BEYOND RECYCLING: THE CIRCULAR OPPORTUNITY FOR PASSENGER CARS IN EUROPE

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CIRCLE ECONOMY

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EXECUTIVE SUMMARY

The European passenger car sector boasts high recycling rates, but is only 40% circular. On paper, the industry is a recycling champion: when vehicles reach their end-of-life in Europe, 78% of materials were recycled in 2020. But boosting circularity requires more than recycling: cycled materials must also be used as input for new passenger vehicles. Currently, 79% of material inputs for new vehicles come from virgin sources. Further, many cars are exported outside of the continent—thereby escaping high-value recycling of components and materials. Aside from these recycling losses, the industry is also heavily invested in producing new cars: 14 million new vehicles were added in 2020, or one new car for every 27 already on the road.

Fortunately, the European passenger car sector is well-positioned for the circular transition. Europe is a front-runner in policy development supporting the circular transition. While policy initially focused on end-of-life and battery recycling, it now also extends to the design phase focusing on recycled content mandates and the recyclability of the full vehicle. These policies will continue to evolve over the coming decade, creating a strategic opportunity for companies that are able to navigate the transition early.

There is significant future earning potential for businesses positioned to leverage the rise of electric vehicles and MaaS models and create more circular solutions. Circularity has an important role to play for passenger cars and especially robo-cab fleets given fleet operators' expected high focus on total cost of ownership.

Much of the growth is expected from the Shared Mobility segment driven by an acceleration of robo-cabs (commercially at scale in the 2030s), which by 2040 is expected to comprise around 17% of global urban transport passenger kilometres. By then, Mobility Services could amount to more than 40% of the profit pool, while essentially all new cars sold will be BEVs.

Circular economy strategies and business models are critical for the European passenger car sector to respond to rising consumer demand and reach net-zero goals. Vehicles will likely remain an imperative mobility solution as the European need for transport continues to swell. Yet the industry will face severe challenges responding to this demand in a business-as-usual scenario: increasing supply chain competition for materials and rising insecurity of critical materials, for example. Net-zero goals will also be at risk: although ditching fossil fuels for BEVs powered by renewables could reduce GHG emissions by up to 70%, this alone won't achieve a net-zero industry. The five circular strategies and emerging circular business models mentioned below can allow businesses to meet these challenges head-on, satisfying the growing demand for mobility within industry policy and sustainability targets.

Five key circular economy strategies can bridge the gap to net-zero—reducing production-related greenhouse gas emissions by 60% and boosting circularity to 66%. The strategies are 1) increasing recycled content in production, 2) optimising material use in vehicles through material innovation and extending the range per weight of batteries, 3) reusing and remanufacturing parts, 4) adopting new business models, and finally, 5) continued innovation and implementation of end-of-life recycling.

BEYOND RECYCLING: THREE ACTIONS FOR A RESILIENT, CIRCULAR AND PROFITABLE INDUSTRY

Harness circular strategies to reach net-zero goals

Circular strategies can cut greenhouse gas (GHG) emissions embodied in materials and are therefore vital to achieving net-zero goals—which cannot be realised through renewable electrification of the vehicle fleet alone. Adopting powerful strategies such as including recycled content, optimising material use and improving recycling efficiency can bridge the gap to net-zero.

Make circularity the new normal across all business models

Further embedding circular strategies such as reuse and remanufacturing within the industry can enhance sustainability outcomes. While the expected shift from private car ownership to Mobility as a Service (MaaS) models, especially robo-cabs, will likely improve vehicle utilisation and thus circularity—integrating reuse and remanufacturing into these offerings will further increase circularity and help drive profitability.

Secure long-term and cost-competitive access to recycled inputs

Increasing demand for circular inputs will require companies to reflect on how they can secure supplies over the long term and at competitive prices. Investing and partnering to secure access and capabilities within end-of-life material recovery and recycling will allow businesses to be less dependent on a volatile and currently limited market of good quality secondary materials.

