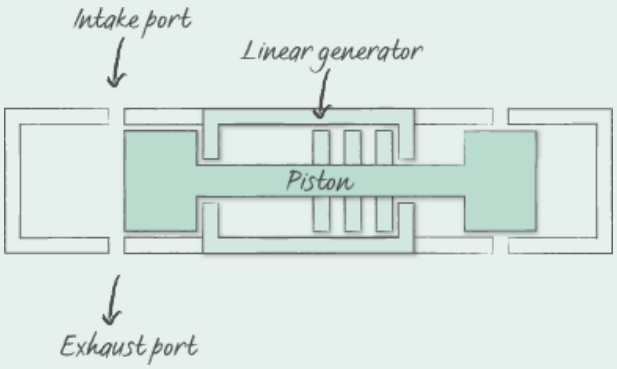
What is a Free Piston Engine?

A Free Piston Engine is a type of internal combustion engine used to generate electrical power from the combustion of a fuel. Unlike conventional engines there is no crankshaft or mechanical powertrain to transmit power and govern piston motion.

Instead, pistons are free to move back and forth under the action of combustion and bounce chamber pressure. A linear electrical machine is coupled directly to each piston to generate power. The same electrical machine can also control piston position dynamically to optimise compression ratio in real time and compensate for cycle-to-cycle variability.



Digital piston motion

Electronic ignition and fuelling have transformed engine efficiency and reliability over the past three decades, bringing what were once mechanically governed processes into the realm of the 'Engine Control Unit' (ECU). More recent innovations in variable valve timing and variable boost systems are now also making the delivery of air into each combustion chamber an ECU-controlled variable.

The advent of 'digital piston motion' made possible by free piston engines will complete the journey of the internal combustion engine from its mechanically constrained origins.

Evolution of combustion engine control

	1960s	1970s	1980s	1990s	2000s	2010s	2020s
Ignition	Mechanical (Distributor)		Analogue (EI)		Digital (Via ECU)		
Fuelling	Mechanical (Carburettor)		Analogue (EFI)		Digital (Via ECU)		
Air	Mechanical (Cam driven valves, turbochargers)			Variable valve lift/timing		Digital (e-valves, e-superchargers)	
Motion	Mechanical (Crankshaft)						FPE 'digital piston motion'

New possibilities for future powertrains

- **Variable compression & expansion ratios**
  - Flex-fuel (Ethanol / gasoline)
  - Start-up
  - Transient
  - Lean-burn & EGR optimisation
- **Advanced combustion cycles**
  - HCCI
  - Split cycle FPE
- **Heat recovery integration**

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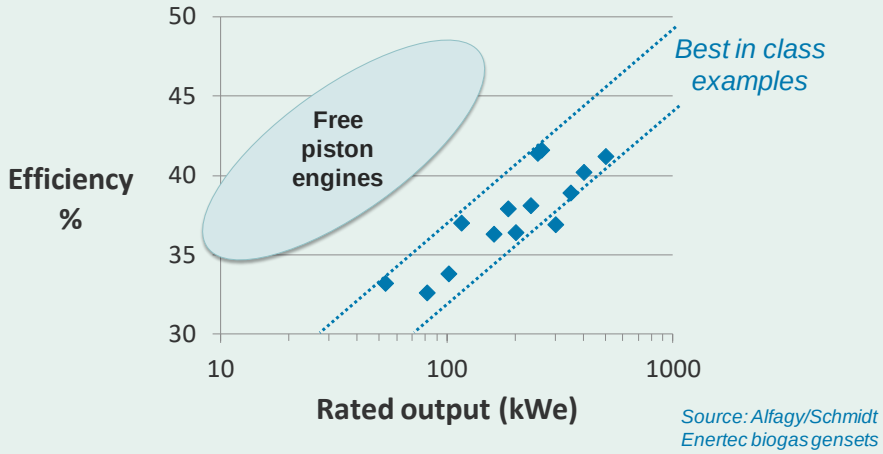
Free piston engine developers around the world are investing to develop this category of engine, aiming to realise numerous benefits:

- **High efficiency**. Free piston engine developers have reported significant efficiency gains, which arise for a variety of reasons. Firstly, in a free piston engine, the piston accelerates away from the 'top dead centre' position much more rapidly than in a conventional engine, reducing the time for heat losses into the chamber walls when combustion temperatures are at their peak. Secondly, precise control of piston motion permits advanced combustion cycles such as 'homogeneous charge compression ignition' (HCCI) to be realised. This results in more of the fuel energy being converted into useful working pressure. Thirdly, the elimination of the mechanical drivetrain removes several components and surfaces that are directly responsible for friction and heat losses in conventional engines. **Taken together, these mean that Free Piston Engines have the potential to produce power with 40-50% efficiency compared with around 25-35% for the most efficient small engine-generator systems today.**



Source: Alfagy/Schmidt Enertec biogas gensets

- **Low emissions**. In theory, an internal combustion engine combines oxygen with just the right amount of fuel to produce carbon dioxide and water, and nothing else. In practice, not all of the fuel is completely burned, and some oxygen molecules combine with nitrogen in the air rather than with the fuel. Both of these undesired processes result in harmful tailpipe emissions. In a conventional engine, these processes are controlled mainly by varying the amount of fuel that is introduced. In a free piston engine, the compression ratio provides a means to control the amount of energy that each fuel and oxygen molecule has. This additional control will make it possible for free piston engine developers to adopt much more effective emissions reduction strategies without compromising engine performance and efficiency.

- **Fuel-flexibility**. The variable compression ratio made possible by 'digital piston motion' in a free piston engine can be tailored according to the type of fuel that is being used, whether this changes day-to-day (as is the case with vehicles using bio-ethanol fuel blends) or hour-to-hour (as can be the case with static biogas generator sets in Europe)

- **Low noise & vibration**. Elimination of rotating parts greatly reduces the scope for vibrations to be transmitted from the engine mountings and into the surrounding structure. A two cylinder opposed free piston engine is intrinsically fully balanced, and compressors using this arrangement have been renowned for their quiet operation.

- **Oil-free**. With lower side loads on the piston skirt, oil lubrication can be replaced with gas bearings. Not only does this approach eliminate the need for oil changes, it reduces the engine's heat and friction losses, reduces hydrocarbon emissions, and in high volume manufacture will also help to reduce the engine's cost.

- **Low cost**. The powertrain from piston to generator is greatly simplified through the elimination of the crankshaft, gudgeon pins, connecting rods and flywheel. Structural housing components can be extruded, rather than cast, further reducing cost.

- **Compact format**. The simplification that reduces a free piston engine's cost also allows more compact engines that can be readily downsized to 1-10kWe scales.