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DRIVEN
EDU-ECO INNOVATION

ENHANCE SKILLS AND COMPETENCES TO BOOST ECOLOGICAL INNOVATION IN AUTOMOTIVE INDUSTRY

Good Practice from the automotive industry powered by circular economy

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Project partners

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Acronyms

ACEA European Automobile Manufacturers' Association
ATF Authorized treatment facilities
B2B business-to-business
B2C business-to-consumer
BEV Battery electric vehicle
CCI Circular Cars Initiative
CE Circular Economy
DSM Digital Single Market
ELV End-of-life vehicle
EPR Extended Producer Responsibility
EU European Union
GDPR General Data Protection Regulation
GHG Greenhouse Gases
ICT Information and communications technology
IoT Internet of things
IPCEI Important Projects of Common European Interest
IPR intellectual property right
IT information technology
LCA Life-cycle assessment
MFF Multiannual Financial Framework
OEM Original Equipment Manufacturer
PEF Product environmental footprint
QR Quick Response
REACH Registration, Evaluation, Authorisation and Restriction of Chemicals (regulation)
RFID Radio-Frequency Identification
R&D Research and Development
RSMS Restricted Substances Management Standards
SDG Sustainable Development Goal
SME Small-and medium-sized enterprise
UN United Nations
VAT value-added tax
WEEE waste electrical and electronic equipment

Terminology

3D PRINTING/ADDITIVE MANUFACTURING are computer processes that join or solidify materials to create a three-dimensional object, often using less material in comparison to traditional manufacturing methods.

APPLICATIONS OR APPS are computer software or programs designed to perform a specific function, and most commonly used and designed for mobile devices.

ARTIFICIAL INTELLIGENCE (AI) is broadly understood as a machine's capability to perform tasks that would normally require human intelligence. It allows machines/programs to 'learn' and alter their operations based on previous 'experience'.

AUTOMOTIVE AFTERMARKET is the auto industry's after-sale market that includes, among others, parts and accessories used in the repair, maintenance, or enhancement of a product.

BIG DATA are large datasets that can be used to analyze and reveal patterns, trends, and associations.

BLOCKCHAIN is a distributed ledger that can be used to record and share information securely and enable online transactions. Information is managed in a decentralized way and made available to those with access.

CIRCULAR ECONOMY (CE) is an economic system that aims to maintain the value of products and materials for as long as possible, minimizing resource use and waste by increasing the repair, recovery, reuse, and recycling of materials and products. It is enabled by novel business models and responsible consumers.

DIGITALISATION of economy and society builds upon increased connectivity and data gathering, sharing, and analysis; to maximize its value to produce better products and services. It starts with digitization, i.e. converting information from a physical format (e.g. paper, images) into digital data. Digitized data and digitally-enabled solutions can be used to improve business models, processes, products, and services, to change thinking and even disrupt current practices.

DIGITALLY-ENABLED SOLUTIONS include physical hardware combined with software (e.g. computers, IoT) or virtual software (e.g. apps, AI) that use data and can be continuously modified. Some solutions are already in use (e.g. apps, sensors, online platforms), while others (e.g. related to AI, IoT, blockchain, 3D printing) are still under development.

DIGITAL TWINS are virtual models or digital replicas of something that exists in the physical world, like a good, a process or a service. They can be used to e.g. predict and optimize production systems before eventually investing in prototypes.

INTERNET OF THINGS (IOT) AND 'CONNECTED DEVICES' are everyday physical objects or devices connected to the Internet, and which can identify themselves to other objects. IoT can be used e.g. to predict when machines need maintenance or to micromanage energy usage.

LIFE-CYCLE ASSESSMENT is the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product throughout its life-cycle.

MACHINE LEARNING is a subpart of AI, whereby a machine is trained to use large amounts of data and algorithms to find connections and perform tasks.

ONLINE PLATFORMS are used for a variety of activities such as information exchange, trading and price comparison.

SENSORS are devices that detect and respond to input from or changes in its physical environment (e.g. light, heat, motion, pressure). The data/information they gather is often transmitted to other electronic devices, such as a computer.

1 INTRODUCTION

This Good Practice Guide is developed as part of the Erasmus+ Project ”Enhance skills and competences to boost ecological innovation in automotive industry”, acronym DRIVEN, Grant agreement number 2020-1-SK01-KA203-078349. The guide will present the most important lessons learned that could be applied by interested organizations. The results can be used in integrated approaches to competitiveness, sustainable development and economic convergence in order to identify new courses of action applicable in the countries participating in the interface between innovation, waste management, transition models, modeling of complex systems, with a focus on sustainable transitions towards the circular economy.

The promotion and practical implementation of automotive sustainable production and consumption patterns bring to the fore the need to identify and support economic development niches in order to achieve social and environmental benefits. Increasing consumer awareness of the re-marketing of new waste products has a key role to play in promoting sustainable business models. In this sense, the transition from the theoretical approach of the circular economy to its implementation requires facilitating the transfer of waste from one company to another company, respectively supporting the implementation of industrial symbiosis processes, both physically and electronically.

The rising popularity of so-called “circular economy” (CE) models has developed in response to this context of environmental degradation. Definitions regarding the circular economy are focused around key concepts such as: sustainable development, the framework of the 4Rs (Reduce, Reuse, Recycle, Recover), the systemic approach (micro, meso, macro), the waste hierarchy. The Ellen MacArthur Foundation [1] associates this concept with an industrial economy that restores or regenerates itself through intention and design. The term “circular economy” encompasses and builds on a number of similar schools of thought, including Cradle to Cradle, the performance economy, biomimicry, industrial ecology, natural capitalism, the blue economy, and regenerative design. Thus, while the ideas behind the CE are not new, the concept carries value, as it brings together existing practices and concepts under a single framework that encompasses a different conceptual approach to thinking about material use and output. CE could represent a fundamental paradigm shift and transformation, in which waste is significantly reduced or eliminated through design, and remaining waste is understood as a resource [2].

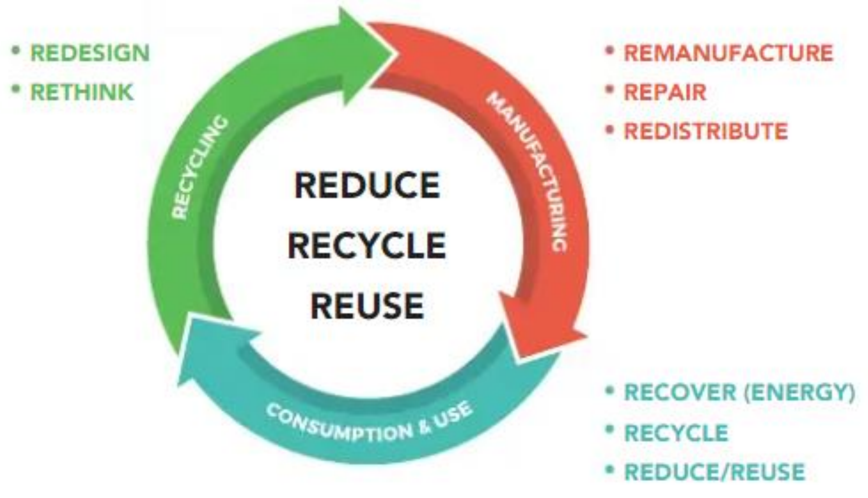
CE is characterized by three key principles:

DESIGN-OUT WASTE: This entails rethinking, reducing, and redesigning products. Waste does not exist when biological or technical components of a product are purposefully designed to fit within a biological or technical cycle.

KEEP PRODUCTS/MATERIALS IN USE: This involves keeping products and materials in the economy through reuse, repair, remanufacturing, and recycling of products.

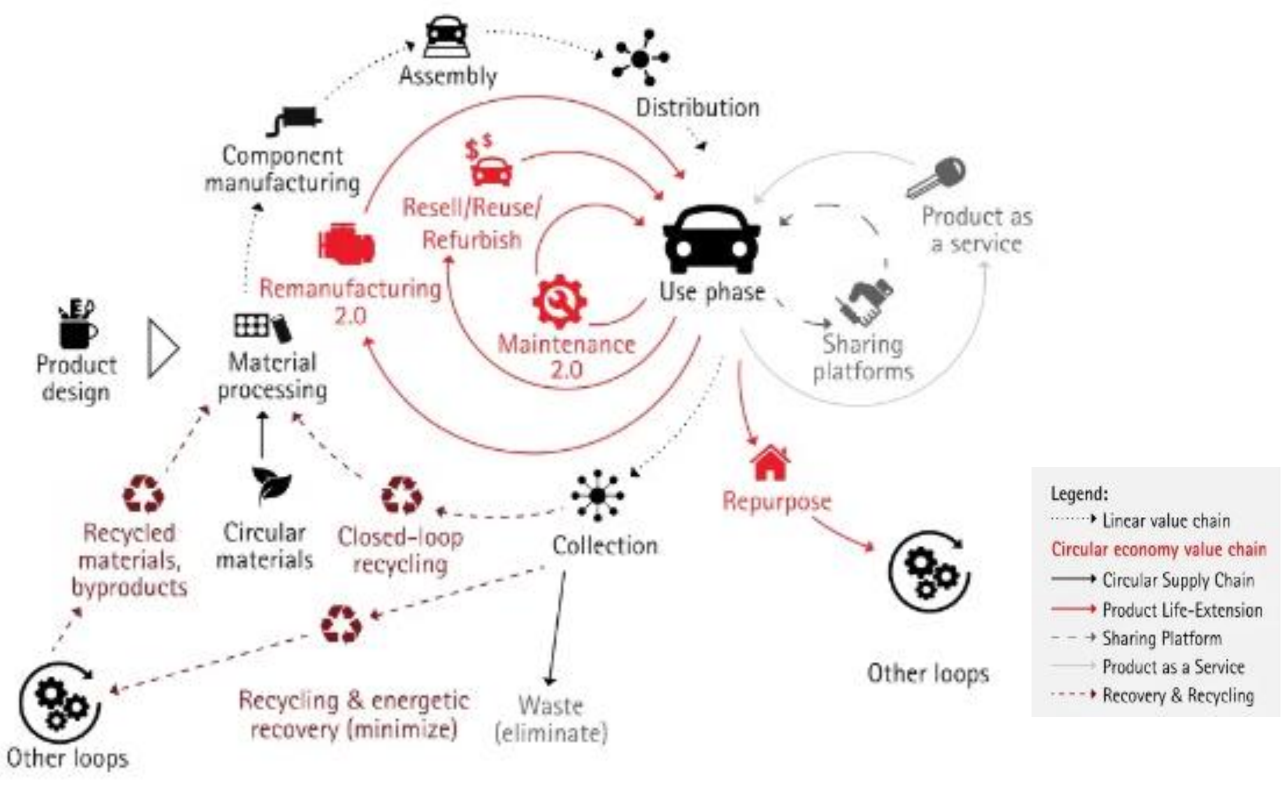
REGENERATE NATURAL SYSTEMS: This requires us to avoid the use of non-renewable resources, and preserve/enhance renewable ones.

A holistic approach to CE can be broken down into several levels and can be illustrated withdifferent "R" concepts. This "multi-R" approach helps outline the CE structure, as illustrated in 1-1. Figure.



1-1. Figure_Circular Economy Multi-R approach
[Source: Association of Cities and Regions for Recycling and Sustainable Resource Management]

By driving circular principles throughout the value chain, automotive players can amplify benefits when it comes to efficiency, revenue and customer loyalty [3]. The circular economy value chain for automotive companies is presented in 1-2. Figure



1-2. Figure_ The circular economy value chain for automotive companies
Source: https://www.accenture.com/dk-en/industries/automotive-index

A basic component of sustainable development, the circular economy involves, also in automotive industry, several concepts such as sharing, renting, reusing, repairing, reconditioning and recycling materials and products. This approach has the effect of extending the life cycle of products and optimizing the consumption of raw materials and energy, such as minimizing the amount of waste generated, reducing the carbon footprint and a more environmentally friendly approach.

2 EUROPEAN FRAMEWORK ON THE CIRCULAR ECONOMY

2.1 European regulations on the circular economy

The goal of transitioning to a circular economy has gained significant importance among policymakers worldwide, including in Europe. The circular economy aims to decouple economic growth from resource consumption by emphasizing resource efficiency, waste reduction, and the reuse and recycling of materials. To facilitate this transition, the European Union (EU) has implemented a comprehensive array of regulations and directives.

European regulations on the circular economy encompass several overarching objectives. Firstly, they strive to stimulate sustainable economic growth by promoting resource efficiency and waste reduction. By embracing a circular economy, Europe aims to enhance its competitiveness, foster job creation, and minimize its environmental footprint.

Secondly, these regulations aim to encourage innovation and the development of sustainable business models. The EU recognizes the potential for industries to innovate and capitalize on the increasing demand for sustainable products and services within the circular economy framework.

Lastly, European regulations on the circular economy target the sustainable use of resources, reduction of greenhouse gas emissions, and mitigation of the environmental impacts associated with resource extraction, production, and waste disposal. By optimizing material usage throughout their lifecycle, these regulations aim to minimize Europe's ecological footprint.

Key Features of European Regulations on the Circular Economy:

- **WASTE MANAGEMENT AND RECYCLING TARGETS**: The EU has established ambitious targets for waste management and recycling to drive the transition towards a circular economy. The Waste Framework Directive sets a goal of recycling 65% of municipal waste and 75% of packaging waste by 2030. Additionally, the directive promotes separate waste collection, waste prevention measures, and the implementation of extended producer responsibility schemes.
- **ECODESIGN AND PRODUCT STANDARDS**: European regulations also prioritize improving the environmental performance of products. The Ecodesign Directive mandates product-specific requirements to ensure energy efficiency, recyclability, and durability. These requirements incentivize manufacturers to design products with longer lifespans, easier repairability, and increased recyclability.
- **EXTENDED PRODUCER RESPONSIBILITY (EPR):** EPR is a fundamental principle of the circular economy that shifts the environmental responsibility of products to manufacturers. The EU has introduced EPR schemes for various products, including

electronics, batteries, packaging, and vehicles. Manufacturers are obliged to take responsibility for the collection, recycling, and safe disposal of their products at the end of their life.

- **SINGLE-USE PLASTICS DIRECTIVE**: To combat the pervasive issue of plastic pollution, the EU implemented the Single-Use Plastics Directive. This directive prohibits certain single-use plastic items, such as cutlery and straws, and sets recycling targets for plastic bottles. It also encourages the use of alternative materials and emphasizes producer responsibility for plastic waste.
- **CIRCULAR ECONOMY ACTION PLAN**: The Circular Economy Action Plan, devised by the European Commission, provides a comprehensive roadmap for the transition to a circular economy. It includes measures to promote sustainable product design, support circular business models, enhance waste management and recycling practices, and encourage sustainable consumption.

2.1.1 The Circular Economy Action Plan

The EU's Circular Economy Action Plan was a comprehensive body of legislative and non-legislative actions adopted in 2015, which aimed to transition the European economy from a linear to a circular model. The Action Plan mapped out 54 actions, as well as four legislative proposals on waste. These legislative proposals were put forward by the European Commission along with the Action Plan and included targets for landfill, reuse, and recycling, to be met by 2030 and 2035, along with new obligations for separate collection of textile and biowaste. The Action Plan covered several policy areas, material flows, and sectors alongside cross-cutting measures to support this systemic change through innovation and investments, and also announced a sectoral strategy for plastics. More than EUR 10 billion of public funding was allocated to the transition between 2016 and 2020 [[4]].

On 11 March 2020, the European Commission adopted a new Circular Economy Action Plan [[5]], one of the main building blocks of the European Green Deal [[6]], Europe's new sustainable growth agenda. The new action plan provides the measures throughout the product life cycle and aims to prepare European economy for a green future, strengthen competitiveness, while protecting the environment and give new rights to consumers. The new Circular Economy Action Plan paves the way for a competitive, climate-neutral economy in which consumers are held accountable.

The Circular Economy Action Plan, part of the EU Industrial Strategy [[7]], presents measures to:

- **MAKE SUSTAINABLE PRODUCTS THE NORM IN THE EU**. The Commission will propose legislation on Sustainable Product Policy, to ensure that products placed on the EU market are designed to last longer, are easier to reuse, repair and recycle, and incorporate as much as possible recycled material instead of primary raw material. Single-use will be restricted, premature obsolescence tackled and the destruction of unsold durable goods banned.

- **EMPOWER CONSUMERS.** Consumers will have access to reliable information on issues such as the reparability and durability of products to help them make environmentally sustainable choices. Consumers will benefit from a true 'Right to Repair'.

- **FOCUS ON THE SECTORS THAT USE THE MOST RESOURCES AND WHERE THE POTENTIAL FOR CIRCULARITY IS HIGH.** The Commission will launch concrete actions on:
    - **electronics and ICT** – a 'Circular Electronics Initiative' to have longer product lifetimes, and improve the collection and treatment of waste
    - **batteries and vehicles –** new regulatory framework for batteries for enhancing the sustainability and boosting the circular potential of batteries
    - **packaging –** new mandatory requirements on what is allowed on the EU market, including the reduction of (over)packaging
    - **plastics** – new mandatory requirements for recycled content and special attention on microplastics as well as biobased and biodegradable plastics
    - **textiles** – a new EU Strategy for Textiles to strengthen competitiveness and innovation in the sector and boost the EU market for textile reuse
    - **construction and buildings** – a comprehensive Strategy for a Sustainably Built Environment promoting circularity principles for buildings
    - **food** – new legislative initiative on reuse to substitute single-use packaging, tableware and cutlery by reusable products in food services
- **ENSURE LESS WASTE.** The focus will be on avoiding waste altogether and transforming it into high-quality secondary resources that benefit from a well-functioning market for secondary raw materials. The Commission will explore setting an EU-wide, harmonised model for the separate collection of waste and labelling.The Action Plan also puts forward a series of actions to minimise EU exports of waste and tackle illegal shipments.

In February 2021, European Parliament adopted a resolution on this plan calling for further measures to achieve a fully circular, carbon-neutral, sustainable and toxic-free economy by 2050. Stricter recycling rules and mandatory targets for the consumption of raw materials by 2030 are also required.

In March 2022, the Commission presented a first package of measures to accelerate the transition to a circular economy under the Circular Economy Action Plan. Proposals include promoting sustainable products, encouraging consumers for the green transition, reviewing building materials regulations and a strategy for sustainable textiles.

2.2 The European environmental regulatory framework

Worldwide regulatory framework is pushing new design methods and practices for environmental purposes. Since the Maastricht Treaty was signed on 7 February 1992, institutions and regulatory methods are changing in environmental rule making within European Union.

The firms are getting more and more involved in the regulatory process and the European automakers are not only establishing their own environmental policies but also acting as responsible for the implementation of a programme that depends both on suppliers and partners. Regarding the recycling regulations, the French automakers were pioneers in Europe in promoting voluntary agreements between all firms involved and the government.

A so-called "l'Accord Cadre" was signed in 1993. This agreement set up goals such as: at 2002 all vehicles produced should be 95% recyclable. On these proposes the French Companies Peugeot, Citroën and Renault have been working together on assembling and "disassembling" technical specifications and materials identifications reaching separation for recycling. It means that recycling criteria has to be integrated into all other functional requirements of the vehicle project. They also have to share this task, and the risks, with their suppliers, comprising the R&D expenses [[8]].

