



# **Freedom Motors**

**Experience the power of freedom!**



# Executive Summary

- ❑ A disruptive Rotapower® engine technology with numerous applications.
  - ❑ Energy production with – Biogas, Ethanol, Methanol, Hydrogen, Natural Gas, Cooking gas and many other fuels.
  - ❑ Transportation – Manned and Unmanned Aerial Vehicles, Auto, 2 Wheelers, EV Range Extenders.
- ❑ Generated working prototypes under both commercial and US government contracts.
- ❑ Key Differentiators:
  - ❑ World leading Power-To-Weight ratio of 3:1
  - ❑ Ultra-compact & Lightweight.
  - ❑ Multi fuel capable including renewable and green fuels including hydrogen.
  - ❑ Very low toxic emissions and low fuel consumption .
- ❑ Headquarters in Dixon, CA, USA.
- ❑ Became an independent C corporation in 2001 to further develop core technology that is now ready for commercialization.
  - ❑ Over \$65 Million spent in R&D.
- ❑ Numerous International and US patents. Several more patents pending.



# Mission and Core Values

**To produce engines so powerful, compact, and emission free that they become the preeminent choice for ground, sea, and air applications**

- ❑ IMPACT: Advancing human progress while preserving natural resources and protecting the environment**
- ❑ INNOVATION: A talent pool of employees**
- ❑ EMBRACE THE FUTURE: Shaping it; not fearing it**
- ❑ QUALITY: Striving for excellence in everything we do**
- ❑ CONTINUOUS IMPROVEMENT: Never being satisfied; challenging everything**

