Net-zero, circular transition in road transport

Addressing social and environmental spillovers of materials demand changes in the road transport sector

This briefing is one of a series assessing social and environmental spillovers associated with the EU's circular transition. Sections 1 and 2 summarise the material flows associated with the EU consumption of aluminium and lithium-ion batteries, as key materials for EVs, and their principal environmental and social impacts. Section 3 introduces the circular economy objectives of the revisions of the EU Batteries Directive, the End-of-Life Vehicles Directive and the Waste Shipments Regulation and sections 4 and 5 map its potential positive and negative environmental and social spillovers, respectively, both inside and outside the EU. Section 6 concludes with some initial policy recommendations for the forthcoming revisions of these circular economy policy proposals.

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In 2019, the transport sector accounted for almost a quarter of the EU's total emissions (Climate Action Tracker, 2022), of which 70% was generated by road transport, with cars responsible for the largest share (60%) (EEA, 2022).

To meet its pledge to reduce its GHG emissions by at least 55% by 2030 (compared to 1990 levels), it is estimated that EU transport emissions must be reduced by 90% for the bloc to meet its 2050 climate goals (European Commission, 2020). To achieve this objective, the European Commission proposed a zero-emission road mobility target for 2035 to reduce emissions produced by new passenger cars by 100% compared to 2021 (European Parliament, 2022).

Electric vehicles (EVs) are set to play the lead role in decarbonising EU road transport, as their average emissions lifecycle are estimated to be around 70% lower than their internal combustion engine (ICE) counterparts (Bieker, 2021). Encouragingly, the uptake of EVs is expanding, as the sale of battery electric vehicles in Q1 2022 (BEVs) almost doubled its market share compared to the same quarter the previous year, now making up 10% of new passenger cars (ACEA, 2022).

The demand for EVs is expected to increase significantly following the Commission's Mobility Strategy setting a target of 30 million EVs by 2030 (European Commission, 2021) and the new car emissions standards set to effectively phase out internal combustion engines by 2035, likely to be replaced primarily by EVs. While these developments are positive regarding CO_2 emissions reduction and a reduction in demand for oil extraction and processing, there are important implications in terms of material consumption patterns, i.e., the sourcing of raw materials for the production of a new fleet of EVs, as well as the waste materials generated from ICE vehicles deemed no longer "up to code".

This briefing estimates that more than 227 megatonnes (Mt) of key materials will be necessary to fully electrify the EU's current passenger car fleet, roughly 3.5% of the EU's total raw material consumption in 2019 (Eurostat, 2022), see below. Although headed towards circularity, the EU is unable to meet the sheer number of materials demanded for this transition on its own. Therefore, in addition to new and revised policies for circular vehicles and batteries, the EU must promote the switch to alternative forms of mobility, to transition to net-zero transport while curbing the growing demand for materials.

At the same time, the EU must be mindful of the social and environmental spillovers that may materialise in- and outside the EU due to the implementation of certain circular economy policies concerning the transition to net-zero road transport. This briefing maps out some of the main spillovers that may be linked to the implementation of policies relevant to reaching a circular net-zero road transport, namely the revisions of the EU Batteries Directive, the End of Life Vehicles Directive and the Waste Shipments Regulation, and presents initial recommendations to address these potential spillovers.

Material flows in the road transport sector

As the EU seeks to decarbonise its road transport, manufacturers of EVs will not only need to keep up with growing demand but must also adhere to new requirements for circularity and sustainability throughout their supply chain.

The 2020 EU passenger fleet total 246.3 million cars, of which 0.5% were fully electric, 0.6% were plug in hybrids and 1.2% were hybrid electric, meaning 97.7% of cars run fully on fossil fuels (ACEA, 2022). If these cars needed to be replaced one-for-one, and taking into account the annual growth in demand for vehicles, **more than 240 million new EVs would need to be produced to electrify the EU passenger fleet**.

The material demand for vehicles ranges from steel, aluminium, plastic, rubber and glass to critical raw materials required for the automobile battery and integrated electronics[1], be it an EV or ICE. The main differences between EV and ICE production lie in the battery – which significantly increases the weight of the EV – and the car body, usually manufactured from steel, but now increasingly being manufactured in aluminium in an effort to reduce EVs' total weight.

Table 1: Materials necessary to fully electrify the EU's 240 million passenger car fleet

Material component	Average material demand of key metals and minerals per EV (kg)	Total material demand of key metal and minerals in the scenario that EU fully electrifies its passenger car fleet (240 million cars)
Steel	700 kg	168 Mt
Aluminium	170 kg	40.8 Mt
Lithium	8 kg	1.9 Mt
Nickel	35 kg	8.4 Mt
Manganese	20 kg	4.8 Mt
Cobalt	14 kg	3.36 Mt
Total	**947 kg**	**227 Mt**

The second column of Table 1 presents the average material demand of key materials necessary to construct the EV body and battery (Djukanovic, 2018; Castelvecchi, 2021), however it does not account for other materials added to the vehicle, such as glass, tires, and seats. The final column of the table estimates the total demand of each of these key materials necessary to produce and electrify the EU's total passenger vehicle fleet of more than 240 million cars.

