



RotaPower LLC

Unleashing Power In Every Rotation

The Methane Problem!

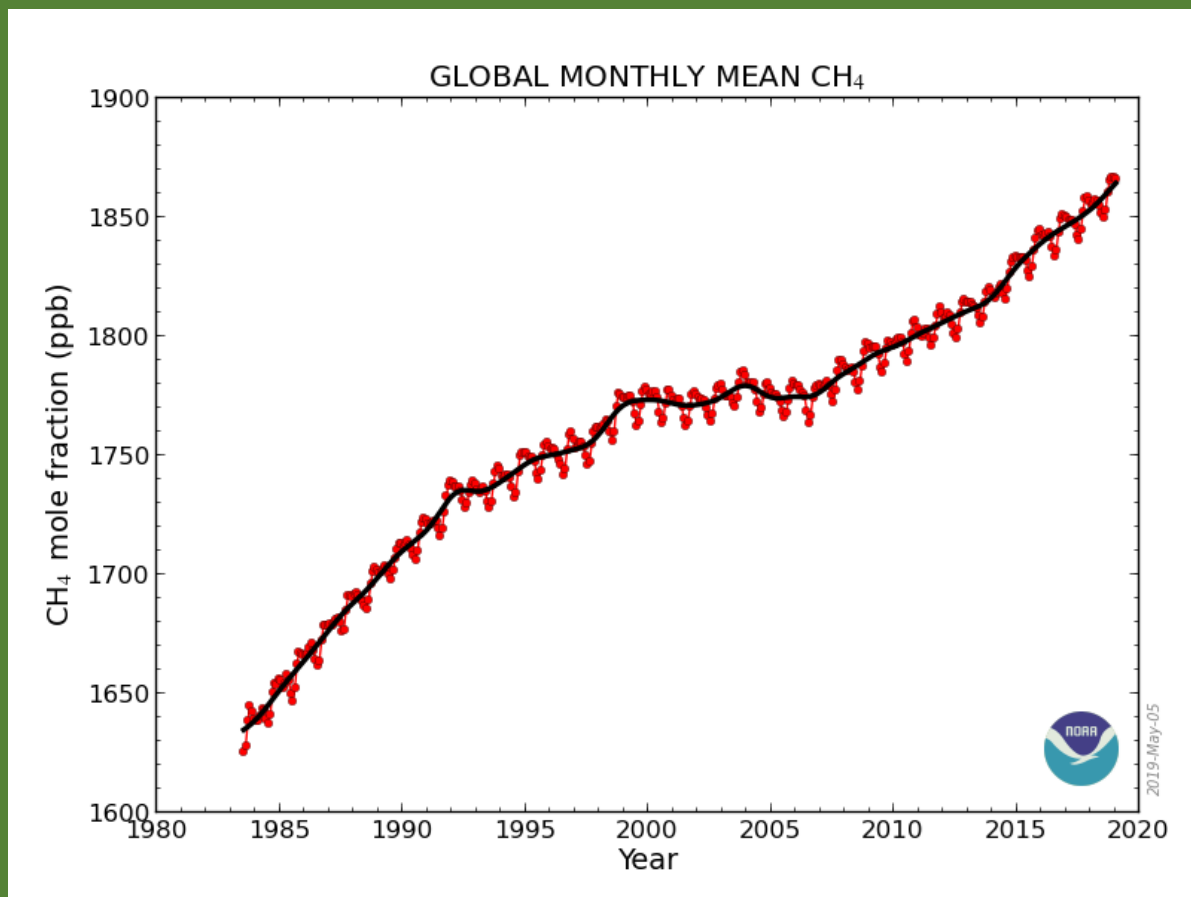


- Methane in biogas may be more important than carbon dioxide as a source of global warming: one molecule of methane retains 86 times more heat than a molecule of carbon dioxide
- Atmospheric methane's rate of growth has recently increased by 20 times while carbon dioxide production has leveled off
- Methane production has a positive feedback loop, which means that its production can increase exponentially, leading to greenhouse runaway, which could end life as we know it
- Over the last one hundred years carbon dioxide has increased by 30% while methane has increased 400%
- Many countries who signed the 2015 Paris Agreement have a daunting task to meet the methane reduction goal