1. GLOBAL AND EUROPEAN MOBILITY TRENDS

The movement of people and goods around the world provides many advantages, from trade to jobs. But today's mobility model cannot meet future demand without contributing to exceeding planetary boundaries.[1] The mobility sector is a dominant emitter—representing 30% of the global emissions footprint[2]—and is highly resource-intensive—representing 10% of the globe's material footprint.[3] The materials used to build mobility solutions and the fossil fuels that power them provide the greatest impacts. Sustainably meeting future demands for mobility will require a thoughtful mix of modes of transport, but demand must not be fed with traditional solutions based on fossil fuel combustion and high rates of private vehicle ownership—especially in higher-income economies. Emissions from passenger cars account for about 40% of the entire mobility sector: circular passenger vehicle solutions are critical to a sustainable future, to businesses' longevity and to reaching net-zero goals. Europe alone is responsible for about a third of the entire global vehicle stock; this is why the European automotive sector should be front and centre in the transition towards a circular economy and is the focus of this analysis.

Now is the time for rapid and accelerated climate action

Pollution, GHG emissions and waste production are increasing at alarming rates, while growing consumption rates will only exacerbate these trends. In 2019, the global economy consumed over 100 billion tonnes of resources—primarily virgin metal ores, fossil fuels, biomass and minerals—and only 8.6% of this was cycled back into use. This wasteful use of resources directly increases global GHG emissions: 70% of emissions are tied to material extraction, processing, use and disposal.[4] To have a chance of limiting warming temperatures to livable levels, we need a circular economy where waste is designed out, materials' value is preserved at the highest level possible and natural systems are regenerated.[5]

Linear supply chains are at risk of critical scarcity thresholds and volatility

The automotive industry is susceptible to stringent and fast-moving regulation, as well as supply chain challenges worsened by pandemics, war and other global events. It is also dependent on critical and scarce materials. These challenges are worsened by the take-make-waste approach of the linear economy, which brings its own range of risks—from resource shortages to supply continuity.[6,7] Pivoting towards a circular economy can provide protection.

With the electrification of passenger cars, more rare and precious metals are needed—many of which are extremely energy- and emissions-intensive to mine. So while the industry may succeed in significantly curbing GHG emissions from vehicles' 'use' phase, it may worsen emissions associated with 'production and resource consumption'. However, EU institutions have recently raised the bar for circularity, with a particular focus on batteries; the newly proposed regulations in late 2020—if passed as expected—would be an innovative regulatory step-change. Batteries must meet the requirements for recycled content, performance and durability, and producers will have the additional responsibility of organising, promoting and financing the separate collection of end-of-life batteries. When recycling is an avenue for lithium-ion batteries, the proposal establishes a required recycling efficiency of 65% by 2025 and 70% by 2030, and material recovery rates for cobalt (95%), nickel (95%), lithium (70%) and copper (95%) by 2030.[8] It also ups the ante on carbon accounting, requiring the life cycle CO2 footprint of the battery to be reported per battery model, batch and battery plant.

Such battery policy and wider recycled content mandates will pressure already scarce supply and price volatility issues—further exacerbated by geopolitical tensions. The Russian invasion of Ukraine has caused a worldwide fluctuation in metal prices. For example, the price of nickel, which is used to make stainless steel and batteries, of which Russia supplies 5-6% globally, nearly doubled to unprecedented highs in March 2022.[9] Meanwhile, Europe and the US have faced magnesium shortages as Chinese production slowed due to sustainability targets based on limiting energy use.[10] Far-reaching and relentless, supply chain disruption is likely to continue.

Rise and acceleration of a disruptive business model: from ownership to MaaS

European mobility is dominated by private vehicle ownership, characterised by a low use rate for cars. In Europe, vehicles sit unused for 95% of the time.[11] Spurred by policy and a pull from consumers seeking more sustainable services, shared mobility solutions can improve car utilisation while driving profitable growth for the sector. According to estimates, self-driving vehicles could cut average vehicle ownership rates by 43%.[12] Robo-cabs are forecast to emerge as a highly lucrative endeavour, especially from 2040 onwards (see more in Chapter three).

2. THE CURRENT STATE OF CIRCULARITY

The European automotive industry is 40% circular. We measure the circularity of the industry using the Circularity Transition Indicator.*[13] Measuring this is an important indicator of progress toward a well-established circular flow of materials and reduced dependence on continued raw material extraction. While this method has its limitations, including its ability to value material quality and address all circular loops (such as vehicle reuse), it provides a useful high-level insight that can be used as a benchmark across sectors.

