Response to the consultation on the "8th Adaptation to scientific and technical progress of exemptions 2(c), 3 and 5 of Annex II to Directive 2000/53/EC (ELV)"

About Olife: (R)evolution in Car Batteries

Current conventional lead-acid batteries (LAB) do not work effectively in start-stop systems. Their life cycle is dramatically reduced due to repetitive ignition and LABs also suffer performance issues if exposed to low temperatures. In Europe, lead acid battery production and use is allowed only due to an exemption from End-of-Life Vehicle Directive 2000/53/EC, (Annex ll, exemption no. 5 – Batteries). The exemption shall be in place until a viable alternative to lead car starter batteries emerges. The time has come. Olife has developed a new car battery that's a milestone in the evolution of the automotive industry: the first full substitute for lead- acid batteries.

This technology, due to its high dynamic charge acceptance and cold cranking power, provides a feasible solution to all the challenges of start-stop batteries. In addition, the Olife lead-free battery fully complies with the EU regulation mentioned above. The technology is patented in more than 50 countries throughout the world. The production technology procedure development has recently been finalised and Olife is currently undergoing the verification of the production technology by producing a limited number of batteries. The aim is to launch full commercial production at the end of 2015. Planned production capacity is hundreds of thousands of pieces per year. In parallel, Olife will build production capability abroad using the "licence producer" model of collaboration with dedicated strategic partners. (www.olife-energy.com)

Consultation Questionnaire

The following pages provide the requested input to the consultation document.

1. **Question 1 – Please explain whether the use of lead in the application addressed under Exemption 5 of the ELV Directive is still unavoidable so that Art. 4(2)(b)(ii) of the ELV Directive would justify the continuation of the exemption. Please clarify what types of vehicles your answer refers to, i.e., conventional vehicles and various types of hybrid and electric vehicles and which functionalities are covered (starting, ignition, lighting and other points of consumption)**

For the battery requirements for the vehicle technologies listed, there are different chemistries available. The most prominent and best developed are the following:

- **Lead acid (LAB)**
- **Lithium – ion (Li-ion)**: several sub groups including: LI- iron phosphate/cobalt/polymer
- **Nickel metal hydride (NiMH)** and other nickel based chemistries including: Ni – iron/cadmium

The main criteria for the battery chemistry choice are:

- **Energy density:** this is measured as energy output vs. weight or volume, i.e gravimetric energy density (watt hours per kilo) and volumetric energy density (watt hours per litre). This is of major importance in EV, and all hybrid electric vehicles. The volume occupied by the battery and the payload are critical factors for all electric vehicles. The main requirement is the provision of energy over a long period of time rather than high power bursts.

- **Power delivery,** the ability to supply high wattage output. For this, the delivery of high current and voltage in a short bursts is important. Particularly, for car starting and micro hybrid applications.
- **Charge acceptance: t**his is a critical parameter which is becoming increasingly important in the challenge to reduce carbon emissions. For all hybrid, mild hybrid and micro hybrid applications, it is essential that the battery can absorb as high a current as possible in order to maintain the battery in a good state of charge. The ability to be recharged quickly from the alternator and or regenerative braking is key to the implementation of all hybrid technology with subsequent carbon reduction benefits.
- **Operating temperature**: vehicles operate in various climate conditions worldwide and battery operating temperatures can vary from -50˚C to +70˚C. It is therefore important that the energy and/or power source functions under any given climate condition. A significant number of vehicle battery specifications, stipulate operating temperatures within the range of -20C to +50C. At low temperatures power delivery for engine starting is greatly reduced in all battery chemistries, particularly below 30˚C. Whereas higher operating temperatures lead to rapid deterioration of the battery materials and drastically reduce life.
- **Cost:** this is mainly a commercial issue but should be calculated over the lifetime of the vehicle. For the ELV directive, the cost of batteries over the lifetime of the vehicle is the true representative cost. In this case a high initial cost would not be a limitation if the battery life is long enough.
- **Recyclability:** an important criteria of the technology is the impact on the environment. The ability to recycle reduces the amount of waste disposal. However, the recycling process whilst minimising solid waste can produce gaseous and liquid emissions which can have an environmental impact. Recyclability should also be considered alongside environmental effects.
- **Public Health**: some materials are toxic and can be dangerous both in their production and use. For example cadmium used in Nickel Cadmium batteries is now banned in some countries. Similarly lead in lead acid batteries is considered a dangerous material with stringent precautions required during its production and use.
- **Environment,** the impact on the environment in total, including all production and recycling emissions, this encompasses all polluting materials including toxic material such as heavy metals and acid along with carbon and sulphur bearing emissions.
- **Availability of raw materials**: there are global reserves of Lithium in a variety of forms. Actual and potential sources of lithium are from pegmatite, continental brines, geothermal brines, oilfield brines and the clay mineral hectorite. Discoveries of Lithium bearing ores and chemicals are increasing annually, including recent discoveries in the Czech Republic and Afghanistan. Appendix 2 gives a brief overview on this.

