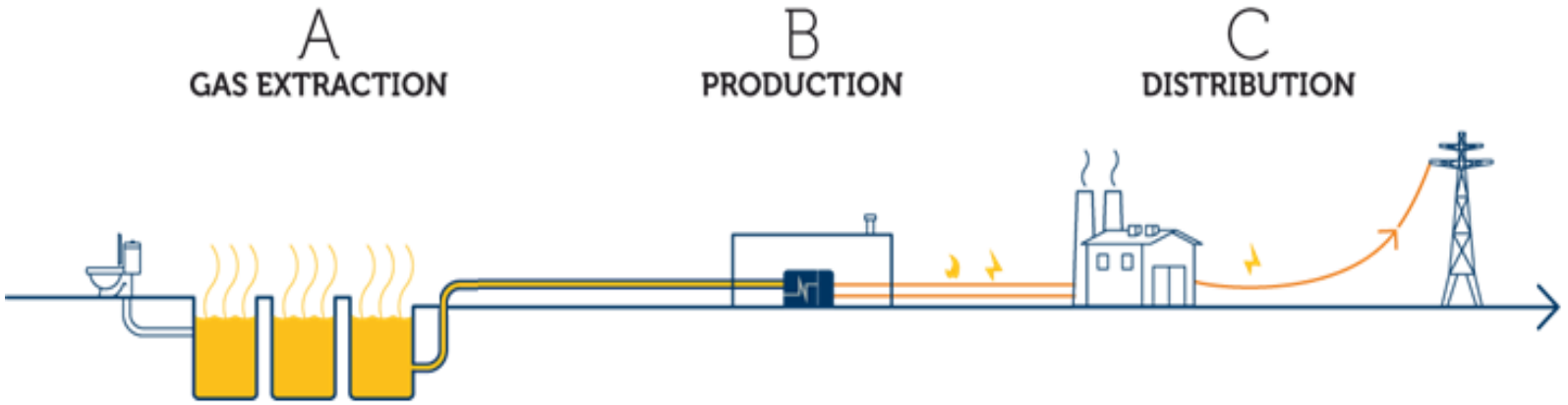
Difficult Gases, Very Low Maintenance



Biogas generated at waste water treatment facilities has a lot of contamination (e.g. siloxanes), which wreak havoc on gas engines.

The GasBox converts the difficult biogas into both electricity and heat.

25 year lifespan of Cleanergy's CHP Stirling solution with close to zero emissions. The heat can be used to heat dry sludge or pre-heat water for a boiler.

State-of-the-art technology for treatment plants with difficult gases

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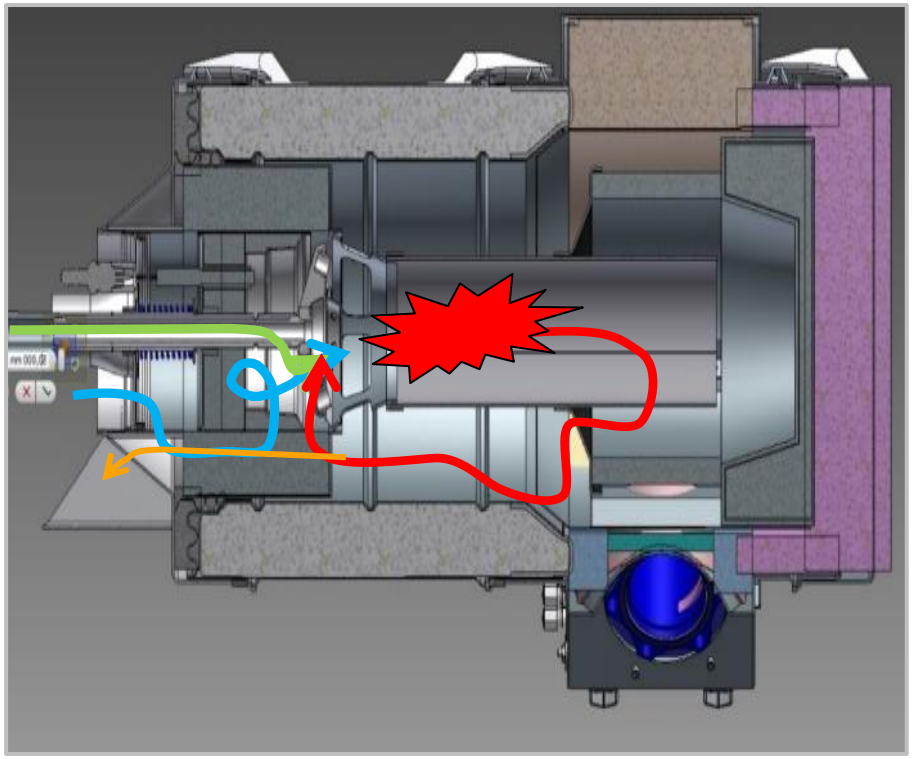
MILD Combustion Burner

