

# Low Carbon Vehicle Partnership



## Technology Challenge 2009

Identifying innovative low carbon  
vehicle solutions from UK SMEs



# Foreword

Professor Neville Jackson

Chairman, Low Carbon Vehicle Partnership  
Group Technology Director, Ricardo UK Ltd

## **Sustaining performance**

The needs for greater fuel efficiency and lower emissions have introduced targets and policy statements creating a major global push to innovation. Whilst the key market driver for lower carbon transport is regulatory, consumers have also shown an increasing desire for lower running costs and a 'greener' image in their vehicle choice.

Together these have driven demand for new innovative products which are both cost effective and, particularly for passenger cars, attractive. More fuel efficient engines, electrification of drive-trains, energy recovery and lightweight materials are opening up new opportunities to improved performance without compromising form or function.

## **Partnering of opportunity**

The UK has a leading edge capability to respond to the low carbon transport challenge and deliver technology and products to the new and emerging 'green' market. The LowCVP Technology Challenge presents a criteria based, peer review process for identifying innovations with major potential being developed by small and medium sized companies.

The winners of the Technology Challenge have an unprecedented opportunity to engage prospective customers and partners, whilst vehicle and component manufacturers have the chance to learn more about relevant innovations.

This simple yet effective approach is raising awareness of novel automotive technologies, accelerating evaluation and realisation of their benefits. I look forward to the next LowCVP Technology Challenge.



# The Low Carbon Vehicle Partnership (LowCVP)

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The LowCVP works to accelerate the shift to low carbon vehicles and fuels and create opportunities for UK business.

## Progress through partnership

A not-for-profit multi-stakeholder partnership of over 350 organisations, LowCVP members work collectively to develop consensual, evidence-based solutions to increase deployment and uptake of options to reduce road transport emissions.

Funded by a Government grant complemented by member contributions, the LowCVP provides an expert, independent advocate for low carbon road transport solutions and helps UK companies capitalise on the business opportunities.

Our broad membership encompasses: the automotive and energy industries; transport users and operators; environmental organisations; academics and policy makers. Together these members take practical initiatives, share knowledge and information, and provide support to Government for policy development.

## Stimulating markets for new technology

New and improved vehicle and fuel technologies can radically reduce the environmental impact of road transport. Creating the conditions in which new markets for low carbon technologies can successfully develop is a key factor in the successful transition to low carbon vehicles and fuels. The LowCVP works to tackle market barriers to the introduction and growth of low carbon vehicles and fuels;

transforming and growing the market in favour of low carbon solutions.

Recent successes include supporting the establishment of new markets for low carbon buses, biofuels and public procurement of low carbon vehicles.

## Encouraging consumer demand

The market for low carbon, fuel efficient vehicles is immature. Vehicle running costs and environmental concerns have risen in importance but remain relatively low priorities for most new car buyers. LowCVP initiatives informing consumer choices are encouraging demand for low carbon vehicles and fuels, essential in the drive to reduce emissions. Through our work, energy efficiency labels are now used in 95% of new-car showrooms and 2,500 used car dealers.



# The Technology Challenge 2009

## Towards 80g CO<sub>2</sub>/km and lower



### Low Carbon Automotive Innovation

New regulations coupled with consumer demands require rapidly improving environmental performance and functionality for passenger cars. Achieving or exceeding 80g CO<sub>2</sub>/km from mainstream passenger cars, whilst still meeting the needs of the consumer, presents a major challenge for the industry. It also presents an opportunity for new ideas and technical innovations to enter the automotive supply chain.

As technology options emerge new business relationships must be forged. Helping connect emerging technology-based companies with the existing automotive supply chain reduces time to market, returns value for early adopters and realises CO<sub>2</sub> savings. It also helps to fine-tune innovations to market needs, create new market segments, reduce costs and maintain the leadership of the UK in skills and excellence.

*“In terms of future development, much greater collaboration and cooperation is required between Tier 1s and vehicle manufacturers and more widely with new technology companies, as the initial costs of the transition to low carbon technology will be high, and the early volumes of viable production low.”*

New Automotive Innovation and Growth Team, Summer 2009.

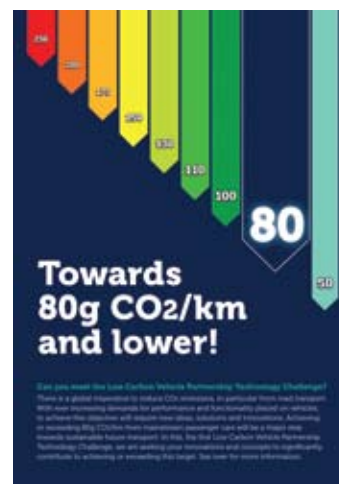


### A Competitive Opportunity

In 2008 a LowCVP study identified that emerging companies developing compelling, innovative technologies had a major challenge to rise above the noise of competing ideas. Similarly, vehicle and component manufacturers faced the challenge of tracking and evaluating developments in the sector.

