Throwing our future away - or are we?

By Andrew Marsh, FIMI

The focus on waste and the impact on our environment in the global sense has never been more forceful. At the heart of this movement is a series of high-profile PR / vote grabbing actions which have serious implications for automotive aftermarket costs. Yet, as will explore, the waste stream is not always managed effectively, nor is it always economically viable.

A high profile target

For some environmentalists the age of internal combustion engine powered personal transport is going to end soon, and end with carefully placed 'views' on the impact of cars, vans, buses, coaches as well as trucks. There is not one form of internal combustion engine powered vehicle transportation with the possible exception of ride-on mowers (!) that is not coming under close scrutiny, with comments linked to 'death', 'impact', 'health' and more. Many of these comments are placed by lobbyist companies, who's full agenda is rarely fully disclosed and the information presented is highly selective.

A useful guide to how much energy is required to build and operate a car powered by a variety of powertrains is outlined by the Low CV Partnership paper published in conjunction with Ricardo Consulting in 2011:

Powerplant	Lifecycle CO_2 emissions (tonnes, estimated)	CO_2 emissions from production	CO_2 emissions from production (tonnes, estimated)
Petrol, internal combustion engine	24	23%	5.6
+ hybrid	21	31%	6.5
+ plug-in hybrid	19	35%	6.7
Pure electric	19	46%	8.8

The assumptions are based on:

- Petrol with 10% bio-fuel content and completing 150,000 km (93,208 miles).
- For the plug-in hybrid and pure electric, 500g of CO_2 is generated for each kWh taken from the power grid.
- For the pure electric vehicle, the battery pack will take 3.78 tonnes of CO_2 (estimated)

Many of these factors are subject to change, not least high voltage traction battery technology in terms of cost as well as energy investment. Broadly the more energy that is used to create materials, components and assemblies for vehicles, the greater the carbon foot print. One very important point to make is the electricity used to charge PHEV or pure EVs counts as zero vehicle tail pipe emissions – hence the phrase 'zero emission'. In truth, away from vehicle emission testing, an on-board electric energy storage system with the capability of accepting charge from an external source incurs a CO_2 impact, even if that source is a wind turbine.

The law

Every single vehicle built or imported into the UK has to meet some form of whole vehicle type approval, since non-compliance means either the vehicle is modified to comply or cannot be sold. The whole vehicle type approval applies to the year of manufacture and covers a diverse range of vehicle functions such as seat belt fitment, minimum crash performance, brake performance, tail pipe emissions and more.

One of the type approval items is to demonstrate each new vehicle range complies with minimum levels of recyclability.

Recyclability – at the end of the vehicle's life

Lets' start with the premise that regardless of outcome, the United Kingdom will continue to adopt European legislation in terms of whole vehicle type approval…… Much of the policy around automotive recycling in our market starts with End of Life Directive 2000/53/EU. However, there is many aspects which are under discussion, with replacement legislation due by 2020.

$$R_{cyc} = (m_P+m_D+m_M+m_{Tr})/m_V \times 100 > 85 \text{ Prozent/percent}$$

$$R_{cov} = R_{cyc}+m_{Te}/m_V \times 100 > 95 \text{ Prozent/percent}$$

Mercedes-Benz method of calculating the percentage of vehicle recovered, re-used or recycled at end of life.

Some definitions:

'Recover' means draining all fluids from the vehicle with appropriate containment to eliminate possible spillage and hence contamination of soil / ground water. Some recovered fluids such as refrigerants can be recycled, as can used engine oil.

'Re-use' means parts which are serviceable can be stripped from a vehicle and sold.

'Recycle' means the waste stream is shredded, and then sorted into ferrous materials, non-ferrous materials (which may be further sorted to purify the waste stream by preventing cross contamination), glass, rubber, electronics, harnesses and plastics.

