

# PML Builds 640hp Electric MINI

## 160hp per Wheel

While the entire world's most famous motoring names look on, a British company, PML, has chosen the UK's most prestigious motor show as the venue to strip away all the misconceptions surrounding electric/hybrid vehicles and to showcase a truly awesome car. Featuring four revolutionary electric wheels, the standard BMW Mini One you can see on Stand 270 is predicted to have a top speed approaching 150mph and to out-accelerate a Porsche 911 Carrera from 0-60mph. Brake horsepower is a stunning 160bhp per wheel - 640bhp in total.

The car, dubbed the Mini QED, has been designed to run for four hours of combined urban/extra urban driving, powered only by a battery and bank of ultra capacitors. For longer journeys at higher speeds, a small conventional internal combustion engine (ICE) is used to re-charge the battery. In this hybrid mode, fuel economies of up to 80mpg can be achieved.

Explains Martin Boughtwood, PML's MD: "Until now, most electric vehicles have been little more than souped-up milk floats, limited by range and speed, with compromised performance. For those with a green conscience who also value an enhanced motoring experience, there is still something missing.



"Working in partnership with our customer, Synergy Innovations, we set out to demonstrate what our electric wheel technology is capable of. We simply took a standard BMW Mini One, discarded the engine, the disc brakes, the wheels, and the gearbox. These components were replaced by four of our electric wheels, a lithium polymer battery, a large ultra capacitor, a very small ICE with generator (so small it almost fits alongside the spare wheel), an energy management system and a sexy in-car display module."

The benefits of PML in-wheel drive technology are;

- It is adaptable to other vehicle chassis
- It eliminates the need for gearing and mechanical drive train
- It allows more space inside the car

The vehicle has three driver-selectable modes of operation:

- Eco mode for town/city frequent start-stop driving;
- Normal mode for daily commuting and ICE- equivalent operation, and
- Sport mode for super car performance.

Other notable features include:

- No (mechanical) brakes (= returned energy!)

All braking is performed by the wheel motors acting as very efficient electrical generators which return almost all of the energy back to the battery system. The beauty of this dual-circuit, ultra safe system is that your green conscience can be quite content even when accelerating hard, since you are assured of collecting most of the expended energy when it is time to slow down rapidly.

## **ABS as standard – even when accelerating**

Because the wheels are high performance motors, ABS comes as a standard function built into each wheel's software. Now anti-skid can also be applied to acceleration since the motor can smoothly control torque delivery to/from the road in both cases. Flooring the brake or accelerator hard merely results in controlled maximum torque, giving the shortest possible stopping or acceleration time.

## **Clever wheels**

The technology eliminates the need for crude differential gears to share power between left and right sides. The wheels are in constant communication with each other deciding 1000 times each second how much torque share is optimum for the current driving conditions. Should one wheel detect a slippery surface and take appropriate anti-skid actions, the other wheels are aware of this instantly and adopt an appropriate compensating strategy to keep the vehicle as stable as possible.

## **640 brake horsepower – for life!**

Each wheel develops 160bhp - 640bhp in total. The original Mini One develops less than 100bhp with an engine that weighs nearly double the weight of the four electric wheels! Apart from wheel bearings there are no wearing parts in the electric wheels; this means the horsepower stays for the life of the vehicle - and beyond.

## **Simple, safe, versatile charging**

As the battery level reduces, the rear mounted ICE/generator starts to automatically top up the battery. So when you arrive at your destination you can simply park the vehicle knowing that when you return the battery will be replenished. Alternatively you can take advantage of lower cost mains electricity and plug in to recharge. So you never need to worry about battery capacity or how to recharge. During operation, as the battery level falls the generator cuts in, enabling an average speed of 60 – 70mph to be sustained with no further battery depletion.

## **Super capacitor – super acceleration**

Capacitors are used to store electrical energy. The difference between batteries and capacitors is that capacitors can release/absorb their energy 10 times faster than a battery. For acceleration or power boost at higher speeds the capacitor enables nitro-like performance, more than doubling the power from the battery

during these events. Very efficient energy recovery means almost nothing is wasted during stop/start city travel.