As an impartial intermediary seeking to accelerate the deployment of low carbon vehicle technologies, the LowCVP was well placed to rise to this challenge. The LowCVP Technology Challenge was formed in early 2009 as a structured process through which suitable candidate innovations could be identified and new relationships between major organisations and emerging companies catalysed.

The LowCVP Technology Challenge ‘80gCO<sub>2</sub>/km’ was launched at the 2009 LowCVP Annual Conference at London’s City Hall.



\* [www.lowcvp.org.uk/events/annual-conference-2009.asp](http://www.lowcvp.org.uk/events/annual-conference-2009.asp)

### Greening Passenger Cars

Entry to the LowCVP Technology Challenge was open to any technologies with the potential to reduce CO<sub>2</sub> emissions from conventional internal combustion engine cars in areas such as: advanced combustion; emissions cleanup; improved aerodynamics and flow control; new and advanced powertrains; energy recovery; lightweight materials and structures, and; design optimisation.

To focus entries toward the near term challenge faced by the sector, applicants needed to demonstrate that their technology:

- would reduce CO<sub>2</sub> emissions from passenger cars and similar light goods vehicles;
- could be commercially deployed in 3–5 years;
- were on-vehicle, and;
- were compatible or could be easily integrated into the existing transport, energy and fuel infrastructures.

### Supporting Low Carbon Automotive Innovation

Seventeen innovations for a diverse range of technologies were submitted. These were reviewed by a panel of experts from the automotive sector familiar with commercialising new technologies and current market requirements who judged entrants against key criteria:

- carbon saving potential;
- alignment with NAIGT Technology Roadmap;
- commercial viability;
- ease of integration;
- market drivers;

- applicability to the broader market
- sustainability;
- prior experience, and;
- added-value to the sector.

The six winners featured in this brochure were selected for their exceptional capacity to meet these demanding criteria.

To support the winners, a workshop was held to advise companies on how to pitch their innovation and engage prospective supply chain partners. Speakers from LowCVP, Highbury, Ricardo and MIRA addressed topics from driving the direction of the sector and testing regimes to intellectual property management and business strategies.

### Repeated Success

Many of the best technological innovations start within small and emerging businesses and LowCVP is delighted to have made steps to support six of the UK's best. Further Technology Challenges are being considered and we welcome involvement and commitment from stakeholders and organisations to support this effective, productive approach.



# Presentation Event

Royal Academy of Engineering, London  
10 December 2009

On the 10th December 2009 the six winners of the LowCVP Technology Challenge presented their technologies to motor industry leaders at an event held at the Royal Academy of Engineering,

## Commitment to Low Carbon

Chaired by Prof. Richard Parry-Jones, recently appointed co-chair of the UK Automotive Council and previously chief technical officer of Ford Motor Company, the event was well attended by senior executives from the sector: Andy Boulton (Alexander Dennis); Martin Joyce (Denso); Barry Gale (Ford); Jon Beasley (GKN UK); Miguel Fragoso (GM UK); Tony Harper (Jaguar Land Rover); Mark Johnson (Jaguar Land Rover); Steve Dunn (Kautex-Unipart); Jerry Hardcastle (Nissan); Darran Messem (Shell International); Adrian Tucker-Peake (SMTC UK); Adrian Mitcham (TRW).

Such strong participation is indicative of both the strong industry interest in sourcing CO2 reducing technologies, and confidence in the ability of UK companies to provide innovative solutions.

Setting the context for the event Prof. Parry-Jones described the changing landscape and challenges for the automotive sector; and the supportive partnership with UK Government, epitomised by the new Automotive Council.

The LowCVP Chair, Neville Jackson then introduced delegates to the work of the LowCVP and the motivation behind the LowCVP Technology Challenge. He highlighted the twin challenges of strengthening environmental regulation with the demands of consumers for attractively



*Greater collaboration and cooperation between Tier 1s and vehicle manufacturers and new technology companies will speed technical innovation and cut carbon emissions more quickly.*

RICHARD PARRY JONES, CO-CHAIR OF THE AUTOMOTIVE COUNCIL

*The Technology Challenge provides a unique opportunity for some of the best of the low carbon automotive technology companies to access potential partners and customers and to learn more about some very innovative technologies.*

GREG ARCHER, MANAGING DIRECTOR OF THE LOWCVP

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priced vehicles, stressing that customers would not compromise on form or function for environmental benefits. He emphasised the opportunities provided through stronger industry collaboration but the difficulties for OEM and Tier 1 organisation in differentiating the exceptional, practical ideas from the just credible; noting the equivalent challenge for emerging businesses to be differentiated from the noise. He concluded by reminding participants that it is against this background and with these drivers that the LowCVP Technology Challenge has been established.

#### **Innovations for Industry**

Each of the winners presented their business motivation and unique technological offerings for lowering CO2 emissions in 20 minute presentations. These outlined the origins of their businesses as new start-ups or spin-outs from universities or larger companies. Many of the winners had previously successfully leveraged public sector funding to accelerate the development of their technologies and to de-risk their offer before securing major investor interest, enabling the strengthening of their teams. To conclude, each winner summarised what they were seeking from delegates, ranging from partners to commercialise their technology to encouraging early adopters and orders.