The End of Life Directive 2000/53/EU places responsibility for vehicle disposal with the original vehicle manufacturer or importer, covering all cars up to 9 seats and vans up to gross vehicle weight (GVW) of 3.5 tonnes. Directly we can see the admittedly smaller population of vehicles above 3.5 tonnes GVW are not directly covered by the Directive. Highlights include:

- From 01st January 2006 vehicles built and registered before 1980 should have 80% by average model mass either recovered or re-used.
- From 01st January 2006 vehicles built and registered after 1980 should have 85% by average model mass either recovered or re-used.
- From 01st January 2015 all cars and light commercial vehicles up to 3.5 tonnes GVW should have 95% average model mass either recovered or re-used. Re-use and recycling should amount to 85% average model mass.
- Materials and components for cars and small vans must not contain cadmium, lead, mercury or hexavalent chromium, unless covered by a specific exemption (in Annex 2 of the ELV Directive). This requirement does not apply to spares, replacement or service parts for vehicles placed on the UK market prior to 1 July 2003.
- Certain plastic and rubber parts weighing over 200 grams (apart from tyres) must be marked in accordance with the regulations to promote their recovery, reuse and recycling.
- Vehicle manufacturers / importers must recover at least 95% by weight and recycle 85% by weight of each end of life vehicle – using the average weight of the model type.
- Where Authorised Treatment Facilities (ATF) accept vehicles outside a vehicle manufacturer / importer free take-back network, they take on the responsibility for meeting the annual targets.

Failure to report the number of vehicles removed each year by each importer / manufacturer or ATF, along with the associated recycling targets can lead to unlimited fines.

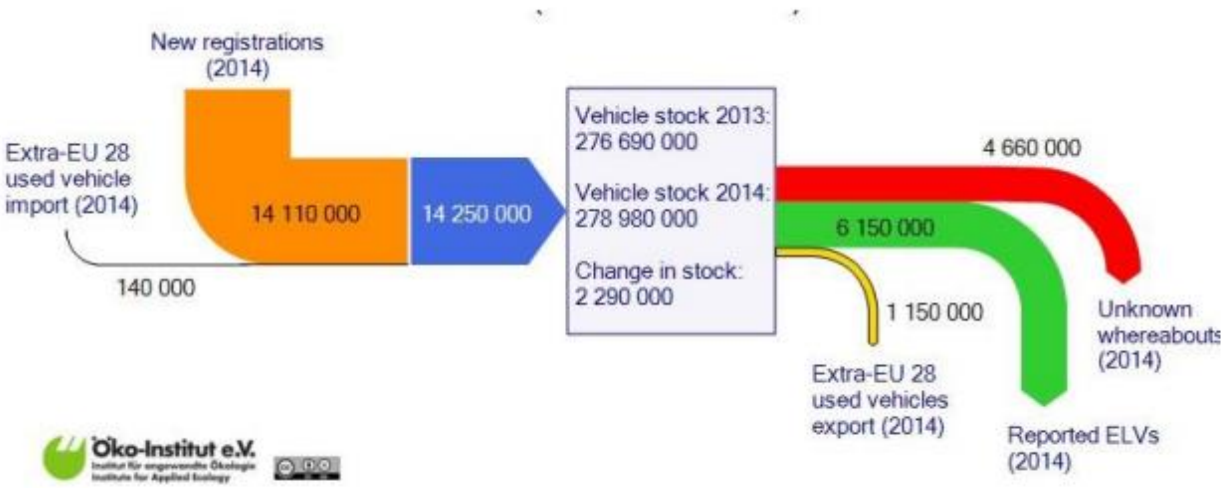
Across the EU the volume of vehicles that reach the end of their useful life due to corrosion, major mechanical failure or accident damage is large. In 2018 the EU commissioned a report about how successful the end of life Directive had been (see below). The data shows vehicles which are imported or exported from the EU by individuals is relatively small, whilst the rate of new registrations exceeded disposal in 2014 by 2.290 million units.

Table 1-1: Results of the calculations for unknown whereabouts of vehicles for EU-28

	2008	2009	2010	2011	2012	2013	2014
Unknown whereabouts (million vehicles)	4.1	3.4	3.4	3.82	3.51	3.69	4.66

Source: Oeko-Institut

Figure 1-1: EU-28 balance for registration of new and import of used vehicles, the change in the vehicle stock and the whereabouts of the vehicles



Assessment of the implementation of the End of Life Vehicle (ELV) Directive with emphasis on vehicles 'lost' each year from 2008 to 2014 – i.e., unknown.

