

## Electric Vehicles on Land - Where, Why, What Next?

By Dr Peter Harrop  
IDTechEx

[p.harrop@IDTechEx.com](mailto:p.harrop@IDTechEx.com)

[www.IDTechEx.com](http://www.IDTechEx.com)

North America IDTechEx, Inc. Suite 0222 222 Third Street Cambridge MA 02142 United States  Tel: +1 617 577 7890 Fax: +1 617 577 7810	Europe (UK) IDTechEx Ltd Downing Park, Station Road, Swaffham Bulbeck, Cambridge CB25 0NW United Kingdom.  Tel: + 44 (0) 1223 813703 Fax: +44 (0) 1223 812400	IDTechEx (Germany) Louisenstr. 7a 01099 Dresden Germany  Tel: +49 371 36777 643 Fax: +49 371 36777 639
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## 1. Introduction

This white paper provides an introduction to hybrid and pure electric land vehicles and a pointer to the best sources of further information. It shares some of the information in the IDTechEx reports, “Hybrid and Pure Electric cars 2011-2-21”, “Electric Vehicles for Military, Police and Security 2011-2021”, “Industrial and Commercial Electric Vehicles 2012-2022” and “Electric Buses and Taxis 2011-2021”.

### 1.1. What is an EV?

The term electric vehicle EV is limited to free running vehicles by land sea and air, so it does not include tethered Remotely Operated Vehicles (ROVs) under the sea that are often used by military forces. It does not include vehicles lacking a large traction battery or similar power source on board so we are not including large diesel electric and nuclear electric submarines and ships for example. Yet what remains is already a fast growing \$53 billion business at ex-factory prices. About 90% of that concerns land vehicles, the subject of this white paper.

Electric vehicles can be pure electric with only an electric power source – a battery and or a supercapacitor bank - on board or hybrid meaning with another major power source on board as well that is not electric. That may drive the wheels when extra power is needed ie a parallel hybrid – or simply charge the battery – a series hybrid.

2.

## Why have them?

For superlative performance, an electric vehicle is often the answer. For example, 0-60 mph in one second is achieved by some pure electric motorcycles and most manufacturers of designer sports cars are racing to make hybrid and pure electric versions because these make their existing products look jaded, not just old-fashioned. Military forces have many reasons for deploying hybrid electric and pure electric vehicles. For example, they can be silent and almost free of vibration as is useful in a robot bomb disposal vehicle or a stealth vehicle used for surveillance. However, there are many other reasons why electric land vehicles are rapidly gaining market share. An electric golf car is cheaper to make than an internal combustion one and easier to refuel, yet it lasts longer, needs less maintenance and has simpler parts.

Electric power trains can be more reliable, easier to repair and last longer. We shall even discuss structural batteries and smart skin coming along where power electrics and electronics become part of the structure of the vehicle. In all cases, reduced maintenance is welcomed in military applications because that equates to greater security and operational flexibility not just cost control.

Green Wheel of China demonstrated the following all-electric jeep style vehicle at eCarTec in Germany in October 2011.

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Fig. 2.1 *Green Wheel jeep style pure electric vehicle*



Source IDTechEx

Industrial electric vehicles are often pushed by legislation. It is illegal to have an internal combustion engine in a warehouse, factory or other building so forklifts etc are electric. The same is true of indoor go-karts. Commercial vehicles are mainly on-road so only pollution laws apply here yet these are also coming in on payback – better fuel economy and lower cost of ownership. With trucks it is less compelling than with buses because buses have a lot of stop-start and frequent speed variation, where hybrid power trains excel over the traditional stuff. Nonetheless, pure and hybrid electric trucks are now a reality.