High recycling, low circularity

The production and maintenance of passenger cars in Europe consumes an estimated 28.4 million tonnes of resources—virgin and secondary—a year. On paper, the recycling of cars at end-of-life in Europe is high: 16.4 million tonnes, or 78%, are recycled. The industry's recycling rates are also often inflated: recycling rates published as an alternative by the industry—~90%—only account for what is collected and sent to recyclers. When recycling losses and efficiencies are considered, this share drops to 78%, falling further to 59% when the number of end-of-life vehicles exported from Europe are considered. While aluminium and steel comprise the largest portion of secondary materials and have relatively high recycling rates, recycling rates for highly precious materials are low. Materials with currently low volumes and recycling rates, such as nickel, cobalt, manganese and lithium, among others, are expected to increase in share as electric and hybrid vehicles become more prevalent.

While the industry reports high recycling rates, it is ultimately not very circular: boosting circularity isn't just about recycling, but also about using circular materials as inputs for new vehicles. However, only 6 million tonnes, or 21% of materials for new vehicle production, stem from secondary sources. Yet there is a large opportunity: for many of the metals used in the automotive industry—steel, aluminium, copper—as well as the critical metals used in batteries, the quality of recycled materials can be as good as their virgin counterparts. In some cases, recycled materials can even perform better.[14] Systems to collect used cars are in place, but what is needed are systems to re-introduce higher volumes of recycled materials into manufacturing processes.

The potential is there; especially with the rise in new service models for vehicles where ownership and end-of-life material collection sits with the fleet operator.

It is expected that end-of-life vehicle policy will evolve to take a full life cycle perspective, potentially spurring policy on targets for value-retention (such as remanufacturing), material recovery targets by material type and quality, and recycled content targets to encourage secondary material use in vehicles. The *Circular Economy Action Plan*[15](CEAP) launched in 2020 as part of the EU Green Deal, for example, targets how products are designed, promotes circular economy practices and encourages sustainable consumption. The European Commission has also supplemented the European End-of-Life Vehicles Directive 2000/53/EC21 with the European Plastics Strategy, which requires manufacturers to use more recycled materials in vehicle production and sets a 85% target for the reuse and recovery of ELVs.

High turnover of new car production and limited market for reuse and remanufacturing

The volume of production for new cars (20.4 million tonnes) is over twice the volume of production of parts for repair (8.7 million tonnes). Despite having 372 million cars on the road, 14 million vehicles are added each year: one new car for every 27 already on the road. This process is highly linear and fails to optimise for utilisation of existing stock or reuse of existing materials. Only 2% of component production is supplemented by reused or remanufactured pieces—for example bodies, chassis, powertrains and transmission systems. There is a vast opportunity to tighten refurbishment and remanufacturing loops with more standardised circular parts design, as well as improved recovery and part recognition processes for reuse and remanufacturing.

Sluggish movement on electrification and MaaS—for now

Figure 1 shows that 79% of new cars manufactured today are ICEs. And while consumer interests are driving an increase in MaaS, especially in urban settings, only 17 million cars across Europe are used for this purpose, out of a total 372 million passenger cars. However, most manufacturers in the automotive sector have confidently set dates upon which ICE production for the European market will cease amid stricter EU emissions limits: Volvo by 2030 and Ford by 2040, for example. The EU also plans to ban the sale of ICE vehicles in 2035 as part of its plan to cut GHG emissions by 55% by 2030 (compared to 1990 levels). So while the number of ICEs still on EU roads may seem high, huge steps have been taken—exceeding the expectations of ten years ago.[16]

AN INDUSTRY RALLYING AROUND CIRCULAR OPPORTUNITIES ACROSS RECYCLING, RECOVERY AND MAAS

Across the board, ambitious circular goals have been set; but these vary with some incumbents setting industry-leading goals in one area—such as recycling—and none in other circular areas—such as recycling efficiency. While targets are welcome, progress is uneven.

Mercedes-Benz is set to increase the share of secondary raw materials used by an average of 40% by 2030 while boosting the use of aluminium. Volvo has committed to 'becoming circular' by 2040: using 25% recycled or bio-based plastics, 40% recycled aluminium and 25% recycled steel by 2025.[17] GM is working toward a corporate goal of 50% sustainable content within vehicles by 2030[18] while Volkswagen's long term goal is to recycle 97% of all raw materials.[19] In terms of reuse and remanufacturing, Volvo leads the pack intending to increase remanufacturing by 60% by 2025.[20]