The regulatory framework has a great power of diffusion concerning global products such as vehicles. Furthermore increasing recyclability rate is also connected to the new system of Environmental Management Systems – EMS – largely regulated by ISO 14000 and other national standards systems of environmental quality.

The **ELV DIRECTIVE 2000/53/EC** [[9]] of the European Parliament and of the Council of European Union on End-of-life Vehicles adopted by European Union members in October 2000 is the state of art of a negotiation process, between interested parties, and public authorities that has lasted for a decade already.

The directive states that for reuse and recovery purposes that preference to recycling must be given to the recovery of components, which cannot be reused when environmental viable recycling process is available, without prejudice to requirements regarding the safety of vehicles and environmental other requirements such as air emissions and noise control. This means that for car industry recyclability does not assure sustainability.

Sustainability claims for protection of human health and ecology, clean technologies (at both levels: production and recycling), enforced environmental legislation, well-organised collection systems and large market assuring secondary materials supply and demand for recycled materials. For these purposes automotive industry is supposed to be responsible for their products (vehicles or auto parts) from cradle to grave. That means that they have to close automotive materials life cycle loop reducing the existent ones and even avoiding extra environmental impacts.

It sets out measures to prevent and limit waste from end-of-life vehicles (ELVs) and their components by ensuring their reuse, recycling and recovery. It also aims to improve the environmental performance of all economic operators involved in the life-cycle of the vehicles.

KEY POINTS

- Vehicle and equipment manufacturers must factor in the dismantling, reuse and recovery of the vehicles when designing and producing their products. They have to ensure that new vehicles are: reusable and/or recyclable to a minimum of 85% by weight per vehicle; reusable and/or recoverable to a minimum of 95% by weight per vehicle.

- They cannot use hazardous substances such as lead, mercury, cadmium and hexavalent chromium.

- Manufacturers, importers and distributors must provide systems to collect ELVs and, where technically feasible, used parts from repaired passenger cars.

- Owners of ELVs delivered for waste treatment must receive a certificate of destruction, necessary to deregister the vehicle.

- Manufacturers must meet all, or a significant part, of the costs involved in the delivery of an ELV to a waste treatment facility. For a vehicle owner, they should incur no expenses when delivering an ELV to an authorised waste treatment facility, except in the rare cases where the engine is missing or the ELV is full of waste.

- Waste treatment facilities must apply for a permit or register with the competent authorities of the EU country where they are located.

- ELVs are first stripped before further treatment takes place. Hazardous substances and components are removed and separated. Attention is given to the potential reuse, recovery or recycling of the waste.

- Clear quantified targets for annual reporting to the European Commission exist for the reuse, recycling and recovery of ELVs and their respective parts. These have become increasingly more demanding.

- This legislation applies to passenger vehicles and small trucks but not to big trucks, vintage vehicles, special-use vehicles and motorcycles.

Different disposal conditions amongst EU Member States were causing high shares of import/export of end-of-life vehicles inside the EU. To monitor this practice, in addition to the aforementioned measures, the recycling and recovery rates from exported vehicle parts are credited to the exporting Member State, according to **COMMISSION DECISION 2005/293/EC**.

DIRECTIVE (EU) 2018/849 [[10]] amends Directive 2000/53/EC giving the Commission the power to adopt:

- implementing acts concerning the detailed rules necessary to control EU countries' compliance with the ELV targets and the exports and imports of ELVs;
- delegated acts to supplement the directive by:
- exempting certain materials and components containing lead, mercury, cadmium or hexavalent chromium (other than in cases listed in Annex II), if their use is unavoidable and establishing maximum concentration levels allowed as well as deleting materials and components of vehicles from Annex II, if their use is avoidable,
- introducing coding standards to facilitate the components suitable for reuse and recovery,
- establishing the minimum requirements for the certificates of destruction,
- establishing minimum requirements for the treatment of ELV.

DIRECTIVE ON BATTERIES AND ACCUMULATORS AND WASTE BATTERIES

In European countries, the placement in the market of batteries and accumulators, including their collection and end-of-life recycling, is currently regulated by **DIRECTIVE 2006/66/EC** [[11]]. According to this directive, Member States must implement every necessary measure to promote and optimise separate collection, preventing these products from being disposed of as mixed municipal waste.

This led to the set-up of pick-up points close to users, allowing them to drop off the used batteries and accumulators for pick-up by manufacturers free of charge.

However, due to the exponential increase of electric vehicles powered by batteries that are growing more and more advanced and complex in technology, this directive (which applies to all types of batteries, regardless of their chemistry and end use) has become obsolete. It is unfit for today's technological developments and has not kept pace to adequately regulate the recovery and disposal of latest-generation accumulators.

This is why it has become necessary to replace it with a new regulation suited to the upward trend in battery demand and more aligned with the climate neutrality objectives the EC is pursuing.

THE NEW EUROPEAN BATTERY REGULATION

The European Union has set a new important objective for the next decades: to boost the circular economy, the sustainability of products and processes, and the support of Europe's technological progress in the battery sector. To this end, it has decided to introduce the new so-called EU Battery Regulation and give a clear direction towards a regulatory framework for batteries in Europe that can ensure sustainability of the entire value chain over the long term.

In July 2023 the European Council adopted a new regulation that strengthens sustainability rules for batteries and waste batteries, that will regulate the entire life cycle of batteries – from production to reuse and recycling – and ensure that they are safe, sustainable and competitive [[12]]. The regulation of the European Parliament and the Council will apply to all batteries including all waste portable batteries, electric vehicle batteries, industrial batteries, starting, lightning and ignition (SLI) batteries (used mostly for vehicles and machinery) and batteries for light means of transport (e.g. electric bikes, e-mopeds, e-scooters).

The new rules aim to promote a circular economy by regulating batteries throughout their life cycle. The regulation establishes end-of-life requirements, including collection targets and obligations, targets for the recovery of materials and extended producer responsibility:

- ☑ sets targets for producers to collect waste portable batteries (63% by the end of 2027 and 73% by the end of 2030), and introduces a dedicated collection objective for waste batteries for light means of transport (51% by the end of 2028 and 61% by the end of 2031).
- ☑ sets a target for lithium recovery from waste batteries of 50% by the end of 2027 and 80% by the end of 2031, which can be amended through delegated acts depending on market and technological developments and the availability of lithium.
- ☑ provides for mandatory minimum levels of recycled content for industrial, SLI batteries and EV batteries. These are initially set at 16% for cobalt, 85% for lead, 6% for lithium and 6% for nickel. Batteries will have to hold a recycled content documentation.
- ☑ sets the recycling efficiency target for nickel-cadmium batteries at 80% by the end of 2025 and 50% by the end 2025 for other waste batteries.
- ☑ provides that by 2027 portable batteries incorporated into appliances should be removable and replaceable by the end-user, leaving sufficient time for operators to adapt the design of their products to this requirement. This is an important provision for consumers. Light means of transport batteries will need to be replaceable by an independent professional.

WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE) DIRECTIVE

Applied since August 2012, and incorporated into national laws in February 2014, the Directive is designed to prevent WEEE, creating ground for the recovery, reuse and recycling of produce. After not achieving the expected results, the legislation was modified in 2016, increasing the collection of electronic waste from 4 kg of annual waste per inhabitant, to a national target of 45% of the annual weight. In 2019 the target increase to 65%. The Directive places responsibility on producers to cover the costs of collecting, treating and - sustainably disposing of waste at determined collection areas.

3 THE CIRCULAR ECONOMY AND ITS INFLUENCE ON THE CAR INDUSTRY

3.1 Priority themes for embedding a circular economy across the automotive sector

In the automotive industry, circular economy practices are coalescing around four main areas [[13]]:

REMANUFACTURING, where used components are repaired and then deployed in used cars or sold in the aftermarket. Among the perceived benefits of remanufacturing include the conservation of natural resources, reduced waste, smaller carbon footprint, and lower costs. Remanufactured components also come with quality assurances since they must meet standard factory specifications in terms of performance, reliability, and durability.

RECYCLING, where raw materials extracted from used components are utilised in new vehicles and other industries.

PRODUCT LIFE EXTENSION, where vehicle parts are proactively serviced before they develop any faults, thereby extending their useful life.

SUSTAINABLE MATERIAL USE, where innovative, eco-friendly materials such as bio-plastics are incorporated into new cars.

Leading car manufacturers are adopting responsible trends in the use of resources. For example, over 2021-2025, Ford intends to use 20% sustainable materials in its vehicles, Volkswagen has committed to halving the carbon emissions per vehicle in all its plants, and Toyota has declared that it will seek a 30% reduction in the global average carbon emissions from its new vehicles, compared to 2010 levels. Likewise, over 2026-2030, General Motors has stated that it will use 100% renewable energy for vehicles manufactured in the US and reduce factory greenhouse gas emissions by 31%, even as a raft of automakers, including Honda, Nissan, Toyota, Volvo, and Volkswagen, are working to achieve carbon neutrality by 2031-2050 [[14]].

3.2 The Circular Cars Initiative - World Economic Forum

The Circular Cars Initiative (CCI) is a private/public sector collaboration focused on leveraging new technologies and business models to align the automotive industry with a

1.5C climate scenario. Through an integrated systems approach, CCI will provide a platform for actors in the value chain to eliminate gaps between economic incentives and social outcomes. A core goal of CCI is to leverage sectoral knowledge, partnerships, funding and creativity to help community members develop technologies and business models to eliminate emissions from automotive utilization and manufacturing [[15]].

The global automotive industry confronts a profound moment of transition. Today the automotive ecosystem is an engine for prosperity, but it's also a major driver for environmental degradation. On an annualized basis, the industry produces more greenhouse gas emissions than the entire European Union and roughly 20% of these emissions are directly attributable to manufacturing. While the shift towards battery electric vehicles will decrease use-phase emissions substantially, in the short term it will also increase manufacturing emissions. This is due to the large carbon footprint of EV batteries. Under a business as usual scenario, by 2040 McKInsey & Co analysis for the Circular Cars Initiative estimates roughly 60% of total automotive lifecycle emissions will be directly attributable to materials – with just 40% coming from other sources including logistics, end of life disposal and utilization. Any clear path toward a 1.5C climate scenario will require significant and aggressive decarbonization of these non-use phase emissions.

The Circular Cars Initiative (CCI) is a partnership between stakeholders from the automobility ecosystem (e.g. industry, policymakers and fleet purchasers) to eliminate or minimize total lifecycle emissions with a special emphasis on manufacturing emissions. The initiative's overarching goal is to achieve an automobility system that is convenient, affordable and firmly grounded within a 1.5°C climate scenario by 2030.

The term "circular car" refers to a theoretical vehicle that has maximized materials efficiency. This notional vehicle would produce zero materials waste and zero pollution during manufacture, utilization and disposal – which differentiates it from today's zero emission vehicles. While cars may never be fully "circular," the automotive industry can significantly increase its degree of circularity. Doing so has the potential to deliver economic, societal and ecological dividends.

In present, half the cost of producing a new vehicle comes from manufactured materials. At end of life, little of this value is recoverable due to non-circular design practices and the lack of circularity-focused business models. Just as vehicles consume non-renewable fuel, producing atmospheric pollution and GHG emissions as atmospheric waste, they also consume vast quantities of currently non-renewable materials that result in massive quantities of liquid and solid waste. These are generally landfilled, processed or downcycled at end of life.

Inefficient utilization of cars is also a problem. Privately-owned vehicles are only in use about 5% of the time, and even then, they tend to operate at low passenger capacity.

All this points toward significant opportunities for innovation and improved materials efficiency – both in manufacturing and utilization. Over the coming decade, to remain competitive, global automotive companies must embrace change and the imperatives of sustainability and climate change. The pathway toward mobility with both zero emissions and zero environmental waste will inevitably include increased reliance on circular cars and economics.

CCI aims to virtually eliminate automobility emissions by targeting what we call "materials efficiency." This key measurement of "materials efficiency" is still in the process of formalized definition. But one simple formula is the quantity of raw materials used to build a vehicle divided by the number of passenger miles provided by that vehicle. Other quantifiable metrics, such as recycled content, or GHG emissions/passenger km may also be included.

One early goal of CCI will be to define “materials efficiency” with respect to key metrics and end goals (e.g. GHG emissions, rare earth elements utilization, etc.) in collaboration with industry stakeholders and regulators. CCI aims to develop appropriate frameworks for measuring materials efficiency and drastically improve the industry’s performance with regard to these metrics – thus reducing the automobile’s lifecycle environmental footprint and at the same time significantly increasing the vehicle’s full life-cycle value. CCI will also generate industry transition tools that point toward the most effective and economic decarbonization pathways.

Some of the strategies for increasing the materials efficiency of automobiles under examination include: implementing new business models like pooled mobility as a service (MaaS); closed loop recycling of aluminium and steel; and life extension of vehicles and key components such as batteries.

CCI will also incubate circularity-focused pilots with members of the CCI community and collaborate to catalyse the development of new markets and materials networks necessary to achieve circularity. The automotive industry is committed to making Europe’s economy more resource efficient by pursuing a circular economy approach [[16]]

Manufacturers have significantly improved the resource efficiency of their production processes and products, and want to reduce their environmental impact even more in the future. Each year, Europe’s automobile sector spends €60.9 billion on innovation, making the industry the EU’s number one investor in R&D. These investments range from reducing the carbon footprint of the production phase to improving the design of motor vehicles in order to allow for their efficient repair.

Auto manufacturers are already actively contributing to resource efficiency by remanufacturing a wide variety of parts, including engines and gear-boxes. In practice, remanufactured components have proven to reduce energy consumption during manufacturing by up to 80% when compared to new parts. Giving components a new life also requires 88% less water and more than 90% less chemicals. This circular approach can reduce overall waste by an impressive 70%.

The automobile industry does not only contribute to the circular economy by remanufacturing components or reducing waste, but also by prolonging the service life of the vehicles it produces. Manufactures believe that they have a responsibility to their customers to support the longevity of vehicles by ensuring that they can be serviced, repaired and maintained. Extending the lifetime of a vehicle is essential to reducing costs for consumers, as well as conserving natural resources and energy.

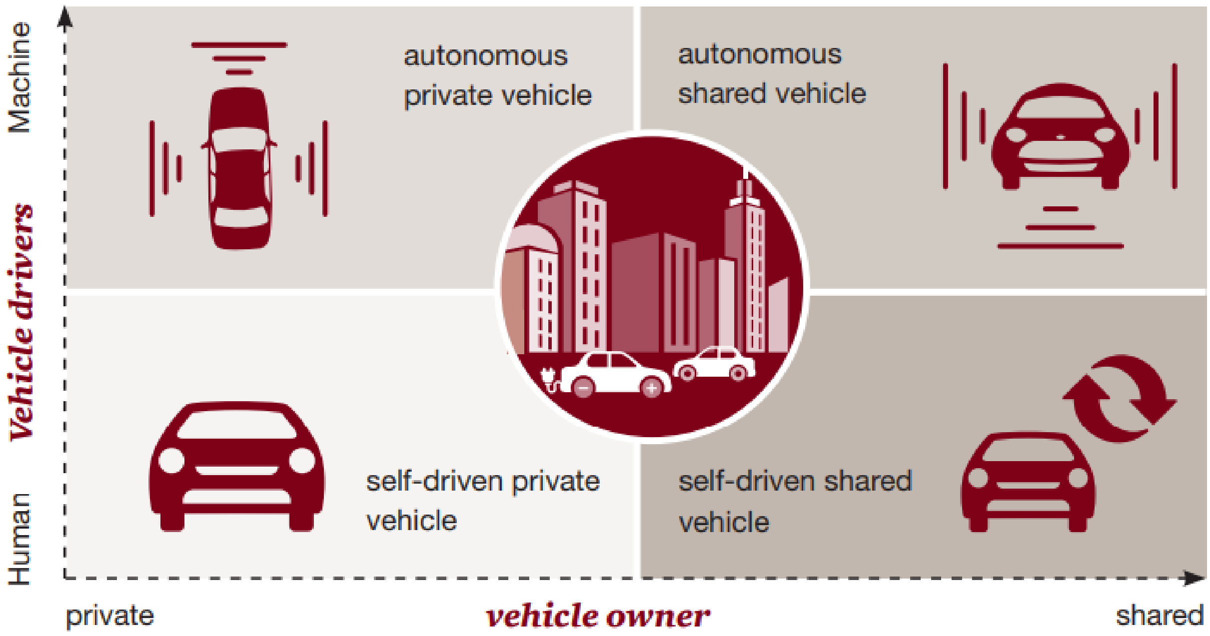
Finally, manufacturers remain dedicated to further improving fuel efficiency and reducing CO_2 emissions, as the use phase of a vehicle still accounts for a large part of the total environmental impact that cars have. Because of the industry’s commitment to the ‘design for sustainability’ concept, vehicles are built to be as sustainable as possible over their entire lifecycle. From prolonging the in-use phase of passenger cars and commercial vehicles to recyclability at the end of their life, the sector focusses its efforts on reducing the overall environmental impact in those areas that matter most.

Besides industry-led initiatives, automobile manufacturers also have to adhere to a wide range of existing legislation promoting sustainable production, more efficient vehicles and their proper dismantling. The End-of-Life Vehicles Directive, for example, already sets a target of 95% recyclability per vehicle per year. As a result of economic incentives, as well as existing legislation, the automotive industry has made the circular economy an integral part of its DNA.

Environmental protection is one of the basic pillars of the carmaker's sustainability and the automotive industry has the opportunity to shape this fundamental restructuring. When devising strategies and business models, companies should not only consider direct product purchasers but all users and groups affected by transport issues. The automobile changed from a technical to a social commodity: it guarantees the personal mobility and social participation, shapes the cities and landscapes, and structures the temporal and spatial thinking. This is why it have to rethink the whole automotive industry – with the focus on the use rather than the production of vehicles, in order to make the lives of individual users more enjoyable, more efficient and safer.

The car of the future is **ELECTRIFIED, AUTONOMOUS, SHARED, CONNECTED AND YEARLY UPDATED: "EASCY"** [[17]].

Five of the top 20 companies with the highest R&D investment are vehicle manufacturers, but they do not feature among the 10 most innovative enterprises. Between 2020 and 2025 the industry will have to find ways of compensating for falling margins and rising investment. Manufacturers and suppliers should put users at the heart of their business model and offer them "eascy" mobility solutions. Implications will be the rapid redistribution of investment in research and development. Decisions regarding the long-term structure will be made between 2020 and 2025 and an illustrative representation of the mobility of the future is given in the figure ......



3-1. Figure_ Manifestation of the mobility of the future

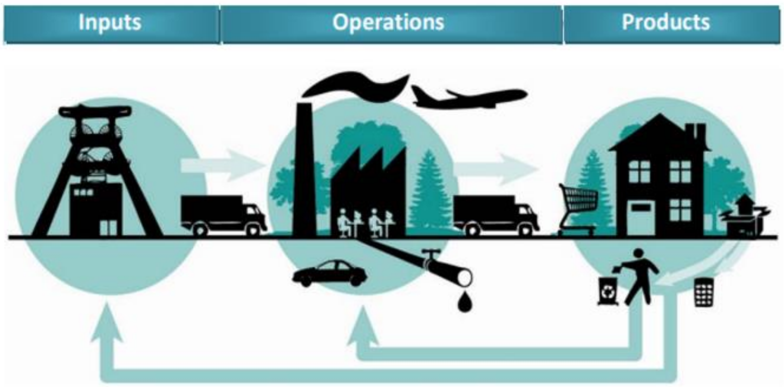
[https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf]

Environmental strategic visions and plans of automotive companies are generally based on the following key objectives [18]: non-waste production technologies; reduction of emissions throughout the life cycle; reduction in fuel consumption and alternative sources of propulsion; replacement of non-recyclable materials; reducing the consumption of energy and water in the production process.