- The Burner is optimized for combustion of different gaseous fuels with low energy content
- Basic principle is **MILD** combustion (**M**oderate or **I**ntense **L**ow oxygen **D**ilution)



Gas flows:

Fuel Gas

Incoming Air (pre heated)

Combustion gases (CGR / EGR)

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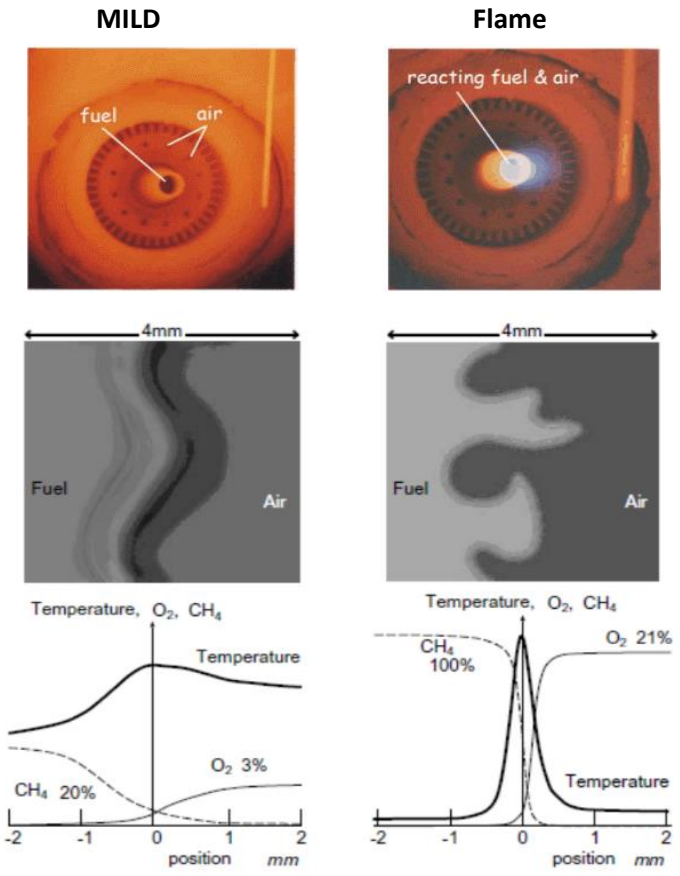
MILD Combustion Burner



Source: Noor et al. International Journal of Automotive and Mechanical Engineering 6(2012) 730-754

Main principles:

- High degree of air preheat 1200 – 1700 F
- High degree of **C**ombustion **G**as/heat **R**ecirculation (CGR) 1500-2000 F

Main benefits:

- Highly energy efficient – typically 70% compared to 35-40% for conventional combustion
- Low NOx & CO emissions
- Low noise levels – 67dBA

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Unit Performance

Input:

- 2.6 SCFM Biogas
- Helium (working gas, small amounts)

Output:

- 7.2 kW electrical
- 58,000 BTU/hr heat output
- 1:2 power to heat ratio

Multiple Units in a Container (up to 7)