# The Methane Problem!

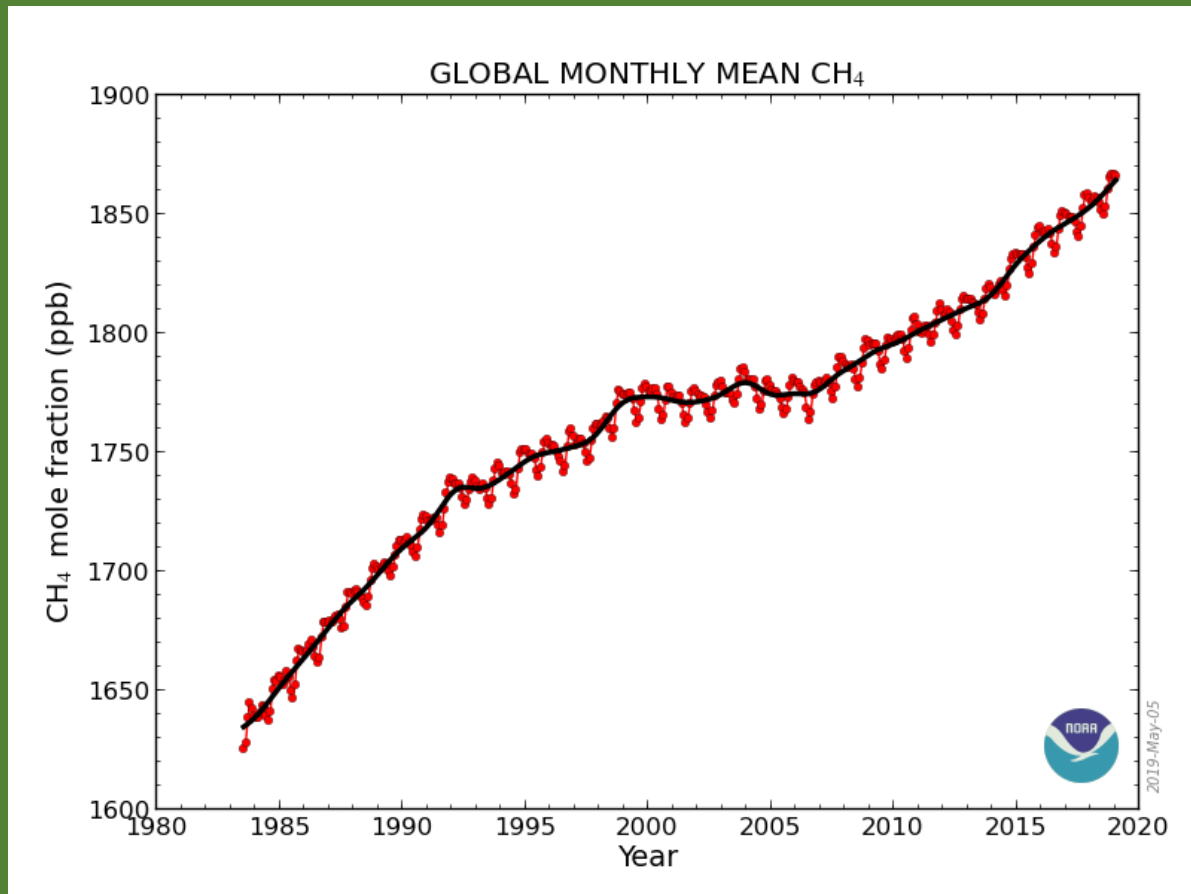


- Methane in biogas may be more important than carbon dioxide as a source of global warming: one molecule of methane retains 86 times more heat than a molecule of carbon dioxide
- Atmospheric methane's rate of growth has recently increased by 20 times while carbon dioxide production has leveled off
- 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

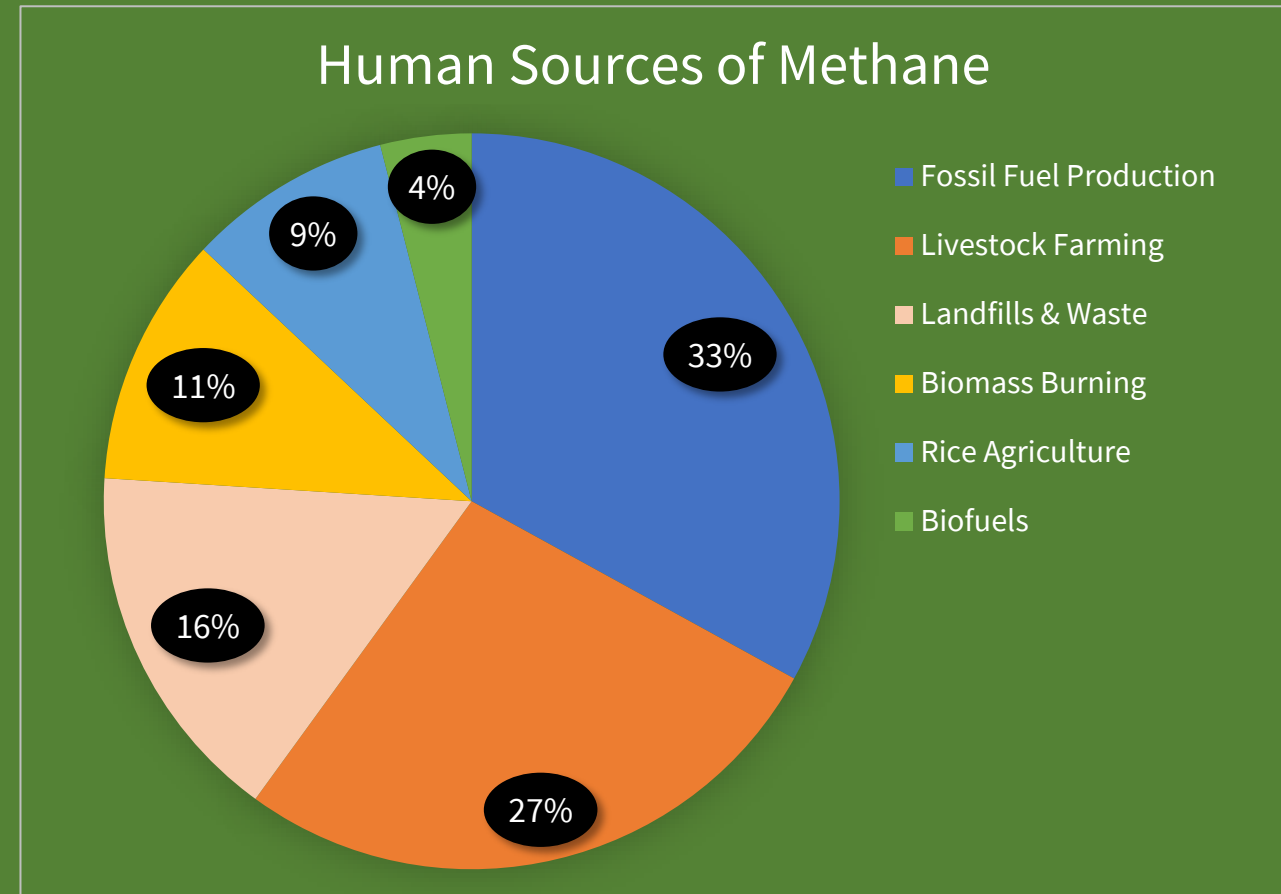


# Global Methane Increase & Sources

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](http://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](http://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