Following each presentation, assembled experts probed the winners to obtain further details: key technologies principles; benefits over existing options; weight and energy balances; assumptions; competitors; intellectual property rights, and; costs.





The event provided for a valuable exchange of knowledge and experience, and all important contacts for those present.

Concluding the event, Richard Parry-Jones declared the Technology Challenge model a very promising approach to catalyse stronger collaboration between new and established industry players to bring forward carbon reducing innovations for the sector. He commented, *“The challenge of climate change is very significant. However after hearing from today’s presenters and learning what innovative UK business are developing and introducing to reduce carbon from cars, I think we should have every confidence that, as has happened before, the ingenuity and capability of UK engineering will respond and deliver the solutions necessary”.*



*Invention is a good idea, but if you want innovation you need to implement it. This is what these winning product developers are doing – introducing near-term, strategically viable options to reduce carbon emissions from mainstream passenger cars.*

ROY WILLIAMSON, LOWCVP

WINNER

# Axon Automotive

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Axon's vehicle-structures technology is a globally patented materials innovation used to create light-weight components and vehicles needed for a low CO<sub>2</sub> future. The technology makes beams using multiple braids usually of carbon fibre. Traditionally carbon fibre has been used to make sheets e.g. body panels or the structural tubs of open race cars. However, conventional road cars can be seen as a set of beams separated by large gaps for doors, windscreen, boot and engine bay. Panels, which bond or bolt onto the beam structure, can be structural or non-structural. The technology is a generic car making system.

## Economic benefits

The technology minimizes the amount of carbon fibre needed to provide the stiffness and strength for seat belt mounts, engine mounts, doors etc. The stiff frame allows the designer to use low cost panels, which are replaceable if damaged. The low tooling cost for the vehicle frame is a major cost advantage for vehicle production volumes up to 30,000 per annum. These volumes are attractive in new markets such as electric vehicles where light vehicles can reduce battery cost and weight for a given range.

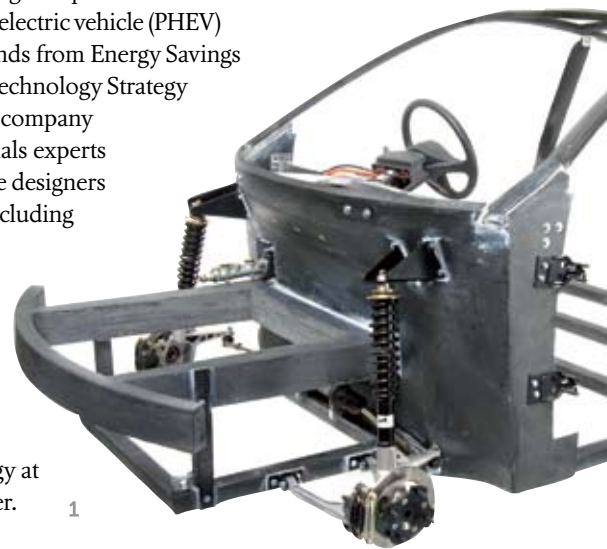
## Mainstream adoption

The Japanese predict that carbon fibre will become widely adopted in the automotive industry in decade 2010–20. Carbon fibre has taken over the commercial airliner industry at Boeing and Airbus. The same drivers – light weight, structural performance and fuel economy, apply on the road. The 'Precursor to Part Plant' being developed

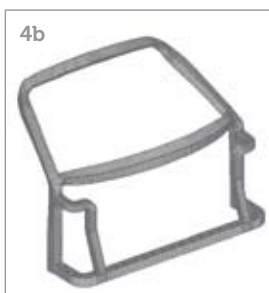
in Japan is to lower cost of carbon fibre vehicle production for all the main car makers. The Toyota Prius concept 1/x is a typical 150mpg product. The Axon car, though more conventionally styled, is also a plug-in hybrid electric vehicle (PHEV), and has the same mass, emissions, engine size and all carbon structure. We view this as a confirmation of our approach.

## The Company

Axon is a spinout from the Honda Ecotechnology Centre at Cranfield University. The core team developed the Axon technology specifically for whole vehicle body structures under the UK Foresight Vehicle programme. In January 2006 Axon Automotive Ltd was formed initially around a contract to make a sports car spaceframe, and then to prototype the Axon car and bring it to production as a plug-in hybrid electric vehicle (PHEV) with UK R&D funds from Energy Savings Trust (EST) and Technology Strategy Board (TSB). The company comprises materials experts and whole vehicle designers and engineers, including powertrain, who are ex-Lotus, MG Rover, Aston Martin and Torotrak. Axon's chairman was director of strategy at Jaguar Land Rover.



Japanese forecasters expect the Automotive industry to follow the aircraft industry and be dominated by light weight carbon fibre vehicles in the decade to 2020. Axon Automotive body structures technology is ready to go...



## Key Points

**The structural material** finds many applications in the vehicle.

**Crash beams** – 20% improvement over aluminium in energy/kg

**Upper body variants** – niche derivatives of existing body in white models as saloon cars or lorry cabs – putting a boot on a hatchback Rover 25 is shown.