The main issue was across the EU was inconsistency in how vehicles which were no longer in continuous use were documented. For example, in Germany, if a vehicle remained inactive for less than a year, all details of that vehicle were deleted. The result of these administrative issues led to the majority of cases where a vehicle 'disappeared'. Further, lack of co-operation meant a vehicle could be registered, moved to another member state, and then appear in yet another one – whilst the full administrative record lost important details during the multiple transfer process.

The upshot was a call for EU member states to tighten up vehicle documentation record keeping and close the 4.66 million vehicle gap recorded in 2014 alone. Yes – the EU requires information about how many vehicles have been disposed each year, but reporting the stats seems to take around 3 years after data is submitted.

How does a vehicle manufacturer classify 'recyclability'?

Since the end of life Directive is a type approval item, the documentation about how much of a vehicle can be recovered, re-used or recycled has to be defined by the engineering teams responsible for every single component. Documents are filled in detailing the way each part should be handled within each sub-system, from which the overall vehicle data is calculated.

More oddities occur. For instance, conventional cross-linked thermo-set rubber is not possible to reform as a raw material. This can be complicated by the reinforcement fibre or metals within the moulded component. The official line? All rubber parts with the exception of tyres could be reduced to shreds, which are then possible to use, for example, as a component of road surface dressing or special surfaces. Thankfully thermo-plastic 'rubber' is now widely used for coolant hoses, frequently without reinforcement which increases the possibilities for recycling.

The classification makes no reference to how long it takes to access a part. The assumption is the end of life vehicle will have had all parts which can be re-used already removed before shredding the rest, followed by sorting the debris. Further, if a 'part' such as a suspension control arm has in effect a rubber boot, ball joint and rubber isolators, where the majority of the assembly weight could be forged aluminium but the ball joint is made from steel, how is the possible to dissemble economically?

Currently the end of life Directive takes no account of design for recycling or re-use. Just as an assembly is built based on specific operations timed to the last fraction of a second, so it should be possible to 'reverse design' assemblies to be stripped with commonly available tools in segments of a few minutes. Such an approach would then allow each assembly or sub-assembly to be classified in terms of time to strip, which would then aid importers / manufacturers or ATFs to scope what can be done within the limits of how much the parts are worth.

One could expect the next revision due in 2020 will have these aspects covered…….

Green parts

This is one of the trickiest parts of recycling….

- SRS airbags are optimised for a model type, and that optimisation may change from year to year. Thus, taking an airbag module from a vehicle built early in the model life cycle and adding it to another taken from a later model, which are then fitted to yet another model year vehicle is not only irresponsible – it's dangerous.
- Similarly, the above logic applies to pop up bonnet pyrotechnics, and items such as pyrotechnic activated head restraints.
- Interior trim which is not related to covering any SRS airbags could be re-used, or, if made from a single polymer, recycled.
- Bumper skins could be recycled or re-used.
- Suspension parts could be re-used, but assessing the condition is critical. If for example the part is not affected by the damage that led to the donor vehicle destruction, the age / mileage are low, and the inspection including crack detection reveal no defects, it could be re-used. More likely, the part will be recycled.

The primary challenge is associating what happened with the component in the first use to enable a retailer or purchaser to assess if the component should be re-used or, if possible, recycled. It is this challenge that prevents grater uptake of 'green parts' in the automotive aftermarket, because whilst some retailers have solved the issue many have not.

Recycling – aluminium

The key to this market is the prevailing price of scrap and the weight of the consignment. If for example there are cast aluminium subframes, engine blocks, cylinder heads and transmission cases then the rate at which the consignment can be built up is fast, due to the greater weight of each component. Conversely, a typical aluminium skin panel made from a sandwich of aluminium alloys takes up lots of space but does not weigh as much.

Aluminium alloy typically takes far more energy to convert from ore to finished product than steel alloy, yet recycling aluminium takes around just 5% of the energy to recycle. A typical skin panel would need to be recycled between 4 and 6 times before there was parity with the energy investment in making the same part from steel alloy. Usually the price of scrap aluminium is significantly higher than for mild steel alloy, making the number of recycling loops a necessity.

Jaguar Land Rover worked with a variety of partners such as Innoval Ltd (aluminium technology specialists), Novelis (aluminium alloy sheet coil supplier), University of Warwick Manufacturing Group as well as their own in-house engineering expertise. The result was to develop recycling processes for the bodyshop stamping process scrap sheet, and then to work with the partners to improve the amount of scrap which could be used to reduce the CO_2 impact of sheet production:

Jaguar Land Rover optimised aluminium body stamping process to increase the amount of recycled scrap, with significant reduction of energy consumed.