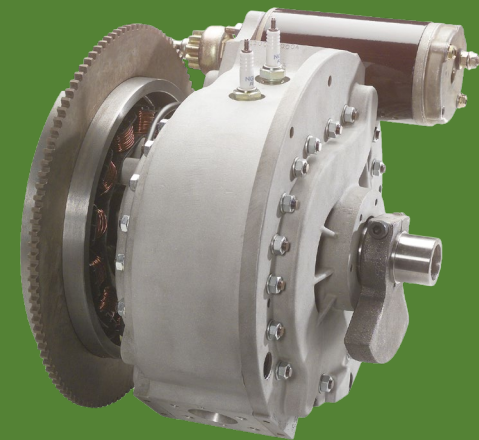
**How do we solve this problem?**

# The Solution!



## Our Rotapower<sup>®</sup> 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



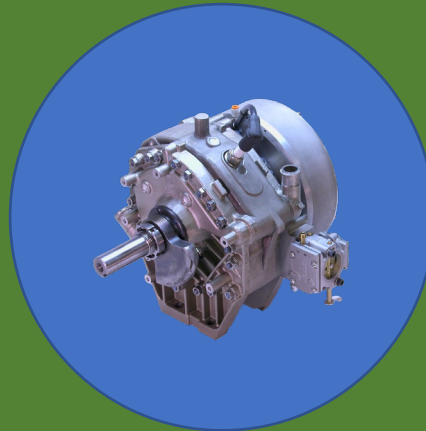
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# Rotapower® Features