If the EU were to replace the number of ICE vehicles one-for-one with EVs, its material demand to achieve this feat would total more than 227 Mt, or roughly 3.5% of the EU's total raw material consumption in 2019 (Eurostat, 2022). This estimate does not account for the car components not taken up into the table, e.g., glass, plastic, rubber, electronics. While the EU is not expected to produce more than 240 million EVs domestically, it will have to source more than its fair share of global raw materials to meet its zero-emission road mobility target for 2035.

The effort to fully electrify the passenger car fleet will significantly increase the EU's absolute material demand which stands in contrast to its objective to reduce materials consumption with the introduction of circular economy policies. Therefore, a more sustainable approach to transitioning to a net-zero road transport would be ensure material demand does not increase

[1] For more information on the social and environmental impacts of electronics, as well as impacts of the "right to repair", consult Meysner, A. & Urios, J. (2022). Link.

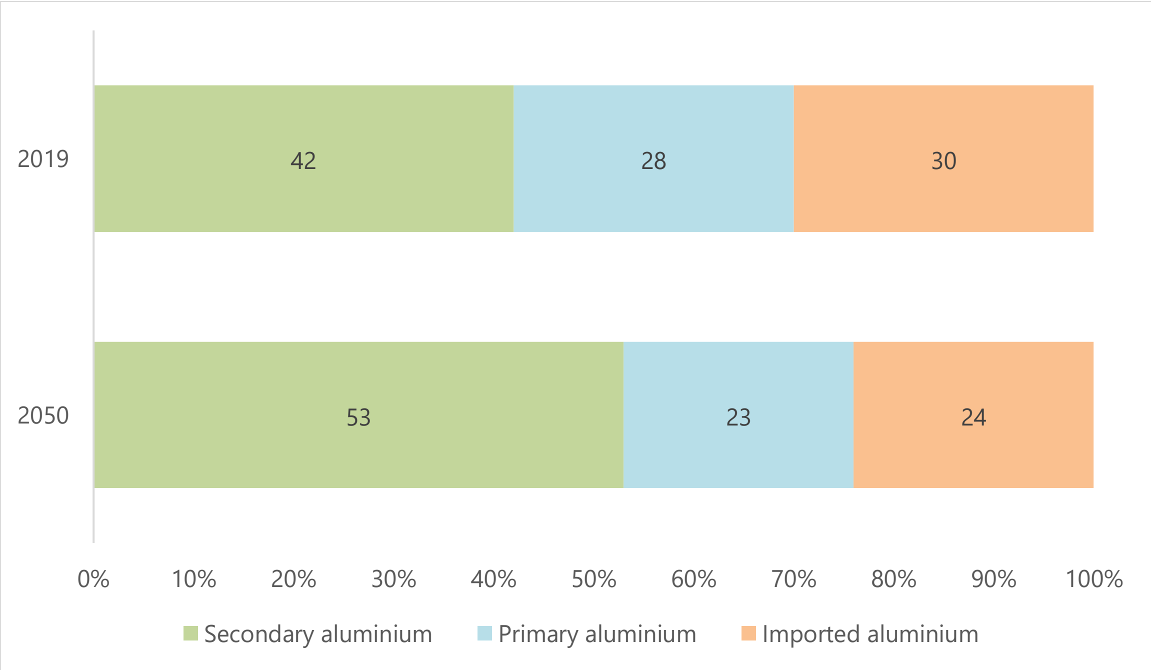
substantially by implementing mobility policies in parallel that promote alternative forms of mobility such as car sharing, public transport, walking, and cycling.

The following sub-sections cover the aluminium and lithium-ion battery value chains, with particular focus on their underpinning critical raw materials, bauxite and lithium. These value chains were selected due to the increased relative important of these materials to the production of EVs, compared to ICE vehicles (i.e., more aluminium is used on average in EVs manufacturing as well as larger batteries) (Djukanovic, 2018; Castelvecchi, 2021).

The aluminium value chain

Over the next 30 years, EU demand for aluminium is expected to increase by 50%, from 14 Mt in 2020 to 21 Mt in 2050. Aluminium is particularly in high demand for clean technologies, not only for EVs, but also for solar photovoltaics, electricity networks, wind turbines and for hydrogen technologies (Gregoir & van Acker, 2022). Currently, the EU meets its demand for aluminium through domestic production of primary aluminium, domestic recycling of aluminium waste and scraps into secondary aluminium, and foreign imports of primary aluminium, see Figure 1 below.

Figure 1: EU sourcing of aluminium, 2019 and projected for 2050 (Gregoir & van Acker, 2022)



The expected increase in EU and global demand for aluminium by 2050 risks putting pressure on the availability of bauxite, aluminium's main ore. The EU contains an insignificant amount of the world bauxite reserves, accounting only for 0.7% of global bauxite production, occurring mainly in Greece (Cassetta, Monarca, Pozzi, Quaglione, & Sarra, 2019), so the EU resorts to importing bauxite from developing countries, mainly Guinea, see Table 2 below.