Summary of available technologies for use in vehicles

Table 1 below summarises the different battery-dependant types of vehicle and the battery technology currently in use. In addition, it lists the most appropriate requirements in order to provide the optimum performance for that application, as well as the current technology and the most suitable available technology.

One of the key requirements for micro hybrid and SLI batteries is the cold crank performance, i.e. the ability to provide high power at temperatures well below freezing point. The CCA standards require for batteries to be tested at -18˚C, but many specifications list temperatures at -30˚C or less. Until recently, Li-ion batteries have not been able to meet this requirement. Recent advances in Lithium technology, in particular LiFePO4 chemistry, have enabled high power draw at temperatures below -40˚C. Putting Li-ion chemistry in the same category as lead acid for cold crank performance.

The use of li-$FePO_4$ combined with super capacitors is another major advance in battery technology, as it guarantees high cranking power at temperatures as low as -50˚C.

TABLE 1- Summary of battery function and effectiveness for Auto Vehicles

(Price not considered)

Vehicle application	Technology in use	Battery technology available	Required battery properties	Most suitable battery technology
Electric vehicles	Lithium-ion	Lithium-ion NiMH, LAB	High energy Density, good cycle life, low temperature energy	Li-ion
Plug in hybrid	Lithium-ion	Lithium-ion NiMH, LAB	Medium energy Density, good cycle life, good charge acceptance, low temperature energy	Li-ion,
Hybrid vehicles	Lithium-ion	Lithium-ion NiMH, LAB	Medium energy density, Good cycle life, Good charge acceptance, Low temperature energy	Li-ion
Mild hybrid	Lithium ion, NiMH,	Lithium-ion NiMH, LAB	Good cycle life, Good charge acceptance Low temperature energy	Li -ion
Micro hybrid	Lithium ion, LAB	Lithium-ion NiMH, LAB	High Power output Good charge acceptance Low temperature energy Low temperature power	Li-on/supercapacitors. Li-ion LAB
SLI	LAB, Li -ion	Lithium-ion NiMH, LAB	High Power output Good charge acceptance Low temperature Power	Li-ion/supercaps Li-ion LAB

2. **Question 2 – Question 2 - Asks to explain the efforts your organisation has undertaken to find and implement the use of lead-free alternatives in the manufacture of batteries for automotive uses and what alternatives you provide for the reduction or total elimination of the lead applied. In its subsection, the question asks to compare the alternatives that you suggest with lead based batteries to clarify on a quantitative basis how alternatives perform in relation to the lead-based batteries in respect of certain requirements**

Olife has patented a substitute and realistic alternative for the lead-acid batteries. It is a technology based on the combination of Li-ion batteries and super-capacitors in one unit. It provides the instantaneous power needed to support the battery in the first fraction of a second. This ensures its 100% operation in freezing temperatures and its reserve energy provides the necessary ranking current for the start-stop system. Tests have shown that the Olife battery/super-capacitor technology provides 30% more cranking power during this period, under cold crank test conditions, than a VRLA micro hybrid battery from a leading manufacturer. Additional testing is being undertaken to examine the effect of different climatic conditions on the battery performance as well as independent laboratory testing for the technologies suitability to fulfil the requirements of micro hybrid endurance testing. According to the norm of prEN50342-6.