Fig. 2.2 *Pure electric truck*



Source Balqon

Fig. 2.3 *Polaris Industries Neighborhood Electric Vehicles NEVs*

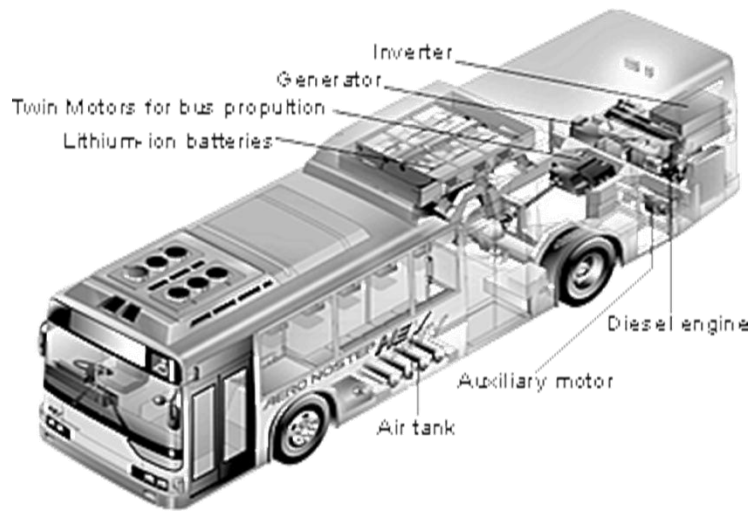


Source Polaris Industries

The range of affordable pure electric land vehicles is problematic at only 160 km (100 miles) recently and 50% more than that for the best today. Top of the market ones have many hundreds of km range and that will permeate down to mainstream land vehicles over the next decade as many improvements are made. However, a long range car, bus or truck has to be hybrid for now. Although a hybrid bus costs up to 100% more than a conventional one, governments and fleet operators buying them tolerate a poor payback of six years or so in some cases in order to burnish their green image and increase ridership. The quieter, more comfortable ride increased ridership in buses in the Netherlands by 13% for example.



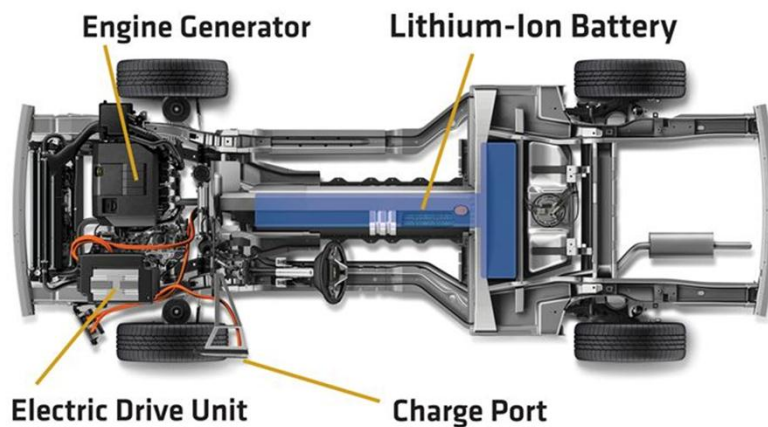
Fig. 2.4 *Mitsubishi Fuso hybrid bus*



Source Mitsubishi

The successful Chevrolet Volt car power train provides plug in charging giving 80 km/ 50 miles pure electric range. It is a series hybrid and sales are stronger than those of equivalent pure electric cars because there is no range anxiety. We are in the age of the hybrid electric land vehicle.

Fig. 2.5 *The successful Chevrolet Volt car power train*



Source Chevrolet

Fig. 2.6 *Pure electric forklift truck with the new lithium-ion battery improving performance and reducing down time and labour costs*



Source Nissan

### 3. Technology in ferment

The technology of land EVs is changing extremely rapidly, offering a stream of improved user benefits and affordability. Some electric buses use supercapacitors instead of batteries, hybrids are starting to employ designed-to-purpose range extenders to charge the batteries. Such range extenders vary from fuel cells in imminent Mercedes, Toyota, Tata Motors and other vehicles but other range extenders include very small jet engines and other options. Printed electronics and electric components are removing up to 40% of cost, weight and wasted space. Three generations of lithium-ion battery are coming in to replace lead acid and make new things possible. Exceptionally lightweight, more powerful electric motors are on the schedule. Energy harvesting is beginning to grab back up to 15% of wasted energy and this is additive, with energy harvesting shock absorbers, regenerative braking, thermovoltaics and photovoltaics adding up to huge gains even before fast charging by the roadside becomes ubiquitous.