Approximately 90% of the imported bauxite is allocated to the production of alumina, mainly taking place in Ireland, Germany, Spain and Greece and accounting for 4.6% of global supply. While the EU is a net importer of bauxite, it is a net exporter of alumina (El Latunussa, et al., 2020).

In 2019, the EU (including EFTA countries) sourced most of its aluminium domestically, see Figure 1. Primary aluminium is mainly produced in Norway, Iceland as well as Germany, France, Spain (Gregoir & van Acker, 2022), while together, Germany and Italy produce almost half of the EU's secondary aluminium (Cassetta, Monarca, Pozzi, Quaglione, & Sarra, 2019).

By 2050, secondary aluminium is expected to make up 53% of the EU's supply of aluminium. The EU meets its demand for aluminium through domestic production of primary aluminium, domestic recycling of aluminium waste and scraps into secondary aluminium, and foreign imports of primary aluminium, see Figure 1 above. Currently, the EU must import about 30% of its total demand for aluminium due to EU demand exceeding domestic production capacity (Gregoir & van Acker, 2022).

Counterintuitively, since 2002, the EU has been a net exporter of aluminium scrap and waste, with around 80% being exported to China, India and Pakistan where it can be recycled more cheaply (European Aluminium, 2020), however, the gains in carbon emissions reduction may not be as beneficial. Yet, the energy crisis is expected to drastically impact the EU's production of primary aluminium in 2022 (Carter, 2022), making the production of secondary aluminium more attractive. In this context, it is possible the EU must evaluate its exports of metal scrap waste for domestic recycling.

Table 2: Summary table of EU share of global production in bauxite, alumina and primary aluminium

Material	EU share of global production	Main exporting country to EU
Bauxite	0.7%	Guinea (63%), Brazil (10%), Sierra Leone (7%)
Alumina	4.6%	EU is a net exporter
Primary aluminium	7%[2]	Russia (22%), United Arab Emirates (15%), Canada (11%) and Mozambique (9%)[3]

Imports of primary aluminium negatively impact the EU's climate ambitions as the global average primary aluminium production emits 17 tonnes of CO_2 per tonne of production, compared to the European average of 6.7 tonnes of CO_2 per tonne of production. For comparison, the production of secondary aluminium emits 0.5 tonnes of CO_2 per tonne of production (European Aluminium, 2020).

[2] In 2019, including primary aluminium production in the EU28 and the EFTA. (European Aluminium, 2020)

[3] Authors own calculations based on 2021 Comtrade data of EU27 imports of "Unwrought aluminium" HS code 7601.

The EU is a frontrunner regarding low-carbon aluminium production, however, the EU's demand for manufactured aluminium products exceeds its production capacity and must therefore import these products from countries where the CO_2 emissions from production are significantly higher than in the EU (European Aluminium, 2020). Indeed, the EU is a net importer of manufactured aluminium products, with its imports mainly originating from China, Turkey, Switzerland and Russia (Cassetta, Monarca, Pozzi, Quaglione, & Sarra, 2019).

With the carbon border adjustment mechanism, the EU aims to tackle this issue by putting a price on the embedded carbon emissions of certain foreign carbon intensive goods equal to the costs domestic firms face. This mechanism aims to be operational by 2026 and is expected to impact countries without carbon pricing systems such as Russia and China. In addition, as a response to Russia's invasion and war on Ukraine the EU has implemented sanctions on Russia targeting fossil fuels and industrial goods, including aluminium (Council of the European Union, 2022).

The lithium-ion battery value chain

By 2030, EU demand for batteries could account for 17% of global demand, largely driven by the demand increase of passenger EVs (European Commission, 2020). However, today, the EU is just on the cusp of launching its domestic EV battery production (Cerai, 2022). As the EU anticipates specialising in the production of lithium-ion batteries, it must reflect on potential issues for the lithium-ion value chain, including the need to secure a reliable source of critical raw materials to produce such batteries.

European demand for critical metals required for EV battery production such as lithium, nickel, and cobalt are expected to increase by 3535%, 103% and 331% respectively (Gregoir & van Acker, 2022). The guaranteed future availability of lithium is particularly concerning as natural reserves are scarce, human rights and environmental issues surround its extraction, and its recyclability is considering hazardous and complex.

The EU is a net importer of lithium EV batteries, meaning European EV manufacturers rely on importing EV batteries from companies in China and South Korea, respectively accounting for 47% and 28% of total lithium battery imports[4]. Importantly, the emissions intensity of EV battery production is dependent on the energy mix of the producing country, which in the case of China (IEA, 2019) and South Korea (IEA, 2020) is still dominated by fossil fuels.

The key component of these batteries, lithium, is mainly being sourced from Chile and Argentina. China mainly imports lithium carbonates from Chile and Argentina, respectively

[4] Authors own calculations based on 2019 Comtrade data of EU27 imports of "Electric accumulators; lithium-ion, including separators, whether or not rectangular (including square)" HS code 850760.

accounting for 60% and 38% of total lithium carbonate imports[5]. Similarly, South Korea sources most of its demand for lithium from Chile, totalling 75% of total imports of lithium carbonate[6].