It is the first real substitute to the lead-acid batteries. The Li-ion Batteries continuously refill the super-capacitors thus serving as a source of Reserve Capacity. The battery has low value of self-discharge and it will stay ready to start even two years after staying out of operations.

Olife operates reliably even if the electronic car accessories are on and the engine is not running. It is ideal for the start-stop system and thanks to its light weight it reduces CO_2 output and it is reliable in any outdoor temperature. The weight of the SLI battery is reduced by about 7 kilos.

Olife contains no toxic materials. It consists of aluminium, copper, nickel, plastics and organic compounds used as electrolyte in the lithium cells and the super-capacitors. It is fully recyclable and it has an extremely long life-cycle.

Extensive performance tests have been conducted along with field trials to ascertain its suitability for micro hybrid and SLI functions. Comparison tests against a leading manufacturer's high specification lead acid battery have been made. In these tests the Olife battery/super-capacitor combination proved superior in its power delivery and charge acceptance tests at ambient temperature and at -18C cold cranking tests

The Technology in a nutshell

Olife combines the most advanced technologies from capacitors and batteries to deliver a lead-free battery that fully replaces current conventional SLI units. It is a unique combination of supercapacitors and safe Li-ion (e.g. lithium iron phos¬phate) batteries in one unit. Unlike batteries, supercapacitors store and release electrical energy as electric charge and not in the form of bound chemical energy. This means that the release of electric current does not require a chemical reaction.

The supercapacitors provide the necessary cranking current regardless of temperature. The Li-Ion Batteries will, at any normal vehicle driving temperature (from -30°C to +50°C), continuously refill the supercapacitors. They also serve as a reliable source of necessary reserve capacity. Thanks to the supercapacitors, almost all of this capacity is available as starting current. The supercapacitors also level out all current peaks during normal operation of the car battery. Bearing in mind the sophisticated fuel-saving systems used in today´s vehicles this gives ideal protection to the Li-Ion chemical cells thus ensuring maximum life.

Main product features:

- Ideal for Start/Stop Systems

- Superb Performance
- Light Weight
- High Range of Operating Temperatures
- Superior Reliability and Durability
- Resistant to Extreme Vibration
- Starting Ability up to 90% DOD (Depth of Discharge)
- Lead/Acid Free
- Non Hazardous
- Eco Friendly
- RoHS Compliant

Summary Olife suitability for lead acid replacement

The Olife PowerPack provides significant advantages, when compared to LAB technology, in the following areas:

- **Cold cracking power**
  Almost the entire capacity of the battery is available in the form of high-voltage cold cracking current. It is significantly higher than lead acid (Table 2). Figure 2 shows a comparison of cold cranking ability at -18˚C of an Olife 30 ah battery with a leading brand AGM of 60 ah. The Olife battery produces a 30% higher-power output over the critical time period required for engine starting.
- **Dynamic charge acceptance**
  A critical feature of a battery is its ability to recharge from the alternator during the time the car is being driven. Frequent stops and discharges from restarting can drain a battery in a short time, particularly in below zero temperatures. If the car journey is short and the number of starts is frequent, the battery may not be able to draw a high enough current to recharge from the car alternator. The electrochemical reactions needed to recharge the battery slow down as the temperature drops, so the ability of the battery to accept a recharge current is also reduced as it gets colder.

  This is a major cause of failure in SLI batteries. The gradual run down in the state of charge during use is a direct result of the electrochemistry of the conventional battery. The relatively slow response is due to the diffusion processes which are required to carry the reacting chemicals to the plate surfaces.

  The Olife technology removes this problem by using supercapacitors combined with Li-$FePO_4$ batteries. The lithium batteries have approximately three times the charge acceptance of lead acid batteries whilst the supercapacitors are charged almost immediately. Using this combination of batteries and capacitors provides the best available technologies to ensure that the maximum charge possible can be stored and made available for use.