Even the actual production processes are more sophisticated, the environmental impacts are formed in the following three main stages: inputs, operations, products [19].

The figure .... shows the interaction between bussines facility and the environment and the impact it may have on the environment throughout the 'lifecycle' of the products that it produces.

Inputs are materials or intermediate products used to manufacture the products, operations are processes to turn inputs into products and activities necessary to operate the production processes (e.g. facility operation, transport of inputs and products, business travel, staff commuting and other overheads) and products represent products manufactured and their use and treatment at the end of their lifetime.



3-2. Figure_ Basic relationships between manufacturing and the environment

[source: The OECD Sustainable Manufacturing Toolkit, 2011]

The rapid increase in the use of electric vehicles with the associated advantages and disadvantages highlights the need for more than the gradual elimination of the combustion engine to drastically reduce carbon emissions so it will be essential to use circular economy strategies to transform products, as well as adapting the way these products are used.

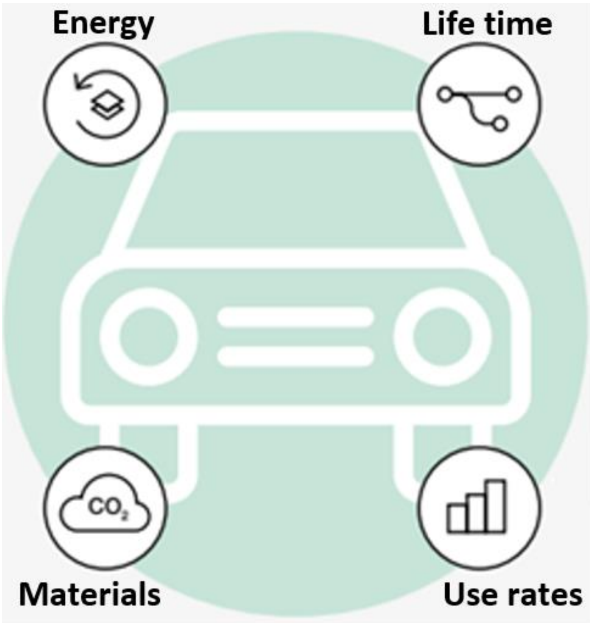
In actual context of the automotive industry, circular economy are part of four strategic ways: decarbonising energy usage, establishing circular material flows, extending and optimising product lifetime and improving capacity utilisation during vehicle usage and producers such as Renault, Volvo, PSA, Daimler, BMW, Volkswagen have already set ambitious targets towards carbon neutrality and aligned their business strategies with an ever-accelerating push for electrifying their products [20].

Original equipment manufacturers are heavily investing in electrification, closing material loops, and developing new service offerings and mobility solutions. investors and regulators are pushing to go further.

Cars are increasingly bought online and flexibly subscribed to for shorter time periods, revenue streams are shifting towards the use phase and the drive towards circularity is slowly picking up speed. Already most automotive materials are recyclable. cars are built to last and to be repaired. These are all important aspects of circularity. The value chain needs to be fundamentally reimagined to minimise lifetime carbon emissions and resource consumption.

THE "CIRCULAR CAR", as a strategic concept, adopts a circular flow in the whole product lifecycle: reduction, recovery, repair, renovation, reuse, and recycling of all components. These processes are a part of the value chain, and the reason is to increase value and the circularity of materials. A circular car maximizes value to society, the environment and the economy while efficiently using resources and public goods. Its value is measured in terms of its ability to provide mobility, and its efficiency is measured in terms of carbon emissions, non-circular resource consumption and use of public goods, such as space or clean air [[21]].

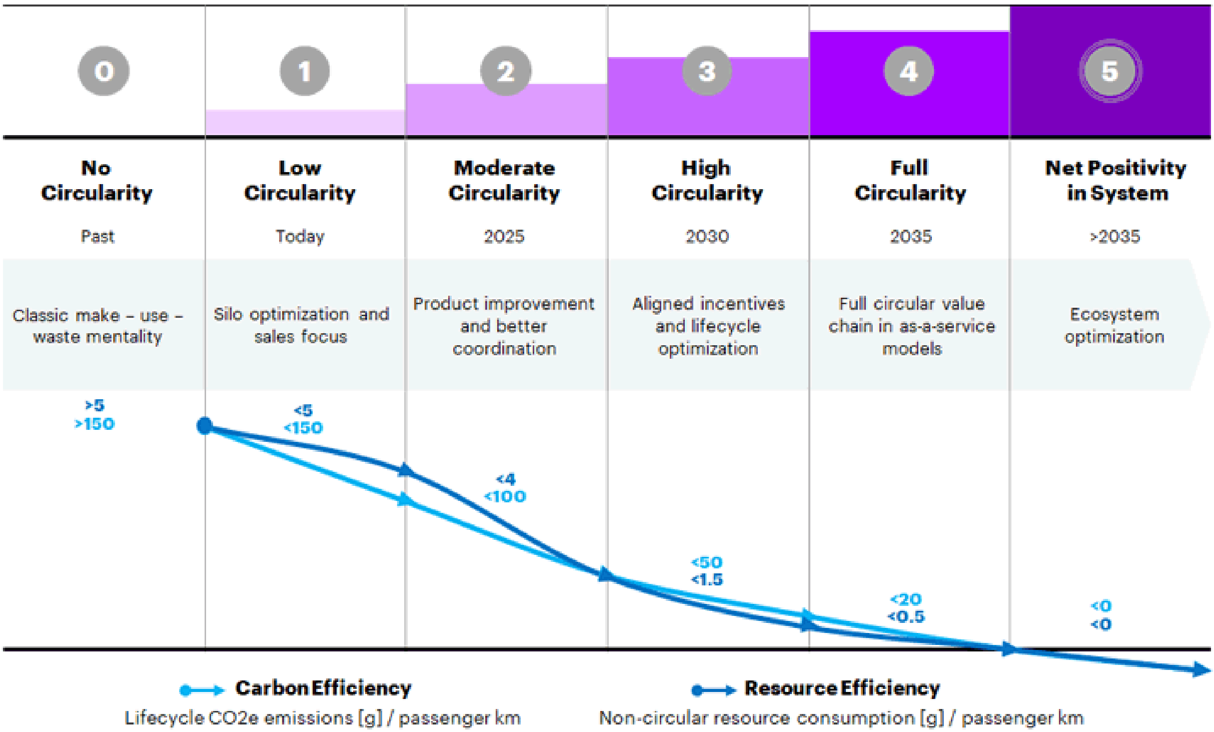
The definition focuses on the relevant variables [1[22]]: energy, materials, lifetime, and use (3-3. Figure). **ENERGY** is used efficiently (per km of movement) and renewable; **LIFETIME** of the vehicle and components is optimized for resource efficiency (by emphasizing efficient design, modularity, purpose-built vehicles, reuse, repair, remanufacturing, etc.). **MATERIALS** are used without waste (reduced, reused, recycled and/or renewed). **USE RATES** are optimized (accounting for resiliency requirements).



3-3. Figure_ The circular economy value chain for automotive companies

[https://www3.weforum.org/docs/WEF_A_policy_research_agenda_for_automotive_circularity_2020.pdf]

Accenture proposes a taxonomy with five levels of circularity based on two primary measures (carbon and resource efficiency) to evaluate and improve the circularity of cars [[23]]. The proposed levels range from single owner use and disposal (Level 0) to an aspirational goal of an automobility ecosystem that has net positive impacts (Level 5).
The levels describe vehicles that are part of an increasingly circular automobility system. Each level can be determined based on the characteristics of both the product and its use, so the producer and the owner of the car are responsible for achieving circularity.



3-4. Figure_Five levels of automotive circularity

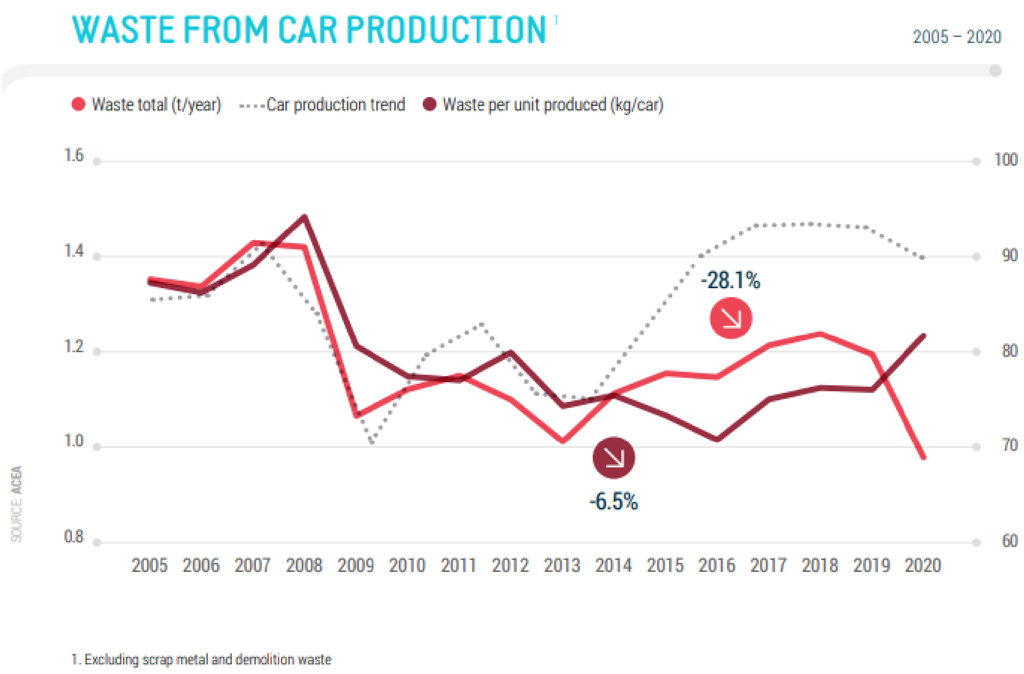
[Source: WEF & Accenture, Raising Ambitions: A new roadmap for the automotive circular economy, 2020]

3.3 Evolution and perspectives in the European automotive industry

The automotive industry has always been and remains a traditional industry in Europe. There are 322 automobile assembly, engine, and battery production plants in Europe, up from 301 in 2021; 213 are in the EU, an increase from 194 in 2021; 127 produce cars, 71 make buses, 56 build trucks (heavy-duty vehicles), 46 make vans (light commercial vehicles), 71 build engines, and 42 make batteries [[24]].

Regarding the localisation of the automotive industry, it is still the case that most production sites are located in the home countries, i.e. the countries where the car manufacturers are based. VW Group has 11 of its 24 factories in Germany, BMW has 4 of its 8 plants in the same country, PSA 5 of 14 in France, FCA 7 of 11 in Italy and Jaguar Land Rover 3 of 4 in the UK. Most production facilities are located in Germany, followed by the United Kingdom and France. Italy and Russia are fourth, each with 11 factories [[25]].

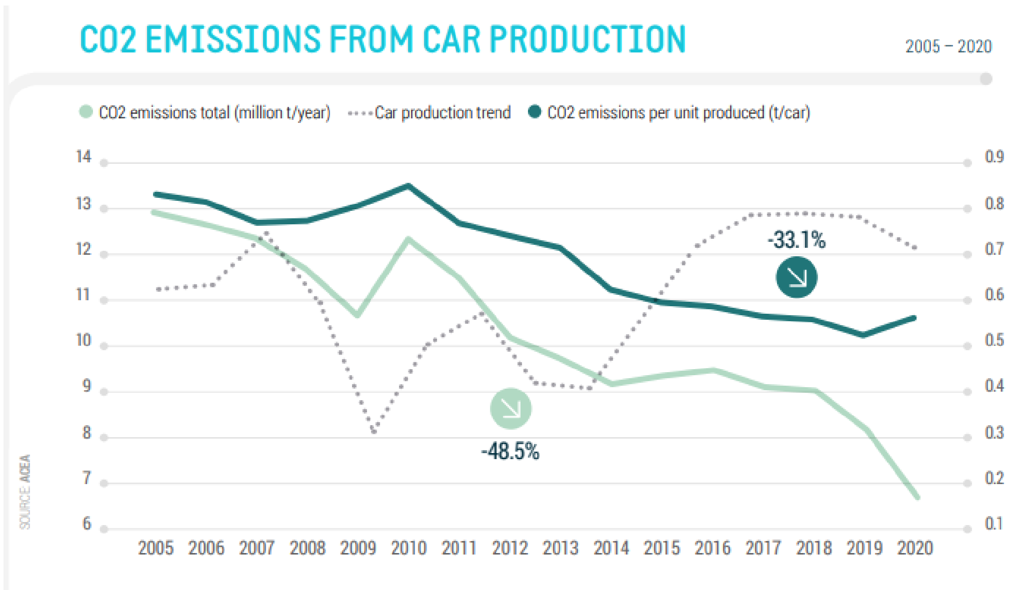
EU manufacturers have dramatically reduced the environmental impact of car production over the last 15 years.



3-5. Figure_Waste From Car Production 2005-2020, EU

[https://www.acea.auto/files/ACEA_Pocket_Guide_2021-2022.pdf#page=11]

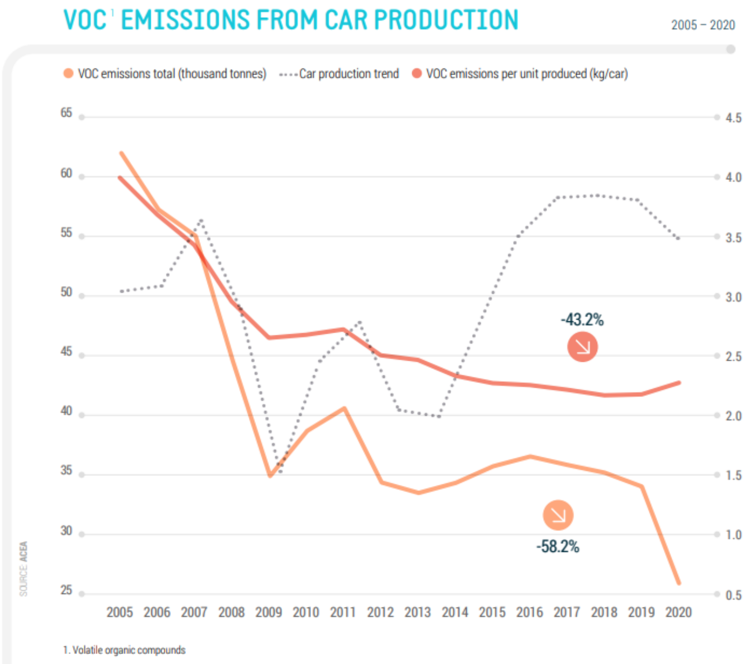
CO_2 emissions from car production have dropped by 48.5% since 2005



3-6. Figure_ CO_2 emissions from car production 2005-2020, EU

[https://www.acea.auto/files/ACEA_Pocket_Guide_2021-2022.pdf#page=11]

Volatile organic compounds (VOC) are organic solvents mainly emitted from paint shops. 3-7. Figure shows VOC emissions per car produced and the absolute emissions of all car manufacturers combined. With new technologies, such as the replacement of solvent-based paints with solvent-free, water-based equivalents manufactures have been able to reduce unit emissions by 43.2% over the last 15 years [26].



3-7. Figure_VOC Emissions From Car Production 2005-2020, EU

[https://www.acea.auto/files/ACEA_Pocket_Guide_2021-2022.pdf#page=11]

This important disruption in sales is expected mainly thanks to a large increase in sales in emerging markets. The increase in revenues therefore is expected to increase by 4.4% per annum, while the already important sales rate increase is expected to lower down to +2% annually. Additionally, the shared vehicles market is expected to grow every year by 40%, and by 2030, it is predicted it will represent 22% of the total revenues in the sector. Opportunities are seen also in developing technologies that enable the use of durable and high-value materials, therefore allowing for end-of-life looping processes.

The study “Growth Within” [27] estimates that this represents a € billion 35 opportunity, for investors that are willing, and able, to invest large sums of capital in R&D. Benefits would amount to € billion 75 per year by 2030, mainly by reduced costs of materials and a smaller vehicle fleet. Remanufacturing, which is understood as the series of steps undertaken on end-of-life products to bring them back to their original -or even improved- performances, represents an important cost saving opportunity for companies operating in the mobility sector. Ellen Mac Arthur Foundation, together with SYSTEMIQ, estimated that by investing € billion 1 spread over the period 2016-2025, the EU could obtain € billion 30 benefits by the year 2030, mainly through reduction of costs of manufacturing [28].

4 INTERNATIONAL IDENTIFIED GOOD PRACTICES IN AUTOMOTIVE INDUSTRY

Various countries and organizations have implemented successful practices to promote the principles of the circular economy on an international scale. These examples of good practices serve as valuable inspiration and guidance for others looking to adopt similar strategies. Let's explore some noteworthy international examples:

1. The Netherlands has taken a leading role in advancing the circular economy. They have established the "Netherlands Circular Hotspot" initiative, which facilitates collaboration and knowledge sharing among businesses, government entities, and research institutions. Additionally, the country has launched the "Circular Economy Programme" to promote circular procurement, product-as-a-service models, and resource recovery.
2. Finland has developed a comprehensive national roadmap called "Leading the Cycle" to guide their transition towards a circular economy. The country focuses on sustainable production and consumption by implementing measures like waste prevention, recycling, and extended producer responsibility. Finland also encourages circular business models, innovation, and eco-design.
3. Germany has been at the forefront of circular economy practices. They have implemented the "Closed Substance Cycle and Waste Management Act," which emphasizes waste prevention, recycling, and eco-design. The country also supports circular economy initiatives through resource efficiency programs, circular procurement practices, and fostering the growth of circular start-ups.
4. Denmark has gained recognition for its effective waste management system and commitment to renewable energy. The country prioritizes waste prevention and recycling through efficient sorting and collection systems. Denmark has also developed a "Circular Economy Strategy" to facilitate the transition to a more sustainable and circular society.
5. Japan has embraced the concept of the circular economy and implemented initiatives to reduce waste and promote resource efficiency. The country places a strong emphasis on the 3Rs (Reduce, Reuse, Recycle) and has developed advanced recycling technologies. Collaborative efforts between industry, government, and academia drive innovation in circular economy practices in Japan. KAIHO INDUSTRY is a car recycling Japanese company that offers a solution that addresses waste treatment and management of ELV (end-of-life) vehicles. The company was presented by the United Nations Organization for Industrial Development as part of the Platform for the Promotion of Sustainable Technologies [[29]]. The company has developed an environmentally friendly car recycling system that contributes to the circular economy. It is delivered in the form of a "package car recycling system", consisting of three components: Installation of automobile recycling equipment and production system - an adaptable standardized recycling technology that allows the separation of scrap metal from used recyclable parts; Installation of computerized business management system called KRA - the system enables quality control and inventory management, using a barcode system to identify the origin, history and specifications of individual parts recovered from vehicles; Provision of training on automobile recycling technologies and management skills - The International Recycling Education Center (IREC) imparts both technologies and management skills

to recycling workers. The recycling solution contains a standard for evaluating the quality of used engines that reach the export market, called the Japan Reuse Standard (JRS). This quality standard for used products complements the Japanese Industrial Standard for new products. The information provided on the quality standard sheet is the essential information to ensure transparency regarding the potential life and performance of the engine and related drive unit.