Extraction of critical metals for clean technologies, including lithium, exerts high environmental and social pressures such as water stress, landscape management and resulting biodiversity implications, as well as tensions between local communities and mining operators (IEA, 2021).

Moreover, the IEA warns that lithium and other clean technology minerals risk becoming conflict minerals in the future (IEA, 2021), due to their concentrated natural prevalence, market scarcity and surging prices brought on by high demand.

In an effort to ween dependence off of primary lithium reserves, countries are moving to boost battery recyclability rates to anticipate the future demand for lithium batteries. South Korean EV battery manufacturers are moving to form a battery waste recycling alliance (Hyun-bin, 2022). EV battery recycling could reduce the GHG emissions by a median value of 20kg CO_2 eq./kWh, one fifth of the lithium-ion battery's life-cycle emissions, compared to primary battery production (Aichberger & Jungmeier, 2020).

However, in the EU, collection and recycling of lithium-ion batteries is virtually non-existent, due to the complexity of the recycling process and low quality of recycled lithium, rendering the whole process cost-ineffective compared to primary supplies of lithium (European Commission, 2020). Despite having no clear pathway towards efficient lithium-ion battery recycling, in 2017, the European Commission and Member States launched the European Batteries Alliance (EBA) to address the expected demand for EV batteries in a sustainable manner aiming to boost the domestic production of lithium-ion batteries. However, considering the unstable supply of primary lithium and the poor prospects of recovering lithium from old batteries it could be beneficial for the EU to consider alternative battery technologies for EVs that are future-proof and sustainable.

A promising sustainable alternative to the lithium-ion battery is the sodium-ion battery. Although the sodium-ion battery for EVs is not yet market-ready – China's top battery manufacturer revealed it planned on setting up a supply chains by 2023 (Sayers, 2022) – the prospective could be remarkable. Benefits of the sodium-ion battery include resource abundance and more sustainable extraction methods, ensuring a reliable and stable supply, and ease of recycling and less hazardous, due to the composition of a sodium-ion battery which is non-toxic and less prone to fires (Galcerán, 2021).

Moreover, the performance of sodium-ion batteries is expected to surpass lithium-ion batteries, delivering a greater lifespan and faster charging technology (Blain, 2022). Yet, the development of sodium-ion batteries is still at a relatively early stage and costs are high

[5] Authors own calculations based on 2019 Comtrade data of Chinese imports of "Carbonates; lithium carbonate" HS code 283691.

[6] Authors own calculations based on 2019 Comtrade data of South Korean imports of "Carbonates; lithium carbonate" HS code 283691.

due to the R&D in new manufacturing technologies. Still, in the future, if scaled up the production could become more cost efficient than lithium-ion batteries.

Environmental and social impacts of material demand in the aluminium and lithium-ion battery value chains

The material demand in the aluminium and lithium-ion battery value chains have major environmental and social consequences both inside the EU and in many other parts of the world, both upstream and downstream in the value chain.

Environmental and social impacts upstream

The extraction and processing of natural resources can be linked to 90% of biodiversity loss, water stress and make up half of total global greenhouse gas emissions (GHG) (IPR, 2019). Moreover, the mining of primary metals and minerals was estimated to have contributed to 10% of total global energy-related emissions in 2018 (Azadi, Northery, Ali, & Edraki, 2020). Other environmental impacts of the extraction of primary metals and minerals include water and soil pollution, erosion, release of toxic gases and radioactive elements, land movements, deforestation, and biodiversity loss (MIT, 2016).

The generated social impacts of the mining sector, largely taking place outside of the EU (Eurometaux, 2022), often take the form of human rights violations. These include forced displacement of people, restricted access to clean land and water, exposure to harassment by mine or even governments (Oxfam, n.d.).

In the case of bauxite mining, in 2017, riots erupted in Guinea's Boke region as local communities reached the tipping point of inadequate services such as a lack of water and electricity, area pollution, a lack of government oversight and tensions surrounding land rights (Human Rights Watch, 2018). Similar social unrest has stirred in Chile and Argentina when it comes to lithium mining, as large corporations extract valuable resources, leaving local communities struggling with water scarcity, local pollution, and little economic return (Frankel & Whoriskey, 2016).

Environmental and social impacts downstream

Downstream, the recovery and recycling of ELVs is met with several environmental and social implications. In 2019, the EU average for the reuse/recovery of ELVs was 95%, covering reuse of dismantled parts, and recycling through backfilling and energy recovery (Eurostat, 2022). However, this percentage includes the processing of car parts being incinerated (i.e., energy recovery) and parts sent abroad for cheaper recycling, often under less stringent environmental and labour rights standards (Kettunen, Gionfra, & Monteville, 2019).

This is a particularly pertinent problem for lithium-ion batteries as their recycling process is considered dangerous and complex due to the composition of the batteries containing hazardous, toxic chemicals that also pose fire risks. The improper disposal of these batteries can lead to soil and water contamination and GHG emissions if burned to extract the valuable metals (PACE, 2019).

