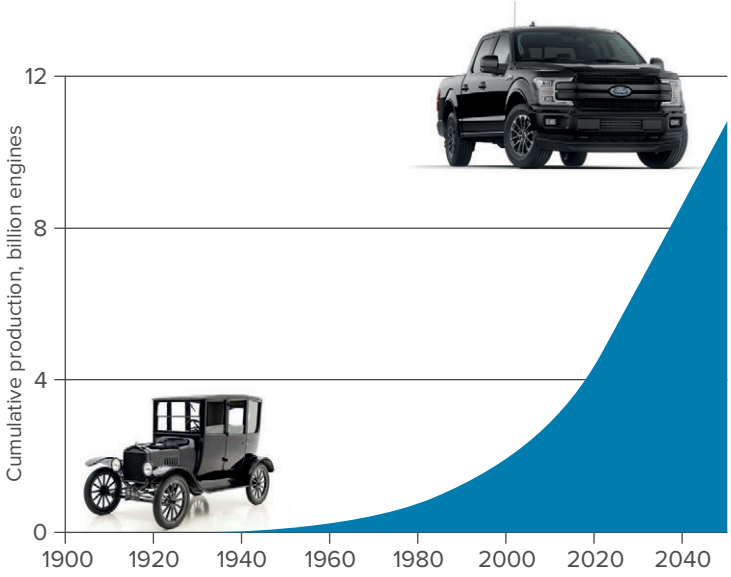

LIBERTINE
LINEAR POWER SYSTEMS

A market driven by change

It took 120 years to produce the first four billion engines.

It will only take another twenty years to double this figure.



Today's fossil fuelled engines clog cities with polluting traffic, change our climate, and use up a limited resource.

Making use of cleaner sources of energy – such as wind, solar, biofuels and biomass – is a priority for sustainable economic growth and for the health of the planet.

Modern engine performance has been radically improved by incorporating electronic engine control units (ECUs) which govern the fuelling, air and ignition during engine operation.

Libertine is enabling the next revolution in internal combustion engine performance, using electronic piston motion control and high performance linear machines to ensure optimal combustion conditions during each and every cycle.

The 'Smart Engines' created by this revolution will play a major role in global transport and power generation for decades to come.

Inside the Smart Engine

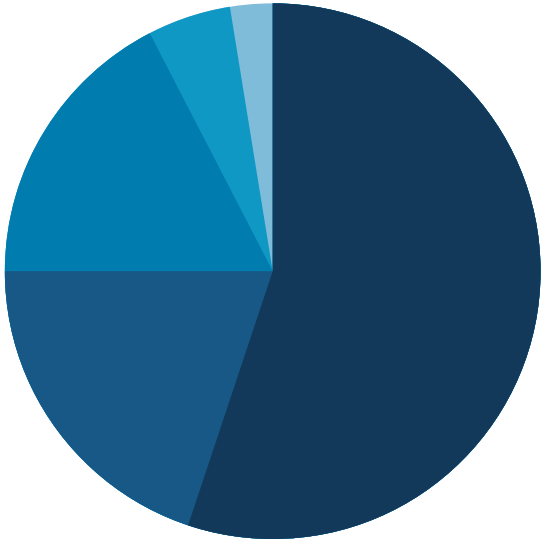
A Smart Engine using Libertine's technology platform has the crankshaft replaced by software-controlled linear electrical machines that generate electrical power and also govern piston motion to optimise the combustion process in what is known as a 'Free Piston Engine'.

This makes engines far more efficient, cleaner and more flexible. Just as nearly all modern engines are now ECU controlled, so most internal combustion engines will ultimately incorporate smart piston motion control.

This approach can produce 30% more power from the same fuel input.

Libertine leads the revolution by solving the challenge of piston motion control. Our Smart Engine technology platform can be applied in a wide range of engines from portable power units and hybrid passenger cars up to much larger bus and truck engines.

Smart Engines using our technology exist today and will be everywhere in the future.



Total addressable market >$100bn

- Hybrid vehicles
- Portable power
- Distributed power
- New applications
- Off-grid

Inside our business

Libertine licenses designs and technology to enable customers to build Smart Engine generator products by incorporating our linear machines and control systems.

Our developer tools help clients achieve faster time to market and reduce programme risk and cost when creating generator products using this novel technology.

The company already has commercial traction with major global companies, has doubled turnover annually and holds 28 granted patents, with multiple new patent families pending.