6. The European Union has been proactive in promoting the circular economy. They have adopted the "Circular Economy Action Plan" to encourage sustainable production and consumption, resource efficiency, and waste prevention. The EU has set recycling targets for different waste streams, introduced regulations on eco-design and extended producer responsibility, and established funding programs to support circular economy initiatives.
7. The Ellen MacArthur Foundation is a globally recognized organization dedicated to accelerating the transition to a circular economy. They work with businesses, governments, and academia to develop circular economy principles and practices. The foundation provides valuable research, guidance, and collaboration opportunities to drive the circular economy agenda worldwide.

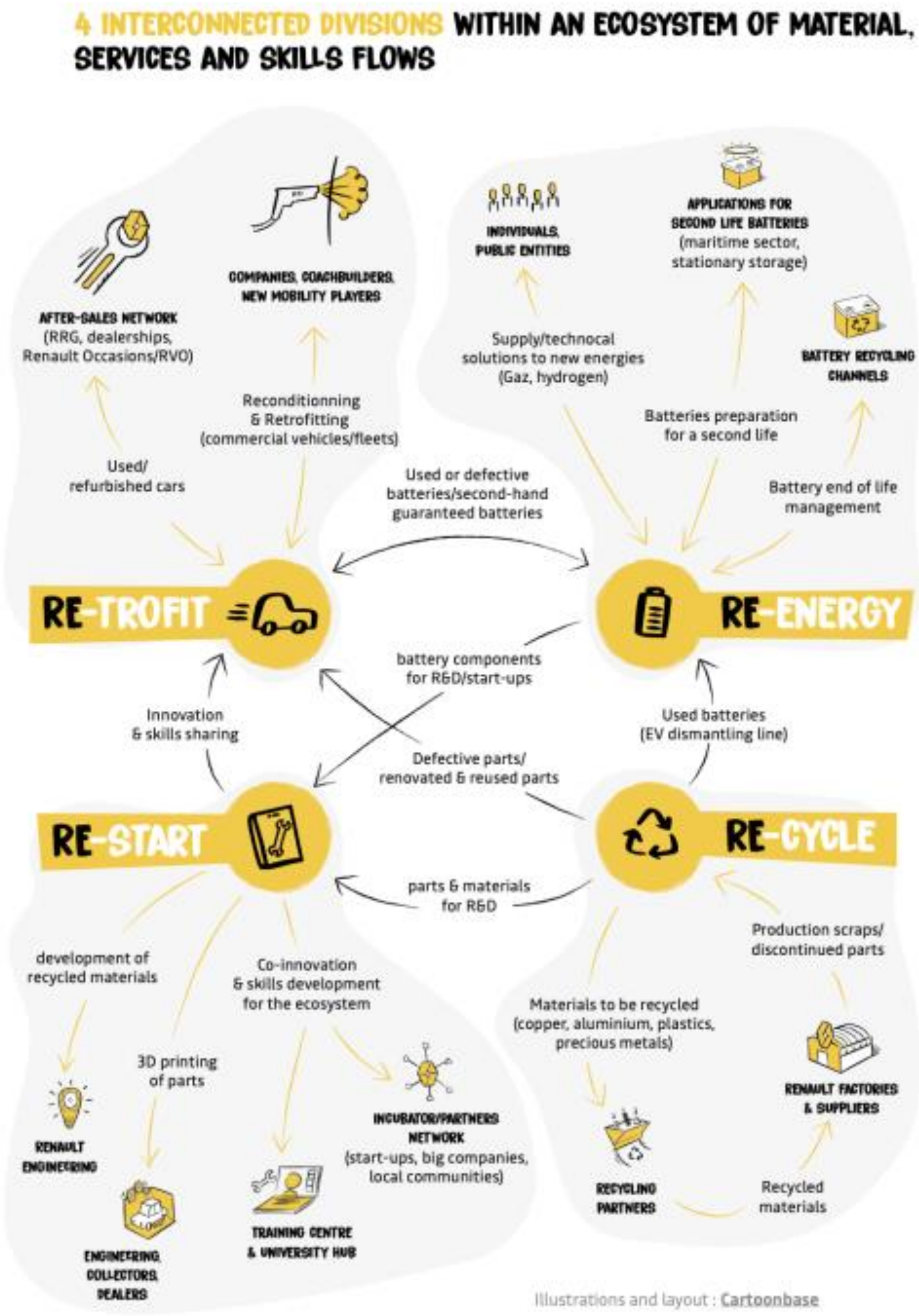
By studying and drawing inspiration from these international good practices, countries and organizations can learn from successful strategies and make progress towards a more sustainable and resource-efficient future.

4.1 Groupe Renault

Renault is a pioneer of the circular economy in the automotive industry. The aim of their circular activities is to extend the life of vehicles and components, and keep materials in use, thereby reducing the use of virgin materials [[30]]. It has achieved this in different parts of the manufacturing process and across different brands. For example, by: remanufacturing vehicle components such as gear boxes and turbo compressors; increasing recycled plastic content; creating a second life for electric batteries.

In 2020, Groupe Renault increased their ambition level and established **'RE:FACTORY',** Europe's first dedicated circular economy factory for vehicles and mobility [[31]].

Renault transformation plan is deployed gradually between 2021 and 2024 and the site will be organised around 4 activity centres, each with its own field of expertise: **RE-TROFIT, RE-ENERGY, RE-CYCLE AND RE-START**, in order to support the entire life of the vehicle by acting on the main components of the circular economy (supply, eco-design, economy of functionality, maintenance, reuse, remanufacturing and recycling) [[32]].



4-1. Figure_Renault's interconnected divions
[Source: https://www.greencarcongress.com/2020/11/20201126-renault.html]

RE-TROFIT: EXTENDING THE LIFE OF VEHICLES

The second-hand market is booming, driven by the awakening of an ecological awareness and new modes of consumption, which favour use over possession. To further pursue this path, Renault wish to bring together the areas of expertise required to extend the lifespan of vehicles and their uses. The main challenge: to succeed in preserving resources through efficient management of the flow of reuse of parts and materials on the same site.

As the environmental regulations are becoming stricter in cities, Re-Trofit wishes to capitalise on the Group's industrial structure and expertise to develop an attractive offer for the conversion of combustion motor vehicles to other, less carbon-intensive energies. This approach is aimed primarily at professional customers, including commercial vehicles.

The Renault division would like to extend its services to vehicle fleets and shared mobility players, such as the ZITY electric car-sharing service.

To support these solutions, a testing and prototyping center will be set up to enrich the design of future products and facilitate the improvement of vehicles throughout their life cycle. Using 3D printers already present on the site, the centre will also offer an additive manufacturing service for parts that have become unavailable, for example, for garages, private individuals or collectors of vintage cars.

RE-ENERGY: PRODUCTION, STORAGE & MANAGEMENT OF GREEN ENERGIES

At the heart of the transformation of the automotive industry are electric vehicle batteries. And above all, the challenge of their life cycle, which is crucial for the environment. Hence the ambition of this cluster to strengthen the collection of batteries, to prepare them for their second life, and to develop portable or mobile storage systems. Not forgetting to develop maintenance and recharging services dedicated to new energies.
The Flins centre aims to reach a capacity of 20,000 electrical battery repairs by 2030, thanks to the development of an industrial structure.
The Flins factory is a reference in this field. It is there that, from 2011, industrial techniques for repairing electric vehicle batteries were created, before being distributed in 17 countries. At the end of its first life in the vehicle and well before recycling, the battery provides an indispensable solution for renewable and intermittent energies: electricity storage.
New operating opportunities such as stationary storage make it possible to perpetuate this service. In this case, the battery makes it possible to integrate electricity from solar or wind power, on the scale of a house, a building, or even an industrial site. Several of the Group's experiments illustrate this approach:
In Porto Santo, stationary storage is ensured thanks to second-life Renault ZOE batteries, thus reducing the island's dependence on fossil fuels, while promoting renewable energies;
Two very large-scale energy storage projects (Advanced Battery Storage in France and Germany, and SmartHubs in the UK) have been initiated to reduce the gap between electricity consumption and production, and increase the share of renewable energy in the energy mix;
Reconditioned batteries have begun a second life on board cruise ships on the Seine in Paris (electrification of the Paris Yacht Marina fleet) and soon on board sailing cargo ships for transoceanic journeys (Neoline Project) [[33]].
Between 2021 and 2030, the second life batteries sold by the Renult Group will represent an annual capacity of more than 200 mwh, the equivalent of 4 000 full charges of a Renault Zoe.
Batteries at the end of their life are systematically recycled. With the support of Renault subsidiary Indra, since 2013 it have developed a long-standing partnership with Veolia for

the recycling of batteries, from which metals are recovered after dismantling. To accelerate the development of this sector, Veolia was encouraged to forge closer ties with Solvay. A fruitful collaboration, as they have set up a circular economy consortium. Its objective: to mobilise the best mechanical and chemical technologies and skills, and to transform metals into high-purity raw materials that can be used directly in the production of new batteries.

RE-CYCLE: OPTIMISING RESOURCE MANAGEMENT

In line with regulations, the automotive industry in Europe has high rates of recycling and recovery of End-of-Life Vehicles (ELVs), as well as a high proportion of recycled materials in its new products, compared to other sectors. The Group already incorporates an average of 30% recycled materials in its vehicles produced in Europe, and want to go further and continue to increase the recycled materials integrated into the production of new vehicles, while reducing procurement costs and the impact on resources.

CREATION OF A DISMANTLING LINE: The transformation of the site includes the installation of a dismantling line starting 2024, to capture additional volumes and increase our capacity to source parts and materials in short loops. The ambition is to be one of the leading dismantling sites in France, and to develop expertise in the dismantling of electric vehicles, with an average of 10,000 vehicles per year.

DEVELOPMENT OF SORTING, REUSE OR RECYCLING: The Renault Group is based on an ecosystem of subsidiaries and partners around recycling and recovery, examples of which are the Gaïa Branch, already established in Flins, whose mission is to qualify and recover vehicles, parts and materials through recycling channels, repair and reuse, or the Choisy-le-Roi factory, which has been dedicated to remanufacturing for 70 years.

RE-START: INNOVATION MADE ACCESSIBLE FOR ALL

The ambition of this centre focuses on enhancing and developing skills, while accelerating research and innovation in the circular economy. Thus, Re-Start will host an incubator for start-ups and partners, as well as a university and training centre, to reinforce the specialisation of the professions present within the Re-Factory. The project will also study inclusion, to promote access to employment.

RE-FACTORY FLINS will integrate an incubator open to its employees and external partners (start-ups, academic partners, large groups, local authorities...) to develop or co-develop innovative projects. It will include a space for "in vivo" experimentation on industrial installations, in collaboration with experts from different fields (vehicle architecture, materials, electric vehicles, energy, recycling, lean manufacturing...). It will also house the Advanced Manufacturing centre of excellence for vehicle prototyping and experimentation, focusing on Industry 4.0 topics such as 3D printing or predictive maintenance.

But while the concept might seem easy to grasp, there are a number of aspects involved. When we talk about the circular economy, the first thing we think of is eco-design, i.e. the use of resources which are renewable, sustainable [[34]] and reusable in other forms. For the automotive industry the challenge is considerable.

In practical terms, for Groupe Renault, it's a question of designing sustainable vehicles with recycled and recoverable materials. For Renault electric vehicles, it's about finding a second life for batteries that are no longer usable, e.g. for storing renewable energy or providing power for buildings [35].

In compliance with European regulations, of all vehicles at the end of life: 95% are recovered (reuse or recycling of materials) and 85% are recycled. At least 50% of the materials contained in used electric batteries and accumulators are recycled. 33%: the average rate of recycled materials used in Groupe Renault vehicles produced in Europe at the end of 2018. 50 kg+ of recycled plastics used in the ESPACE V.

4.1.1 Renault mobility

According to the UN [36], the global population in 2050 will reach 9.8 billion, of whom almost 70% will live in urban areas. Hence, the growing demand for urban mobility in the years to come is driving the need to develop effective schemes that are at once clean, sustainable and shared. Groupe Renault is working on the development of various types of services: car-pooling, car-sharing, ride-hailing, driverless vehicles [37].

Renault Mobility is the per-hour or per-day self-service vehicle hire scheme in France. Then there's Zity [38], Madrid's electric car sharing scheme, and the Marcel ride-hailing service [39]. Renault is trials mobility services that are smart, shared, autonomous, electric, public or private, via two projects and autonomous ZOE prototypes: Rouen Normandy Autonomous Lab and Paris-Saclay Autonomous Lab.

With the **ROUEN NORMANDY AUTONOMOUS LAB (RNAL)**, Renault are starting to test on open roads an end-to-end autonomous mobility service. This is a first in Europe and it includes four electric Renault ZOE robo-vehicles equipped with sensors and embedded intelligence, a customer application to book the trip, a remote fleet control center, connected infrastructure and secure telecommunications networks [40].

The purpose of the **PARIS-SACLAY AUTONOMOUS LAB PROJECT** is to devise and test different smart, autonomous, electric and shared public and private mobility services to supplement the existing transportation systems in the Paris-Saclay area. A comprehensive autonomous transportation system comprising autonomous vehicles, a supervision system, connected infrastructure and customer applications will be set up and experiments will be conducted to determine the requirements for scaling up an autonomous mobility service. The experimental system using autonomous electric vehicles – three Renault ZOE Cab prototype cars and a Transdev-Lohr i-Cristal shuttle – will be progressively made available to a panel of users [41].

Renault's vision of future urban and communal mobility is represented by the 4 robot-concept vehicles unveiled in 2018 and 2019: EZ-GO, EZ-PRO, EZ-ULTIMO and EZ-POD. EZ-GO, EZ-PRO and EZ-ULTIMO offer a mobility experience that has been designed for everybody and can be accessed by as many as possible. A customizable and fully connected experience that plugs into the ecosystem of the intelligent cities that are developing, and has a positive impact on them [42].

4.1.2 The Future Is NEUTRAL - Closed-loop recycling solutions, car-to-car

Every year in Europe more than 11 million vehicles, which include around 85% recyclable materials, reach the end of their life cycle. However, this resource is under-exploited: new vehicles contain only 20% to 30% recycled materials, which come from all industries.

Currently, recyclable materials from end-of-life vehicles are mainly recovered for other industrial applications (metallurgy, construction, etc.).

The objective of The Future Is NEUTRAL is to maintain the value of parts and materials for as long as possible and to enable the automotive industry to use in the future in the manufacture of new vehicles a much higher percentage of recycled materials from end-of-life cars.

The new company has a network of subsidiaries and partners that ensure, throughout the entire life cycle of a vehicle, the collection of parts, materials and batteries from various sources, from factory scrap to car workshops. Thanks to this ecosystem, The Future Is NEUTRAL develops circular economy loops at every stage of a vehicle's life, from production, to use, to end-of-life.

Specifically, The Future Is NEUTRAL benefits from the expertise of the Gaia subsidiary whose activities in the field of battery repair, collection and reuse of parts and recycling of materials recovered at the end of a car's life cycle are carried out in the factory in the French city of Flins.

INDRA, a competitive end-of-life vehicles treatment branch, recovers up to 95% of car mass

The Future Is NEUTRAL will also offer advisory and training services dedicated to the circular economy to the automotive sector, with the support of the Campus of the Circular Mobility Industry (ICM) based in the city of Flins, within the company University "ReKnow University" of the Renault Group.

4.2 Mercedes-Benz to use green steel in vehicles in 2025, reducing its carbon footprint

Stuttgart, Germany, May 24, 2021 – Mercedes-Benz AG is the first automaker to take a stake in Swedish start-up H2 Green Steel (H2GS) as a way to introduce CO2-free steel into series production. Together with its steel suppliers, the company is restructuring its supply chain to focus on preventing and reducing CO_2 emissions rather than offsetting them. The partnership with HSGS is another step towards CO_2 neutrality, which Mercedes-Benz is pursuing as part of Ambition 2039, its goal of achieving a fully connected and CO2-neutral vehicle fleet in 2039 – 11 years earlier than the legislation requires EU [[43]].

With a stake in H2 Green Steel, Mercedes-Benz is sending an important signal to accelerate change in the steel industry and increase the availability of carbon-free steel.

As the preferred partner of the start-up, Mercedes-Benz will introduce green steel in various vehicle models as early as 2025.

A Mercedes-Benz sedan, for example, is made of about 50% steel, which accounts for about 30% of CO2 emissions from production.

Through the partnership, Mercedes-Benz is actively and consistently addressing one of the biggest challenges in the automotive industry on the road to CO2 neutrality.

CO2 FREE MANUFACTURING TECHNOLOGY: By using a new, innovate manufacturing process, the production of steel at the supplier level is CO_2 free. By contrast, steel produced using a classic blast furnace, emits an average of more than two tons of CO_2 per ton. In the new process, the supplier uses hydrogen and electricity from 100 % renewable energy sources instead of coking coal in steel production. The hydrogen serves as a reduction gas, which releases and binds the oxygen from the iron ore. Unlike the use of coking coal, this does not produce CO2, but water. The supplier uses electricity from 100% renewable sources for the energy requirements generated in the manufacturing process.

ACTIVE ENGAGEMENT FOR A SUSTAINABLE STEEL SUPPLY CHAIN: Mercedes-Benz and all its steel suppliers are working consistently to reduce CO2 emissions in the steel supply chain on the way to producing green steel. In addition, the company is committed to a responsible steel supply, relying on the application of recognized standards and robust certificates. Mercedes-Benz is a member of the Responsible Steel Initiative and is actively involved in the development of a certifiable sustainability standard for the steel industry. The aim is to ensure environmentally friendly and socially acceptable steel production along the entire value chain.

CO2 NEUTRAL MERCEDES-BENZ SUPPLY CHAIN: Mercedes-Benz AG pursues the goal of a CO2 neutral new car fleet along the entire value and supply chain. Suppliers representing more than 85% of Mercedes-Benz's annual purchasing volume have already signed an Ambition Letter, agreeing to supply the company only with CO2 neutral products in the future. This includes important steel suppliers. At the same time, Mercedes-Benz is working with its partners to gradually increase the proportion of secondary materials in components and materials.

H2 GREEN STEEL: H2 Green Steel (H2GS) was founded in 2020, aiming to build a large-scale fossil-free steel production facility in northern Sweden. H2GS will produce 5 million tons of fossil-free steel by 2030. By doing this, the company will contribute to the decarbonizing of the European steel industry, one of the largest carbondioxide emitters. H2GS will establish operations in Boden and Luleå. The founder and largest shareholder is Vargas, which is also co-founder and one of the largest shareholders in Northvolt.

4.3 Volkswagen Group

The Volkswagen Group [44] created concepts for the reconditioning and recycling of vehicle components early on. One important driver of the circular economy is the ongoing decarbonization of the Volkswagen Group. The growing use of secondary materials and the establishment of closed loops of materials help to significantly reduce the CO_2 emissions [45]. Circular economy is also a key issue in the "NEW AUTO – Mobility for Generations to Come" Group strategy NEW AUTO strategy through 2030 - a new plan of transformation into "a software-driven mobility company."