The working conditions in the recycling sectors abroad typically do not adhere to EU standard, as most of the recycling takes place in the informal economy and is often carried out by migrants, children and other vulnerable groups. Working conditions are for the most part poor, unsafe and unhealthy. In addition, rights at work are often not respected for these workers (ILO, 2019).

Another issue regarding the recycling of ELVs is that in practice it is difficult to distinguish between an ELVs and a "used car". This has led to the export of ELVs to African countries such as Libya, Nigeria, and Ghana under the guise of being second-hand vehicles. As a result, these vehicles no longer meet EU safety and environmental conditions, are being driven abroad with the associated environmental and safety consequences (Human Environment and Transport Inspectorate, 2020).

The external implications of the phase-out of ICE vehicles in the EU should be treated with care. On one hand, the export of used ICE vehicles could benefit importing countries with regards to GHG emission reduction, compared to the ICE vehicle previously in use. On the other hand, the continued export of the EU's unwanted vehicles should not remain reliant on the recycling facilities abroad, where workers rights and safety are not treated with the same amount of attention, as recycling facilities within the EU (ILO, 2019).

Box 1: The EU legislative landscape

- In the context of the European Green Deal, the European Commission released a new Circular Economy Action Plan (CEAP), with a section dedicated to the vehicles and batteries value chain (European Commission, 2020).
- To improve the sustainability of the vehicles and batteries value chain, the goal of the CEAP would be revise the EU Batteries Directive, the End-of-Life Vehicles (ELV) Directive, and the Waste Shipments Directive.
- EU Batteries Directive aims to ensure the sustainability and competitiveness of EU battery value chains. The proposed revision would introduce requirements for recycled content, mandatory minimum recycled content, carbon footprint minimisation and tracking, supply chain due diligence obligations, recycling efficiencies and material recovery targets, relevant for the recycling of EV batteries and the reuse of key critical raw materials such as lithium, nickel, and cobalt (Halleux, 2022).
- The revision of the ELV Directive, planned for late 2022, intends to encourage circularity of ELVs, by setting clear standards and requirements to prevent waste from vehicles, to promote their reuse, recycling and recovery as a whole and in parts, and improve the overall environmental performance throughout the vehicle life cycle (European Commission, 2021). The revision of ELV Directive could ensure better material efficiency for car parts, as well as recycling of aluminium scrap and battery waste.

- The recent revision of the Waste Shipments Regulation restricts the export of hazardous and hard to recycle waste to non-OECD countries, and only allows the export of waste if a country has notified the European Commission that it wishes to accept the waste exports. In that case, the country must prove they are capable of sustainably and safely recycling the waste product (European Commission, 2021). This revision ensures that old lithium-ion batteries and ELVs are not exported to countries that cannot recycle this waste in a safe and environmentally responsible manner.

Is the EU policy landscape fit for a circular, net-zero transition in road transport?

As discussed in Box 1, the European Commission's CEAP recognises the need increase the circularity of the vehicles sector. Not only is the Commission preparing for the expected future demand for EVs, but it also aims to mitigate the environmental and social impacts that would otherwise result from a transition to net-zero in road transport with unrestrained material demand. The following section assesses the level of circularity of the policies listed in Box 1 concerning the aluminium and lithium-ion batteries value chains, as well as the recycling of ELVs.

While the revision of the **EU Batteries Directive** plans introduce new circular requirements for the recycling and manufacturing of new batteries, the current proposal does not adequately address the very low level of lithium-ion battery recovery and recycling. Considering the EU's ambition to domestically produce lithium-ion batteries, it is imperative that the EU also accounts for the proper recycling of these batteries.

The proposal for the revised Batteries Directive does not clearly state where the EU plans to recycle lithium-ion batteries (domestically or abroad), or how it expects to ramp up the recycling process of lithium-ion batteries (e.g. by addressing the complex design of the batteries which make them difficult to recycle). Moreover, while the proposal aims set a mandatory minimum recycled content for EV batteries (4% for lithium by 2030, increasing to 10% by 2035), and a materials recovery target of 35% for lithium by end of 2025, increasing to 70% by end of 2030 (Halleux, 2022), the quality of secondary lithium is considered too low for reuse in EV batteries (European Commission, 2020).

Moreover, stakeholders have criticised the proposal for lacking circularity beyond recycling, for example the proposal does not sufficiently address increasing the materials efficiency of batteries manufacturing (Halleux, 2022), nor the reality that the EU is not able to source enough secondary lithium to meet the demand for EV batteries. Neither the proposal for a Batteries Regulation nor the accompanying impact assessment include any mention of the potential of alternative battery technology such as on sodium-ion batteries. This puts the net-zero road transport transition in a similar dependence scenario for lithium, as the EU is now facing with oil and gas.

In the 2022 State of the European Union, von der Leyen addressed this issue by announcing a forthcoming European Critical Raw Materials Act, citing the need to begin to secure a reliable supply for critical raw materials for the green and digital transitions (Breton, 2022). This strategy would foresee the establishment of raw materials alliances for identified critical raw materials, strengthen supply chains by sourcing from within the EU where possible and from secondary sources, and setting up a strategic storage.