#### 3.1. Many new forms of range extender

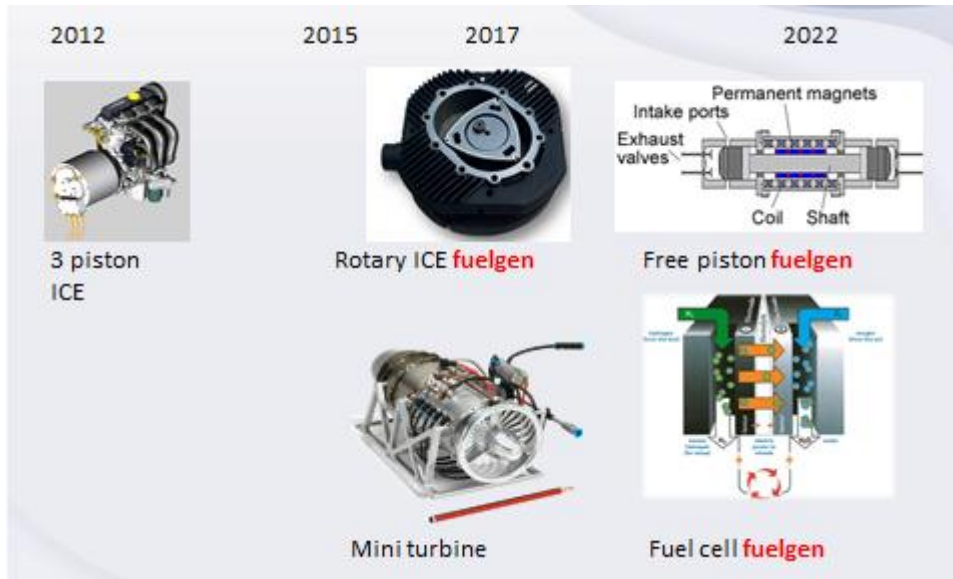
Range extenders that simply charge the battery are appearing in many guises from fuel cells to mini turbines (jet engines). Fuel generators are forms that inherently produce electricity without a rotating shaft driving a separate generator.

Fig. 3.1 *Planned Jaguar supercar with two micro turbine range extenders generating 140kW total*



Source Jaguar

Fig. 3.2 *Examples of range extenders using a generator and ones with inherent electricity generation marked fuelgen*



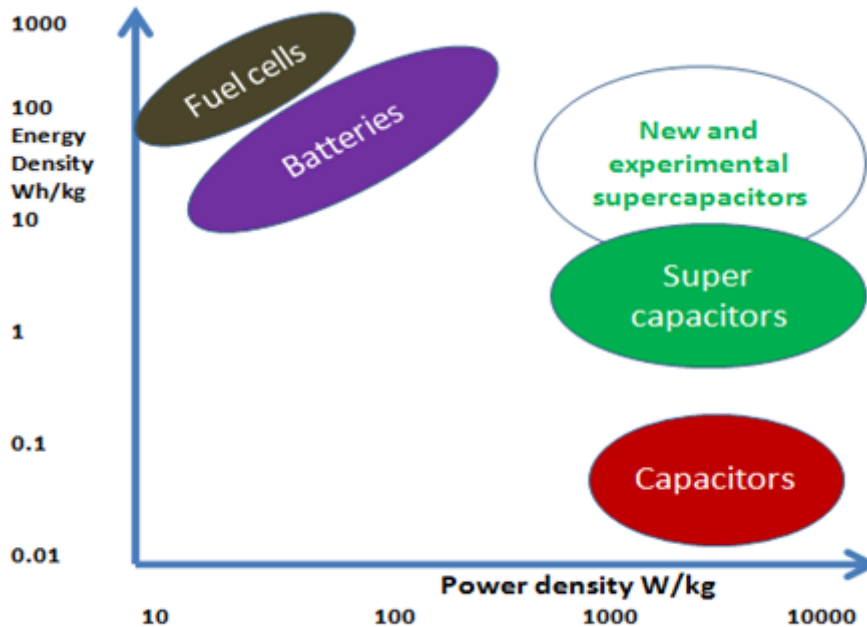
Source IDTechEx

### 3.2. Supercapacitors

Look out for deployment of supercapacitors that take over much of the function of traction batteries beyond today's assistance with fast charge and discharge. This will be because supercapacitors and later supercabatteries (Asymmetric Electrochemical Double Layer capacitors) will offer longer life and greater reliability and possibly other benefits in military vehicle design.

New and improved supercapacitors and their variants such as supercabatteries are becoming more and more useful in EVs. They started by being used across batteries to cope with fast charge and discharge but some now have useful amounts of power stored yet still the advantages over batteries such as life of over 20 years and very high reliability.