An integrated turnkey solution, modular in size and with all auxiliary equipment

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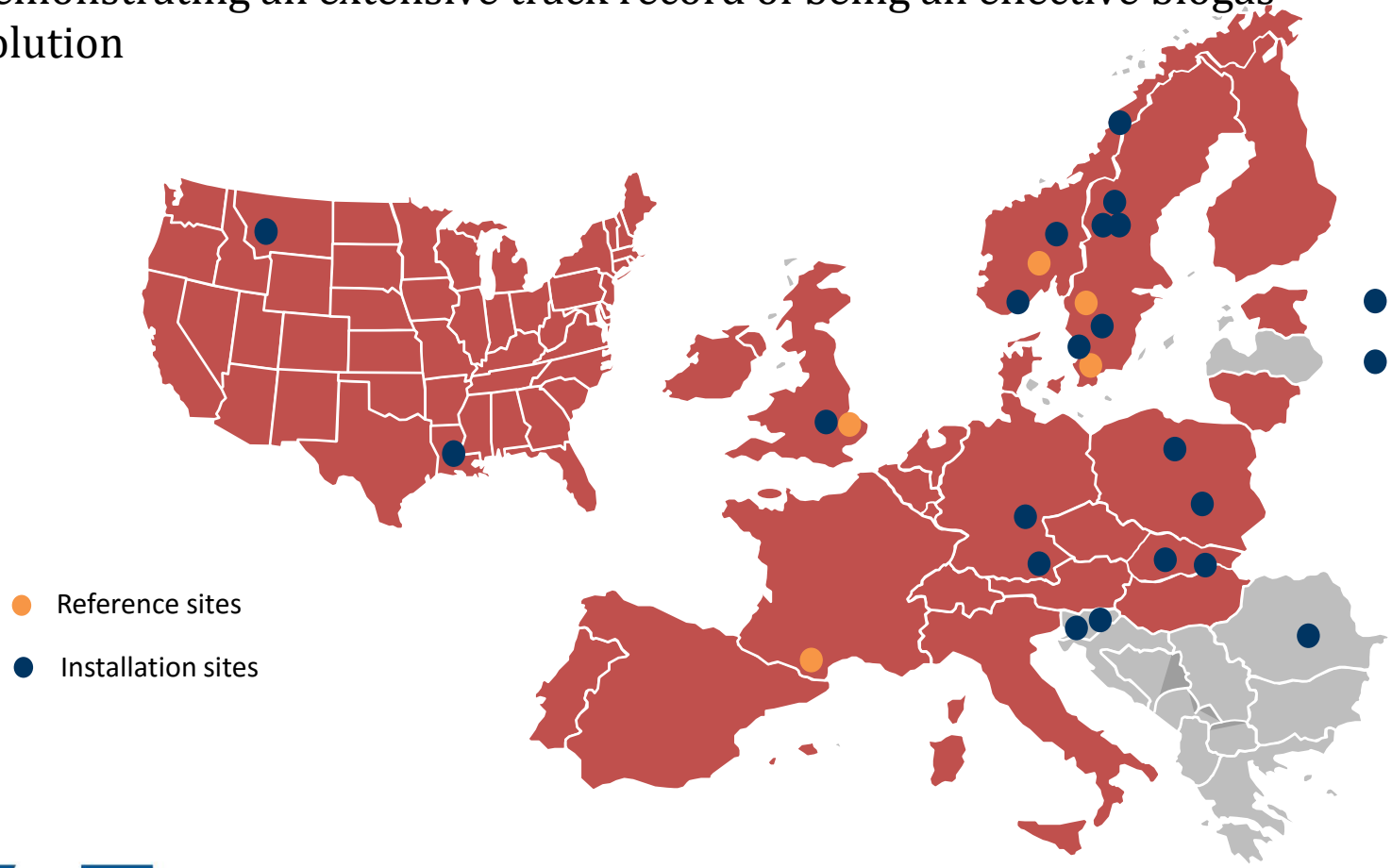
Reference Sites

This technology has been installed at a number of locations, demonstrating an extensive track record of being an effective biogas solution



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Reference Sites

Operation of reference sites	
Generated Power	1,750,000 kWh
Generated Heat	3,500,000 kWh
Methane Utilized (from Biogas/Landfill gas)	24,720,000 ft^3 (500 tons)
Running hours	250,000 h