Crucially the technology relies on selection of aluminium alloy types that are result in fewer material defects once the process is completed, and – importantly – the aluminium alloy sheet is recycled back into aluminium alloy sheet. Once the aluminium alloy is diverted into castings or forgings the energy saving is still present but not so effective. Jaguar Land Rover completed two phases of this research and then rolled out a further phase in September 2017 – they plan to use aluminium alloy for body construction with a new 'MLA' platform which will replace the existing aluminium intensive platforms from 2020 onwards.

However, steel alloys offer a wider range of strengths at lower cost with good recyclability. The future of automotive body engineering is centred around panel by panel material selection based on the loads each panel will endure. Whilst aluminium intensive vehicles will remain in production way into the future, such structures will feature selective steel panel reinforcements.

Recycling – plastics

The biggest environmental issue for the automotive sector after internal combustion emissions is the use of plastics throughout the product. The automotive industry has used all kinds of plastics for many, many decades, to the point that the sector has frequently been on the cutting edge of process technology.

Most polymers are derived from oil, and many components are made from a mix of polymers. Such parts can have multiple functions requiring simultaneous or sequential moulding. Seats, for example, can have variable density foam formed within the fabric facing, so eliminating additional sewing operations on less expensive cars. The problem is just what to do with these parts after first use…..

There are essentially two groups of plastics:

Thermoplastic: The polymer has a melting point which allows the material to be forced into an injection moulding cavity under pressure, cooled in situ and then released from the mould. The polymer will soften before eventually melting, and the temperature that this will occur is anywhere from 60 C to more than 140 C. The process is reversible, and possible to recycle.

Thermoset: The polymer is prepared as a dough or sheet which is forced into a mould cavity (dough) or placed into the mould cavity (dough or sheet). The combination of heat and pressure causes the polymer molecules to cross link, creating a different material composition. When finished the component can be exposed to typically higher temperatures than thermoset polymers, although the gap has closed in recent decades. Once the polymer exceeds its thermal limit, it will start to burn. The process is not reversible, and can only be recycled by breaking the part into smaller pieces for use as a filler in subsequent manufacturing processes.

Think way back in time to early forms of plastic bumper, which needed to replace inherently more expensive chrome finished or stainless-steel items. The driver was fashion, in that plastic bumpers could be bigger than steel items yet weigh less. Polypropylene – a thermoplastic - was widely used, with a synthetic rubber (EPDM - ethylene propylene diene monomer rubber) which transformed the properties of the polypropylene. Such parts were very tough but almost to paint or decorate except via mechanically fastened items. By 1984 ICI had developed a paint system that could remain attached to a polypropylene bumper, which was introduced with some success on the Rover 200.