## Energy flow management

A significant key to super performance is optimum energy management which continuously decides where the energy flow should be – battery, super capacitor, generator or wheels. By clever optimisation of the flows, best use can be made of available reserves, enabling a fun driving experience whilst protecting the planet.



## Small engine and generator

The small ICE weighs a mere 15kg (less than 1/10th of the original Mini One engine) and delivers peak power of 20kW and continuous power of 15kW. A high efficiency electrical generator is fitted to the engine to provide power when the battery depletion level demands. The key point is that the engine is run at a continuous speed and load – which results in optimum efficiency fuel conversion. After delivering the energy to the battery system the mileage equivalent translates to between 65 and 80mpg!

## In-car display

With all this advanced technology the driver needs to have clear and complete information presented. The in-car display module uses the latest touch screen technology with intuitive display and scroll options. Selectable driving modes allow economy mode to sport boost mode at a touch. Displaying available mileage allocated by battery and fuel along with boost status, the display gives comprehensive information. As well as standard speed, diagnostic and status functions, the display is GPRS enabled allowing future options of:

- Remote diagnosis of any fault
- Auto tracking of speed limits (optional!)
- Auto management of generator to prevent inner city operation
- History storage and system configuration interface

## **QED: What Next?**

Having developed its high performance in-wheel drive systems, PML worked in partnership with Synergy Innovations to demonstrate, once and for all, that environmentally-friendly Electric/Hybrid vehicles can maintain or even surpass the performance of cars powered by conventional internal combustion engines.

Furthermore, Martin Boughtwood predicts that developments in battery and ultra capacitor technology in the near future will eliminate the need for any charging ICE and generator. Although PML's Electric/Hybrid Mini will not be generally commercially available, the company is interested in discussing possible one-off orders and collaborations.

## **Who is PML?**

PML (originally Printed Motors Limited) invented and patented the printed armature motor some 40 years ago. The printed armature motor was the first "pancake" format motor and led the world in compact high performance brushed motors. In the last 4 years, under private ownership, PML has concentrated on the pancake format brushless electric traction "wheel motor" and wind turbine generators. This year marks the launch of several new products pushing forward direct (gearless) motor drive systems. Synergy Innovations was set up to research and develop alternative approaches to use of the planet's resources and has partnered with PML over the last 8 months to help turn the vision of the electric Mini QED into reality.

The Mini project was undertaken to demonstrate the super high performance now possible from PML Hi – Pa drive and QED technology. With very high efficiency, light weight and extreme levels of reliability, PML wheel drive systems are suited to harsh environments needing high levels of safety.

Set to take off in a big way, PML is a British company investing heavily in R&D to take advantage of the benefits of super efficient lightweight wheel motor drive systems in a global economic climate looking for major changes in transport efficiency improvements.

With the odd exception of some rather impractical and eccentric examples, today's electric or hybrid electric vehicles substantially under perform when compared both with high performance gasoline cars and also with theoretical limits of electric drive systems. Why are major manufacturers not putting more emphasis on in-wheel electric drive systems?



As PML is a leader in high performance motor and drive system technology, we felt it time to demonstrate what really can be achieved today using the best technology available! Produced in conjunction with our

partner Synergy Innovations, the car you see today is one of 2 vehicles and is the result of 8 months of intense effort following PML's 4-year product development programme.

The MINI was chosen as the platform because of its broad appeal and iconic styling. However it is not a light vehicle and has limited space to integrate the substantial component set required for a top performance electric vehicle – if we can successfully convert this vehicle then most others should be easy by comparison!