Fig. 3.3 *New and improved supercapacitors and their variants are becoming more and more useful in EVs*



Source Industry

### 3.3. Energy harvesting

The main forms of energy harvesting being used or considered for military electric vehicles are harvesting of motion, heat and light. Primarily, capturing motion consists of the favoured brushless traction motors working in reverse to capture and electrically return up to 15% of braking energy and, soon to be introduced, dampers capturing vertical energy – up to 1kW per damper on a large vehicle. However, complete energy harvesting active suspension is being researched and there are dreams of body flexing also generating energy. Wind turbines can be deployed when the vehicle is stationary. Air and marine vehicles achieve the equivalent of regenerative braking by soaring, mooring in a tidestream or sailing with the propeller trailing.

Next most popular is capturing light using photovoltaics (solar cells), here the progression is towards transparent or translucent film over the whole vehicle, even underneath as it is developed to capture infrared not just light,. Indeed, in the laboratory, some photovoltaics captures ultra violet as well. Meanwhile, structures that unfold or expand when parked gain more area and therefore electricity and some vehicle manufacturers are looking at self-sufficient rear lights etc thanks to local photovoltaics, reducing the large cost and vulnerability of wiring.

Examples include nantenna=diode photovoltaics promising flexibility with double the best efficiency achieved

with PN junction and photoelectrochemical “DSSC” photovoltaics today. Meanwhile, we expect Copper Indium Gallium Diselenide CIGS photovoltaics to be a front runner for long life flexible, conformal photovoltaics. The much needed photovoltaics that harvests UV, visible and IR and/or that is transparent to be many years away.

### 3.4. Printed electronics and electrics

Printed electronics and electrics will save up to 40% of weight, space and cost of control clusters and other human interfaces and wiring in electric vehicles, eventually encompassing much of the battery pack electrics and electronic circuitry and several forms of energy harvesting feeding the battery, multi-mode harvesting becoming commonplace, first in marine military vehicles the in air and land military vehicles. For more on this see the IDTechEx report, “Printed Organic and Flexible Electronics Forecasts, Players & Opportunities 2012-2022”.

### 3.5. Structural components and smart skin

Dumb vehicle bodies and chassis will progress to smart forms with advanced structural composites married to smart skin performing many functions including energy harvesting, storage and sensing condition in real time. Something of a halfway house is the incorporation of components into the body of the vehicle as with T-Ink printed tape replacing the much bulkier and heavier copper wire. Then there are the structural batteries in the Drayson racing cars being built in the UK in 2012 that have lessons for the military. Battery geometry is changing with this. Flat, wide batteries employed in aircraft wings, such as those of surveillance UAVs at over 10,000 meters up turn out to have faster charge-discharge and simpler cooling when well-made and this is now being applied to land vehicles. Add that to the conformal thin film photovoltaics now favoured, the capacitive skin that destroys incoming ordnance, printed logic and power circuits and so on and clearly various forms of smart vehicle skin are on their way for land, sea and air vehicles. That happens inside as well as outside, as with the printed and laminated T-Ink lighting and controls that release up to 40% of space, weight and cost of dashboard and overhead instrumentation. In-wheel motors are another devolution of function to the outer parts of the vehicle.

Fig. 3.4 *Drayson electric racing car in the UK pioneers many new technologies including continuous charging and structural batteries*



Source Drayson Racing Technologies

### 3.6. Innovative charging

Drayson Racing Technologies and HaloIPT have teamed up to develop a new on-the-go charging system for electric cars. HaloIPT had previously announced that they were working on the technology and have now brought Drayson Racing Technologies into the project. The technology will be tested on race cars with the technology built into the track to wirelessly provide power so drivers don't have to stop to charge the vehicle. This copes with misalignment over the transmitter pads, which is a common problem with on-the-go charging. Primarily developed by HaloIPT (IPT standing for inductive power transfer), the technology got its start from UniServices a University of Auckland commercial subsidiary in New Zealand. In EVs best practice often comes from all over the world and in the more unusual types of vehicle.