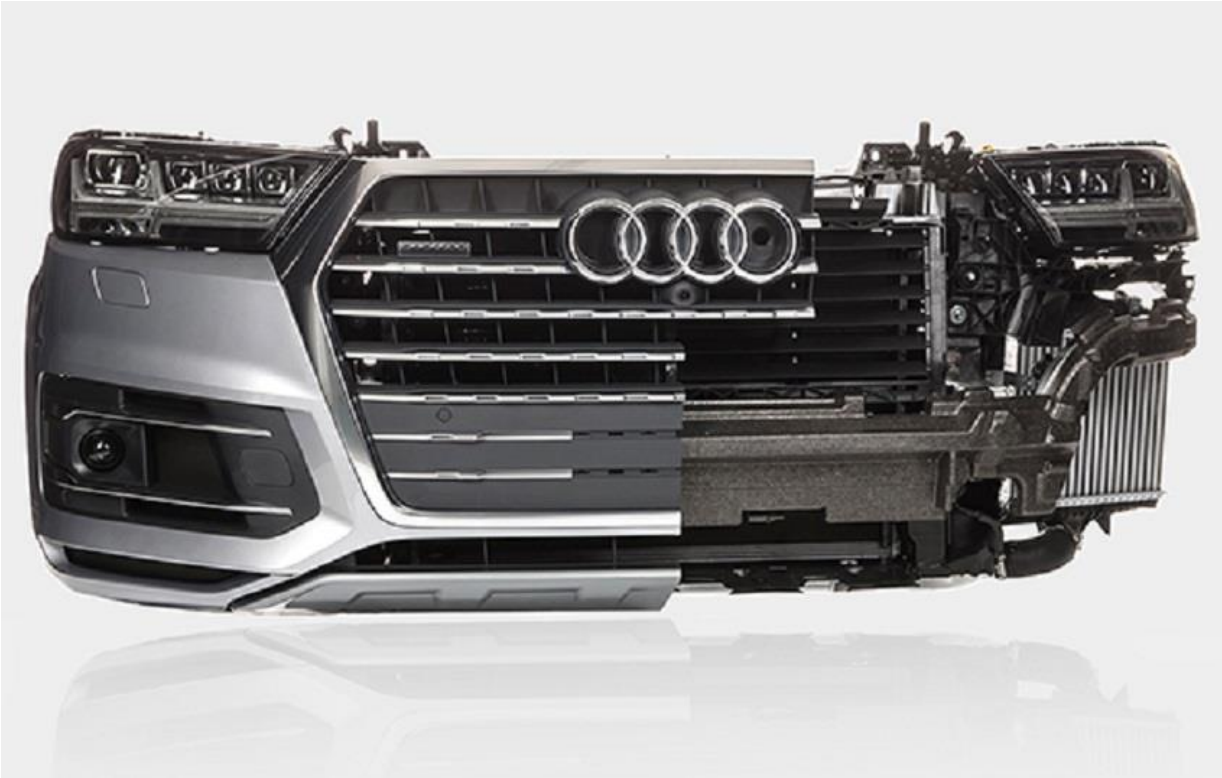
This illustrates that even for a large moulding like a bumper skin, selection of specific polymers and moulded forms take into account design as well as function such as resistance to low speed impact, pedestrian safety at the front of the vehicle, stiffness to prevent flapping at speed and more. Modern bumper skins are frequently made from not only external finishers but even sub-sections to allow for manufacturing flexibility as well as better repairability.

Plastics and the environment…

The above scenario is played out across the entire vehicle – selecting polymers for specific material properties. Thus, when we see an internationally recognised symbol such as ‘PP’ for polypropylene, for example, it covers a huge array of possible formulations which includes those which are altered by the forming process.

The problem is the ‘value’ of plastics. At the same time many of these polymers are difficult to replicate with other processes or non-oil based materials at anything like the cost, yet the perception is plastic is inherently ‘cheap’. That in turn limits the way such materials are treated, because copper, aluminium or steel have historically greater value and use than many plastics.

Some plastic parts have become structural elements in their own right. A common application is the carrier for the radiator, cooling fan, air conditioning condenser, intercooler, headlights and more. This part is usually reinforced with short glass fibres, which means that if the polymer is a thermoplastic the only way to recycle such parts is to ‘cook’ them and drain off the molten polymer. If on the other hand the polymer is a thermoset, the part can only be shredded and the resulting material used for filler in other manufacturing processes.



Audi Q7 front module complete with bumper skin, bumper beams, impact pad, headlights, headlight washer jets, fog lights, active shutter upstream duct, intercoolers, air conditioning condenser, radiator and cooling fans. One assembly!

General waste

Much of what we have covered so far seems to have little impact on retail of replacement parts for the automotive aftermarket. However, most businesses have to pay for waste disposal, and that includes cardboard, pallets, as well as plastic sheet. In the case of plastics most of the issues outlined so far apply to this type of waste which unless occurs in significant quantity and with identical formulation – otherwise potential recyclers are not interested.

The end point for plastics?

The fastest way to yield the energy within plastic is to burn it. However, this cannot be done in anything but an expensive incinerator with extensive exhaust gas scrubbing to remove as many toxic fume elements as possible.