The revision of the **ELV Directive**, intends to encourage circularity and environmental performance of vehicles throughout their lifecycle. This will on one hand require higher content of recycled materials for car parts, such as aluminium and steel. However, additional requirements in the upstream section of the vehicles value chain to address material efficiency by ensuring vehicles are designed to facilitate their dismantling and remanufacturing when they reach the end of their lifecycle.

Moreover, the ELV Directive, in coherence with the Waste Shipments Regulation, must set out clear criteria and procedures surrounding ELVs and their recycling, as the EU plans to phase out ICE vehicles and replace them with EVs, a large portion of these vehicles will end up outside the EU, either as waste or second-hand vehicles.

Firstly, the grey area between ELVs and second-hand vehicles must be addressed to ensure that ELVs are not labelled as "used cars" when shipped abroad. Secondly, under the revision of the Waste Shipments Regulation, ELVs can only be shipped outside the EU if the recycling process has been explicitly reviewed and approved by the Commission. This would reduce the likeliness of ELVs deemed not roadworthy and polluting being driven in importing countries as opposed to being correctly dismantled and recycled.

Lastly, in accordance with the upcoming due diligence legislation, the need for the European Commission to explicitly review and confirm that the ELV recycling abroad is up to its standards, could benefit the foreign recycling sector over time. However, countries reliant on an informal recycling sector could see an end to the unregulated export of ELVs from the EU, with the resulting consequences of a decrease in economic livelihoods.

The proposed revisions of the above policies are headed in the right direction to reach a circular transition to net-zero road transport. However, some efforts can still be made to ensure both a reduction in material demand and an increase in material efficiency. The following section of this briefing provides an overview and brief explanations of potential positive and negative social and environmental spillovers resulting from the implementation of the revised EU Batteries Directive, the ELV Directive and the Waste Shipments Directive, in- and outside the EU.

Prospective positive spillovers

Although the transition to circular and net-zero road transport has many associated positive and negative spillovers, the following sections focus on the social and environmental spillovers most closely associated with the aluminium and lithium battery value chains.

	Inside EU	Outside EU
Social	• Job creation in the recycling sector for lithium-ion batteries, and aluminium • Increased strategic autonomy	• Job creation in the recycling sector for lithium-ion batteries, and aluminium • Increased due diligence regarding the exports of waste and ELVs
Environmental	• Increased recycling rates of batteries, aluminium and ELV parts	• Increased due diligence regarding the exports of waste and ELVs • Increased recycling rates of batteries, aluminium and ELV scraps • Decreased primary resource extraction • Higher environmental standards applied to imported EV car parts

Job creation in the recycling sector for lithium-ion batteries and aluminium, in- and outside the EU

The EU has ambitions to ramp up European lithium-ion battery production to meet demand for EVs. It is estimated that by 2030, the number of direct and indirect jobs created by battery recycling, specialising in lithium-ion batteries, could range from 250k to 735k new jobs in the EU (Menon Economics, 2022; Raw Materials & Fraunhofer, 2021; Transport & Environment, 2019). Although the EU is at a preliminary stage of domestic production, there is no clear pathway to building a comprehensively sustainable domestic lithium-ion battery supply without a concrete plan to ramp up battery recovery and recycling to meet the ambitions in the EU Batteries Directive.

The European aluminium industry directly employs around 230k workers and another 1 million workers indirectly. Primary and secondary production respectively account for 5% and 2% of total employment in the aluminium sector, as the majority of workers are employed in the manufacturing of aluminium products (Cassetta, Monarca, Pozzi, Quaglione, & Sarra, 2019). It is unclear the potential job creation in the aluminium sector, however as the share of secondary aluminium is expected to increase by 2050 (Gregoir & van Acker, 2022), it is most likely jobs will increase.

The extent to which the EU will rely on domestic recycling facilities will influence the level of jobs within the recycling sector abroad. Currently, the EU is exporting ELVs to be dismantled as well as aluminium scrap and waste to be recycled more cheaply. If the EU continues to rely on foreign recycling capacity as it transitions to net-zero road transport, then countries reliant on the EU's waste exports may not necessarily see a decline in their recycling sector. However, if the EU decides to reshore recycling of ELVs then these countries will see a decline in EU exports of waste, that could potentially negatively impact their economic livelihoods.

Increased due diligence regarding exports of waste and ELVs

As the EU seeks to ramp up recycled content requirements with various circular economy initiatives, the EU should see an eventual decrease in waste production, as well as an increase in waste recycling potential.

A significant problem in the current ELV Directive is the number of missing ELVs. It is estimated that per year 4 million deregistered vehicles are not properly tracked or accounted for. Research speculates that these missing vehicles are either shipped/sold outside the EU and failed to adhere to the reporting requirements or were illegally treated as ELVs and exported outside the EU (European Commission, 2021).

The revision of the ELV Directive in synergy with circular economy policies, provides Member States the opportunity to better support the ELV sector in the administration, processing, dismantling, and recycling of ELVs. This could reduce the number of ELVs exported to LDCs, legally and illegally. Moreover, the faster the EU makes the shift to EVs, the quicker used EVs could make their way to LDC roads, reducing their transport emissions. However, the implications of proper and safe processing of ELVs in LDCs must be taken into account.