- **Weight**
  With Olife the weight of the SLI battery is reduced by approximately 50%. The Olife battery is significantly lighter than a lead acid battery (particularly the Enhanced LAB flooded and AGM versions). In the standard L5 size, the Olife battery is more than 10Kg lighter than a LAB, what

can provide significant carbon savings. Every vehicle with an Internal Combustion Engine is equipped with a lead acid battery weighing from 10 to 25kg. The weight of the SLI battery is reduced by about 7 kg without compromising the performance.

Olife is currently undergoing and conducting tests with and independent laboratory to verify the levels of carbon reduction, which can be achieved.

- **Life cycle**
  Olife's integrated supercapacitors are designed to withstand more than 500.000 charge discharge cycles to 100% depth of discharge. The ability to provide a long service life is critical for economic and environmental reasons. The End of Life Vehicle Directive requires that battery should have as long a service life as possible. Published data indicates that the life expectancy of a Li-ion battery is at least four times the life of a lead acid battery, (Appendix 3).

  When compared with conventional lead acid batteries' expected life of 300-400 cycles at 75% depth of discharge, Olife's technology provides a high multiple of the service life. It is unlikely that SLI batteries are discharged more than 30% depth of discharge even with start-stop operations. Olife powerpack shall provide tens of thousands of cycles.

- **Power and energy density**
  Test results for diesel engine starting showing power requirements with time. Figure 1 shows a graph taken from direct measurement of voltage and current with time for a 2 litre diesel delivery vehicle engine. The maximum power draw occurs within the first 2 seconds. The Olife battery has significantly higher voltage than the leading brand LAB despite having half the capacity. The power density is at least twice that of the leading brand LAB AGM technology.

  LiFePO4 chemistry has a potential to exceed LAB technology by at least 300%. The Olife battery and supercapacitor configuration should comfortably exceed the current Weight and volume energy densities achieved by LAB.

- **Minimal environmental impact**
  Olife is particularly proud of its environmental credentials. This is exemplified in the design and construction of the Olife power pack:
  - Fully compliant with the RoHS 2 Directive it contains no hazardous materials
  - The manufacturing processes do not create any health, safety or environmental dangers
  - It contains no rare earth metals such as lanthanum used in NiMH batteries
  - It can safely be disposed of in landfill sites

- **Design and logistics flexibility**
  The lead acid battery has to be replaced several times during the lifetime of the vehicle and has to be removed prior to the vehicle's disposal, in accordance with the ELV Directive. In order to have easy access, the manufacturer is restricted in where to locate the battery within the engine compartment. The olife alternative has zero maintenance, extended calendar life and lower weight removing the above mentioned restrictions and gives more freedom of choice for automobile designers. This also applies to logistics, whereby the materials and components for

production, as well as the finished product, pose no environmental hazard. There are no restrictions for transport which saves time and costs across the entire distribution chain.

- **Cost**
  The anticipated selling price for the Olife battery is likely to be about double of the retail price of an equivalent AGM lead acid battery. The anticipated life of the Olife battery particularly in microhybrid applications is four times that of lead acid.

- Op**erating temperature range**
  Lithium batteries are able to operate over a wide temperature range at least -20C to +70C. Recent developments by various manufacturers are extending the operating range, Values of -50 to +80 are now being quoted. Olife has conducted successful field trials in hot climates with under hood temperatures exceeding +60C. Independent testing by TUV will be carried out to determine the maximum safe operating range. Figure 3 is a graph of the temperature profile obtained during the field trials in a hot climate.

- **Technology readiness**
  Prototype production processes are established and prototypes have been successfully on trial this year in start-stop vehicles. Figure 4 shows a finished prototype battery in the L1 size. Full scale production is targeted for the end of Q2 2015. Equipment procurement for production and process scaling is underway, in collaboration with an industry partner in the Czech Republic.