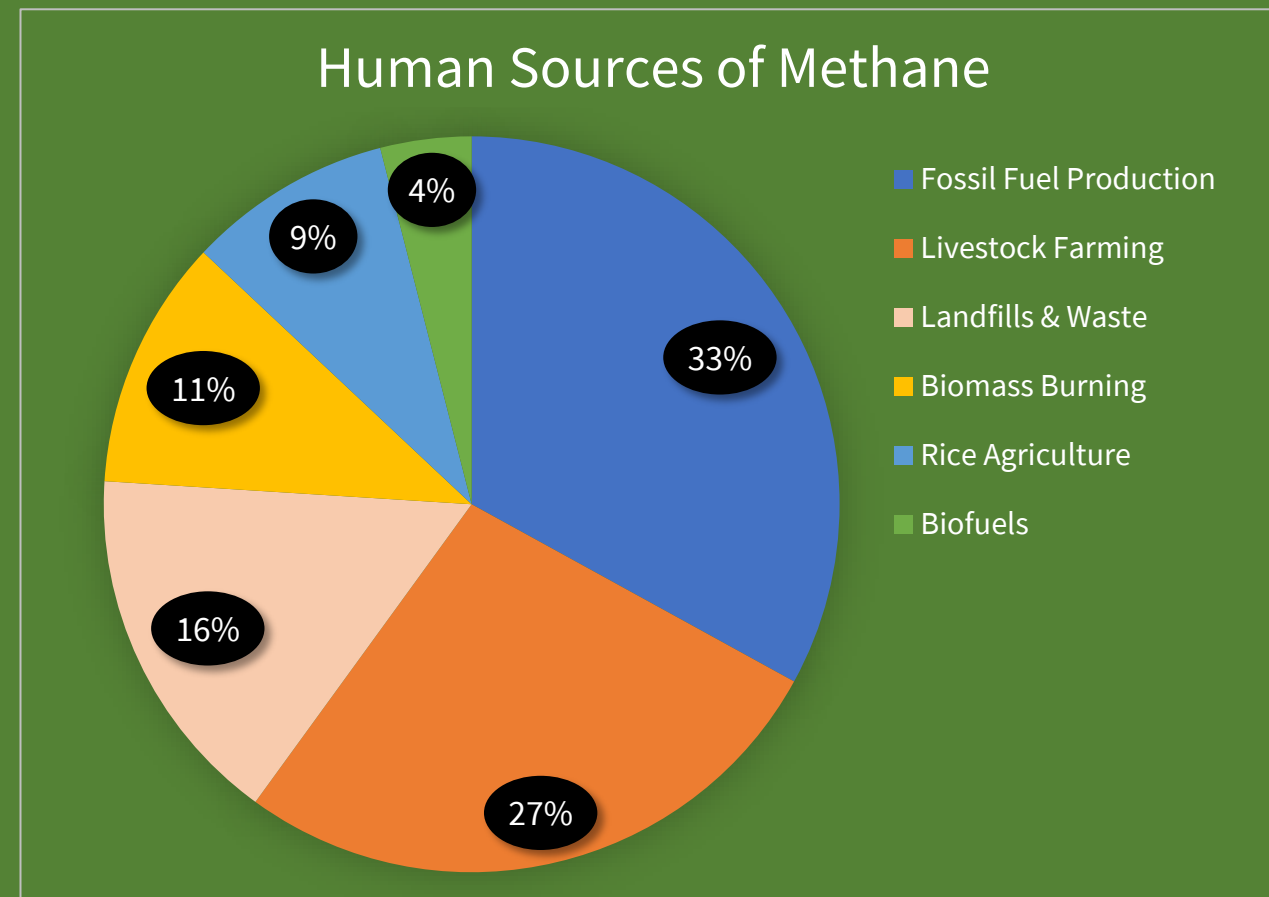


Global Methane Increase & Sources

The largest human source is from the production, distribution and combustion of fossil fuels. This creates 33% of human methane emissions, whereas, livestock farming, landfills & waste contribute 43%



Source: Full record global methane. The recent global monthly mean plot showing the full NOAA time-series starting in 1983



Source: Bousquet, P. et al. (2006). Contribution of anthropogenic and natural sources to atmospheric methane variability



Earth Scientists are Concerned!