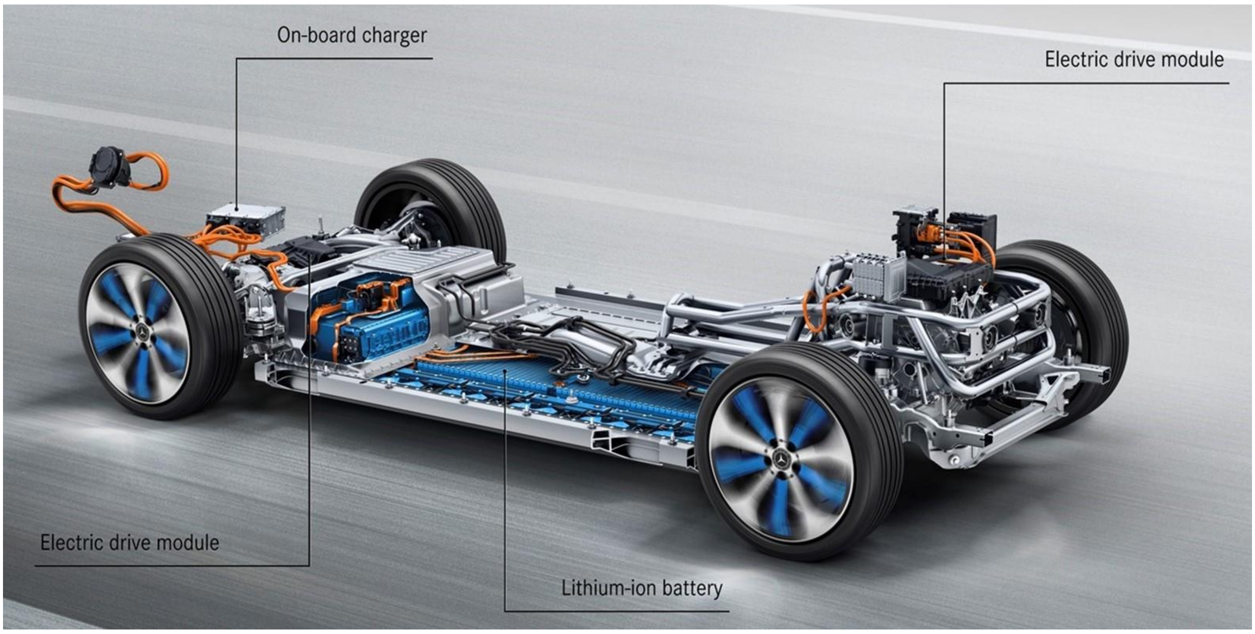
Another route is to set up equally expensive processing plants to turn plastics back into some form of oil, which could then be burnt. Across the EU such industrial plants have been built either as a proof of concept or in preparation for production. Politically this has become very sensitive, with the result that the policy is mired in blocking manoeuvres. The counter argument that is made runs something like this:

1. Internal combustion engines should be banned as soon as possible.
2. Converting plastic waste into oil to be burnt in internal combustion engines feeds a broken environmental model.
3. Thus, the conversion plants should not operate.

This selective argument is based on the premise that vehicles cause most if not all air pollution – something that is not true. Further, it assumes it is acceptable to have streams of grossly undervalued polymers finding their way from land fill into the ground water or directly dumped at sea. The United Kingdom Government followed the EU Commissioner / European Parliament lead to ban small plastic items like cotton buds and drinking straws because replacements made from paper were readily available. In one fell swoop a miniscule issue may have been resolved whilst the majority of plastic disposal remains chaotic at best.

A tip for the future. Just as with 'valueless' coal mine tips, which were subsequently re-worked as the value increased, in the future land fill sites will be opened up to extract plastics because the price of oil will have become so expensive the value of plastic polymers will finally be aligned to their usefulness.