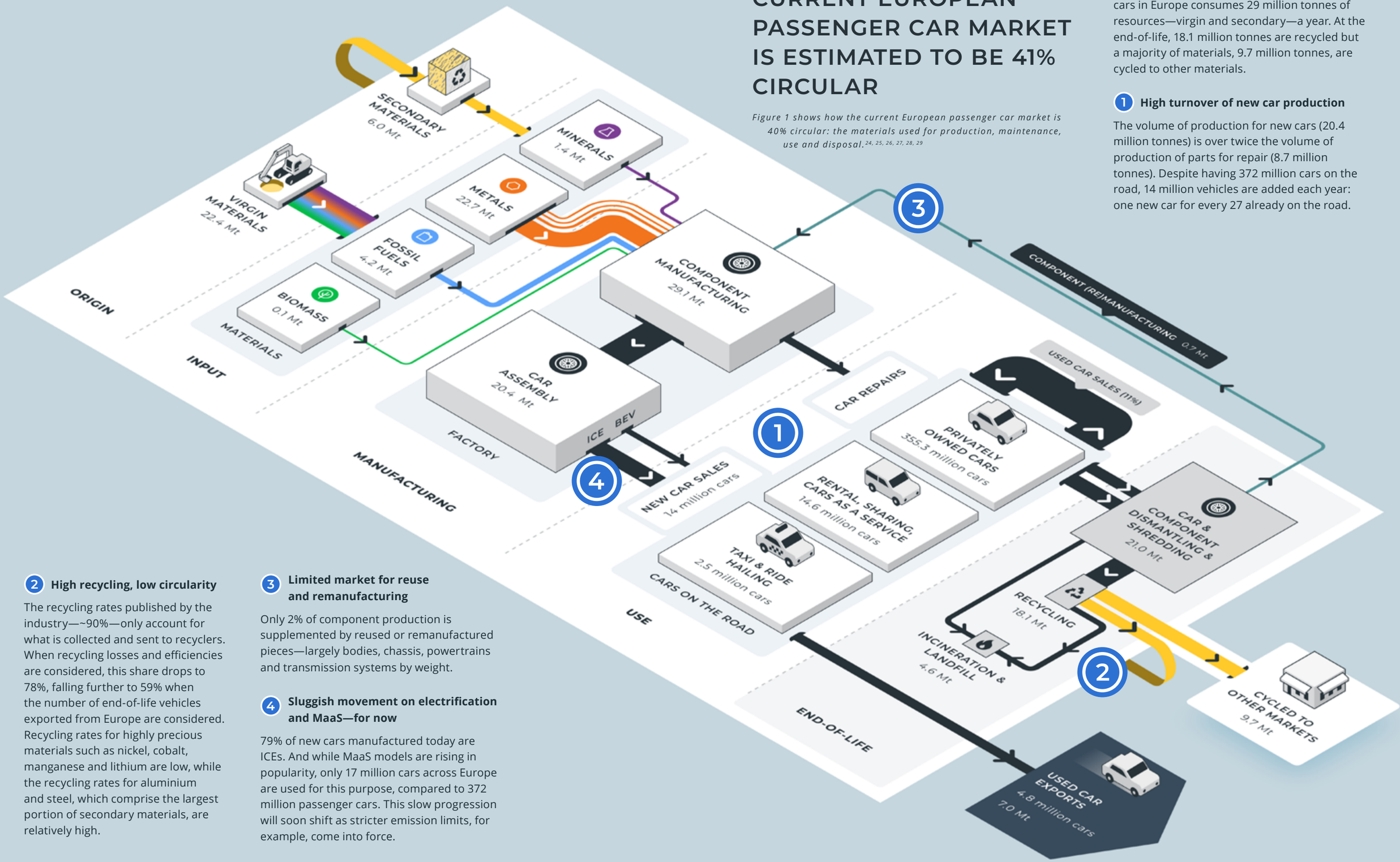
Scale-ups are accelerating the recyclability of BEV batteries and involving incumbents as strategic partners. Swedish battery developer Northvolt already has customer contracts in place worth more than US$30 billion, namely from Polestar and Volvo.[21,22] The company produces battery cells with recycled nickel, manganese and cobalt recovered from battery waste. Mercedes-Benz is building a battery recycling plant in Germany, using the materials to make more electric vehicles.

Disruptors are proving the viability of new MaaS sharing models, such as BlaBlaCar and Getaround, while incumbent manufacturers are experimenting with MaaS offerings: Renault has committed to increasing the use-rate of vehicles by at least 20% with service models. And BMW and Mercedes-Benz had a joint car-sharing business, Share Now,[23] which in 2022 was sold to Stellantis.