- “We could hit a tipping point where it’s a runaway warming effect”. Dr. Paul Palmer, Earth Scientist University of Edinburgh. (See: "Methane causes vicious cycle in global warming" NPR 2010-01)
- “Looking at the scenario for future emissions, methane is starting to approach the most greenhouse gas-intensive scenario.”... “That’s bad news. We are going in the wrong direction.”, Dr. Robert Jackson, Earth Scientist of Stanford University, part of the renowned Global Carbon Project. (See: “Surge in methane emissions threatens efforts to slow climate change”; phys.org, 12 Dec 2016)
- “The growth of atmospheric methane is accelerating”. It clearly seems as if the warming is feeding the warming. It’s almost as if the planet changed gears”. Dr. Euan Nisbet, Earth Scientist at Royal Holloway, University of London. (See: “Methane in the atmosphere is surging, and that’s got scientists worried” phys.org/news/2019-03)

Current Technology Limitations



- Biogas is often contaminated by hydrogen sulfide and silica. Only very large biogas operations can economically remove these contaminants
- Powerplants like microturbines and piston engines are destroyed by these contaminants
- What is needed is a powerplant that can tolerate these contaminants while driving a generator to create electricity

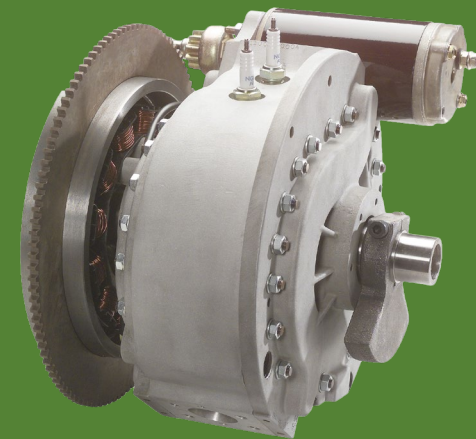
What do we need to solve this problem?

The Solution!



Our Rotapower® Engine Technology.....

- Tolerates both hydrogen sulfide and silica
- Can operate on biogas with low methane content
- Achieves high thermal efficiency
- Creates ultra low emissions
- Is very competitively priced
- Low maintenance due to only two moving parts
- Seal life demonstrated at over 20,000 hours

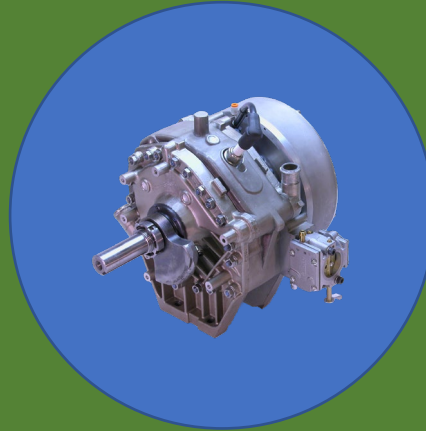


Experience the power of freedom

Rotapower® Features



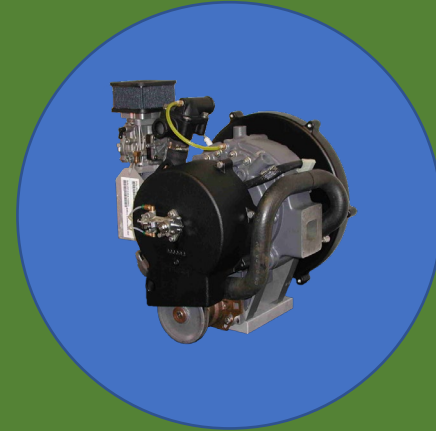
27cc



150cc



530cc



650cc

- Super Lightweight
- Fuel Independent
- High Fuel Efficiency
- Ultra Low Emissions
- Patented plasma coating to tolerate heat and fuel contaminants
- Patented parallel cooling for rotor
- Patented oil injection lubrication system
- Patented cooling towers
- 20,000+ Hours Life

Rotapower® Engine Performance



Rotapower® Combustion of Landfill Gas (LFG) (Without Pilot/Coolant Fuel)

Assumptions: Single Rotor Displacement (cc): 530, Est. Thermal Efficiency: 27%, Est. Volumetric Efficiency (Naturally Aspirated): 70%, % Methane in LFG: 60%, Generator Efficiency: 90%
Biogas Density (25°C, 1 atm): 1.15 kg/m³