- **Technology replacement: Micro hybrid, all categories, SLI**
- **The important parameters for the replacement of LAB with the Olife Li-ion/supercapacitor technology are:**
- **Power delivery**

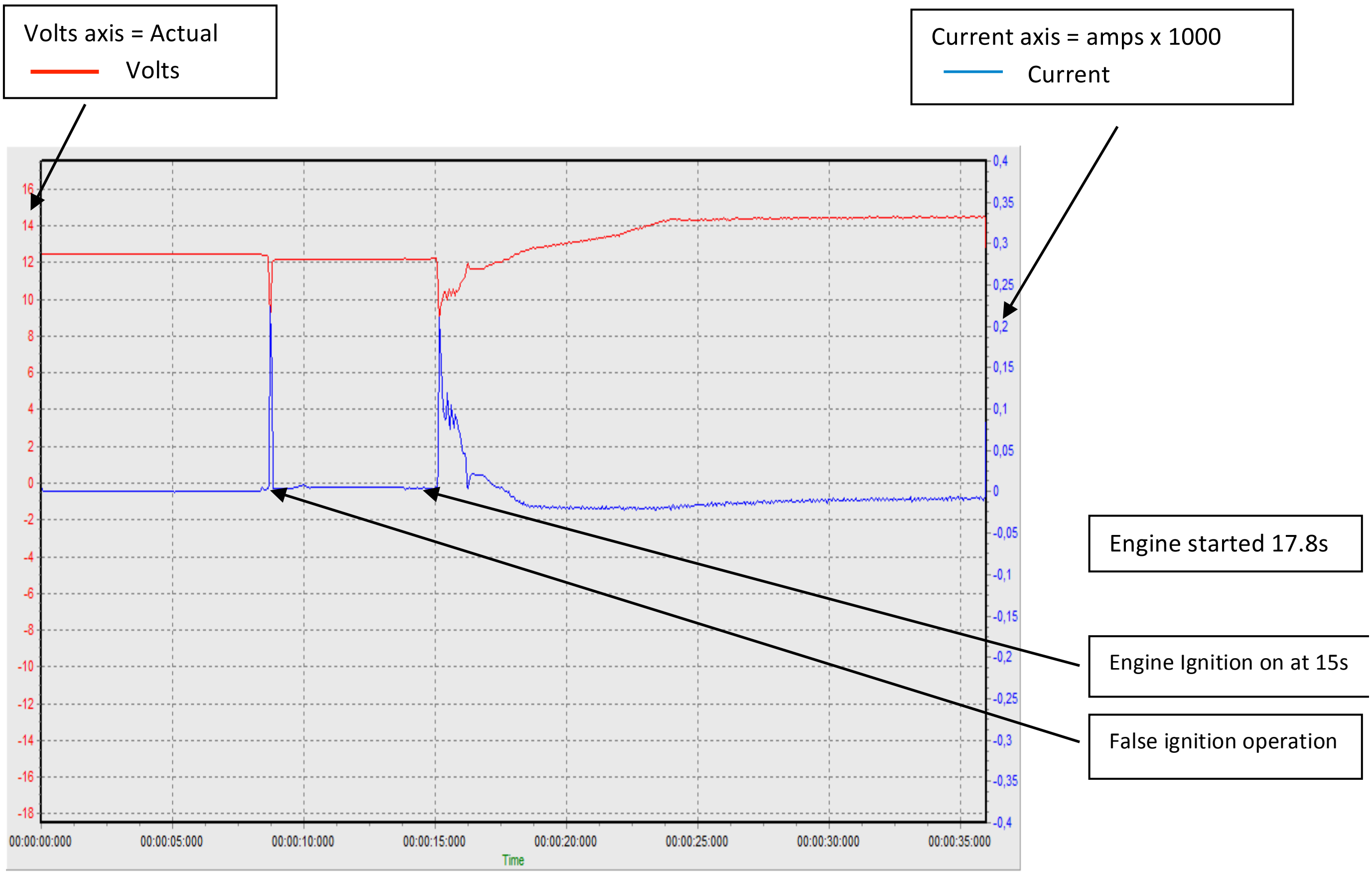
TABLE 2 - COMPARISON OF OLIFFE POWER BLOC (OPB) WITH AGM LEAD ACID BATTERY (LAB)