* CTI is a consumption-based measure, expressed as a percentage, representing a weighted average of the fraction of an industry's secondary inputs out of its total material consumption and its percentage of wastes and outflows that are reused or recycled.

CURRENT EUROPEAN PASSENGER CAR MARKET IS ESTIMATED TO BE 41% CIRCULAR

Figure 1 shows how the current European passenger car market is 40% circular: the materials used for production, maintenance, use and disposal.[24, 25, 26, 27, 28, 29]



The production and maintenance of passenger cars in Europe consumes 29 million tonnes of resources—virgin and secondary—a year. At the end-of-life, 18.1 million tonnes are recycled but a majority of materials, 9.7 million tonnes, are cycled to other materials.

1 High turnover of new car production

The volume of production for new cars (20.4 million tonnes) is over twice the volume of production of parts for repair (8.7 million tonnes). Despite having 372 million cars on the road, 14 million vehicles are added each year: one new car for every 27 already on the road.

2 High recycling, low circularity

The recycling rates published by the industry—~90%—only account for what is collected and sent to recyclers. When recycling losses and efficiencies are considered, this share drops to 78%, falling further to 59% when the number of end-of-life vehicles exported from Europe are considered. Recycling rates for highly precious materials such as nickel, cobalt, manganese and lithium are low, while the recycling rates for aluminium and steel, which comprise the largest portion of secondary materials, are relatively high.

3 Limited market for reuse and remanufacturing

Only 2% of component production is supplemented by reused or remanufactured pieces—largely bodies, chassis, powertrains and transmission systems by weight.

4 Sluggish movement on electrification and MaaS—for now

79% of new cars manufactured today are ICEs. And while MaaS models are rising in popularity, only 17 million cars across Europe are used for this purpose, compared to 372 million passenger cars. This slow progression will soon shift as stricter emission limits, for example, come into force.

3. MOVING THE INDUSTRY TOWARDS CIRCULARITY BY 2040

While many companies have set specific circular ambitions, there is still a significant gap in goals to reach a near-full circularity by 2040—as this analysis models. To harness the full potential of circularity, the industry must mainstream five key circular strategies. These strategies are based on a simple breakdown of the aims of the circular economy: narrowing flows (using fewer materials to produce products and services), slowing flows (using mate-rials for longer and extending product life cycles) and cycling flows (using materials again through recovery and recycling). On their own, each strat-egy may have limited impact on circularity, emis-sions reduction and financial impact, but together they deliver huge improvements. Building on this and mainstreaming other key circular strategies and business models, our model finds that by 2040 the industry's circularity could rise from 40 to 66%, contributing up to 60% reduction in production-re-lated GHG emissions.

A 66% circular industry by 2040 could meet rising demand for mobility with greater material efficiency. This is due to the optimisation of material use where materials, such as carbon fibre, can help achieve better fuel efficiency, handling and emissions reductions. Our analysis finds that there is an opportunity to improve circularity by optimising material use in vehicle bodies and EV batteries to reduce vehicle weight up to 30%. This can help to partially offset increasing vehicle weights resulting from the transition to heavier BEVs as well as the increasing size and additional equipment (like technology or office-ware) added to vehicles (especially autonomous), resulting in an overall marginal impact on carbon footprint.

The increase in recycled content used for new car production could massively boost the circularity of the industry. While recycled content currently accounts for 21% of the materials used, with circular strategies this could rise to over 48%. Collection and recycling of key raw materials used in passenger vehicles is improving, which provides design engineers and supply chain leaders an opportunity to increase the share of recycled content in vehicles— including steel, aluminium and plastics up to 90% and lithium up to 50%. It will be imperative to ensure a secure supply of recycled content, as industries across the board currently face difficulties in accessing high-quality and cost-competitive recycled content.[30]

The life cycles of vehicle parts can be extended through reuse and remanufacturing, bringing both environmental and financial positives for the industry. The expansion of this existing industry can result in a repair market in 2040 that uses 12% recycled parts with profit margins potentially 25 to 75% higher than the new components market. Compared to only 2% in 2020, this future scenario would see 12% of components being reused or remanufactured. This would lead to both a huge reduction in GHG emissions as well as a significant financial impact: a reused or remanufactured engine requires up to 85% less emissions to produce than a new one, and used parts can offer improved margin opportunities within existing application areas within the aftermarket channel.