**Specialist vehicles** – weight reduction such as an electric streetsweeper.

**Electric vehicle** – new designs in low volumes with weight reduction allowing battery cost reduction and similarly for hydrogen vehicles.

**New vehicles** – Low investment exploration of new niche light vehicles of whatever powertrain

**Light structural components** for vehicle sub-assemblies.



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1. Axontex structure for car prototype
2. Crash beam in Axontex
3. Machine deposition of Axontex
- 4a. Using Axontex to create a boot for a hatchback
- 4b. The Axontex structure used to create car boot
5. A-pillar showing cross-section for windscreen

WINNER

# Brunel University

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Brunel RegenEBD is a novel and cost effective engine technology of Regenerative Compressed Air Supply for high efficiency low carbon buses and delivery vehicles by enabling engine stop/start operation and replacing the engine-driven compressor. It helps overcome turbo-lag for faster engine response and reduce black smoke during acceleration. In particular, Brunel RegenEBD is achieved through novel application of proven Engine Braking Technology (EBD) technology and hence represents a reliable, affordable, and quickly deployable solution for fuel saving and CO<sub>2</sub> reduction from vehicles.

## Needs & opportunities for buses and delivery vehicles

It is commercially and environmentally imperative for buses and delivery vans to achieve fuel saving and CO<sub>2</sub> reduction to meet the imminent CO<sub>2</sub> and fuel consumption targets. There is an urgent need for a solution that is affordable, effective, and quick to deploy. Current electric hybrid approaches are expensive, complex and heavy.

## Benefits to engine makers offered by Brunel RegenEBD

Brunel RegenEBD is highly attractive to engine manufacturers by offering added function and added value at low cost and hence is well suited for high volume market adoption. The system can be easily implemented by novel application of proven technology and therefore it has low risk. There is a unique opportunity for engine makers to achieve sustainable competitive advantage over competitors using the licensed technology.

## Benefits to vehicle builders offered by Brunel RegenEBD

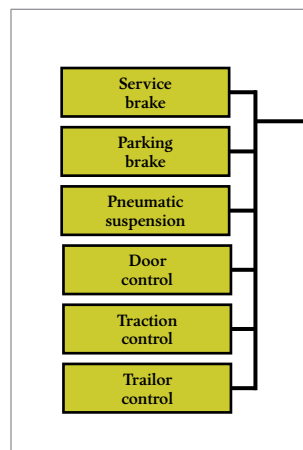
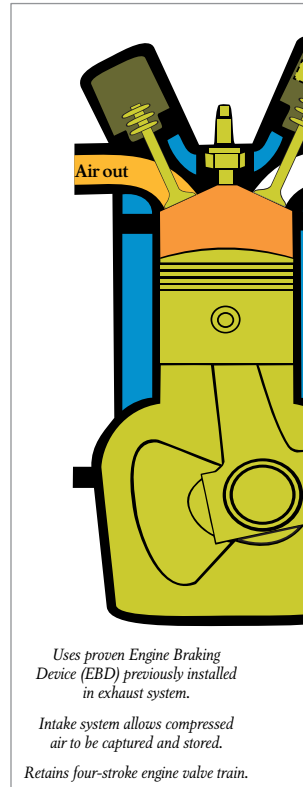
Brunel RegenEBD offers a new product for low cost low carbon vehicles. Fuel saving from engine stop/start is achieved by free energy for every engine start, which is provided from a simple regeneratively produced compressed air supply. Additional benefits include more responsive performance and low exhaust smoke from diesel engines.

## Benefits to operators offered by Brunel RegenEBD

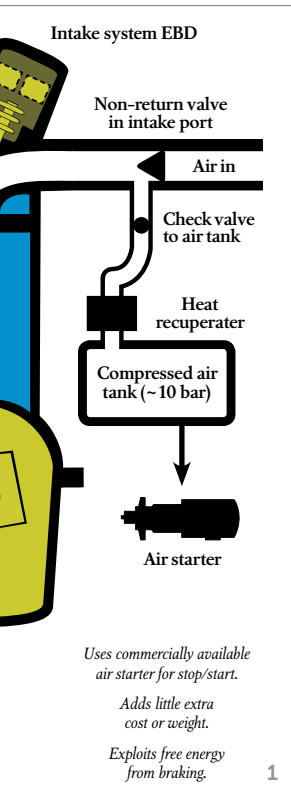
Brunel RegenEBD allows the bus operators and delivery companies to reduce operating cost through reduced fuel consumption by providing free energy for vehicle service air (~2%) and for engine stop/start (~6%) using free energy. The engine braking function will also reduce maintenance costs by minimizing the usage of or replacement of the engine driven compressor as well as reduced brake wear.