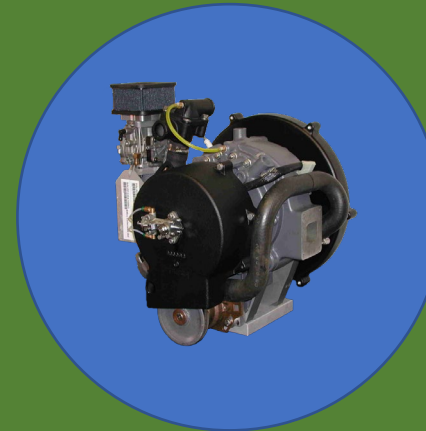
**27cc**



**150cc**



**530cc**



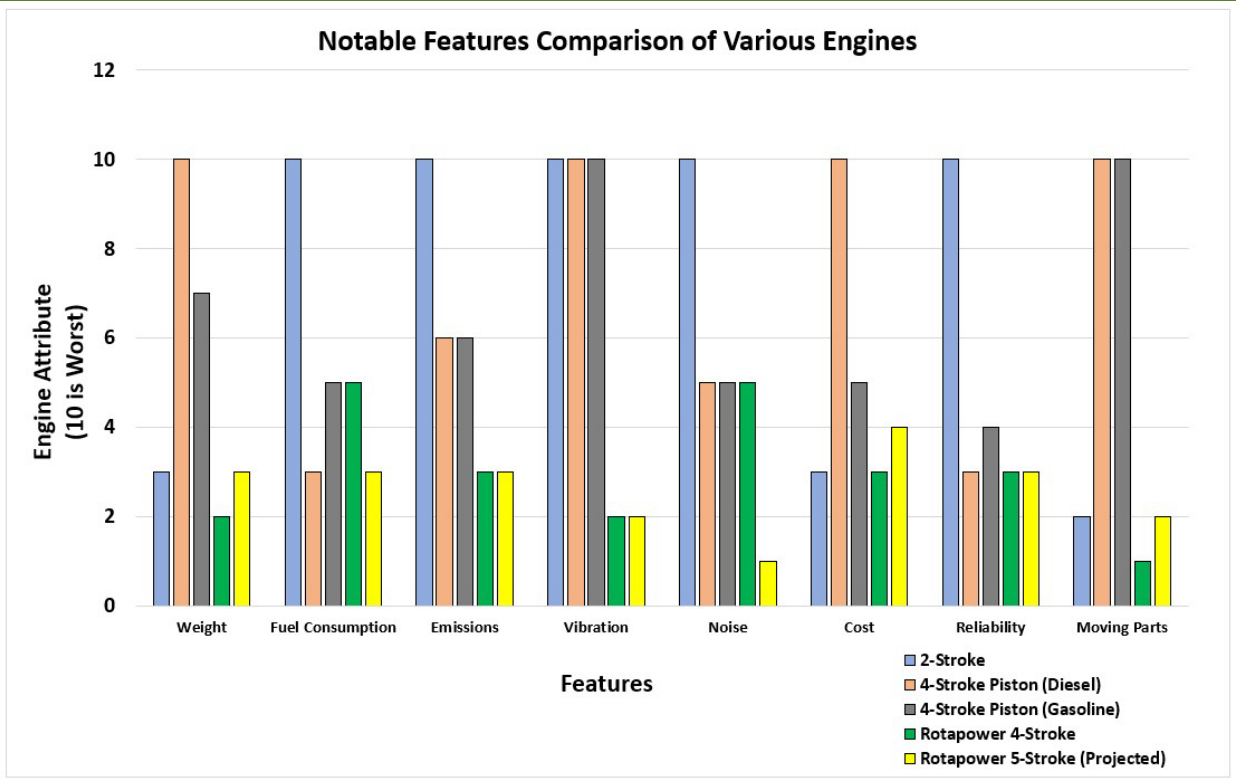
**650cc**

- 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

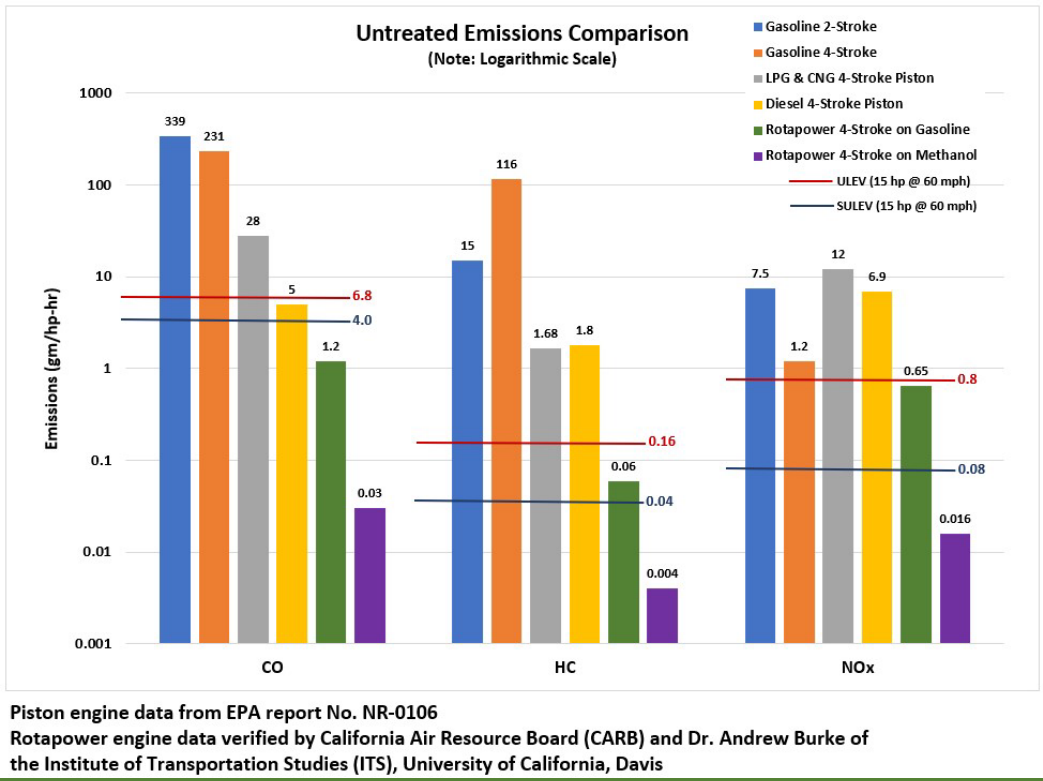
# Key Differentiators



## Engine Features



## Engine Emissions





# 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



## 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

Global Market to Reach US\$10.1 Billion by 2022



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

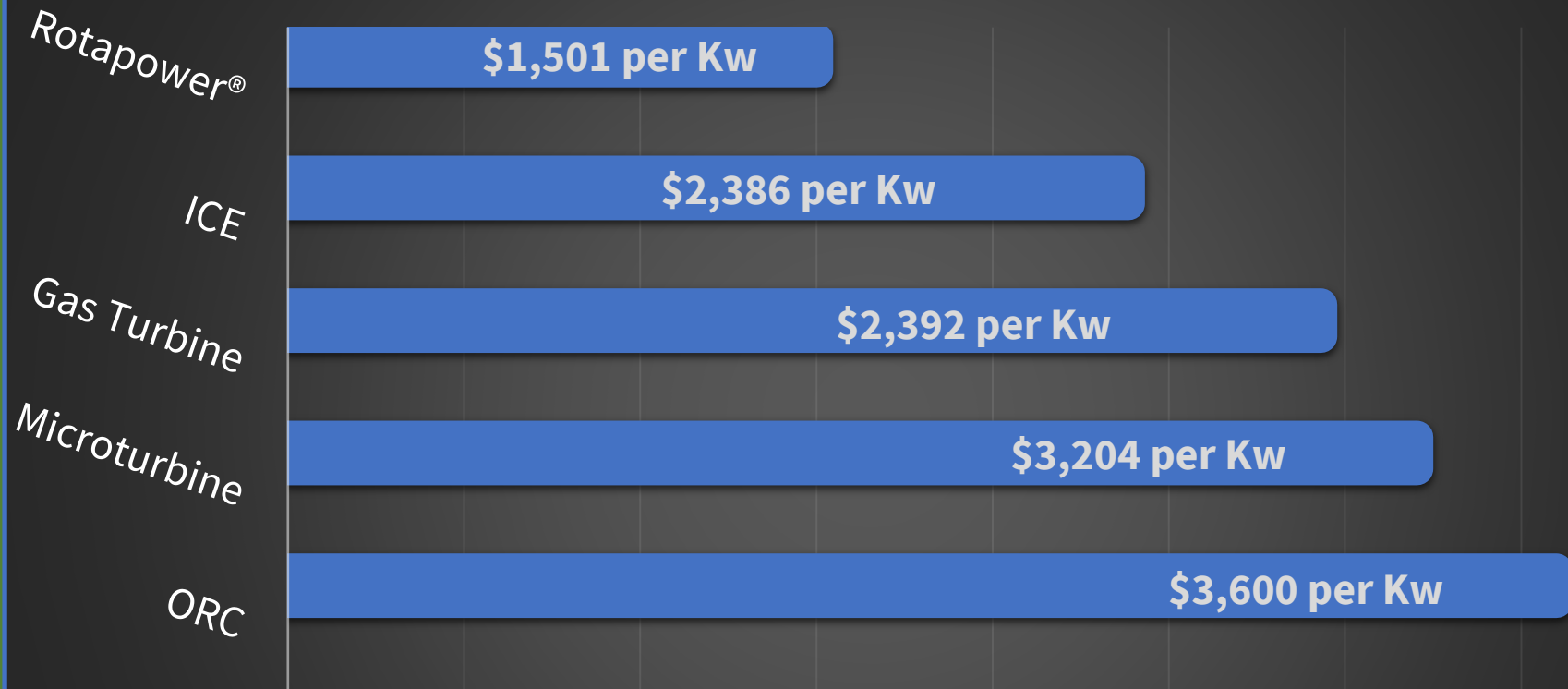
# Freedom Motors Competitive Advantage



The following features allow the Rotapower<sup>®</sup> rotary engine to efficiently utilize biogas to create energy:

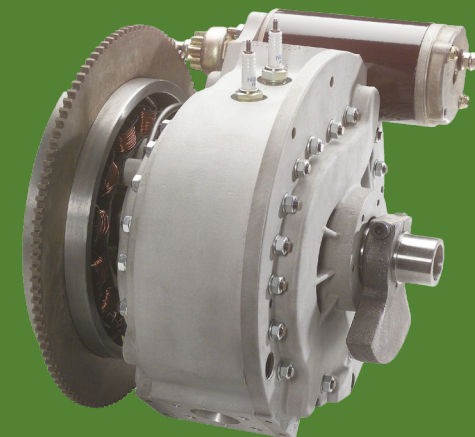