End-of-life processing and material separation techniques are already developing, partly necessitated by policy, to maximise the value extracted from a vehicle. In the 2040 scenario, common materials found in vehicles today, as well as in EV batteries, will see high recycling rates. This includes FE, Non FE, & RE metals being recycled up to between 90 and 99%, glass up to 90% and textiles up to 50%. Recycling efficiency will rise to 97% in 2040, compared to its current 78%. This will increase circularity as well as support emissions reductions—primarily from a reduction in embodied carbon that will stem from a smaller material footprint.

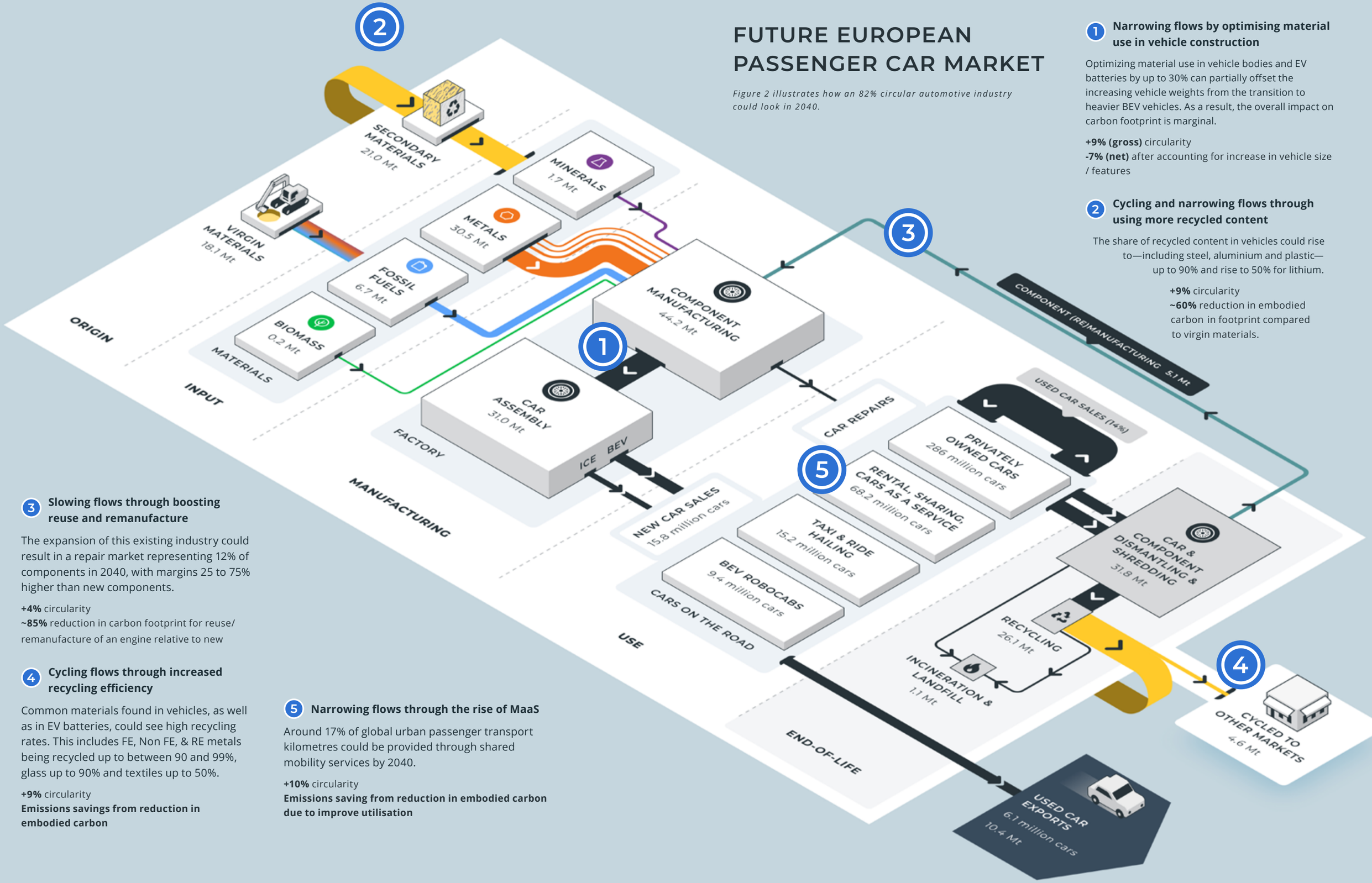
Business models: from ownership to MaaS

In 2040, our analysis finds that around 17% of global urban transport passenger kilometres will be through shared mobility. The growth in MaaS means that new car sales could already peak by 2024 at 18 million new cars sold. Producing these millions of cars at their current usage rates (about 5%), in a business as usual scenario, sustains a large resource footprint and uses plenty of scarce urban space for parking, particularly in busy cities. Growth in MaaS will be key to improving utilisation rates and could stabilise the car fleet in Europe for at least a decade. So, while we might expect greater mobility in 2040, it's likely that this will be delivered by a smaller vehicle stock due to increased MaaS offerings.