Fundamentally, VW pursue four lines of action at Group level in the area of circular economy:

- ☑ First, efforts are already intensifying to use recyclable and reusable materials in vehicle designs – for example, from production waste.
- ☑ In addition, VW wants to further improve the supply of circular materials, i.e., secondary materials and renewable raw materials – for example by buying back end-of-life vehicles – and thus bring valuable materials back into the loop.
- ☑ Another approach is to preserve recyclable materials through reuse and repurposing – for example, in the recycling of high-voltage vehicle batteries in Salzgitter.

- ☑ VW are working intensively on developing business models that simplify the recovery of raw materials from their products.

The topic of circular economy is also a core element of the "goTOzero" Group environmental mission statement, on which VW orient the strategic design of this action area. With this Group mission statement, the Volkswagen Group is setting itself the target of, among other things, further improving its resource efficiency and promoting reuse and recycling approaches in the areas of materials, energy and water. Other topics that contribute to the circular economy are embedded in the "goTOzero – Zero Impact Factory" program. It is guided by the vision of creating a factory that has no adverse environmental impact.
IN-HOUSE EXPERTISE IN BATTERY RECYCLING: Volkswagen Group Components opened the Group's first facility for recycling high-voltage vehicle batteries at the Salzgitter site at the start of 2021. The objective is industrialized recovery of valuable raw materials such as lithium, nickel, manganese and cobalt in a closed loop and also of aluminium, copper and plastic, with a recycling rate of more than 90% in the future. Batteries are only recycled if they can no longer be used in other ways – for example, in reconditioned form in mobile energy storage systems such as flexible fast charging stations or charging robots. The facility has been initially designed to recycle up to 3,600 battery systems per year in pilot operation [[46], [47]].

The innovative and CO_2-saving recycling process does not require energy-intensive melting in a blast furnace. The used battery systems are delivered, deep discharged, and dismantled. The individual parts are ground into granules in the shredder and then dried. In addition to aluminium, copper and plastics, the process mainly yields valuable "black powder" containing lithium, nickel, manganese, cobalt, and graphite, which are important raw materials for batteries. The separation and processing of the individual substances by hydrometallurgical processes – using water and chemical agents – is subsequently carried out by specialized partners. As a consequence, essential components of old battery cells can be used to produce new cathode material.

The material recovered can be used to support battery cell production in the future. The CO_2 savings are calculated to be approximately 1.3 metric tons per 62-KWh battery manufactured using cathodes made from recycled material and green electricity. That is more CO_2 emissions than are generated during the production and logistics processes of a new ID.3.

4.3.1 Skoda

Czech carmaker Skoda, part of Volkswagen Group, is actively engaged in applying the principles of a circular economy [[48]]:

- ☑ minimise negative impacts on the environment,
- ☑ diminish resources inputs and the loss of these resources,
- ☑ conversely maximising the circulation of resources.

Skoda is working with an interdisciplinary team to implement these concepts in coordination with the ecology and occupational protection department.
Circular economy is 'an integral part' of Skoda's strategy. The brand closely cooperates with recyclers and suppliers to cut down on primary materials and extend the lifetime of used materials. The efficient use of resources, also shows financial benefits.
Skoda's milestones on the sustainability front:

At Czech production sites, it have zero production waste to landfill. That means, all the waste from production is either materially or energetically reused, adding that Skoda has also expanded circular activities to its production sites in India.
The carmaker uses seat covers made from recycled PET bottles, combining wool with recycled polyester. It is also involved in pilot projects focused on reusing end-of-life glass from cars in the manufacturing process. In its paint shop, Skoda deploys ground limestone, which absorbs residual paint particles, thus eliminating the need for water in a process known as 'dry separation'.

USE OF RENEWABLE RAW MATERIALS

ŠKODA, in collaboration with the Technical University of Liberec and the supplier, has developed a sustainable, ecological material made from sugar beet pulp which can be used in dyed form in the interior of vehicles to create certain design accents. In addition, ŠKODA is working on another material based on the miscanthus reed which will also be used in the interior of models in the future [[49]]. The use of rice husks, hemp, cork and coconut fibres is also being researched.
ŠKODA is deploying used high-voltage batteries from electric vehicles in stationary energy storage systems before they are recycled. This second life cycle effectively reduces the batteries' CO2 footprint [49].
The VW Group is investigating the use of other ecologically sourced materials, such as materials based on cellulose. One flagship project is cooperation with a recycling company. As part of this, a process has been developed to turn painted bumpers into granules. These can then be used for new bumpers.

4.3.2 AUDI

4.3.2.1 Turning old into new: MaterialLoop project tests circular economy potential of end-of-life vehicles

With the "MaterialLoop" project, Audi closes several material cycles in the automotive industry. Together with 15 partners from the research, recycling and supplier sectors, **AUDI looks at the reuse of so-called post-consumer materials, which are taken from customers' vehicles at the end of their life cycle, from the automotive industry and uses them for the production of new cars**, as part of Audi's circular economy strategy [[50]].
To date, very few of the materials used in the production of new vehicles are recovered from old cars. Steel, for example, usually ends up as structural steel after end-of-life vehicle recycling.
Audi wants to change this by reusing secondary materials taken from end-of-life vehicles in the production of new cars. Recycling, which leads to a loss of material quality, should be avoided.
The MaterialLoop project outlines the vision to operate a highly efficient circular economy concept for end-of-life vehicles:

- AUDI's objective is to recover as many materials as possible at a high level of quality and reuse them in production. This will save valuable raw materials and reduce the ecological footprint of the products. At the same time, direct access to secondary materials can help increase security of supply. Raw materials should no longer be extracted.
- In October 2022, 100 vehicles were dismantled as part of the joint MaterialLoop project.

- ❑ Only the targeted disassembly of individual components enabled the retention of high-quality secondary materials such as larger pieces of plastic for recycling.
- ❑ After disassembly, the remaining bodies were shredded and sorted into material groups including steel, aluminium, plastic and glass in cooperation with partner companies.
- ❑ To test the reuse of such materials in new car production, Audi defined and piloted the further recycling process together with project partners from the recycling industry, the Audi supply chain and academia.

Together with its suppliers, Audi has identified chemical recycling as a real opportunity within the CO_2 workshops. The objective of Audi's CO_2 program is to use resources as efficiently as possible and reduce CO_2 emissions in the value chain, with a clear focus on materials that are either required in large quantities or involve consuming manufacturing processes high energy.

A case of success is the **ALUMINIUM CLOSED LOOP**: Audi and its suppliers managed to recover aluminium waste and bring it to the level of new product quality, thus avoiding, in 2019 alone, approximately 150,000 metric tons of CO_2 entering the the environmental balance sheet [51].

To use even less primary aluminium in manufacturing in future, Audi launched the Aluminium Closed Loop years ago.

Audi introduced the “Aluminium Closed Loop” at the Neckarsulm site back in 2017. The aluminium sheet offcuts that are produced in the press shop are sent straight back to the supplier. The supplier recycles these into aluminium sheets of equal quality, which Audi then uses in production. Audi at Neckarsulm now employs this Aluminium Closed Loop with two suppliers, thus increasing the amount of aluminium managed in the closed loop. This achieved a savings of roughly 150,000 metric tons of CO2 in 2019, two-thirds more than the year before. In addition to the plant in Neckarsulm, the Audi plants in Ingolstadt and Győr have now also joined the Aluminum Closed Loop process.

Secondary aluminium is currently used in various body parts of the Audi A3, A4, A5, A6, A7 and A8, and also in parts of the Audi e-tron and e-tron Sportback. This ensures that high-grade aluminium scrap is not sold for profit on the scrap metal market, but is fed back into the material loop. Excess aluminium offcuts from the press shop are returned to the producer, where they are recycled and supplied back to Audi in the next step as secondary aluminium. The recycling rate is almost 100 percent. Compared with primary aluminium, up to 95 percent less energy is consumed during production.

The process itself and the resultant net CO2 savings of more than 633,881 metric tons of CO2 since 2017 have been verified by independent third parties. The calculation of the CO2 savings from the Aluminum Closed Loop Project was updated compared with the prior year because the press shop offcuts were reassessed [52].

4-2. Figure_ Audi's Aluminium Closed Loop

[Source: https://www.audi.com/en/company/sustainability/core-topics/value-creation-and-production/co2-program-in-production.html]

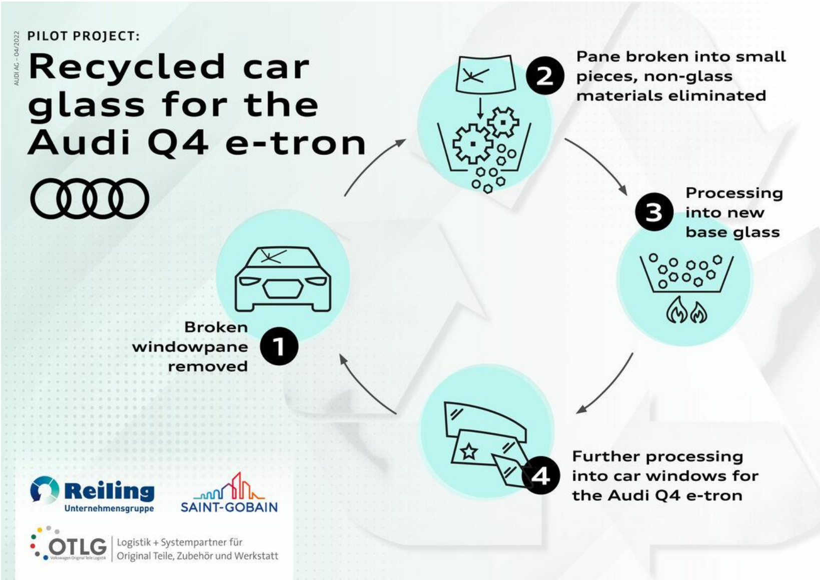
The company plans to gradually further increase the volume of recycled materials in the manufacture of its car models.

A recent example is the use of PET plastic in the production of the Audi A3 model. PET is a plastic polymer that can be separated from the materials with which it was combined, being therefore easier to recycle. For example, three upholstery options are available for the Audi A3 made from up to 89% recycled materials. Upholstery is currently not made entirely from recyclable materials. The challenge lies in the base material used, which is attached to the upper material with an adhesive and AUDI is working on replacing this with a recyclable polyester.

AUDI's goal is to manufacture the upholstery entirely from the same type of material so that it can be recycled. If its technical feasibility is proven, Audi plans to industrialize the technology in question and then progressively apply it to more and more components.

4.3.2.2 Glass-recycling pilot project

Broken car windows often go to recycling when they cannot be repaired, there is still no closed material loop for damaged car windows. Audi and its partner companies Reiling Glas Recycling, Saint-Gobain Glass and Saint-Gobain Sekurit are conducting a joint pilot project to turn damaged car glass into recyclable material for the production of new models. They developed a multi-step process for using an innovative recycling process: car windows are first broken into small pieces; all non-glass impurities such as glue residue are then removed; the resulting glass granules are melted down and turned into new glass. That sheet of glass is then turned into a new car window [53].



4-3. Figure_Recycled car glass for Audi Q4-E-TRON

[Source: https://www.audi-mediacenter.com/en/photos/detail/recycled-car-glass-for-the-audi-q4-e-tron-108899]

Audi is now shifting the "GlassLoop" pilot project into standard production; for the windshields in the Audi Q4 e-tron, the company will use glass made of up to 30% recycled material from car windows damaged beyond repair. Audi, in cooperation with its partner companies, is the first premium auto manufacturer to set up a glass cycle of this kind.

Until now, car windows damaged beyond repair—mainly windshields and panoramic roofs—have been used for less demanding purposes, such as bottles or insulation, in what is known as downcycling. The pilot project was the first to demonstrate that glass could be reused at comparable quality [54].

4.3.2.3 Audi & KIT: The pilot project for chemical recycling of plastics in automotive engineering

Audi and THINKTANK at KIT are working on a special method of recycling plastics used in the automotive industry that will create intelligent circular systems in supply chains and use resources efficiently [55].

Launch of the pilot project: chemical recycling enables the creation of a closed circuit for plastics in the automotive industry. Recycled plastic waste is turned into pyrolysis oil, which can then be used to create new components.

A large number of car components are made of plastic materials. They must meet the exacting requirements regarding safety, heat resistance and quality. For this reason, until now, only petroleum-based materials have been suitable for the manufacture of plastic automotive components, as they can be subjected to particularly intense wear. In most cases, such materials are not recyclable. While plastics of the same kind can often be mechanically recycled, recycling mixed plastic waste is a major challenge.

Audi and the Karlsruhe Institute of Technology (KIT) are therefore launching a pilot project for chemical recycling within THINKTANK's main activity "Industrial Resource Strategies", contributing such mixed plastic waste to the continuity of the conservation system of resources.

It is intended to integrate into AUDI's own distribution chain intelligent circular systems and use resources in an efficient manner. In this sense, chemical recycling has great potential: if plastic components can be produced from pyrolysis oil instead of petroleum, then it would be possible to significantly increase the volume of sustainably manufactured car components. In the long term, this method can also play a key role in the recycling of end-of-life vehicles.

The pilot project "Chemical recycling of plastics in automotive engineering" aims to create intelligent circular systems for plastics and their integration as a complementary method in mechanical recycling and energy recovery.

In partnership with KIT, Audi plans to initially test the technical feasibility of chemical recycling and evaluate the method in terms of its impact on the economy and the environment. These evaluations are carried out at KIT in collaboration with the Institute of Technical Chemistry (ICT) and the Institute of Industrial Production (IPI).

For this purpose, the company uses plastic components from Audi models returned from the German distribution network, which are no longer needed, such as, for example, fuel tanks, wheel rims and the radiator grille.

These plastic components are transformed, through chemical recycling, into pyrolysis oil. The quality of this oil corresponds to that of petroleum products, and the materials made from it reach high standards, similar to new ones.

In the medium term, components made from pyrolysis oil can be used again in automotive production.

To date, chemical recycling is the only method that can be used to process mixed plastic waste into products that match the quality of new ones. As a result, a wider range of plastics can be recovered, such closed circuits of materials presenting several advantages. They conserve valuable resources, as less raw material is required. In turn, this saves energy and costs, and is also good for the environment. Audi is one of the first car manufacturers to test this recycling method in a pilot project with plastics from its own car production.

4.4 FORD

Ford has set an target of using 20% recycled and renewable plastics in new vehicle designs by 2025 at its factories in North America and Europe and a 10% target for its factories in China and Turkey. Ford also uses a closed-loop system to manufacture its F-series trucks and is the largest closed-loop aluminium recycling automaker in the world, according to its 2022 sustainability reports [[56]].

In the Integrated Sustainability and Financial Report, 2023 [[57]] FORD sets also the ambitious sustainability aspirations, as follows: achieve carbon neutrality no later than 2050, use 100 percent carbon-free electricity in all manufacturing by 2035, use only recycled or renewable content in vehicle plastics, attain zero emissions from our vehicles and facilities, make zero water withdrawals for manufacturing processes and use freshwater only for human consumption, reach true zero waste to landfill across our operations, eliminate single-use plastics from their operations by 2030.

Over 85% of vehicle parts and materials are recycled and reused at the end of their life. Understanding that the metal parts of vehicles are already highly recycled, FORD is focusing on recycled and renewable plastic content.

The implementation of the circular economy FORD takes into account the following:

- ☑ **USING RECYCLED MATERIALS FOR VEHICLE PARTS**

While not every polymer can easily use recycled material, there is potential for recycling to reduce the carbon footprint of plastics by 70-90%. Through activities such as transforming recycled plastic bottles into vehicle parts FORD is helping to play a major role in promoting environmentally friendly auto parts. Due to its light weight, recycled plastic is ideal for the manufacture of underbody shields, engine under shields and front and rear wheel arch liners that can help improve vehicle aerodynamics. FORD also uses postconsumer nylon and polypropylene carpeting for cylinder head covers, fans and shrouds, cam covers, and carbon canisters.

- ☑ **CONVERTING CO2 TO POLYURETHANE FOAM**

Ford has been awarded a grant by the U.S. Department of Energy to conduct research on using CO2 as a feedstock to make polyurethane foams. The $2.5 million grant is one of 30 DOE projects to help decarbonize the U.S. industrial sector, advance clean manufacturing and improve America's economic competitiveness. Using polyols that are derived from captured waste CO2, Ford will develop and scale up technology to produce polyurethane foams used for automobiles for seating and other applications such as for crash protection and noise, vibration, and harshness reduction. Machine learning will be used to accelerate the development and formulation of the polyol molecular platform and foams to meet manufacturability, performance, and cost metrics while improving sustainability as measured through Life Cycle Assessment (LCA).

- ☑ **USING RENEWABLE MATERIALS FOR VEHICLE PARTS**

Renewable, plant-based materials are also part of FORD sustainability strategy. Ford is using nine plant-based materials in current and past vehicle production. These robust materials have multiple benefits including enabling lighter weight parts that improve fuel economy, sequestering carbon and reducing global warming impacts, and also require less energy to manufacture. Ford industry-first sustainable materials include soy foam, wheat straw, rice hulls, tree-based cellulose, and coffee chaff.

Soy seat cushions, backs and headrests were one of many Ford firsts. They have been used in every Ford North American built vehicle for more than a decade, over 18.5 million vehicles. Bio-based foams have reduced greenhouse gas emissions by over 228 million pounds, and use of soy foam, launched on Mustang and now on all American vehicles, has helped save 5 million pounds of petroleum annually since 2008.

Ford Advanced Polymer Technologies team continues to pioneer the development of new sustainable plastic materials including using waste from olive production to reinforce plastics, captured carbon dioxide in plastic formulation and polymer resins made from renewable feed stocks. For example, it is tested whether the tree-based cellulose composites, that were incorporated into Lincoln Continental consoles, can be used in other applications. Ford experts are also deriving value from waste material, using recycled ocean plastics in the Bronco Sport.

- ☑ **BATTERY RECYCLING**

Ford views batteries of end-of-life vehicles as a crucial part of supply chain, and are committed to increasing battery recycling over time. To further these efforts Ford are supporting various battery recycling companies, including with letters of support for US DOE grants. In Europe, new regulations will require manufacturers to report on their extended producer responsibility for proper battery recycling. In advance of the European Battery Regulation, Ford are partnering with Everledger to pilot a battery passport. The pilot leverages Everledger's technology platform to track EV batteries throughout their life cycle to ensure responsible management during use and recycling at the end of their useful life.

This will allow Ford to gain visibility on out-of-warranty batteries, validate responsible end-of-life recycling, and gain access to data such as recycled critical minerals produced and associated carbon dioxide emissions savings.

- ☑ **CLOSING THE LOOP IN ALUMINIUM RECYCLING**

Ford's closed loop recycling system maximizes aluminium recycling in their plants and minimizes the need for primary metal. As a major global automotive aluminium recycler, Ford has worked closely with its aluminium sheet suppliers to create unique alloys. The system recovers aluminium scrap during parts stamping but keeps the various aluminium alloys separated so they can be recycled back into fresh alloy for new vehicles. Ford currently recycles up to 20 million pounds of aluminium each month at Dearborn Stamping, Kentucky Truck and Buffalo Stamping facilities. This represents 20-30% of Ford aluminium sheet coil purchases. Making recycled aluminium only takes around 5% of the energy needed to make new aluminium, according to the Aluminium Association, and minimizes the need for primary metal.