Discharge time seconds	OPB Power Watts	LAB Power Watts	**OPB % power gain over discharge period**	Current draw Amps	OPB volts Volts	AGM volts Volts
0.00	0	0	**-**	0	14.5	13
0.20	7820	5984	**30.68**	680	11.5	8.8
0.40	7344	5576	**31.71**	680	10.8	8.2
0.60	7004	5440	**28.75**	680	10.3	8
0.80	6732	5372	**25.32**	680	9.9	7.9
1.00	6528	5304	**23.08**	680	9.6	7.8
1.20	6256	5236	**19.48**	680	9.2	7.7
1.40	6052	5236	**15.58**	680	8.9	7.7
1.60	5848	5236	**11.69**	680	8.6	7.7
1.80	5644	5236	**07.79**	680	8.3	7.7
2.00	5440	5236	**03.90**	680	8.0	7.7

Test data from high rate discharge test at -18^{0}C

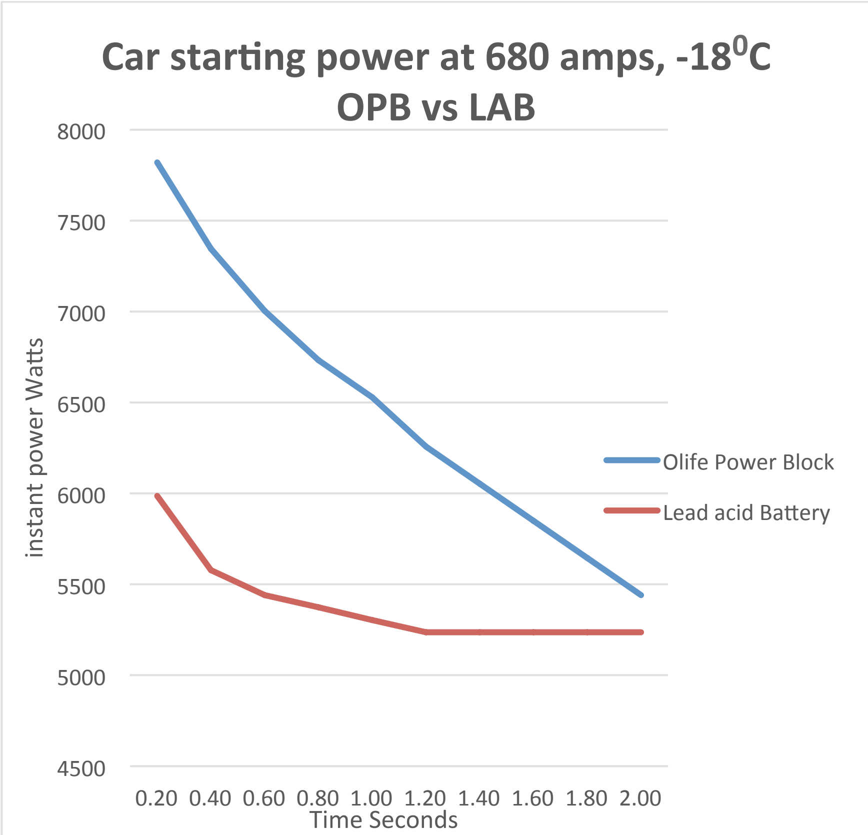
FIGURES

FIGURE 1 – Engine cranking results voltage and current draw with time



This graph is a direct measurement of an engine starting condition and illustrates the peak current experienced and the time required to start an engine when the engine ignition is switched on. The engine was switched on almost 15 seconds after the measurement instruments were started.