As discussed, the revision of the Waste Shipments Regulation has its role to play in ensuring that waste products such as waste batteries and ELVs are only shipped to countries that are able to safely and sustainably dismantle and recycle these products, as well as eliminating the grey area between ELVs and used cars.

For example, the recyclability of lithium-ion batteries is considered dangerous and difficult, due to the complex composition of the batteries, containing hazardous, toxic chemicals that also pose fire risks. The Waste Shipments Regulation and the associated due diligence requirements will ensure a country recycling the EU's waste batteries meets the requirements to safely do so. Moreover, the new due diligence requirements could positively impact countries dependent on recycling the EU's waste to implement better environmental and labour standards in order to continue to import waste streams from the EU.

Increased recycling rates of batteries, aluminium and ELV parts inside and outside the EU

The proposed targets for higher recycled content, and material recovery put forward in the Batteries and ELV Directives may be challenging considering today's limited recovery and recycling of lithium-ion batteries, for example. However, if successful it could reduce the total amount of battery waste generated by electrifying the entire passenger fleet, and decrease the EU's reliance on primary lithium extraction.

For the aluminium sector, a more circular production and automotive manufacturing, for example by setting minimum recycled content standard for aluminium in EVs, would reduce GHG emissions, as secondary aluminium produces a mere fraction of the **CO_2 compared to the EU production average** (European Aluminium, 2020). Moreover, increased secondary aluminium production could address the EU's growing needs for aluminium, while enhancing its strategic supply by reducing its reliance on imports from countries such as Russia and China. The EU could look to curb its exports of aluminium waste and scrap and recycle it within its borders; however, this would negatively impact the economic outlooks of the aluminium recycling currently happening abroad, as discussed above.

Finally, the revision of the ELV Directive will be crucial to secure clear circularity standards for newly produced cars, as well as clearer guidelines to deregistering vehicles. As a result, to the extent that ELV are being dismantled and recycling in- and outside the EU could significantly reduce the amount of waste generated from electrifying the EU's passenger car fleet.

Increased strategic autonomy and decreased primary resource extraction

The Batteries Directive and the newly announced European Critical Raw Materials Act intend to decrease the EU's reliance on primary resource extraction, by promoting the economic viability of secondary critical raw materials. This is relevant to the production of primary aluminium and lithium-ion batteries, as the natural reserves of bauxite and lithium are concentrated in a handful of countries.

The environmental and social benefits of the EU reducing its reliance on these raw materials accrue at the extraction site, by reducing environmental pressures for primary resources, such as water stress, soil degradation, CO_2 emissions, deforestation and biodiversity loss outside the EU, as well as the associated benefits to local communities.

Higher environmental standards applied to imported EV car parts

A final positive spillover is the potential policy impacts of the EU on other countries. The EU is considered a leader in environmental standards and the circular economy. As part of the CEAP, the EU seeks to support cooperation between its trade partners and the African Union to better promote circular economy policies and support regulatory harmonisation to facilitate trade in secondary goods (Blot, Oger, & Watkins, 2022).

Prospective negative spillovers

	Inside EU	Outside EU
Social	• Shift from ICE to EV manufacturing job losses and shifts • Potential social impacts related to the recycling of lithium-ion batteries	• Potential loss of jobs in the recycling sector • Loss of jobs in primary resource extraction • Potential social impacts related to the recycling of lithium-ion batteries
Environmental	• Potential environmental impact related to the recycling of lithium-ion batteries	• Potential environmental impact related to the recycling of lithium-ion batteries

Shift from ICE to EV manufacturing job losses and shifts

The shift to a fully electric fleet of private vehicles will undoubtedly affect employment in the automobile sector. It is estimated that 2.7 million EU citizens are directly employed by automotive manufacturing (Amelang, 2021). The employment rate in the transition to net-zero transport is expected to remain near constant overall, provided the industry invests in reskilling of existing employees (Kuhlmann, et al., 2021).

Not all sections of the automotive industry are impacted equally, especially automotive manufacturing and SMEs in the ICE components supply chain. In fact, it is expected that the increase of EV and decrease of ICE vehicle manufacturing will result in net loss of 275k jobs from 2021 to 2040 (CELPA, 2021). This is because the manufacturing process of EVs is less labour-intensive than ICE vehicles (Küpper, Kuhlmann, Tominaga, Arora, & Schlageter, 2020).

It is likely that increases in employment in other sectors, such as electronics and utilities, as well as the repair sector are projected to compensate for these losses across the EU, but specific communities, Member States and individuals will be adversely affected and will require support during the transition (European Commission, 2021).

Loss of economic prospects the extraction and recycling industries outside the EU

On one hand, the objective to reduce the EU’s reliance on primary critical raw materials, as stated in the Batteries Directive and the European Critical Raw Materials Act, by increasing the EU’s sourcing of secondary raw materials could negatively impact the income of people reliant on the primary resource extraction industry. While these workers often do not have stellar working conditions to begin with, the loss of socio-economic opportunities risks putting local communities in an even worse position than they are currently in (ILO, 2019).