## Brunel University, Centre for Advanced Powertrain and Fuels (CAPF)

Brunel RegenEBD has been developed from an EPSRC sponsored research on innovative air hybrid concepts by Prof. Hua Zhao and Dr Tom Ma in the Centre for Advanced Powertrain and Fuels (CAPF) at Brunel University. As one of the largest engine research centres in UK, the centre's activity covers both gasoline and diesel engines and involves substantial experimental work and modelling studies. Professor Zhao has over 20 years experience in combustion engines research and is the author and editor of four



**A novel engine technology of Regenerative Compressed Air Supply for high efficiency low carbon buses and delivery vehicles through novel application of proven Engine Braking Technology (EBD) technology.**



books on combustion engine diagnostic techniques, CAI/HCCI combustion engines, DI gasoline and diesel engines. Prof. Ma has over thirty years experience in advanced engines research and development in industry and more recently at Brunel University.

Brunel RegenEBD is underpinned by strong patents and recognised world class

technical capability at Brunel University. Brunel is seeking to partner with engine makers and vehicle builders to bring the technology to market. The collaboration offers a licencing opportunity to acquire a unique, differentiated position in a highly competitive market.

### Key Features

- Meets market need for fuel saving and CO2 reduction
- Enables engine stop/start, saving ~6% fuel for a city bus
- Replaces engine-driven air compressor, saving ~2% fuel
- Engine boost-assist from stored air
- Overcomes turbo-lag for faster engine response
- Reduces black smoke during acceleration

#### Benefits for bus and van operators

- Reduced operating costs
- Reduced CO2

#### Benefits for vehicle builders

- Provides regenerative compressed air supply for free

#### Benefits for engine makers

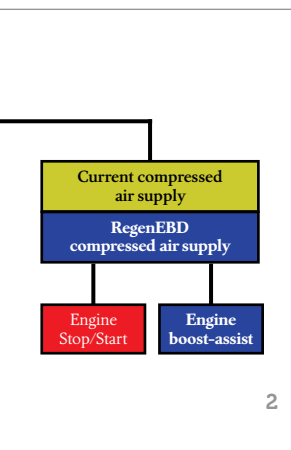
- Low cost simple addition for next generation engines
- Ideal for low carbon vans and buses



Professor Hua Zhao

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1. Brunel RegenEBD Engine
2. Utilisation of compressed air

# Controlled Power Technologies

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One of the major advantages of CPT's *RegEnBoost* concept for reducing internal combustion engine CO<sub>2</sub> emissions is that it allows the retention of a relatively simple, low mass powertrain. It is therefore easier to package and can be implemented for high volume production at significantly lower cost than developing a full hybrid vehicle. It also offers a design route with minimum intrusion on base engine layout.

The synergistic combination of CPT technologies within the *RegEnBoost* system enables a family-sized car to achieve less than 100g/km CO<sub>2</sub> with a 1-litre gasoline engine but, when required, offers the same lively performance and in-gear acceleration as a 2-litre naturally aspirated powertrain. This CO<sub>2</sub> level is comparable to that emitted by equivalent sized full hybrid vehicles, yet avoids their need for high voltage and the significant impact a hybrid's large batteries and traction motors have on overall vehicle cost, mass and packaging.

It is well understood that radical downsizing of a conventional powertrain offers excellent CO<sub>2</sub> and fuel economy benefits; a small displacement engine has lower parasitic losses and operates more efficiently under part load conditions. A smaller engine can also be turbocharged to deliver comparable torque and power to a larger naturally aspirated engine. However, with a conventional turbocharging system, the turbine size necessary to maximise efficient high speed performance gives unacceptable low speed response, which affects the driveability of the vehicle.

The boosting element of CPT's technology, which addresses this issue, is derived from an

electric supercharger, which can be installed in series with a simple fixed geometry turbocharger. Unlike a crankshaft driven supercharger, the CPT method of boosting is highly responsive and independent of engine speed and offers precise electronic control. This crucial difference means the technology is perfectly suited to maintaining vehicle performance and driveability – now widely recognised as a critical marketing issue for any car maker contemplating radical engine downsizing.

Power for the electric supercharger is supplied by a high efficiency starter-generator and exhaust driven turbo-generator. All three CPT technologies are integrated into a powertrain electrical power network (PEPN), which incorporates an enhanced performance valve-regulated lead acid (VRLA) battery, optimised for fast energy storage and release.

The *RegEnBoost* system is based on high efficiency switched reluctance (SR) electrical machines which, because of their flexibility, can be readily scaled to support engines up to approximately 3.5-litres capacity. A major part of CPT's effort has concentrated on optimising the technology for automotive applications and establishing a manufacturing strategy and supply base. World class manufacturing partners have already been identified.

CPT was founded in 2007 as a management buy-in funded by venture capital initially to acquire advanced powertrain technologies from Visteon Corporation and its technology development partner Emerson Corporation. It comes with a highly experienced team of automotive engineers and is backed by investors specialising in the energy and environmental sectors.



**Controlled Power Technologies' engine boosting and power regeneration system known as 'RegEnBoost' combines three complementary technical developments for delivering significant CO<sub>2</sub> reduction. The technology facilitates radical downsizing of gasoline and diesel engines without compromising vehicle performance.**



## Key points

**VTES** (variable torque enhancement system) has an extremely rapid air boosting capability that enables an engine to react instantly to high transient load conditions. The production-ready electric supercharger has already been incorporated in a major project by engine developer AVL and will also feature in the Ricardo-led £3m HyBoost programme co-funded by the Technology Strategy Board.