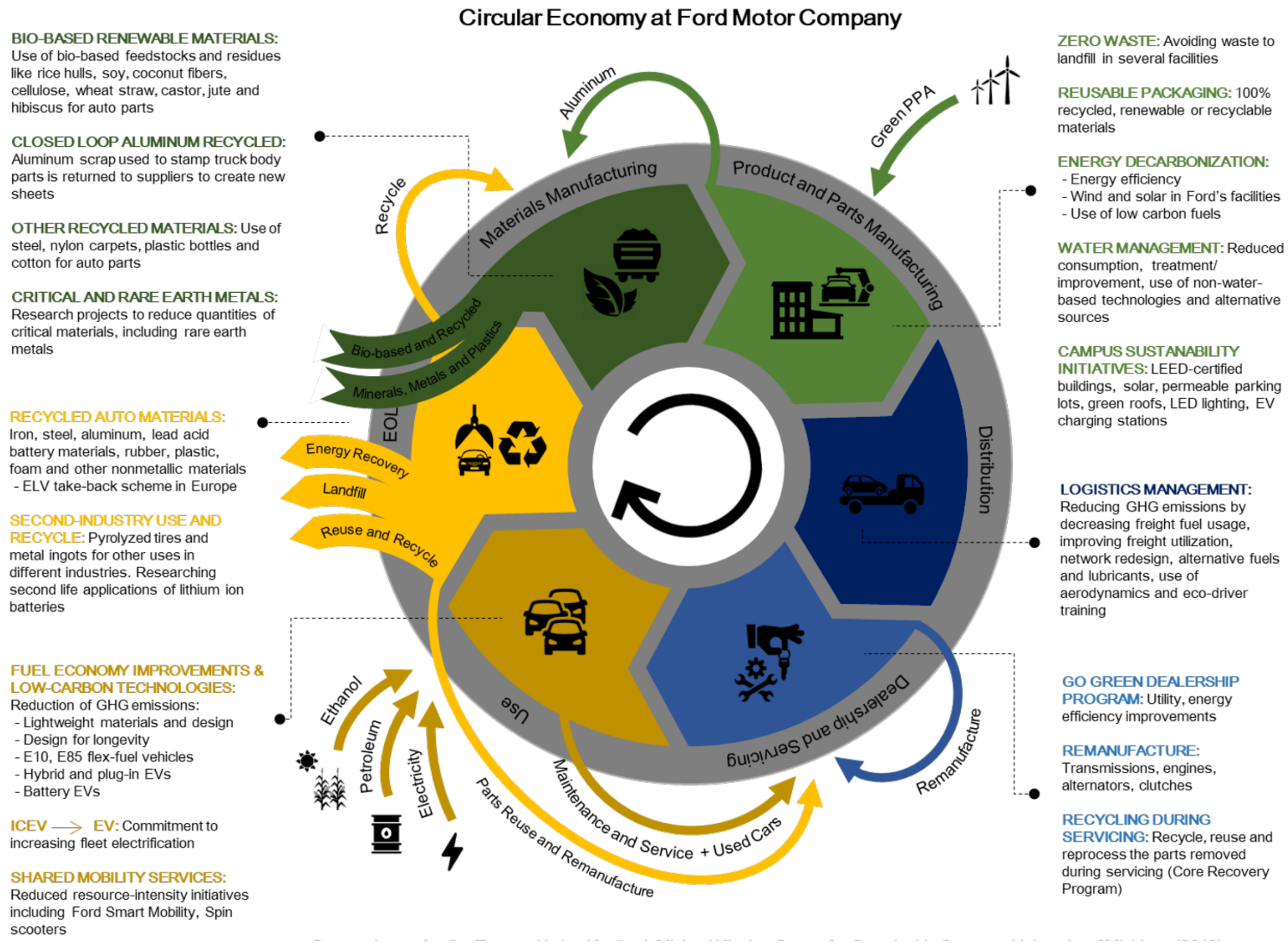
- ☑ **REMANUFACTURING** has been an important part of Ford's sustainability effort since the 1940s.

Remanufacturing turns a previously used, sold or worn-out part into a like-new or better-than-new condition which can be warranted in performance level and quality. Remanufacturing saves considerable energy, utilizes much less raw material compared to a new unit, substantially reduces CO_2 emissions, and helps extend the life cycle of the vehicle product line.

Ford has remanufactured powertrain assemblies, turbos, injectors, steering components, brake components, electronic modules and starters/alternators. Reclaimed powertrain material supports Ford sustainability objectives.

In 2022, Ford reclaimed 3,794 metric tons of steel and 2,777 metric tons of aluminium from transmission material and 1,284 metric tons of cast iron, 289 metric tons of steel and 515 metric tons of aluminium from engine material. Combined, Ford supplied 104,000 remanufactured engines and transmissions in the U.S. Going forward, Ford are looking to expand the program beyond Ford Blue and remanufacture certain components of their EVs.

Circular Economy at Ford Motor Company is presented in 4-4. Figure_ Circular Economy at Ford Motor Company4-4. Figure.



4-4. *Figure_ Circular Economy at Ford Motor Company* [Source: [58]]

Material and energy flows are depicted by arrows, with Ford's specific sustainability initiatives displayed on either side.

4.5 VOLVO

Volvo has committed to becoming a circular business by 2040 - maximizing resource efficiency for vehicles, components and materials. It focuses on eliminating waste, making greater use of recycled material, and remanufacturing and reusing parts. Volvo already begun by mapping out how, by 2025, can save costs of SEK 1 billion and reduce emissions by 2.5 million tonnes through circular initiatives [].

- ☑ **Design for circularity**

A circular economy maximizes resources by designing products for sustainability, reuse and recycling. From the beginning, Volvo considers the entire life cycle of a vehicle and how to maximize the value delivered during this time. When finished, the disassembly and recycling process can provide raw materials of high quality and quantity. Volvo is also considering designing the next generation of products, packaging and services according to the principles of a circular economy, including offers that significantly increase the longevity and intensity of product use.

- ☑ **Recycled materials**

One of Volvo circular economy ambitions is to significantly increase the share of sustainable recycled and bio-based materials in their cars by 2025, as follows: 25% Recycled or bio-based plastics; 40% Recycled aluminium; 25% Recycled steel.

☑ **More remanufacturing**

Compared to producing new parts, remanufactured parts use around 85 per cent less raw material and 80 per cent less energy. Volvo currently remanufactures different component groups, including engines, gearboxes, turbo compressors and clutches. In 2022 Volvo saved over 4,800 tonnes of CO2 by remanufacturing over 33,000 parts.

☑ **Less production waste**

In 2022, 94 per cent of our global production waste was recycled – so we avoided creating additional carbon emissions and were able to keep valuable material in circulation. This also reduced the amount of virgin material needed.

☑ **Recycling**

Volvo's largest waste stream is metal from car production, which amounted to 188,000 tonnes in 2022 and is entirely recycled.

An example of good practice: **VOLVO CARS COMMISSIONED CIRCULOR TO IMPLEMENT A TECHNOLOGY-ENABLED TRACEABILITY SOLUTION**, to enable an end-to-end chain of custody to be constructed, initially for Cobalt and subsequently for Mica, with other materials being planned [[59]].

VOLVO CARS EV BATTERY MATERIALS TRACEABILITY

The production of minerals such as cobalt, lithium, mica, or nickel used in the manufacture of lithium-ion batteries has potential adverse social and environmental impacts. Volvo Cars recognised this challenge and the fact that increasing legislative and consumer demands for greater transparency in the provenance of raw materials sourced required a more innovative and effective solution to prove that materials used in their product supply chain had indeed been responsibly sourced. These raw material supply chains are complex and involve a web of highly diverse actors further upstream. Raw materials, by their nature, are difficult to tag reliably - the material transforms on its journey from source to end-use. This means that a new identity needs to be added after each transformation that inherits the provenance of the material and destroys the old identity.

The solution spans Volvo's entire battery supply chain for electric vehicles (EV) to provide full traceability of cobalt from source to the EV itself in order to manage the risk and demonstrate that responsibly sourced material only enters the supply chain.

Volvo Cars worked with Circulor to implement a platform based on distributed ledger technology, and other technologies to create an immutable chain of custody record in the supply chain which, when combined with supplier audits, creates a totally new standard in verified responsible sourcing.

Artificial intelligence algorithms support due diligence and identify data anomalies to target compliance and investigative action. Bringing transparency and traceability into the supply chain is the first step towards closing the loop.

4.6 BMW

The responsible use of resources is fundamentally important for the BMW Group. They aim to reduce consumption of resources by using high-quality secondary material, and also want to be able to track further use of raw materials in line with the principles of the circular economy.

4.6.1 RE:BMW Circular Lab

The BMW Group is pioneering the development of a circular economy and efficient resource management. With the RE:BMW CIRCULAR LAB, a platform launched in 2021, the BMW Group shares an authentic insight into the company's contribution towards holistic product development, the careful use of resources and the transformation towards a circular economy. The platform is also an invitation for collaboration and exchange [60].

BMW Group consistently follow the guiding principle of the circular economy: RE:THINK, RE:DUCE, RE:USE and RE:CYCLE [61].

- ☑ **RE:THINK**

VENTURING INTO VALUABLE TECH: Through its own venture capital fund BMW i Ventures, the BMW Group has invested in key technologies that can make a decisive contribution towards achieving its long-term vision of carbon neutrality. In 2020, for example, BMWi Ventures invested in PureCycle, the first company in the world that can recycle polypropylene (an essential vehicle component) into a colourless and odourless native state. The BMW Group also invested in Prometheus Fuels, which has developed a technology that enables carbon-neutral synthetic fuels to be produced using green energy.

- ☑ **RE:DUCE**

MINIMISATION OF WASTE GENERATION.

The BMW Group has developed recycling initiatives to minimise waste generation. These are adapted to the waste streams at the plants, to regional legal requirements and to the locally available disposal structures. Digital finishes on surfaces means a reduction of hardware variants. Inside the car, smart control islands reduce the use of materials. Over-the-air updates and cloud computing keep the product technically up to date for longer.

- ☑ **RE:USE** Extending the use of products as much as possible.

BMW extend and expand the value, possible applications and use of the products by means of modernisation, digital functions and many other options. [62].

- ☑ **RE:CYCLE**

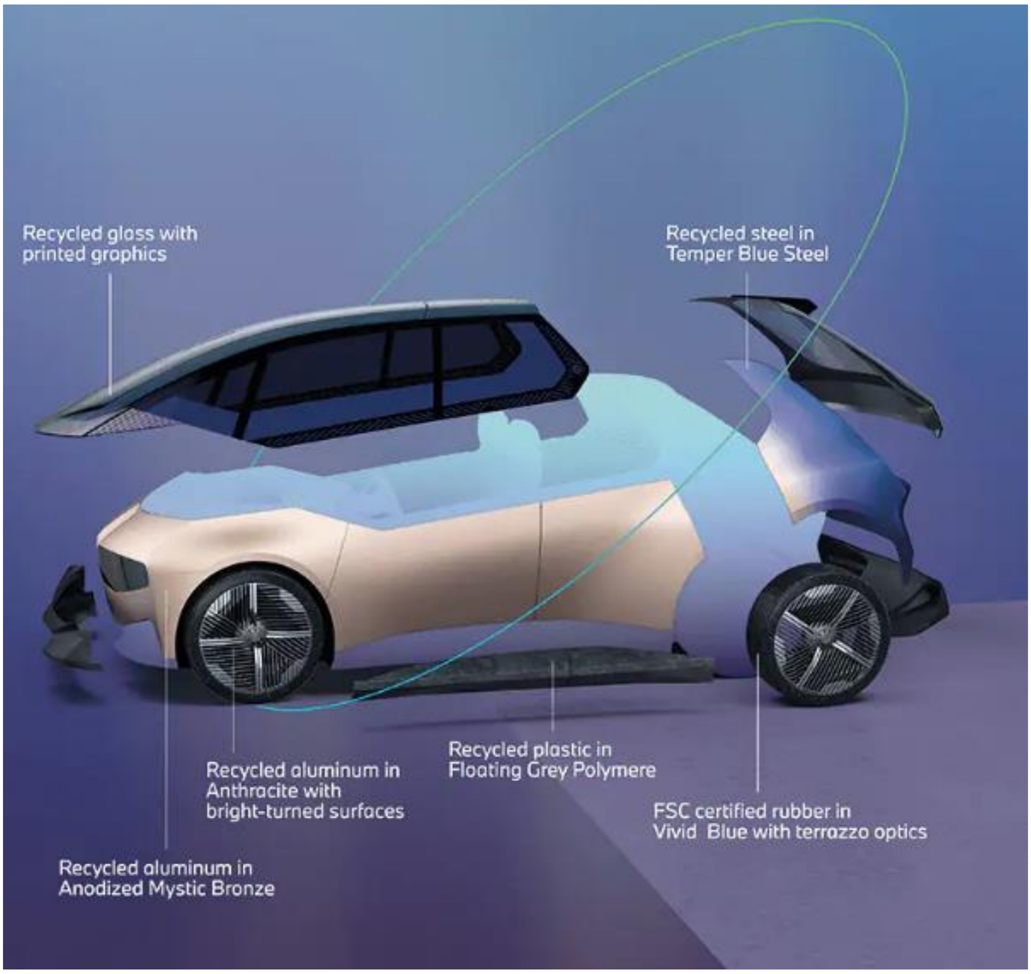
All vehicles launched since 2008 meet global legal requirements for recycling end-of-life vehicles, components and materials. Even today, 95 per cent of vehicles registered in the European Union must be recyclable. BMW Group vehicles are currently made from up to 30 per cent recycled and reused materials. The "Secondary First" approach will successively increase this figure to 50 per cent.

Refurbishing and redesigning extend the life cycle of end-of-life vehicles. However, the BMW Group, together with its national sales companies, goes further with more than 2,800 return points in 30 countries offering environmentally friendly recycling.

4.6.2 THE BMW I VISION CIRCULAR

THE BMW I VISION CIRCULAR – a fully-electric four-seater with a consistent focus on sustainability and luxury – is emblematic of the ambition of the BMW Group to become the most sustainable manufacturer for individual premium mobility.

The BMW i Vision Circular is a vision vehicle from the automobile manufacturer BMW and gives a foretaste of the year 2040. The car was presented to the public at the IAA 2021. The focus of this concept car is on sustainability and luxury. It consistently followed circular economy principles in its design with the intent to reduce CO2 emissions.



4-5. Figure_ BMW i Vision Circular [https://www.bmw.com/en/events/iaa2021/bmw-i-vision-circular-domagoj-dukec-first-look.html]

4.7 Continental - Sustainable materials in tire production

Continental is constantly optimizing tires in the direction of increased sustainability. Proposed objective by 2050 at the latest: **tires made entirely from sustainable materials**.
The design of tires and the interaction between the different materials that go into their composition is extremely complex, so Continental **aims to offer maximum safety on the road thanks to the ideal mixture of raw materials**. For this, Continental's materials experts and engineers have initiated a discreet transition.

No later than 2050, all tires will be made from sustainable materials. Step by step, it can already see which are the raw materials that will be used in the future in the manufacture of tires. These include **agricultural waste - such as rice husk ash, dandelion rubber, recycled rubber or PET bottles, everything from the origin and provenance of the materials used to the reuse and recycling of tyres** [[63]].
Currently, between 15 and 20% of renewable or recycled materials are already used in the manufacture of Continental's standard car tires. To further increase the proportion of sustainable materials and conserve valuable resources, Continental constantly analyzes and reviews all raw materials used in tire production.

- ☑ **Perfect material compatibility for maximum safety.**

Natural rubber is still essential because of its exceptional properties. The company uses an integrated approach aimed at making complex and fragmented supply chains for natural rubber more sustainable. Including through the use of state-of-the-art digital technology, local involvement and close collaboration with capable partners, with the aim of improving transparency and traceability along the entire value chain.
Through the Taraxagum project, Continental is pursuing an innovative approach to ensure it can become less dependent on natural rubber grown mainly in Southeast Asia. The tire manufacturer is working with partners to industrialize the extraction of natural rubber from specially cultivated dandelion plants [[64]].

- ☑ **Sustainable plant-based raw materials**

In addition to rubber, raw materials such as silicon are essential for the assembly of tires. Silicon, for example, helps optimize characteristics such as grip, rolling resistance and tire life. In the future, rice husks will be used as a raw material for sustainably produced silicon. Rice husk is a waste product of rice production and cannot be used as food or animal feed. Silica derived from rice husk ash is more energy efficient when used in production than that obtained from conventional materials such as quartz sand.
Plant-based oils - such as rapeseed oil and resins based on waste materials from the paper and wood industry - already offer an alternative to crude oil-based raw materials in Continental tires. Only oils that meet technical quality standards and are not suitable for consumption are used. Oils and resins allow flexibility in tire compositions and thus improve the grip of the material.

- ☑ **Expanding the circular economy**

Continental aims to achieve fully circular operations in tire production by 2050 at the latest.
In addition to using renewable materials, the company is systematically working on using recycled raw materials in tire production. This is meant to ensure that carbon black - another crucial raw material in rubber compounds - can be widely obtained in the future. Continental recently signed a development agreement with Pyrum Innovations to further optimize the recycling of waste tire materials.
To do this, Pyrum breaks down old tires into their constituent parts in an industrial oven, using a special pyrolysis process.

4-6. Figure_Pyrolysis process at Continental: recovered carbon black (rCB). [https://cdn.continental.com/fileadmin/_processed_/e/a/csm_continental_pp_infographics_pyrolysisprocess_en_a6044b3e73.jpg]

In this way, the valuable raw materials contained in end-of-life tires can be extracted and recycled.