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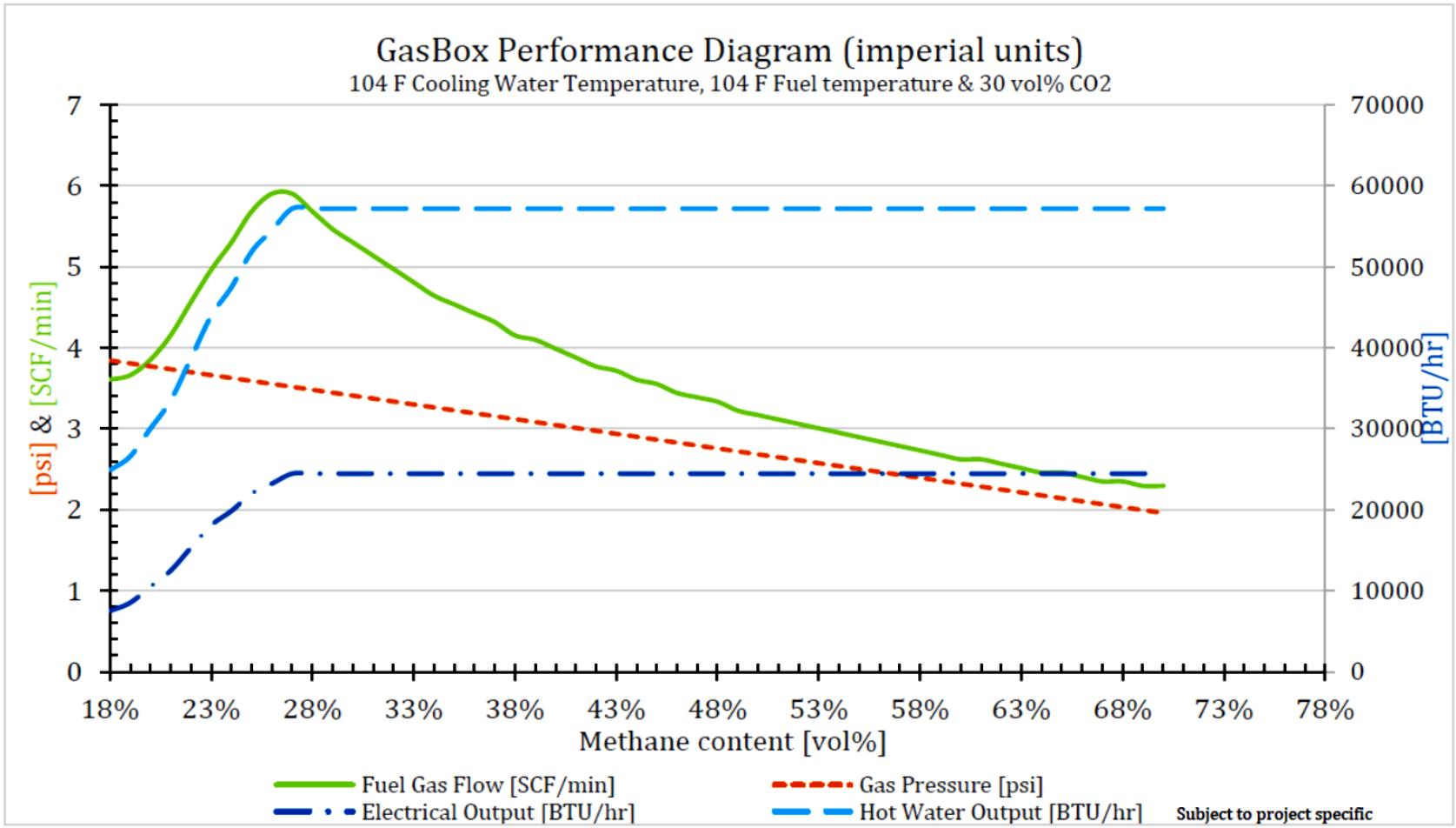
GasBox Performance at Varying Methane %



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Reference Cases: Wastewater Treatment Plants in Europe

GasBox for Wastewater Treatment Plants

More than 100 hundred installed GasBox on the market in Sweden, Norway, UK, Russia, Poland, Germany, Slovenia etc.