**SpeedStart technology** is the world's first bespoke belt-driven Integrated Starter Generator (B-ISG) capable of starting a 2-litre diesel engine using a conventional 12-volt electrical system; its premium performance delivers a very high and efficient power output and its state-of-the-art power and control electronics are fully integrated into the liquid-cooled unit.

**TIGERS** (turbo-generator integrated gas energy recovery system) comprises a liquid-cooled switched reluctance generator coupled to an exhaust driven turbine. The technology is currently in the proof-of-concept hardware test phase and is expected to be production-ready by 2014/15.



Image 1. VTES  
Image 2. SpeedStart  
Image 3. TIGERS



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Power Technologies is available at  
**www.cpowert.com**

# EVO Electric

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EVO Electric Limited ('EVO') was established in June 2007 as a spin-out from Imperial College London to develop advanced electric machines, drive systems and other integrated products based on proprietary axial flux technology. Its flagship product, the AFM-140 Axial Flux Motor, is designed to meet the requirements of electric and hybrid electric vehicles and a wide range of demanding industrial applications (see Fig.1).

### What is Axial Flux?

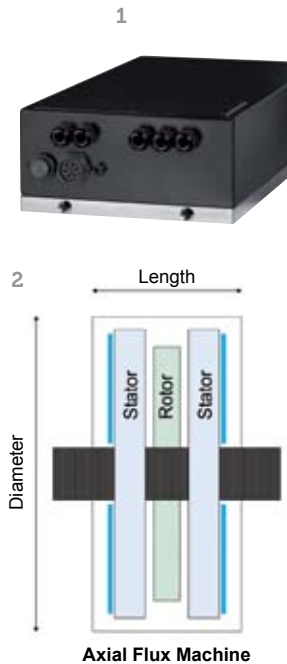
Axial Flux motors and generators are characterised by very high torque and power density, made possible by a greater availability of active electromagnetic area per unit of volume compared to conventional radial flux machines. Their disc-shaped geometry allows for torque to increase with the cube of the machine radius, whereas the torque of radial (drum shaped) machines increases only with the square of the radius (see Fig. 2). This makes it possible to dramatically cut the weight, size and cost of electric motors and generators.

Although the principles of axial flux machines have been known since the days of Michael Faraday, a number of issues including high manufacturing and material costs and the lack of advanced composite materials have constrained their use until now. EVO's innovations in machine cooling, winding and manufacturing have finally enabled a breakthrough in large axial flux machines of particular relevance to automotive applications.

### DuoDrive

The application of EVO technology to existing hybrid and electric powertrains offers immediate benefits in terms of weight, volume and cost. However, innovative powertrain designs that make full use of EVO motor/generators, especially their high torque, can enable even higher gains. For example, the high torque density of EVO machines allows, in some cases, the elimination of gearboxes which enables additional cost, space and weight savings.

In fact, EVO is developing its own gear-less powertrain concept, the DuoDrive hybrid system, in order to demonstrate the full potential of its axial flux technology (see Fig. 3). DuoDrive was designed for light commercial vehicle applications, combining the best elements of all-electric, series and parallel hybrid drivelines in one simple unit. The system includes a generator, connected



**EVO's innovations in axial flux technology and hybrid powertrain design enable vehicle manufacturers to cut the weight, complexity and cost of electric and hybrid vehicles.**



directly to the diesel ICE (or other power source) and linked by an electronically controlled clutch to the drive motor, which is, in turn, directly coupled to the prop-shaft without a gearbox or power splitting device (as in the Toyota system).

The elimination of the gearbox results in a 40kg weight reduction and eliminates a number of conversion steps. Combined

with the higher efficiency of EVO machines, this results in an efficiency gain of about 10% over conventional electric powertrains. Moreover, both the motor and generator are contained in a compact housing (400mm diameter by 460mm long), designed to fit in the space normally occupied by the gearbox. This provides a low-cost route to designing advanced electric and hybrid vehicles.

### EVO motor/generators

**Very high torque** and power density  
15Nm/kg, 4.2kW/kg peak;

**Low unit cost**, made possible by the higher torque and power (and hence lower material bill per Nm and kW of output) as well as proprietary innovations in machine manufacturing;

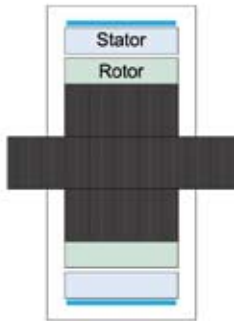
**Low implementation cost**, made possible by the short axial length and overall small footprint of axial flux machines;

**High scalability**, made possible by the flat ("pancake") shape of axial machines. For example, up to three AFM-140 machines can be combined using a common drive shaft to supply up to 1800Nm peak torque, for only 120kg of weight;

**High efficiency:** up to 96.5% peak efficiency;

**Lower gearing requirements**, made possible by the high torque of EVO machines. In some cases this allows for the complete elimination of the gearbox, resulting in further cost and efficiency improvements.

