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Circular Metals Case Study:

Electric Vehicles – Design for Recycle

1. EV market:

Total global car sales[1] were 67.3m in 2022, 75.3m in 2023 and are predicted to be over 77m in 2024. Global electric vehicle (EV) sales[2] were over 10m in 2022, 15% of the total, 14m in 2023, (19% of the total) and over 17m in 2024, 22% of the total. The global EV fleet is predicted[2] to reach 230m by 2030, over 10% of the total (2.3b), on the basis of current worldwide policies, and 380m, 16% of the total, if we are to achieve net zero by 2050.

Total UK car sales[3] were 1.6m in 2022, predicted to rise to 1.9m in 2028, with the current stock of 32m vehicles predicted to grow to 44m by 2050 on a "business as usual" basis[4]. In the UK, the zero emissions vehicle (ZEV) mandate[5] requires 28% of new car sales to be EVs in 2025, 52% in 2028, 80% in 2030 and 100% in 2035. This is still the law, despite the recently announced delay in banning sales of petrol and diesel cars from 2030 to 2035.

There are major issues with both generating and distributing enough green electricity to satisfy the corresponding growth in demand.

2. Metals and alloys

About 10-20% of all pollution, energy use and greenhouse gas emissions (GGE) is caused by the manufacture of metals and metal products[6]. Most of this is steel and Al alloys, and most is in the packaging, construction and transport industries, with a major part in the manufacture of cars and other vehicles. More than 2b tonnes of metals and alloys are produced each year, mostly steel (and to a lesser extent Al alloys). Well over 60% of scrapped steel (and Al) is recycled, representing about 40% of all production, just over 1b tonnes[7]. A significant proportion of this is prompt scrap generated directly during manufacture in the factory or mill. Most recycled scrap is taken back to the smelter, i.e. has to be fully reprocessed to be reused. Clearly, we should aim to increase recycling, but also reduce the amount of scrap by extending metal and product lifetimes, and reuse rather than recycle back to the smelter.

3. Vehicle end of life

Most cars and other vehicles are scrapped well before most of the metals and components in them have reached their end of life, although remanufacture has become much more important in recent times. Most of the alternators, fuel pumps, suspension systems, engines, gearboxes etc. are still perfectly usable, as is most of the metal in the body and structural frame. End of life is dominated by fashion and a replace rather than fix ethos. About two thirds of cars and more of heavier vehicles is metal (steel or Al) and the rest is mostly plastic and plastic composite. This percentage is expected to rise.
There is considerable opportunity for a new servitisation business model, with service companies supplying fleets (and later individuals) with component supplies. While lease models have existed in the sector for a long time, research is inconclusive on whether or not they contribute to extending the life of vehicles and their components. Remanufacturing of

vehicles has been adopted as a profitable business model, helping to extend the life of metal parts in vehicles (e.g. Renault Fins-Refactory, France).

4. **Al in EVs**

More Al alloy sheet, castings, and extrusion is needed to make lighter EVs according to Hydro Aluminium[8] and Ducker/European Aluminium[9]. The green transition will require 5m tonnes more Al in Europe, 3.1m tonnes for EVs. By 2030 it is expected that the Al content in cars will have increased by more than 50kg/car. Worldwide Al demand from the green transition is expected to increase by 20m tonnes from 2022 to 2030, mostly from recycled secondary rather than increased primary Al.

In the UK EV sales ended 2023 positively as the industry got ready for the ZEV mandate, Pure electric cars were almost 20% of sales in December 2023, and electric vans were 10.5% of van sales. An electric car was sold in the UK almost every 90s in 2023.

According to Ducker[9] EVs will require 54 kg more Al per vehicle in 2030 compared to 2022 for specific components and 15kg more for the body-in-white. Castings, extrusions and sheet gains will be 22, 15 and 14kg respectively between 2022 and 2030. The main components driving increased Al are electric drive housings (22.7kg), battery enclosures (11.8kg), large and mega castings(8.4kg), battery penetration protectors (7kg) and battery cooling plates (5.1kg). Castings remain by far the largest Al product form reaching 145 kg/vehicle in 2030, with strong growth in extrusions for battery enclosures, sills and crash management and braking systems, and sheet for battery protection plates, cooling plates and front and rear doors.

5. **Fatigue life**

EVs face significant challenges related to fatigue in steel and Al alloy components, particularly suspension systems[10] and battery boxes[11]. The unique dynamics, weight distribution, and the need for lightweight structures present obstacles in designing components capable of withstanding cyclic loading and road-induced vibrations. Battery boxes, crucial for on-board energy storage and supply, endure demanding operational conditions, including varying loads, thermal fluctuations, and stringent safety requirements. The substantial future increase in EVs will create a massive demand for battery boxes and suspension systems, placing a premium on developing technologies and strategies for recovering and rejuvenating these components to extend their crash resistance and cyclic fatigue life.

6. **Batteries**

EV batteries require critical raw materials (CRMs) such as Li, Co and Ni. This has led to a steep increase in global CRM demand, which could double or more than triple by 2030, depending on the speed of transition, according to the IEA (2023)[12]. Li-Ion batteries are projected to increase to 2000GWh in 2030, over 80% of total demand[13] to produce battery cells for EVs, with a corresponding increase[14] by 18-20 fold in Li demand by 2050. Low Co and Li battery chemistries are being developed but mainstream adoption is unlikely to occur before 2030. There are major environmental and political implications of increases in CRM mining and refining that need to be considered. Life extension, recycling and recovery of

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CRMs are, therefore, essential. We have shown[15] that different battery circularity strategies can significantly reduce Co but only by increasing Ni. Other recent contributions have also explored this topic in detail[16,17].

7. Other EV metals

EVs have approximately 3.5 X as much Cu wiring than ICE vehicles, with an opportunity for increased recycling of Cu, but contamination problems with vehicle shredding for steel/Al recycling. All vehicles contain a large number of small electric motors, currently difficult to reuse or recycle. EVs contain large electric motors with opportunities for recycling of (e.g.Nd from permanent magnets, Cu windings and Al casings). Battery recycling will be essential, with recovery of critical metals such as Co and Li. Similarly, power electronics recycling can enable the recovery of semiconductor materials.

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