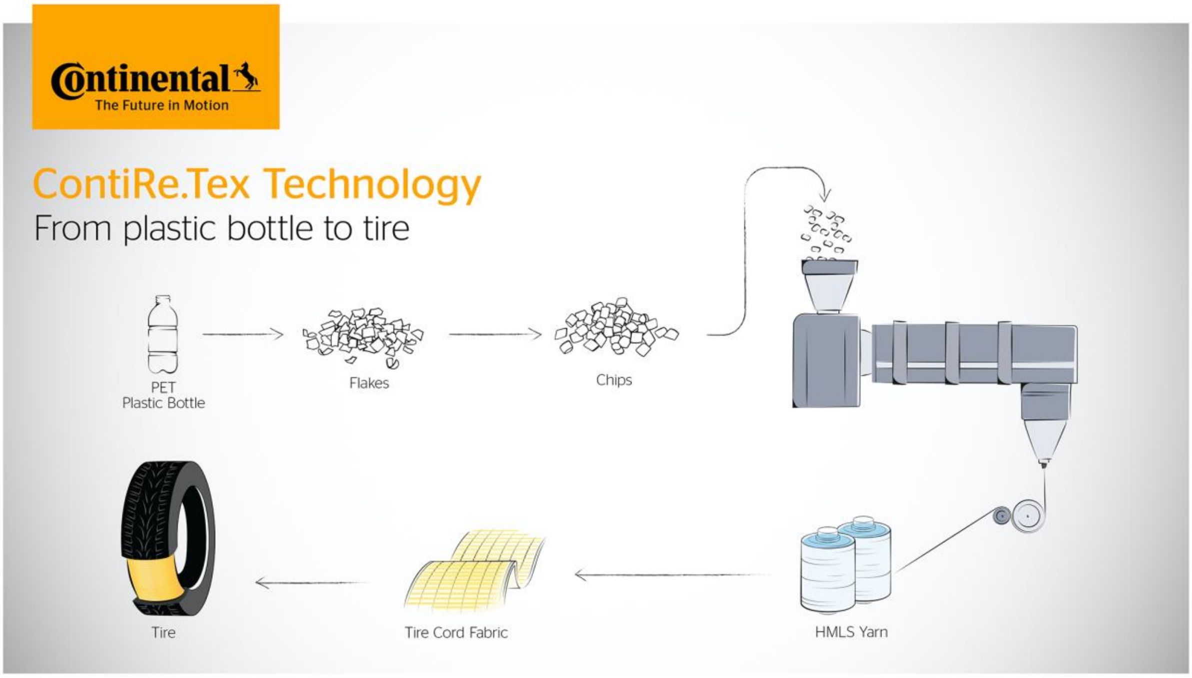
☑ **Recycled rubber from end-of-life tires**

In addition to pyrolysis, Continental also uses the mechanical processing of end-of-life tires. Rubber, steel and textile cables in particular are separated from each other in a highly sophisticated process. The rubber is then prepared to be reused as part of new rubber compounds.

Continental has a rich history of consistent work to bring end-of-life tires into the circular economy to conserve resources and the environment. A material known as "Conti-Reclaim" has been obtained as part of the truck tire retreading process at the company's plant in Stöcken, Hanover, since 2013. It has been used in Continental's tire production for years in order to expand the range of applications for recycled rubber and to optimize the properties for different areas of application, Continental uses not only "Conti-Reclaim" but also recycled rubber from other suppliers.

☑ **Recycled plastic bottles used in tire casings.**

Recycled raw materials will play an important role in making more sustainable tires. Continental uses recycled materials whenever possible. Quality and material properties similar to conventional raw materials are essential. For example, Continental works with partners to source high-quality polyester yarn for its tires from recycled PET bottles. Otherwise, PET bottles often end up in incinerators or landfills.



4-7. Figure_ContiRe.Tex technology: from plastic bottle to tire [https://cdn.continental.com/fileadmin/_processed_/3/2/csm_continental_pp_infographic_contire.tex_en_bbba4e9cfd.jpg]

With ContiRe.Tex technology, the tire manufacturer has developed a more energy-efficient and environmentally friendly alternative that allows it to reuse 9 to 15 plastic bottles for each tire, depending on its size. Recycled PET has already replaced conventional polyester in some tire casing structures. The PET bottles used come exclusively from regions where there is no closed recycling circuit.

☑ **Systematic evolution towards sustainable development**

Continental works tirelessly to advance innovative technologies and promote sustainable products and services throughout its entire value chain, from sourcing sustainable materials to recycling end-of-life tires. The company aims to achieve 100% carbon neutrality by 2050 at the latest.

4.8 FIRST-OF-ITS-KIND PLASTIC RECYCLING USING A BY-PRODUCT OF SHREDDED END-OF-LIFE VEHICLES

Eastman - a global specialty materials company- and partners have successfully demonstrated first-of-its-kind plastic recycling using a by-product of shredded end-of-life vehicles. Eastman has announced the successful completion of its closed-loop recycling project for automotive mixed plastic waste [[65]]. Through a collaborative effort, Eastman, the United States Automotive Materials Partnership LLC (USAMP), automotive recycler Padnos, and global automotive interior supplier Yanfeng demonstrated first-of-its-kind plastic recycling using a by-product of shredded end-of-life vehicles [[66]].

4-8. Figure_ Circular Economy from Eastman: Closed-Loop Recycling of Automotive Mixed Plastic Waste [https://www.plasticstoday.com/sites/plasticstoday.com/files/styles/article_featured_standard/public/Eastman-1540x800.jpg?itok=AkIIQIHG]

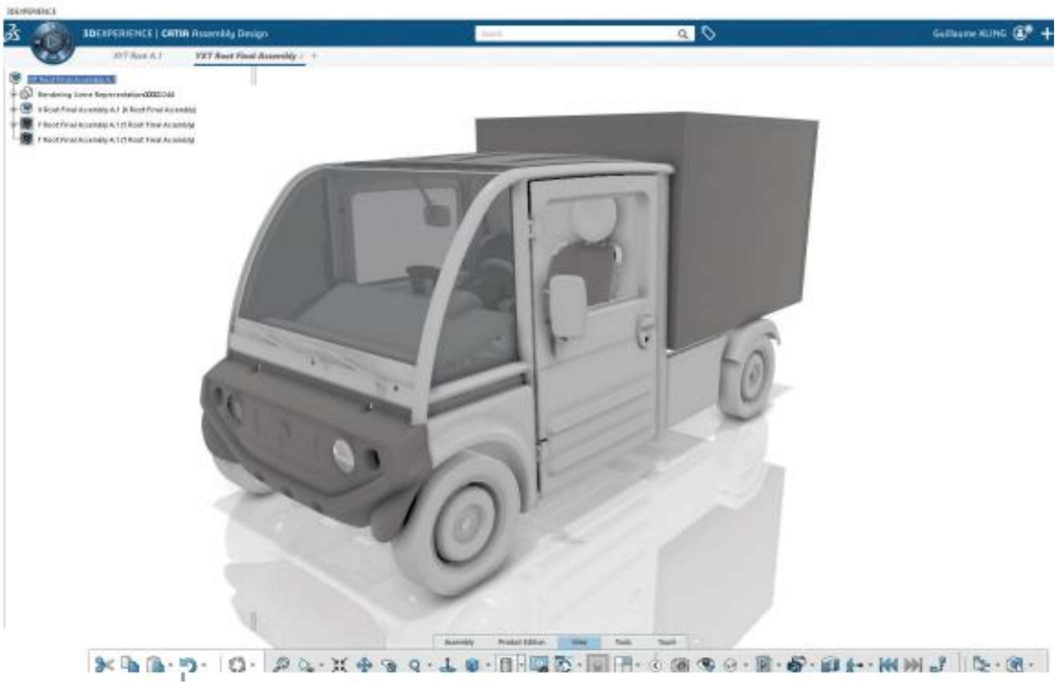
Technology diverts plastic waste from landfill: When automobiles are at the end of their life, metals, tires, and glass account for 80 to 90% of the materials that can be recycled through traditional mechanical recycling streams. The other 10 to 20%, referred to as automotive shredder residue (ASR), consist of mixed plastic and other nonrecycled materials that currently end up in landfills or are recovered through waste-to-energy technologies. Under this initiative, Padnos supplied a plastic-rich fraction of ASR as a sustainable feedstock to Eastman's carbon renewal technology. Eastman successfully demonstrated addition and conversion of that ASR feedstock into a synthesis gas (syngas), which is subsequently used downstream in the production of its polyester and cellulosic thermoplastics.
Resins from this production process were further formulated and then supplied to Yanfeng. The parts molded by Yanfeng for demonstration were successfully tested to meet a variety of OEM – Ford, GM, and Stellantis – requirements, thereby demonstrating proof of concept for a truly circular solution.

Project proves feasibility of molecular recycling: The study proved feasibility of Eastman's carbon renewal technology (CRT), one of Eastman's two molecular recycling technologies, which breaks down the plastic-rich ASR into molecular building blocks. By recycling these

complex plastics in CRT, Eastman can replace fossil-based feedstock and create polymers without compromising performance for use in new automotive applications.
In addition to diverting waste from landfills, USAMP, a subsidiary of the United States Council for Automotive Research LLC (USCAR), also sees the potential for energy savings and reduced overall greenhouse gas emissions.

4.9 XYT- Modular, electric and sharable vehicles

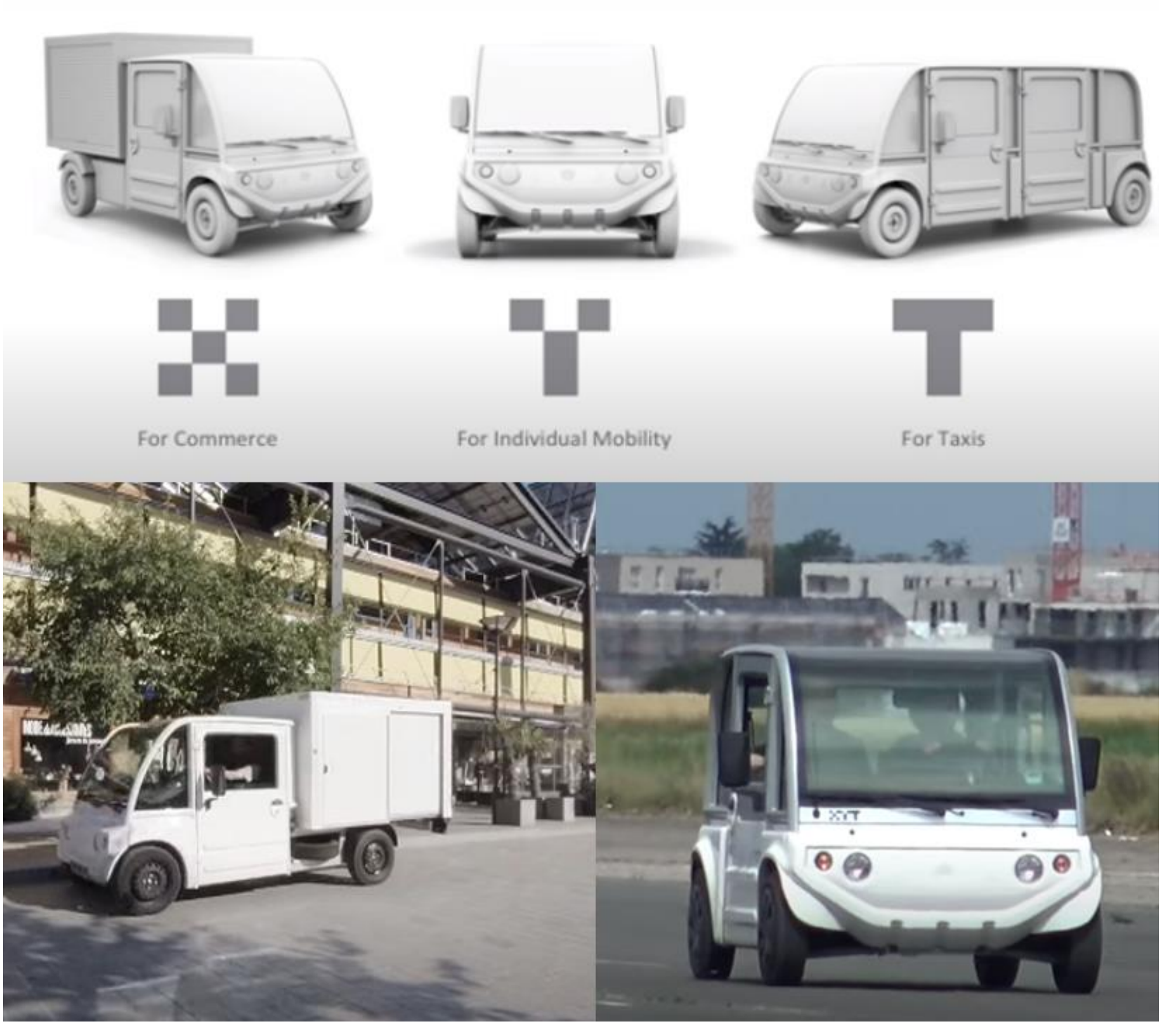
XYT is an automotive start-up based in Paris, and currently working on launching some of the first modular, upgradable and electric utility urban vehicles in Europe. XYT is a new generation automotive manufacturer developing modular electric vehicles with a strong focus on efficiency, durability and singularity. XYT already has a fleet of 80 vehicles, currently operating on the roads and a good order book for 2021 [[67]].
Through the 3DEXPERIENCE Lab program, a Dassault Systèmes' start-up accelerator [[68]], XYT uses the platform on the cloud with great benefits, as follows: simplify and optimize exchanges throughout the value chain in a collaborative environment; reduce the complexity of design, production and certification; unify access to resources; customize vehicle configurations quickly and dynamically; manage components and sub-systems' suppliers. The platform enables XYT to split the vehicle design into integrated modules and functions: electricity, belts, brakes, etc. Each engineer can work separately on specific modules, which remain automatically integrated into the original global model. If a part or component evolves within a module, the master automatically integrates the latest changes.



4-9. Figure_ All XYT vehicle components have been designed and can be customized on the 3DEXPERIENCE platform

[Source: https://www.3ds.com/assets/invest/2020-03/xyt-case-study-2019.pdf]

Three Pixel models are available: the X, a modular rear utility vehicle, the Y in smart format, and the T, the size of a Twingo that can carry 7 people.



4-10. Figure_ Pixel models available: the X, a modular rear utility vehicle, the Y in smart format, and the T, the size of a Twingo
[Source: https://www.3ds.com/assets/invest/2020-03/xyt-case-study-2019.pdf]

The modular & open vehicle platform "PIXEL" already tested through a million kilometres has been designed and optimized to create the best last mile mobility and work experiences for goods and people. All are recyclable and upgradeable for extended life. Everyone is free to design their own vehicle with a hybrid or electric engine, different electronic systems, or even customized interior linings.
Pixels have passed crash tests and meet the safety standards in force in France. Each model has a range of 100 to 200 kilometers and can travel at a maximum speed of 100 km/h.
To expand its platform portfolio already composed of the PIXEL X for last mile logistics and the PIXEL Y for individual mobility, XYT is currently developing a new 7-seater version targeting public, shared or private people transportation as its new PIXEL T product line.

The true differentiation of its value proposition comes from the level of personalization offered to customers. All components of the vehicles can indeed be personalized: work

experiences, body, interior experience, accessories, energy sources (hybrid or electric), batteries capacity, etc. Literally, clients can compose their own tailored vehicles to their image, needs and desires.
The innovation brought by XYT is through the design of its vehicles. Composed by only 600 highly durable components, they can be easily replaced or repaired following the "Lego" principle. Additionally, the overall weight of the models is half of conventional vehicles. Although the returns on investment are expected to be longer, the company believes in the economic sustainability of the concept, based on modularity and durable vehicles, as it believes that the initial cost of the vehicles -due to the battery costs and product quality- will be compensated by the higher life-span of the product and its saved costs in maintenance and repair.
To accelerate its development, XYT is currently raising funds and building strategic partnerships with long-term leasing companies. In addition, XYT mentions that there is no real EU certification framework to integrate vehicle upgrades & evolutions, everything being defined for brand new cars. Such considerations could also help the development of such modular & circular industrial models [[69], [70]].

4.10 AIMPLAS, Spain

AIMPLAS is a Technological Center with more than 30 years of experience in the plastics sector which provide solutions to the main problems facing automotive and transport companies throughout the value chain, from raw material manufacturers to transformers and end users [[71]].

Development of efficient heating systems based on Joule heating (resistive heating). Weight reduction: long-fibre thermoplastic (pellets and tapes) and thermoset composites. Electronics integrated into plastic parts and in-mould electronics. Autonomous vehicles: sensor integration, materials for electromagnetic shielding and RADAR/LIDAR transparency. Development of self-cleaning surfaces (hydrophobicity and photocatalysis), odour control and reduced maintenance in shared vehicles.

The main examples of good practices of AIMPLAST are presented below.

4.10.1 LIFE CIRC-ELV Project: Channelling plastic from end-of-life vehicles back into the manufacturing chain

The LIFE CIRC-ELV project (2018 - 2022) has developed a new process for managing end-of-life vehicles to recover bumpers and fuel tanks, recycle the materials and use them to manufacture pipes and new parts for vehicles. Using this recycled plastic in products from this industry and others will help reduce the carbon footprint by 85% [[72] ,[73]]. A new plastic recovery process has been successfully implemented by one of the members of the consortium, the Valencian company Desguace Cortés. The process separates the polypropylene bumpers and polyethylene fuel tanks of end-of-life vehicles. These materials are recycled for reintroduction into the production cycle, thus promoting the circular economy.

The project developed two recycled demo samples:

A CLOSED LOOP SAMPLE (plastic remains in the automotive industry), involving wheel liners for vehicles manufactured by the Aragon firm Sigit Automotive,

AN OPEN LOOP SAMPLE, in which pipes and pipe fittings were manufactured at a production plant in Portugal.

The technology developed in the project can be applied to other authorised treatment facilities (ATFs) to obtain recycled plastics ready to be used to produce new products, such as household appliances, pest control devices and even farm tools.

The implementation of this part separation model in European ATFs is supported by the French company Indra, a pioneer in managing end-of-life vehicles. SIGRAUTO has also helped disseminate and transfer the project results.

MAIN RESULTS: Plastic from ELVs generally ends up in landfills, damaging the environment and wasting resources. This project has developed an efficient method for bringing this plastic back into the value chain. The project achieved a 20% reduction in the CO2 emissions generated during the manufacturing process of the new products thanks to the use of 30% recycled plastic from end-of-life vehicles. The use of this recycled plastic in products for this industry and others will help reduce the carbon footprint by 85%.

4.10.2 AIMPLAS research: Thermoplastic composites for vehicle batteries

AIMPLAS research: thermoplastic composites for vehicle batteries could improve both energy efficiency and recycling rates [[74], [75]]. The VETERIA project, funded by the Valencian Regional Government and implemented by AIMPLAS, will develop new and efficient transformation processes for thermoplastic composites that can be used to replace the metal content of electric vehicle batteries [[76]].

These materials ensure a major reduction in vehicle weight, thus extending battery life. They are also easily recyclable.

The mobility and transport sectors are currently responsible for a quarter of all greenhouse gas (GHG) emissions. Strongly encouraged by legislation and market demand, this industry has now started to make the shift towards vehicle electrification, which is expected to contribute significantly to reducing GHG emissions but involves a number of challenges, including battery autonomy. In this context AIMPLAS, the Plastics Technology Centre, is developing the VETERIA21 project as part of a collaboration agreement with the Valencian Regional Government's Ministry of Innovation, Universities, Science and Digital Society. Together, they will provide funding through grants for technology centres in order to carry out innovation projects in 2021 in collaboration with companies within the framework of smart specialisation.

The aim of the project is to optimise the transformation processes of thermoplastic composites in order to improve their properties so they can replace metals in electric vehicle battery casings. This will reduce battery weight and, therefore, battery consumption, while providing a sustainable new solution based on circular economy criteria.

MAIN RESULTS: Currently made of stainless steel and aluminium, li-ion battery modules are big and heavy: they account for 20 to 30 % of vehicle weight. In general, 73 % of vehicle weight corresponds to the metal components. Thermoset composites are therefore a lightweight alternative for battery casings. However, their recyclability and production rate work against them. For this reason, thermoplastic composites represent a good alternative.

Thermoplastic composites have become a trend in vehicle weight reduction for several reasons other than their reduced weight: mechanical resistance, adaptability to different manufacturing processes, short manufacturing cycles, ability to be combined with other materials, weldability, easy recyclability and adaptability to the circular economy.