**Compact Footprint:** The AF140 Motor/Generator has the compact size length of 115mm and diameter 380mm.



Radial Flux Machine



Fig 1. AFM-140 Axial Flux Motor

Fig 2. Comparison between Axial and Radial topology

Fig 3. DuoDrive fitted in London Taxi vehicle demonstrator



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# Libralato Holdings

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The number one priority of the UK Carbon Reduction Strategy for Transport (July 09) is to develop more efficient engines.

The NAIGT Technology Roadmap identifies higher efficiency IC engines, engine downsizing, and optimized range extender engines as research priorities. The Libralato engine is a new type of rotary engine, with a new thermodynamic cycle, which is ideally suited to operate in hybrid electric vehicles – HEVs or PHEVs (parallel, series or dual mode).

The Libralato rotary engine has two rotors fixed by their own bearings, connected by a sliding vane. The rotors have different (overlapping) diameters of circumference and their motion forms and reforms three separate chambers within the engine during each revolution. The leading rotor is engaged with the expansion of the air/fuel mixture and a first stage compression of intake air. The following rotor is engaged with aspiration and a second stage compression. Air enters via a port at the centre of the engine and at one point also via the rotating exhaust port at the periphery of the engine. The first stage compression is used to scavenge the exhaust gas at low pressure. The engine has a power phase in every revolution.

This unique design avoids the problems of the Wankel engine by: large sealing surface areas of the rotors; short flame paths acting against an acute angle working surface area; good thermal dispersion via fresh air scavenge phase; and low bearing wear due to dynamic balance. A 50kW gasoline version of the engine suitable for segment C/D cars is calculated to deliver the following attributes: \$880, 28Kg, 600cc; CR 10:1; ER 1:14.2; RPM 4,000; BMEP 8.82 Bar; Nm 119, BSFC 200g/kWh.

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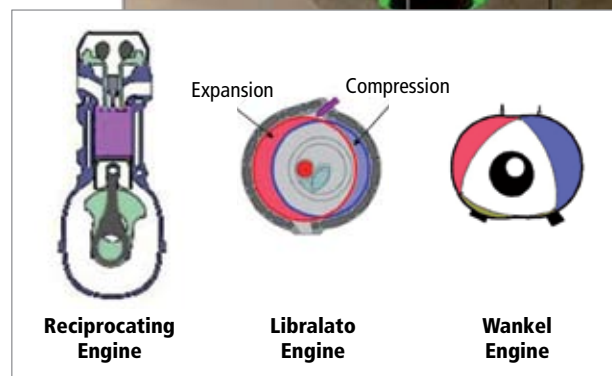
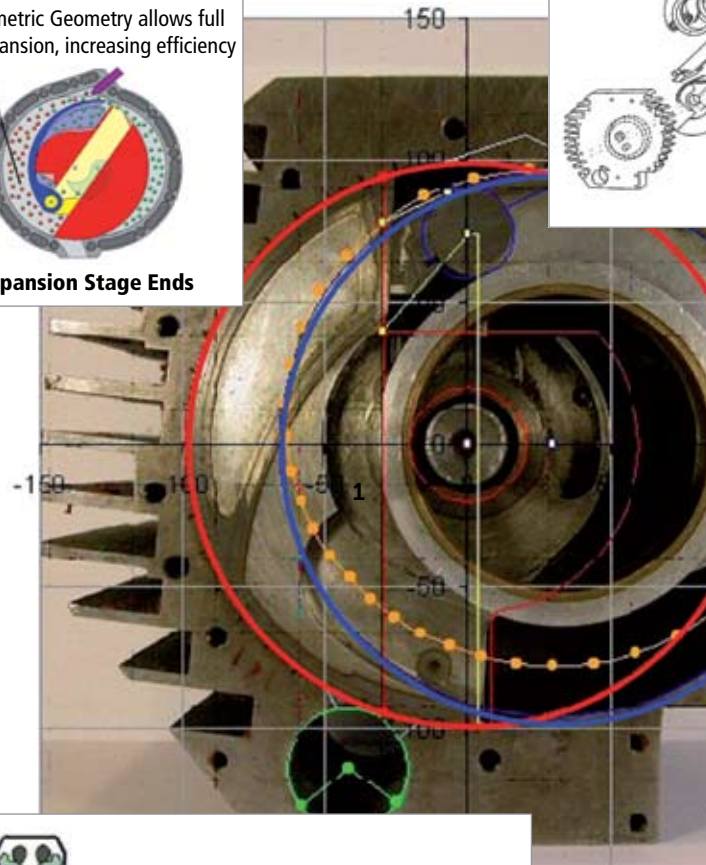
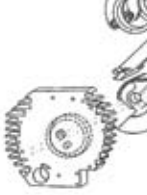
Asymmetric Geometry allows full gas expansion, increasing efficiency



Expansion Stage Ends

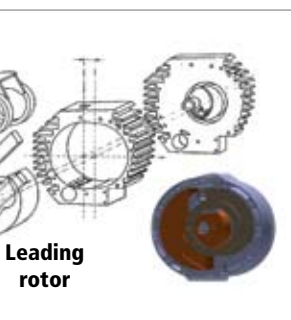
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Following rotor