Our investors include Sir Robin Saxby, former chief executive of ARM Holdings, and Sir Rob Margetts, Chairman of the Energy Technologies Institute and former Vice chairman of ICI.

Our facility in Sheffield sits at the heart of the UK's high-tech manufacturing and electrical machines cluster. Together with our control engineering team in the US, we have drawn on decades of experience in the automotive industry, integrating consumer product engineering and low-cost manufacturing techniques.

A mission driven business

Our mission is to create widespread use of Smart Engines in power and transport markets, enabling our customers to build products that address the global need for clean, low carbon and cost-effective power generation.

Libertine's technology will bring clean, reliable and affordable power to wherever it is needed, transforming the lives of millions of people.

It will accelerate the decarbonisation of transport and help make decentralised power generation the norm.

Access to our world-leading technology and expertise is the best way for innovative companies to become the future global leaders in Smart Engines.

Smart Engines built on our platform will deliver:

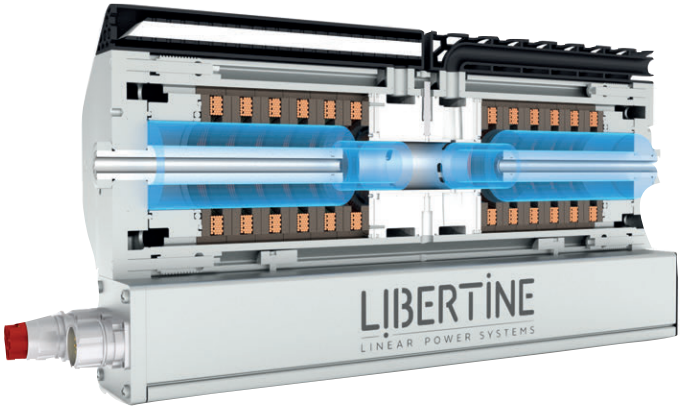
- **Exceptional efficiency**
- **Fuel flexibility**
- **Low maintenance**
- **Low emissions**
- **Low noise & vibration**
- **Compact packaging**
- **Fast start-up**
- **Short time to market**

intelli GEN

SMART ENGINE TECHNOLOGY

The shortest path to your Smart Engine product

IntelliGEN 20-40kWe Smart Engine platform for OEMs targeting series hybrid buses, trucks and cars as well as distributed power applications.



- Robust and flexible platform for lab-based combustion development and prototype validation
- 20-40kWe* two stroke engines with uni-flow scavenging, configurable for light, heavy and gaseous fuels
- Ground-breaking free piston motion control solution for the most demanding combustion applications
- Advanced controls platform and analytics for low temperature combustion methods
- De-risks and accelerates Smart Engine generator product development programmes

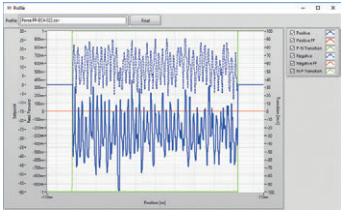
We are delivering 20kWe development platform systems into customer engine programmes in 2019.

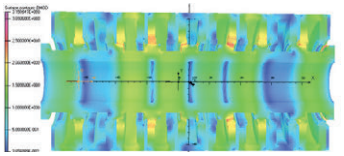
www.intelli-gen.com

*kWe is a kilowatt of net electrical power output

OPEN FPE

SMART ENGINE TECHNOLOGY





A uniquely flexible research platform

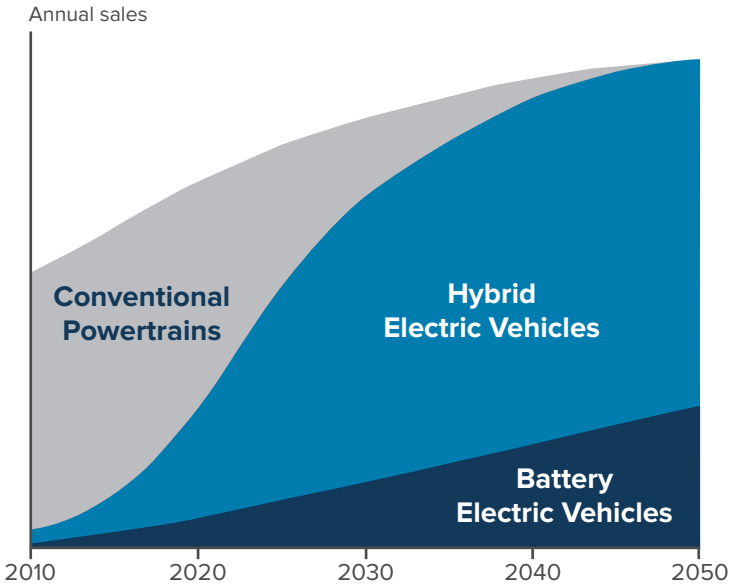
OpenFPE 1-20kWe turn-key Smart Engines and tools for academic research and low temperature combustion development activities.