As Robo-cab operators are expected to retain ownership and control of their vehicles through to end-of-life, there is a profitable opportunity to secure circular supply while capturing value. Mobility services, led by the growth of Robo-cabs, is expected to represent more than 40% of the global automotive profit pool by 2040. Although new vehicle registrations are anticipated to be higher in 2030 than today, no growth is forecast in the after sales and maintenance phase, this is because BEVs typically require less maintenance relative to ICE vehicles.

FUTURE EUROPEAN PASSENGER CAR MARKET

Figure 2 illustrates how an 82% circular automotive industry could look in 2040.



1 Narrowing flows by optimising material use in vehicle construction

Optimizing material use in vehicle bodies and EV batteries by up to 30% can partially offset the increasing vehicle weights from the transition to heavier BEV vehicles. As a result, the overall impact on carbon footprint is marginal.

+9% (gross) circularity
-7% (net) after accounting for increase in vehicle size / features

2 Cycling and narrowing flows through using more recycled content

The share of recycled content in vehicles could rise to—including steel, aluminium and plastic—up to 90% and rise to 50% for lithium.

+9% circularity
~60% reduction in embodied carbon in footprint compared to virgin materials.

3 Slowing flows through boosting reuse and remanufacture

The expansion of this existing industry could result in a repair market representing 12% of components in 2040, with margins 25 to 75% higher than new components.

+4% circularity
~85% reduction in carbon footprint for reuse/ remanufacture of an engine relative to new

4 Cycling flows through increased recycling efficiency

Common materials found in vehicles, as well as in EV batteries, could see high recycling rates. This includes FE, Non FE, & RE metals being recycled up to between 90 and 99%, glass up to 90% and textiles up to 50%.

+9% circularity
Emissions savings from reduction in embodied carbon

5 Narrowing flows through the rise of MaaS

Around 17% of global urban passenger transport kilometres could be provided through shared mobility services by 2040.

+10% circularity
Emissions saving from reduction in embodied carbon due to improve utilisation

4. THE WAY FORWARD

The European automotive industry must mainstream five key circular strategies into its operations to become 66% by 2040. Our analysis finds that companies pioneering this transition do three things well: scan the existing value chain to identify the potential for improving circular flows, combine *today-forward and future back* perspectives to capture new opportunities and scale the ecosystem for success.

Scan the existing value chain to identify the potential for improving circular flows

While Figure 1 and Figure 2 show the materials used for production, maintenance, use and disposal at the sector level, the picture can look quite different for an individual company. Mapping the circular flows at the company level helps leaders to identify resource use and waste in their own value chain and explore potential for improving circular flows that create new value, such as expanding the sourcing and use of remanufactured vehicle components.

Combine *today-forward and future-back* perspectives to capture new opportunities

Grounded in an understanding of the current value chain and circular potential, leaders should apply *future-back* thinking to anticipate disruption and navigate among potential futures. This helps to inform how value creation will shift as the industry goes circular, and allow them to position around new control points in the value chain, such as direct to consumer subscriptions or MaaS offerings.

Scale the ecosystem for success

Leaders are strengthening their ecosystem with a clear perspective on where to collaborate and where to compete. Industry coalitions are helping to shift industries, aligning on new standards while providing a platform for companies to build and strengthen their own partnership ecosystem, such as the Global Battery Alliance which is a public/private collaboration of 100+ organisations to help establish a sustainable battery value chain. When building (or buying) solutions, leaders are doing this on scalable platforms that suppliers and other external partners can use.