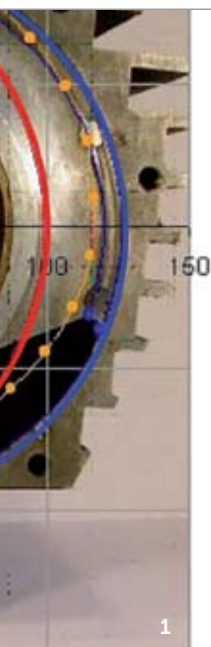


3

**The most cost effective method to reduce CO2 from LDVs to below 75g/km is through hybridisation. The Libralato engine can increase hybrid engine efficiency by 33%, reduce mass by 50% and reduce costs by 30%.**



Leading rotor



1. Proof of Concept engine mechanism
2. Asymmetric geometry
3. Engine size comparison
4. Principal Libralato engine parts

## Key features

**Only four principal moving parts:** leading rotor, following rotor, sliding connecting vane, rotating exhaust port – dynamically balanced with exceptionally low NVH.

**Predicted 30% reduction in production costs due to:** reduced mass, redundancy of con-rods, crankshafts, valvetrains, camshafts etc, reduced manufacturing tolerances.

**Predicted 50% size and weight reduction** due to rotary design (similar to Wankel).

**New Libralato thermodynamic cycle** based on gas exchange between three chamber interfaces.

**Predicted 10% absolute efficiency increase** (33% CO<sub>2</sub> reduction relative to 30% efficient gasoline engine and 25% reduction relative to 40% efficient diesel engine).

**Predicted 5% thermal efficiency increase** due to asymmetrical compression and expansion volumes (~ Atkinson Cycle; reference Toyota Prius engine 36% efficient).

**Predicted 5% mechanical efficiency increase** due to rotary design – torque transferred directly to output shaft (reference REVETEC engine 38.5% efficient).

**Predicted to meet Euro VI emissions standards due to:** more complete combustion of HC, lower residual exhaust gas, lower demand for aftertreatment.

**Potential to integrate all HEV/PHEV components** (including batteries) within existing engine cavities – enables hybrid versions of existing models/retrofitting for minimised costs.

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WINNER

# Oxy-Gen Combustion

20

Homogeneous Charge Compression Ignition (HCCI) and Controlled Auto-Ignition (CAI) have been widely touted as a key technology in the future road map of the automotive industry. Engines that can simultaneously reduce fuel consumption and emissions but, unlike hybrids, do not require a change in the vehicle or engine architecture.

## Future Growth

By 2050 the global fleet of vehicles is likely to quadruple to 3 billion with the growth largely in emerging markets such as Brazil, Russia, India and China. However this poses a problem for Hybrid or Electric Vehicles where the unit cost is greater than conventional vehicles. With poor sales in wealthier developed nations it is even more difficult to envisage widespread adoption in emerging markets. The solution is likely to be a fossil- or bio-fuel motor engine which can burn fuel leaner and reduce emissions without costly after-treatment systems.

## Current IC Engines

The modern spark ignition gasoline engine has seen its market share diminish recently to more fuel efficient compression ignition diesel engines. The drawback with the gasoline engine is that it operates close to the stoichiometric mixture of air and fuel in order for the catalytic converter to effectively treat nitric oxide emissions. Lean combustion is not possible and throttling losses are common. A controlled auto-ignition (CAI) engine compresses a lean mixture of air and fuel to the point of auto-ignition. With no spark plug, combustion is flameless with multiple points of ignition. The result is lean,

low temperature combustion reducing nitric oxide emissions close to zero. Removing the need for a three-way catalytic converter and delivering the fuel efficiency of a diesel engine.

Compression ignition diesel engines also have limitations and emissions remain a significant problem. Even though combustion is leaner it results in high particulate and nitric oxide emissions. Both of these emissions are treated in the exhaust system but the treatment systems can reduce the efficiency of an engine by as much as 8%. A Homogeneous Charge Compression Ignition (HCCI) diesel engine makes the transition to flameless low temperature combustion reducing the nitric oxide emissions close to zero and, because the air and fuel is premixed, the particulate emissions are also reduced close to zero.

Oxy-Gen Combustion can deliver these emissions and fuel savings through its enabling HCCI and CAI technology.

1. Low cost and low carbon
2. Oxy-Gen's HCCI Concept Engine
3. Vehicle architecture unchanged
4. Fuel lean combustion



**Lean low temperature combustion, reducing fuel consumption and CO<sub>2</sub> emissions by as much as 15–30%. HCCI and CAI will remove the need for costly exhaust after-treatment systems to reduce nitric oxide and particulate emissions.**



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4

**80**

**Towards  
80g CO<sub>2</sub>/km  
and lower**



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Find out more about our current initiatives, benefits of LowCVP membership, and future Technology Challenges at our website:  
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## Technology Challenge 2009

Identifying innovative low carbon  
vehicle solutions from UK SMEs



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*low carbon vehicle partnership*