On the other hand, EU policies such as the revision of Waste Shipments Regulation as well as the environmental and human rights due diligence legislation aim to minimise adverse environmental and social impacts of natural resource extraction and waste recycling abroad. As previously discussed, these policies will likely reduce the amount of untraceable, unregulated and environmentally- and socially unfriendly produced goods from entering and exiting the EU market.

The Waste Shipments Regulation and the environmental and human rights due diligence legislation aim to address working conditions abroad by improving supply chain traceability. However, it is possible that some countries – whose recycling sectors rely on the EU’s stream of waste exports to create high value materials – that currently do not meet the EU’s requirements for safe and sustainable recycling could lose an important source of income. If the implementation of the revision of the Waste Shipments Regulation and the due diligence legislation are not accompanied by measures to ensure countries elevate their social and environmental standards, these policies could risks leaving these countries behind, as the EU pursues its own sustainable transition (Blot, Oger, & Watkins, 2022).

Potential social and environmental impacts related to the recycling of lithium-ion batteries in- and outside the EU

As previously stated in this briefing, recycling of lithium-ion batteries is considered dangerous and complex due to the composition of the batteries containing hazardous, toxic chemicals that also pose fire risks. Moreover, the improper disposal of these batteries can lead to soil and water contamination and GHG emissions if burned to extract the valuable metals (PACE, 2019).

The EU's ambitions to electrify its passenger car fleet and compete on the global market for lithium-ion batteries means that it will have to find a viable way in which to recycle the spent lithium-ion batteries that will inevitably be generated.

It is possible that the EU could find a recycling facility abroad, that adheres to the necessary requirements in terms of safety and sustainability to be determined by the revision of the Waste Shipments Regulation. However, if the EU wishes to secure a sustainable supply of lithium, according to the announcement of the European Critical Raw Materials Act, it could consider investing in recycling facilities within its borders.

Towards policy recommendations for a socially- and environmentally-just circular transition

The shift to a circular, net-zero road transport sector will rely on the ambitious and concrete implementation of several policy measures, that will inevitably lead to both positive and negative spillovers, in- and outside the EU. The following policy recommendations aim to maximise the benefits of the circular transition to a net-zero road transport, while minimising the negative outcomes.

- **Reduce absolute material demand by promoting policies supporting alternative mobility options** such as the new European Urban Mobility Framework (European Commission, 2021) promoting public transport, car sharing, cycling and walking. The absolute material demand necessary to electrify the entire existing EU passenger fleet far exceeds what the EU can produce on its own, including the increased material efficiencies from recycling. Not only does the environment benefit from a reduced material demand, investments in public transport and green infrastructure are a socially viable option for lower-income households that cannot afford to purchase a private EV.

- **Mitigate risks in relevant sectors** by preparing for the shifting needs of employment within the automotive sector through the means of reskilling and retraining.

- **Support economic opportunities in relevant sectors** such as the potential increase in employment in the recycling sectors for batteries, aluminium and ELVs. Moreover, if the EU anticipates expanding the domestic manufacturing of lithium-ion batteries, it is imperative to ensure the circularity of the lithium-ion battery value chain as both domestic production and recycling are at early stages.

- **Leverage the expertise of the European Batteries Alliance** to produce a circular strategy for the entire lithium-ion battery value chain, addressing the need for a reliable supply of lithium, as well as the waste generation and recyclability issues.

- **Diversify inputs materials required for future green technologies by researching alternative technologies** such as the sodium-ion battery, together with the European Batteries Alliance. Although in its infancy, the sodium-ion battery already has an advantage over the lithium-ion battery regarding resource abundance and a more sustainable extraction process, as well as a safer recycling process.

- **Ensure the most ambitious implementation of the revisions of EU Batteries Directive, ELV Directive and the Waste Shipments Directive** in coherence with other relevant EU climate, environmental and circular economy policies:

    - The EU Batteries Directive must address the absolute reduction of material demand by setting criteria for the design, production and recycling of lithium-ion batteries.

    - The ELV Directive and Waste Shipments Regulation must establish clear criteria for the export of used cars versus ELVs. Moreover, The Waste Shipments

Regulation must define and communicate clearly the requirements recycling facilities abroad must meet in order to continue to import EU waste.

- In synergy with the environmental and human rights due diligence legislation, these circular policies must ensure that the EU is not importing goods relevant to the automotive supply chain that have contributed to environmental degradation or human and labour rights violations.

- **Harness trade agreements and cooperation** with like-minded trade partners to secure a sustainable supply of critical raw materials for the net-zero and more broadly the green transition, such as Strategic Partnerships for Critical Raw Materials, in accordance with the European Critical Raw Materials Act (Blot, Oger, & Watkins, 2022).

- **Encourage the uptake of Aid for Trade and development cooperation policies** to mitigate negative impacts on the least developed and most vulnerable countries by providing technical assistance to allow them to meet the elevated environmental standards set by the EU (Blot, Oger, & Watkins, 2022).

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