### 3.7. Military land vehicles and in-wheel motors

The US Army sees hybrid-electric powered trucks and the hybrid-electric Future Combat Systems FCS as key in its objective of 75% lower fuel consumption by 2020. This is as much to do with operational flexibility - permitting previously impossible speed of deployments - as

cost saving and reduction of pollution. Significant savings have already been demonstrated. Operating as a hybrid, with a 24-gallon tank, a truck travels 375 miles without refuelling compared to a conventionally powered vehicle, travelling less than 60% of that range. Primarily, savings do not relate from the cost of fuel itself, but to reduced army logistical transportation requirements - as fuel takes up about 70% of the logistical tonnage haul in a heavy armored division. Several military EVs have in wheel motors – up to six of them. This permits better steering and traction but it involves extra cost, often involving a completely new vehicle platform, so in-wheel motors are little used in non-military applications as yet since the up-front cost of both hybrid and pure land EVs is already much more than the traditional equivalent. The exception is in-wheel motors in two wheel vehicles, particularly the popular e-bikes ie with a throttle.

Fig. 3.5 *Millenworks light hybrid vehicle*



Source Millenworks

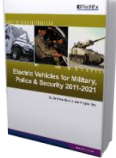



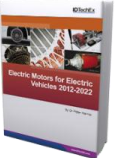
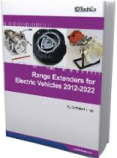
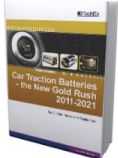
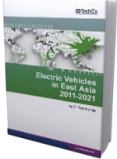
### 3.8. Third generation traction batteries

The increasingly favoured lithium-ion traction batteries come in three generations. First generation is high energy density but sub optimal temperature stability and safety unless external means are employed such as cell sensing into a sophisticated battery management System and often water cooling. Lithium cobalt oxide cathodes are employed, just like those in a laptop or phone battery. Second generation is inherently safer due to cathodes such as lithium iron phosphate that tolerate higher temperatures and/ or polymer + gel electrolyte instead of the flammable organic liquid electrolytes traditionally used. Third generation batteries are claimed to off the best of both worlds – high energy density and thermal stability though no lithium-ion cell is inherently fully safe. An example of a third generation battery is the Oxis Energy lithium-sulfur version to be shown in a motor cycle and a microcar in 2012. Earlier use of lithium sulphur was seen in Military Vehicles and Unmanned Air vehicles UAVs, in both cases using Sion Energy versions. All this is driven by the demand for longer electric range for both plug in hybrid and pure electric vehicles.



# 4. IDTechEx Electric Vehicles Reports

Table 4.1 IDTechEx Electric Vehicles Reports

<p><b>Electric Vehicles by Application</b></p> <p><i>All these reports forecast numbers, ex-factory unit value and total market value for ten years</i></p>							
<p><b>MASTER REPORT</b></p>  <p>Electric Vehicles 2012-2022</p>							
 <p>Industrial and Commercial Electric Vehicles 2012-2022</p>	 <p>Electric Buses and Taxis 2011-2021</p>	 <p>Electric Vehicles for Military, Police &amp; Security 2011-2021 <i>including land, sea and air</i></p>	 <p>Hybrid &amp; Pure Electric Cars 2011-2021</p>	 <p>Light Electric Vehicles 2011-2021 <i>including e-bikes and mobility vehicles for the disabled</i></p>	 <p>Electric Aircraft 2011-2021 <i>including manned and unmanned aircraft and airships</i></p>	 <p>Marine Electric Vehicles 2011-2021 <i>including surface craft, AUVs, private &amp; commercial submarines, sub-aqua scooters</i></p>	
<p><b>Electric Vehicle Technologies</b></p> <p><i>All these reports forecast numbers, ex-factory unit value and total market value for ten years except for the Advanced Energy one</i></p>							
 <p>Electric Motors for Electric Vehicles 2012-2022</p>	 <p>Range Extenders for Electric Vehicles 2011-2021</p>	 <p>Electric Vehicle Traction Batteries 2011-2021</p>	 <p>Car Traction Batteries – The New Gold Rush 2011-2021</p>	 <p>Advanced Energy Storage Technologies – Patent Trends and Company Positioning</p>	 <p>Energy Harvesting for Electric Vehicles 2011-2021</p>	 <p>Electric Vehicle Charging Infrastructure 2011-2021</p>	 <p>Wireless Power Transmission for Consumer Electronics and Electric Vehicles 2012-2022</p>
<p><b>Geographical</b></p>  <p>Electric Vehicles in East Asia 2011-2021 <i>with forecasts for China, India, Japan, South Korea, Other East Asia</i></p>							
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