Examples:

Wastewater treatment plant in Jecenice, Slovenia

Working hours	*4719h*
Prod. Power	*27,023kW*
Produced Heat	*81,069 kW*
Availability	*>80%*

Wastewater treatment plant in Åmål, Sweden

Working hours	*20,033h*
Prod. Power	*144,230 kW*
Produced Heat	*2,884,600 kW*
Availability	*>80%*

Wastewater treatment plant in Niederfrohna, Germany

Working hours	*300h*
Prod. Power	*2,000 kW*
Produced Heat	*~6,000 kW*
Availability	*>90%*

GasBox installation in Jecenice, Slovenia

GasBox installation in Åmål, Sweden

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Key features of the Cleanergy GasBox

- Service interval from 6,000 - 8,000 hours
- Low emissions
- Lifetime of 25 years
- Able to process low methane content biogas
- Handles contaminated gas through external combustion

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Helena, Montana Installation

- Slated for Sterling Installation 10 Years Ago (supplier went out of business).
- High Siloxane: 15,205 ppbv (Typical is 5,000 ppbv)
- Testing one engine, looking to install 7.
- Small gas booster blower installed (4 psi pressure)
- Siloxane accumulation requires periodic cleaning of burner.
- Some scrubbing may be added to increase runtimes to have cleaning coincide with engine rebuild (~9 months).

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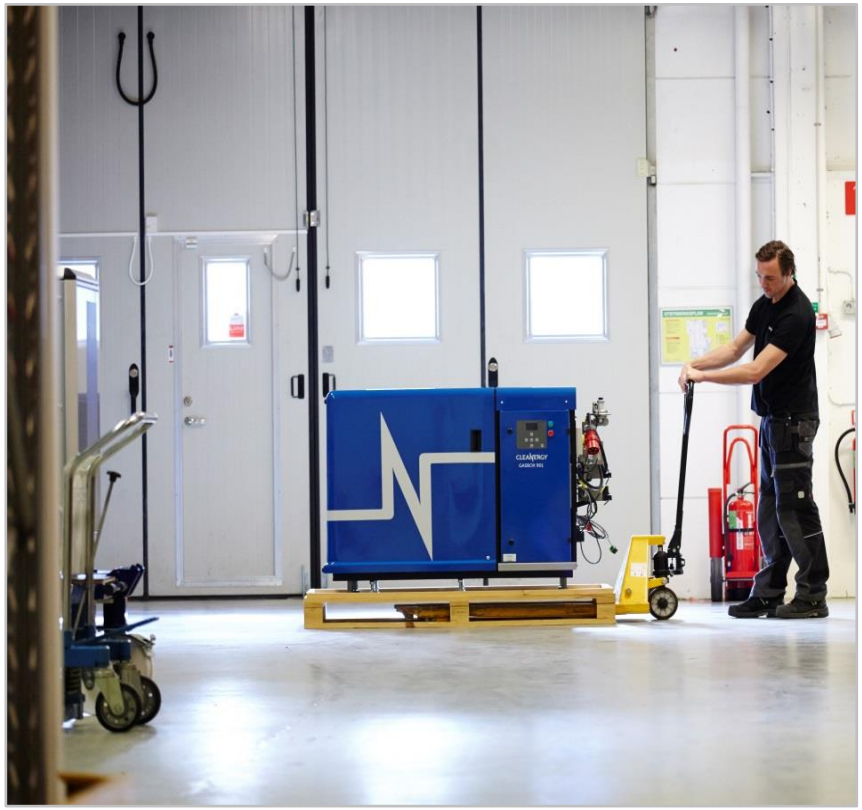
Ideal Candidate Facilities

Small WRRFs

- High energy costs
- Renewable energy grants
- Desire for sustainability
- Reduce Flaring
- Emissions Restrictions
- Reduced Maintenance
- Other special conditions

Landfills

- Able to process biogas with methane content as low as 18%...long after other engines can’t burn it.



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Acknowledgements

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Questions?