- Uses a lubrication system where very small quantities of oil are metered to the roller bearings and seals. Any remaining oil then exits the engine before becoming acidic due to hydrogen sulfide
- Can tolerate silica by using chrome carbide wear surfaces and silicon nitride seals (9 Mohs versus 6-7 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<sup>®</sup> engines is substantially less than for those powered by either piston or microturbine engines

# Rotapower® Generating System Cost Comparison



All costs are in US Dollars and include installation; with one exception – the removal of silica and hydrogen sulfide – not required for the Rotapower engine

Experience the power of freedom





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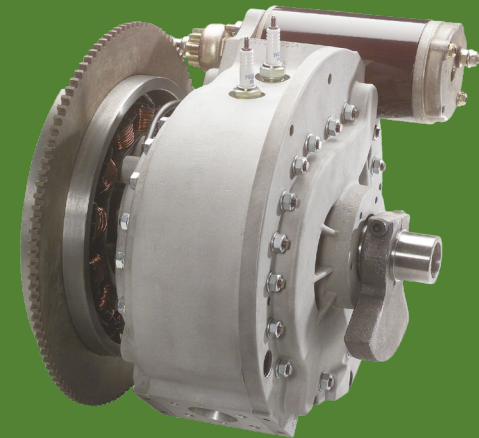
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