Rotors	Disp (cc)	RPM	Engine (cfm)	Methane [CH ₄] (cc)	Landfill Gas [LFG] (cfm)	Landfill Gas [LFG] (cmd)	Landfill Gas [LFG] (kgd)	Air Used (cfm)	Energy from CH ₄ (BTU/hr)	Mechanical Power (BHP)	Electrical Power (kW)
1	530	3600	47.2	4.2	7.0	287.0	330.1	40.1	244,280	26	17
		4400	57.6	5.2	8.6	350.8	403.4	49.0	298,564	32	21
		5200	68.1	6.1	10.2	414.6	476.8	58.0	352,849	37	25
		6000	78.6	7.0	11.7	478.4	550.1	66.9	407,133	43	29
2	1060	3600	94.3	8.4	14.1	574.0	660.2	80.2	488,560	52	35
		4400	115.3	10.3	17.2	701.6	806.9	98.1	597,129	63	43
		5200	136.2	12.2	20.3	829.2	953.6	115.9	705,698	75	50
		6000	157.2	14.1	23.5	956.7	1100.3	133.7	814,267	86	58
3	1590	3600	141.5	12.7	21.1	861.1	990.2	120.4	732,840	78	52
		4400	172.9	15.5	25.8	1052.4	1210.3	147.1	895,693	95	64
		5200	204.4	18.3	30.5	1243.8	1430.3	173.9	1,058,547	112	75
		6000	235.8	21.1	35.2	1435.1	1650.4	200.6	1,221,400	130	87
4	2120	3600	188.6	16.9	28.2	1148.1	1320.3	160.5	977,120	104	70
		4400	230.6	20.6	34.4	1403.2	1613.7	196.2	1,194,258	127	85
		5200	272.5	24.4	40.7	1658.4	1907.1	231.8	1,411,395	150	101
		6000	314.4	28.2	46.9	1913.5	2200.5	267.6	1,628,533	173	116
5	2650	3600	235.8	21.1	35.2	1435.1	1650.4	200.6	977,120	104	70
		4400	230.6	25.8	43.0	1754.0	2017.1	245.2	1,492,822	158	106
		5200	340.6	30.5	50.8	2072.9	2383.9	289.8	1,764,244	187	126
		6000	393.0	35.2	58.7	2391.9	2750.6	334.4	2,035,667	216	145
6	3180	3600	283.0	25.3	42.2	1722.1	1980.5	240.7	1,465,680	156	104
		4400	345.8	31.0	51.6	2104.8	2420.6	294.2	1,791,387	190	128
		5200	408.7	36.6	61.0	2487.5	2860.7	347.7	2,117,093	225	151
		6000	471.6	42.2	70.4	2870.2	3300.8	401.2	2,442,800	259	174
7	3710	3600	330.1	29.6	49.3	2009.2	2310.5	280.9	1,709,960	181	122
		4400	403.5	36.1	60.2	2455.6	2824.0	343.3	2,089,951	222	149
		5200	476.9	42.7	71.2	2902.1	3337.4	405.7	2,469,942	262	176
		6000	550.2	49.3	82.1	3348.6	3850.9	468.1	2,849,933	302	203
8	4240	3600	377.3	33.8	56.3	2296.2	2640.6	321.0	1,954,240	207	139
		4400	461.1	41.3	68.8	2806.4	3227.4	392.3	2,388,515	253	170
		5200	545.0	48.8	81.3	3316.7	3814.2	463.6	2,822,791	300	201
		6000	628.8	56.3	93.9	3827.0	4401.0	535.0	3,257,067	346	232
9	4770	3600	424.4	38.0	63.4	2583.2	2970.7	361.1	2,198,520	233	157
		4400	518.8	46.5	77.4	3157.2	3630.8	441.3	2,687,080	285	191
		5200	613.1	54.9	91.5	3731.3	4291.0	521.6	3,175,640	337	226
		6000	707.4	63.4	105.6	4305.3	4951.1	601.8	3,664,200	389	261

Biogas Industry Growth Projection

Research Findings

- Volatile Energy Prices
- Legislation of Stringent Emission Regulations
- Rising Costs of Conventional Power Generation
- Need to Reduce Dependence on Fossil Fuels
- Focus on Renewable Energy amid Environmental Concerns
- Applications in Transportation & Power Generation Sectors