- Evaluation systems include 1kWe and 20kWe two-stroke gasoline spark ignition combustion chamber designs with uni-flow scavenging
- Re-configurable for other fuels and combustion methods (including diesel or natural gas fuelling and compression ignition) made possible by a ‘swap-out’ cylinder and free piston design
- Compact, fully balanced designs do not require conventional test cell dynamometer installation or complex lab infrastructure. Our smaller 1kWe system enables ‘bench-top’ combustion experimental set-up
- Libertine’s Free Piston Engine Control Unit provides a wide range of combustion control functionality and facilitates low temperature combustion research using software-configured real-time piston motion control
- Advanced analytics, diagnostics and simulation suite accelerates model validation, and drives experimental insight and research productivity

www.openfpe.com

Trends in automotive

In future, most vehicles will require an electrical power generator



Hybrid electric powertrains are rapidly growing in popularity and are expected to replace mechanical transmissions in the majority of vehicle powertrains in future. Electric vehicles are cheaper to fuel, don't require oil for lubrication, run quieter, are less bulky, and are less mechanically complex. Electric vehicles don't need a mechanical transmission, so they are easier to drive, and power delivery is smoother and more responsive.

However, they require electricity – either created far away in a power station or created on board the vehicle using of one of a variety of fuels. Vehicles that use a fuel to charge a battery or power the wheels directly are known as 'series hybrids'. This class of vehicle is expected to reach a market value of $1.4 billion by 2025 with some markets such as electric buses growing by over 30% annually.*

Smart Engines are the answer to enabling the growth of the series hybrid market.

* Source: Grand View Research, MarketsandMarkets, Toyota

Trends in power generation

Rapid economic growth across Asia, Africa and South America puts pressure on existing grid power infrastructure, especially in rural areas. Many new power generation applications such as off-grid telecoms base stations therefore rely on local generation of power from a stored fuel, often as part of a hybrid system that may also include solar and battery power. Other such 'distributed power' applications use variable renewable fuels such as biogas from agricultural or municipal wastes and residues.

Distributed power generation makes use of locally available fuel sources and does not require expensive and inefficient grid infrastructure. In addition, surplus heat can often be used for hot water or heating.

Smart Engines built on Libertine's technology platform can deliver up to 100kWe of local power. These generators can be configured for more efficient combustion of traditional liquid and gas fuels, or for alternative fuels and blends including bioethanol, methanol and syngas from waste gasification.

Smart Engines can also reduce operation and maintenance costs, lowering the total lifetime cost of distributed power generation by up to 50%.

How we work

"PETRONAS has an established programme of free piston engine research and development. We built Libertine's Smart Engine technology into our research engine programme to improve piston motion control and allow us to accelerate our research into high efficiency, fuel-flexible combustion systems."

Professor Abdul Rashid Abd Aziz
Deputy Vice Chancellor for Research and Innovation, UTP

Today we are delivering solutions to companies developing their own Smart Engine products.

We have completed multiple research engine systems now operating in Europe and Asia. Our proven technology platform integrates with existing OEM technology and provides comprehensive analytics and diagnostics data to accelerate development.

Libertine enables customers to focus on their core product development expertise to create clean, efficient combustion engine power generator products. Our advanced linear machines and control solutions remove the pain points associated with Free Piston Engine development, reduce programme cost and risk, and enable faster time to market.

To join Libertine on the journey to deliver the next generation of Smart Engines, contact fpe@libertine.co.uk

AQUARIUS

AB Dynamics

PETRONAS

SwRI®

“Libertine has the experience and track record needed by customers developing tomorrow’s Smart Engines, slashing development time and cost. We are working with the world’s leading Free Piston innovators to transform the internal combustion engine ready for its essential role in a low carbon future”

Sam Cockerill, CEO

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