The target specification was defined at the outset as follows:

- Emissions Zero
- Autonomy 1000km
- Top speed 200kph minimum
- Acceleration 0–100kph in 6 seconds
- Braking No mechanical brakes
- Fuel Zero carbon
- BHP 250bhp minimum

The specification as it stands today is:

- Emissions Zero - for 4 hours combined
- Urban and extra urban driving
- Autonomy 1000km (predicted from bench fuel consumption trials)
- Top speed Approaching 240kph
- Acceleration 0-100kph in under 5 seconds
- Braking Regenerative only (other than handbrake for parking)
- Fuel Gasoline
- BHP > 640bhp
- Fuel consumption 65 – 80mpg

Some key features are:

- Independent Quad Electric Drive
- Traction control and anti-skid built into each wheel
- Regenerative braking recovers almost all energy
- Blistering acceleration and high top speed
- Efficient, range-extending onboard engine/generator
- No need to recharge (although you can “plug in” if you wish)
- Seriously attractive and feature rich in-car display

The vehicle development will continue for some time, especially in the area of engine/fuel options and GPRS services and features. Today, the vehicle incorporates the very best drive system technology available anywhere in the world. It is truly an outstanding example of British innovation at its best!

*BMW (UK) Ltd has requested that we mention they have no involvement with this project and that such conversions invalidate warranty!*

## **Specifications**

### **Motors**

4 x 750Nm 1800rpm high efficiency Brushless permanent magnet sine wave Hi-Pa drive™ 24 phase water-cooled

### **Drive electronics**

4 x 480Amp 450V Hi-Pa drive™ 24 phase sine wave inverter IGBT water cooled CAN bus communications

## **Battery**

300V nominal 70Amp Hour Lithium Polymer 700Amp peak

## **Battery Management system**

Active cell balancing, temperature and voltage monitoring CAN bus communications

## **Ultra Capacitor**

350V 11 Farad 700Amp limited

## **Energy re-circulator**

1400Amp continuous IGBT water cooled CAN bus communications

## **Generator**

Engine: 250cc 2 cylinder 4 stroke gasoline 15kW at 7000rpm

Generator: 20kW continuous at 250V 80Amp

Controller: 350V 80Amp water-cooled CAN bus communications

## **Display**

Touch screen high resolution LCD with steering wheel and 4 area screen menu indexing

Displays battery, ultra cap, fuel status, mileage calculator, boost display and options for GPRS link to allow remote diagnostics and tracking

Diagnostic and configuration menus CAN bus communications

## **Software and safety features**

### **Anti-skid**

Dynamically monitors wheel to detect skid onset. Manages state to obtain maximum non-skid torque from wheel in either acceleration or braking modes.

### **Traction control**

Dynamically distributes torque when any wheel is in skid management mode to obtain optimum tractive effort and stability.

### **Steering sensor**

Optional addition to provide feed forward input to traction control system. Allows driver intent and wheel alignment to influence vehicle stability and tractive effort functions.

Vehicle attitude, yaw and gyroscopic sensors

Optional addition to provide further stability inputs to traction control system. Allows vehicle orientation and direction (if different from steering wheel implied direction) to be accounted for in determining optimum tractive effort distribution.

## Differential/torque share functions

Standard feature incorporated within each wheel to allow optimum speed and torque share when cornering. Minimises tyre scrub and power wasted energy.

## Efficiency optimisation

Dynamic management of power delivery to wheel ensures best use of available power. Accounts for motor related efficiency variations across speed and torque ranges.

## Key safety items

- Dual circuit power distribution
- Dual circuit brake and accelerator systems ensure 100% redundancy
- Hi-Pa™ drive ensures multi level redundancy in critical power systems
- Dual wheel sensors
- Dual CAN bus systems
- Temperature monitors of all drive electronics, motor windings, battery cells and ultra capacitors. All
- temperature monitors fitted with fold-back control function.
- Software and hardware over voltage and over current monitors
- CAN watchdog
- Processor watchdogs

PML is also active or involved in Wind turbine generators and controls; Marine and underwater motors and drives; robotics; winches and hoists; very large diameter motors and drives (i.e. 2m to 22m diameter); other integrated motor and electronics systems for various wheeled applications including lightweight plastic wheels; joysticks and sensors.