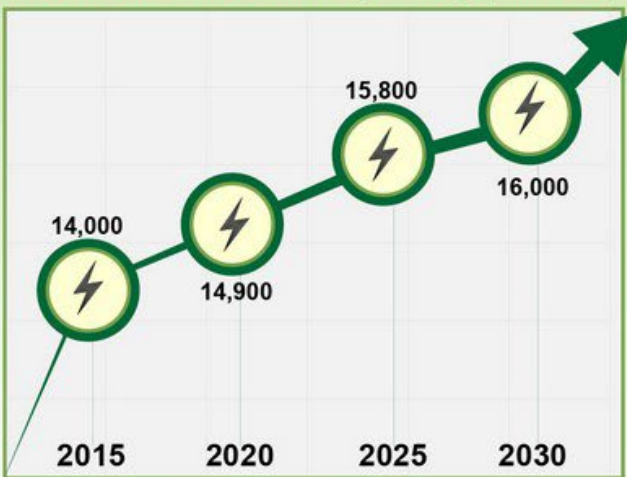
Key Players



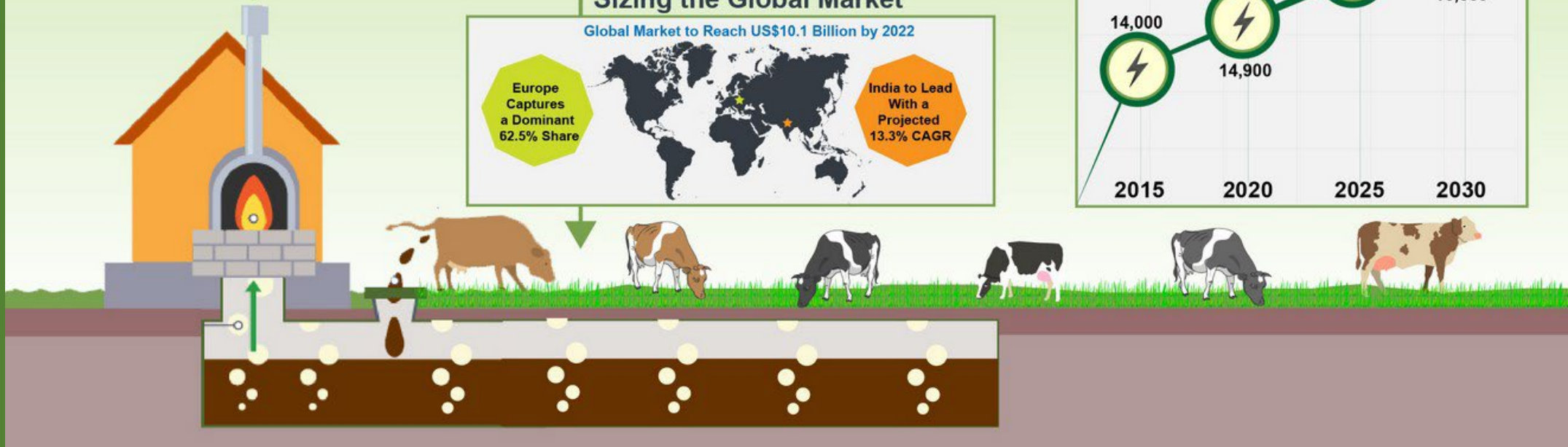
Schmack Biogas GmbH Guild Associates, Inc.
 UTS Biogastechnik GmbH Greenlane Biogas
 Air Liquide DMT Environmental Technology BV

Growing Energy Consumption & Focus on Sustainable Energy for All Drives Interest in Biogas Plants

Global Demand for Primary Energy (In Mtoe)



Sizing the Global Market



Source: Global Industry Analysts, Inc. "Focus on alternative energy to reduce GHG emissions drives the global market for biogas plants. *Published: May 2019*"

RotaPower LLC Competitive Advantage



The following features allow the Rotapower[®] rotary engine to efficiently utilize biogas to create energy:

- Uses a lubrication system where very small quantities of oil are metered to the roller bearings and seals. Any remaining oil then exits the engine before becoming acidic due to hydrogen sulfide
- Can tolerate silica by using chrome carbide wear surfaces and silicon nitride seals (9 Mohs versus 6-7 Mohs for silica). The rotary engine does not need or use valves
- Uses a stainless-steel rotor with a low thermal conductivity as opposed to aluminum used in piston engines. This results in a rotor surface temperature of up to 900°F versus a piston at 400°F. This contributes to combustion of biogas with lower methane content
- The rotary engine, as distinct from a piston engine, has an intake chamber that is separate from the expansion chamber. This prevents the expansion chamber surfaces from being pre-cooled by the intake charge, which further aids in combustion
- A two-rotor rotary engine has only three moving parts. By comparison, a two cylinder piston engine can have over fifteen moving parts with each subject to the corrosive effects of hydrogen sulfide
- The estimated capital cost for gensets powered by Rotapower[®] engines is substantially less than for those powered by either piston or microturbine engines