FIGURE 2 - Power available from Olife 30 ah battery and leading manufacturers 60 ah AGM LAB



Appendices

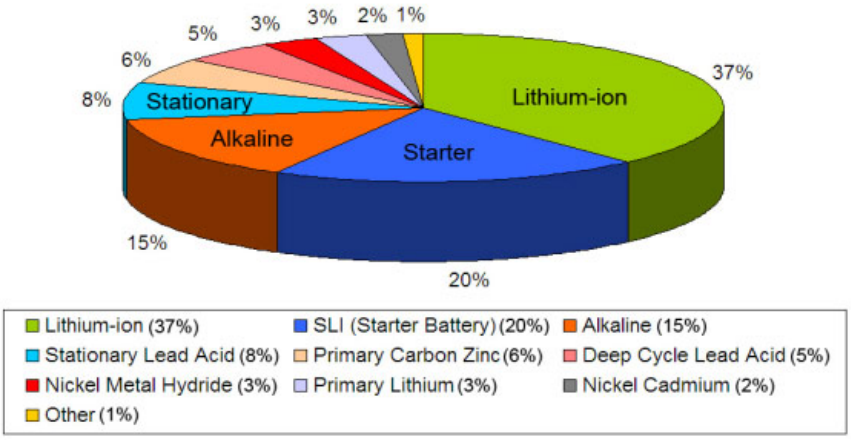
Types of battery applications

1. **Electric vehicles (EV);** these are powered only by the battery, which supplies energy to the electric motor.
2. **Plug in hybrid electric vehicles (PHEV);** there is a dual source of vehicle power, the internal combustion engine and the electric motor. Designed for medium distance operation using only battery power, it is recharged mostly from a separate charger.
3. **Hybrid electric vehicles (HEV**); There are two variants, moderate and strong, where electric power is used to provide moderate power assistance to the ICE and provide independent electric propulsion respectively.
4. **Mild hybrid electric vehicles (MHEV);** two categories here also, Mild 1 and Mild 2. Mild 1 provides power on launching the vehicle from standing, Mild 2 provides a small amount of power assist during vehicle motion.
5. **Micro hybrid electric vehicles (Micro HEV**); this describes the technology classed as start stop wherein vehicles switch off their engines when the vehicle stops. With this technology the battery starts the engine plus it provides energy for the car to function when there is no power from the engine's alternator. Again there are two categories, Micro 1 and Micro 2. With Micro 1 the battery is recharged solely from the alternator, whereas with Miro 2 the battery is recharged with a combination of alternator and regenerative braking.
6. **Internal combustion engine (ICE),** There is no assistance from the battery, other than to start the engine

Global battery markets

Revenue contributions by different battery chemistries

Courtesy of Frost & Sullivan (2009)



Availability of materials Courtesy of Talison Minerals

Lithium consumption (2008)

Batteries consume the largest share of lithium, and with the advent of the electric vehicle the demand could skyrocket. The world has enough proven lithium reserves. (http://minerals.usgs.gov/minerals/pubs/commodity/lithium/). Lithium is inexpensive. The raw material costs a fraction of one cent per watt, or less than 0.1 percent of the battery cost

Lithium mine production (2011) and reserves in tonnes[37]

Country	Production	Reserves[note 2]
Argentina	3,200	850,000
Australia	9,260	970,000
Brazil	160	64,000
Canada (2010)	480	180,000
Chile	12,600	7,500,000
People's Republic of China	5,200	3,500,000
Portugal	820	10,000
Zimbabwe	470	23,000
World total	**34,000**	**13,000,000**

Cycle life

- All electrical and electrochemical devices have a limit as to how often they can be used. The more often a device is operated the shorter its lifespan. In order to provide a guarantee it is useful to specify the number of times a device can be operated, or switched on and off (cycles). The number of times or cycles that occur until the device fails is called the cycle life. This is a number often defined by limitations of use and quoted on the product label

- Oilfe's integrated supercapacitors are designed to withstand more than 500,000 charge discharge cycles to 100% depth of discharge. The supercapacitors have a capacity of 1200 farads, this is more than required for one engine start. Potentially this provides a minimum of half a million starts

- It is public knowledge that lithium ion batteries will complete more than 2000 charge discharge cycles to 75% depth of discharge. Since it is highly unlikely that the batteries would be discharged to more than 30% depth of discharge even with start-stop operations. This would increase the cycle life to many thousands of cycles. When compared with a lead acid batteries expected life of 300 – 400 cycles at 80% depth of discharge, it is clear that the Olife technology will provide many times the service life of a conventional LAB