Recycled commodity of our age



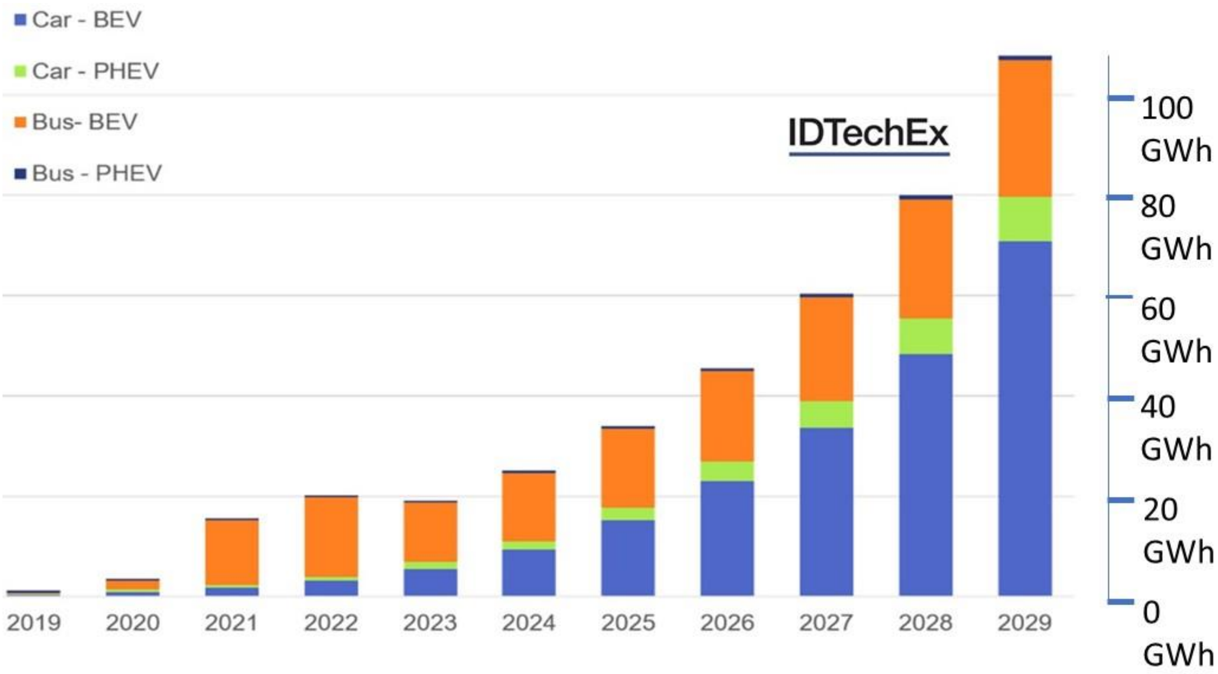
The first pure electric SUV from Mercedes-Benz brand, the EQC with an 80 kWh Li Ion battery pack

In the same way we expect an internal combustion engine to carry fuel around with it, we will realise the folly of creating vast battery packs for pure electric vehicles. Until then, it's full steam ahead for electric assisted internal combustion engine powertrain (hybrid, plug in hybrid or range extender) and pure electric vehicles.

Already we have seen multiple advances in Li Ion battery technology which have raised the amount of energy stored per unit of volume to around 20% of either petrol or diesel – which means that by over sizing the battery we can have pure electric vehicles with almost no range anxiety issues. In turn the technology has merged the function of a battery (good at storing energy, does not like receiving or discharging energy quickly) with capacitors (great at rapid charge and discharge but managing storage is fun). That development alone has done more to make electric assisted powertrains or pure electric powertrains viable for real-world use.

However, such a traction battery will gradually take longer to recharge and not take well to accepting full energy during regenerative braking. At that point the battery pack could be swapped for a new module - but is there a use for the 'old' module? The answer is yes.

Electricity energy generation companies are struggling to find technologies that can be used to store excess power. Finally, there may be an answer, and it will not cost much to implement. The idea is instead of having capacity configured to peak demand plus a safety margin, the generation capacity is at a sub-optimal level where excess power produced during low demand periods can be stored and drawn off at peak demand. Enter the market in waiting, the used Li Ion traction battery:



Global used EV and PHEV battery capacity from 2019 to 2029, cumulative

Conclusion

The vehicle manufacturer, importer or authorised Authorised Treatment Facilities (ATF) bear main responsibility to remove and process vehicle parts/ fluids at the end of life. The article shows how manufacturers classify and calculate the minimum recycling mass for each model range.

The discussion shows the complex pitfalls which occur trying to do the right thing, ranging from how vehicles are tracked across the EU to specific way materials should – or should not – be handled. The core issue is the cost of disposal either for re-use or recycling, where the waste stream might well be geographically scattered. Most businesses are well aware of the cost of waste disposal, and any steps to reduce or eliminate this cost are welcome.

The key is certain commodities have to become more valuable in order to justify less destructive ways of disposal. Due to the complexity of the subject there is no harm to track some commodities which your business today does not handle, but might well do so in the near future. That might even include purchasing an old land fill site on the off chance that what was considered worthless a few decades ago might well be worth something now.