REFERENCES

1. Joint Research Centre, Sala, S., Benini, L., Crenna, E., & Secchi, M. (2016). *Global environmental impacts and planetary boundaries in LCA.* Luxembourg: Publications Office of the European Union. Retrieved from: European Commission website
2. Circle Economy. (2021). *The circularity gap report 2021.* Amsterdam: Circle Economy. Retrieved from: CGRi website
3. Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press. Retrieved from: IPCC website
4. Circle Economy. (2021). *The circularity gap report 2021.* Amsterdam: Circle Economy. Retrieved from: CGRi website
5. Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press. Retrieved from: IPCC website
6. Chin, Y., Wallace, J., & Horner, W. (2022, March 8). Nickel prices sent on wild ride by Russia-Ukraine War. *The Wall Street Journal.* Retrieved from: Wall Street Journal website
7. Yang, S. (2021, October 27). China says the West should respect its "own pace" as Europe and US face magnesium supply crisis. *ABC News.* Retrieved from: ABC News website
8. Vahle, T., & Teuber, A. (2022, April 14). EU Parliament and council pave the way to sustainable circular batteries. *Systemiq*. Retrieved from: SYSTEMIQ website
9. Chin, Y., Wallace, J., & Horner, W. (2022, March 8). Nickel prices sent on wild ride by Russia-Ukraine War. *The Wall Street Journal.* Retrieved from: Wall Street Journal website
10. Yang, S. (2021, October 27). China says the West should respect its "own pace" as Europe and US face magnesium supply crisis. *ABC News.* Retrieved from: ABC News website
11. Khalid, M., Cao, Y., & Wang, K. (2020). Toward autonomous valet parking: A broader perspective. In P. Dhawankar & M. Raza (Eds.), *Toward sustainable and economic smart mobility: Shaping the future of smart cities* (pp. 99-109).
12. DeGroat, B. (2015, February 11). Driverless vehicles: Fewer cars, more miles. *University of Michigan News.* Retrieved from: University of Michigan website
13. WBCSD. (2021, February 1). Circular Transition Indicators v2.0 – Metrics for business, by business. Retrieved from: WBCSD website
14. Pipitone, E., Caltabellotta, S., & Occhipinti, L. (2021). A Life Cycle Environmental Impact Comparison between Traditional, Hybrid, and Electric Vehicles in the European Context. Sustainability, 13(19), 10992.
15. European Commission. (2020). *A new Circular Economy Action Plan for a cleaner and more competitive Europe.* Brussels: European Commission. Retrieved from: EUR-Lex website
16. Xu, C. (2020). Stock dynamics model and result analysis for future material demand for automotive lithium-based batteries. Retrieved from: Figshare website
17. Mercedes-Benz Group. (n.d.). On the road to the circular economy. Retrieved from: Mercedes-Benz website
18. General Motors. (2021, April 30). *General Motors releases annual sustainability report, setting baseline for accelerated goals* [Press Release]. Retrieved from: General Motors website
19. Volkswagen. (2019, February 20). Lithium to lithium, manganese to manganese. *Volkswagen Newsroom.* Retrieved from: Volkswagen website
20. Volvo Group. (n.d.). Retrieved from: Volvo Group website
21. Colthorpe, A. (2022, January 5). Upstream action: Northvolt produces first cells, sodium-ion startup acquired by India's Reliance. *Energy Storage News.* Retrieved from: Energy Storage News website
22. Frangoul, A. (2021, November 12). Goldman and VW-backed Northvolt produces battery cell with recycled nickel, manganese and cobalt. *CNBC*. Retrieved from: CNBC website
23. Share Now. (n.d.). Retrieved from: Share Now website
24. UBA (German Environment Agency), BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety). (27 June, 2018). End of Life Treatment data from Annual report on end-of-life vehicle reuse/recycling/recovery rates in Germany for 2016. Retrieved from: BMU website
25. Recycled content and recycling data from various sources specific to material composition of vehicle.
26. Wilkerson, J. (2022, February 1). Recycled lithium-Ion batteries can perform better than new ones. *Scientific American.* Retrieved from: Scientific American website
27. European Commission. (2020). A *new Circular Economy Action Plan for a cleaner and more competitive Europe.* Brussels: European Commission. Retrieved from: EUR-Lex website
28. European Commission. (2000). European End-of-Life Vehicles Directive 2000/53/EC. *Official Journal of the European Communities.* Retrieved from: EUR-Lex website
29. Carroll, S. G. (2021, July 15). EU signals end of internal combustion engine by 2035. *Euractiv.* Retrieved from: Euractiv website
30. Gore-Langton, L. (2022, May 4). Fabricating the loop: How fashion disrupts the circular plastics economy, and what the EU must do. *Packaging Insights.* Retrieved from: Packaging Insights website

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