4.10.3 SMARTCOVER: Development of a plastic component for the automotive industry with integrated sensor function through smart fabric lining

Objectives [[77]]: Study and development of an innovative smart fabric for car buttons using fewer materials and parts, and a simplified manufacturing and assembly process, thus facilitating recycling at the vehicles' end of life.

SMARTCOVER project aimed to make part design simpler, thus generating ergonomic products and ensuring optimal comfort. The number of electrical components was also reduced, making product integration easier. The element was simplified functionally, eliminating unnecessary connections, improving maintenance and functionality, eliminating wear in moving parts and the subsequent noise caused by vibrations. At an environmental level, the fact that there are fewer parts also improves the recyclability of the final product. Moreover, the ensuing weight reduction directly decreases fuel consumption and the CO2 emissions produced by cars.

4.10.4 PEGASUS: Integrating engineering processing and materials technologies for the European automotive sector

Objectives of the PEGASUS Project [[78]] are to develop a new Integrated Design and Engineering Environment (IDEE) for SMEs supplying the automotive sector, to develop reliable and highly advanced materials that can be processed and to develop a new supply chain concept.

Description:

1) To develop an innovative "flexible process that can be configured on demand" to combine the latest plastic moulding technologies through the IDEE to each "component's" requirements in a single industrial process. It will incorporate standardised technical, environmental and economic parameters in the decision-making process.

2) To develop breakthrough materials to fulfil special functionalities: intrinsic colouring: making use of nanoparticles in colouring technology for plastic automotive components to avoid additional painting using organic stabilised dyes attached to nanoparticles. This will increase colour choice, reduce VOCs from painting down to 0% and still give a satisfactory finish, reducing production times by 30% (previously devoted to painting) and overall paint line space in the factory by 50%.

3) To disassemble on-command components by using adhesives filled with nanoparticles which will expand by the application of heat or microwaves, helping to de-bond the components for the **recycling process and reduce disassembly times by 25%**.

4.10.5 ECO-RUBBER: Innovative rubber sintering process for recycling used tyres to make eco-friendly street furniture

Objectives of the ECO-RUBBER Project [79] are to implement an eco-friendly tyre recycling and rubber sintering production system to place high-quality recycled-rubber street furniture on the market. ECO-RUBBER optimises the current rubber recycling process to obtain high quality street furniture. This has been done by adapting existing grinding technologies and implementing a new production process, known as High-Temperature High-Pressure Sintering (HTPS).

4.10.6 NONTOX: European project to recover contaminated plastics from automotive, construction and electrical appliance industry waste

Increasing plastic recycling rates is key to creating the circular economy of plastics promoted by the European Union, therefore is essential for research to continue developing new recycling processes, including procedures to recover plastic waste containing hazardous substances and then use it to produce safe, high-quality plastic products. The European NONTOX Project aims to eliminate hazardous and unpleasant substances from plastic waste and thus convert non-recyclable plastics and recycling waste into new resources [80].

The research developed by the different project partners will focus on the recovery of plastic materials from waste electrical and electronic equipment (WEEE), end-of-life vehicles (ELV), and construction and demolition waste (CDW), all of which contain hazardous additives and unpleasant compounds such as flame retardants, stabilizers and filling materials. Two different technologies will be used (Extruclean and CreaSolv®) to eliminate these hazardous substances from waste plastics such as ABS, EPS, PS, HIPS, PE and PP, which jointly account for about half of EU demand for plastics, hence the importance of recycling plastics rather than continuing the current practice of landfilling or incinerating a significant part of this waste.

The unique combination of mechanical and chemical recycling technologies imparts several techno-economic benefits over single conventional methods. The project focused on unique parts of the NONTOX value chain beginning right from gathering the reliable statistics to novel pretreatment steps and from challenging the recycling technologies with complex plastic waste to defining the innovative approaches to valorize the recycled plastics. Its approach is critically assessed not only from the techno-economic perspective but also from the strict environmental boundaries [81].

IMPACT

- Significant reduction in incineration of valuable plastic waste approximating over 5 Mt/yr
- Reduction of almost 1 Mt CO_2 eq/yr
- Job creations from increased recycling facilities.

- Efficient use of raw materials in EU by implementing Eco-design concept.

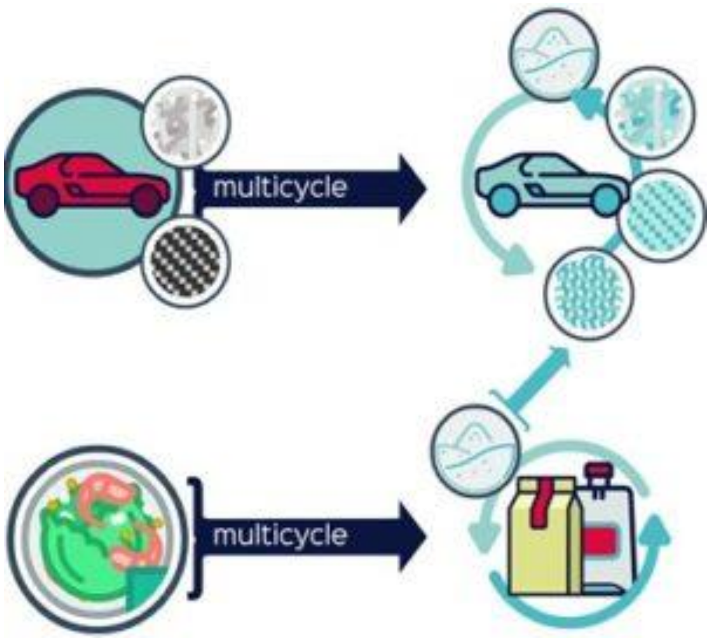
4.10.7 MultiCycle: New collaborative project to pilot selective recovery of pure plastics from multi-materials waste

The MultiCycle, a three-year EC Horizon 2020 Innovation Action project will deliver an industrial recycling pilot plant for thermoplastic-based multi-materials allowing selective recovery of pure plastics and fibres from mixed wastes without downgrading as a key enabling step towards the realization of a circular plastics economy [82].

Plastics deliver value through convenient, versatile and lightweight consumer products and advanced performance in high end applications but, as the environmental consequences of single-use, linear plastics consumption have hit our screens, public perceptions of plastics are currently at an all-time low. Less than a third of plastic packaging is currently recycled due to technological and economic limitations, and a mind-set that undervalues plastics as a single use commodity.

In its Plastics Strategy, the European Commission sets out a vision for “A smart, innovative and sustainable plastics industry, where design and production fully respect the needs of reuse, repair, and recycling, brings growth and jobs to Europe and helps cut EU’s greenhouse gas emissions and dependence on imported fossil fuels.” The vision refers to cost-effective recycling, an expanded European recycling capacity, and a more integrated plastics value chain where the chemicals industry works closely with plastics recyclers to identify wider and higher value applications for recycled materials [83].

MultiCycle will make a significant contribution towards realizing this EC’s vision, stopping resource depletion, landfilling and incineration of valuable resources and demonstrating the shift to a circular economic model in two important industrial segments – multilayer packaging /flexible films and fibre-reinforced thermoplastic composites in the automotive sector.



4-11. Figure_Demonstration of Recovered Materials

[Source: http://multicycle-project.eu/multicycle/files/2020/09/Brochure-MultiCycle.pdf]

The project is based upon the Fraunhofer IVV patented CreaSolv® Process, which will be taken to pilot scale and digitised for industrial readiness. CreaSolv® is a selective, solvent-based extraction process which allows recovery of pure plastics and fibres from mixed wastes without downgrading. Subsequent processing and formulation of recovered materials into valuable products will also be optimized, and the project will evaluate the environmental, social and economic sustainability and techno-economic-environmental feasibility of the proposed developments. As well as recommendations for future upscaling, MultiCycle will produce policy recommendations promoting waste management and resource efficiency improvements for the target packaging and automotive applications [84].

4.11 GENAN, Denmark: transforming tires into new products

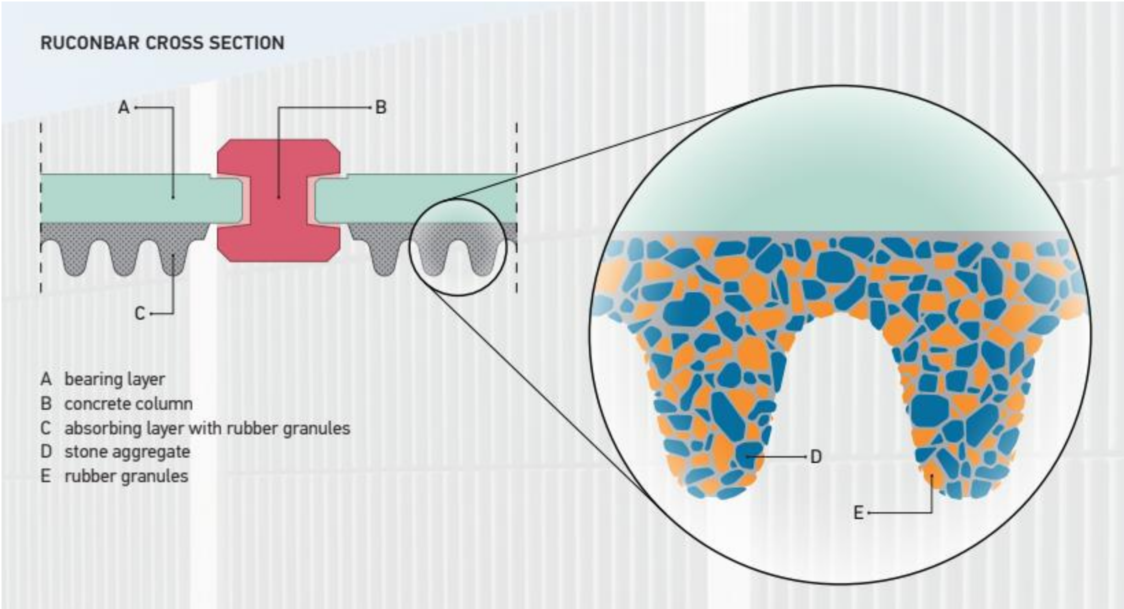
The Danish company Genan recycles 80% of all tires in Denmark. In 2003, Genan built the largest recycling unit in the world in Germany. The company has developed a product made of dust and rubber granules that can be used for the surfaces of athletics fields or as artificial grass on football fields. This product can also be used in paints, floors, retreading of new tires or as a noise reduction component in new asphalt. Recycling materials by the Genan method reduces CO2 emissions by 1-2 tons compared to other methods of disposing of used tires. Pioneering in a new market has allowed it to grow and become one of the largest recycling companies in the world for car tires in just a few years [85].

4.12 RUCONBAR, Croatia: Innovative mixture of recycled waste tyres and concrete

RUCONBAR noise barriers was developed as part of a project coordinated by the Faculty of Civil Engineering of the University of Zagreb, in partnership with Beton-Lucko LTD, Gumiimpex-GRP PLC and Institut IGH, and the Zoological Garden of Zagreb [86].

RUCONBAR is a highly absorptive, environmentally-friendly concrete noise barrier, an innovative mixture of **RECYCLED WASTE TYRES** and concrete which forms a porous, lightweight, sound absorbing panel. The project developed an easily transferable and highly replicable method for recycling waste tyres, designing an environmentally-friendly product which meets the standards required to be placed on the market.

RUCONBAR promotes noise mitigation and waste management. The absorbing layer is made of recycled waste tyres and concrete. In its nutshell, it is a concrete based solution composed of an absorbing and a bearing layer. By incorporating in its absorptive layer 40 % of rubber granules recycled from old automobile tyres, an innovative product has been created, which is a novel solution in the sphere of noise protection, absolutely unique on the market [87].



4-12. Figure_Ruconbar cross section

[Source: http://www.ruconbar.com/rcnb/wp-content/uploads/2014/06/RUCONBAR_brochure_A4_EN_web.pdf]

4-13. Figure_Ruconbar: Recycling end-of-life car tyres

[Source: http://www.ruconbar.com/rcnb/wp-content/uploads/2014/06/RUCONBAR_brochure_A4_EN_web.pdf]

MAIN RESULTS: Reduction of GHG emissions and consumption of non-renewable resources; Recycling waste tyres; 40% of the rubber granules used in absorptive layer are recycled from old tyres. Yearly, about 3.4 million tonnes of old tyres are disposed of in Europe. RUCONBAR provides an innovative solution for turning old tyres into a useful material (i.e. it will take 7800 end-of-life tyres to make 1 km of RUCONBAR wall).

4.13 WIPAG – Open loop and closed loop recycling

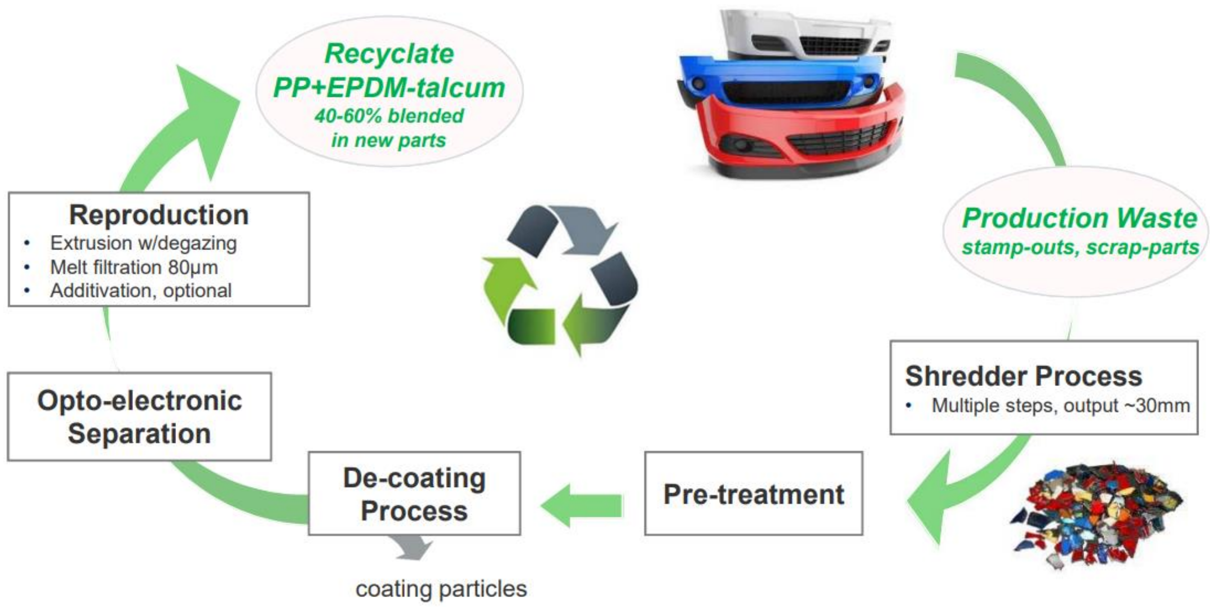
Automotive industry: plastic recyclates offering prime-like performances in new parts

WIPAG recycles post-industrial and post-consumer plastic waste from several industries with its main focus on automotive parts. Recycled parts comprise bumpers, dashboards, wheel-arch-liners, rocker-panel, front-ends, etc. [88]

Production residues such as stamp-outs and scrap parts (post-industrial) or parts from end-of-life vehicles (post-consumer) go through a complex recycling process including shredding, delamination, density separation and electrostatic separation [89].

WIPAG initiates material cycles: Using open-loop and closed-loop technologies, it produces a wide portfolio of recycled compounds of various grades and high-tech carbon fiber compounds for customers. This means that old plastics do not end up in landfills, but are returned to the value creation cycle. The use of new materials can be reduced – in some cases even completely replaced.

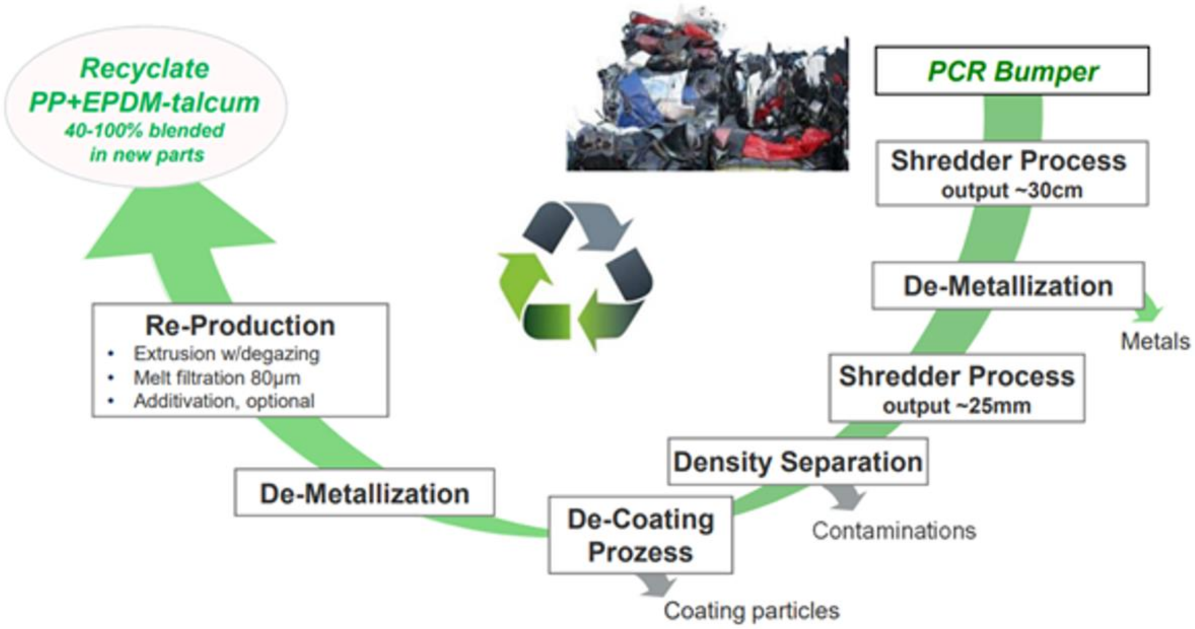
WIPAG – CLOSED LOOP RECYCLING VALUE CHAIN >> BUMPER TO BUMPER (PIR)



4-14. Figure_ WIPAG – Closed loop recycling value chain >> bumper to bumper (PIR)

[Source: https://circulareconomy.europa.eu/platform/sites/default/files/bsp_albis_wipag_open_loop_closed_loop_raas_10_19s.pdf]

WIPAG – CLOSED LOOP RECYCLING VALUE CHAIN >> BUMPER TO BUMPER (PCR)



4-15. Figure_ WIPAG – Closed loop recycling value chain >> bumper to bumper (PCR)
[Source: https://circulareconomy.europa.eu/platform/sites/default/files/bsp_albis_wipag_open_loop_closed_loop_raas_10_19s.pdf]

End products are Wipalen PP-GF compound or Wipelast PP-EPDM TV20 compound for the production of new automotive parts.

Wipalen can be included in new production up to 35%; from 40 to 100% of total amount.

While automotive plastic parts recycling proves efficient in terms of industrial results, the business considers stringent specification regimes at OEM/Tier1 level and sometimes cost pressure from low priced prime polymers, as a challenge for recycling momentum in automotive and other industries.

The benefits are obvious: lower raw material acquisition costs and more durable plastics that help reduce the CO2 balance and reduce the ecological footprint, while maintaining a high standard of quality.

5 GOOD PRACTICES IN ROMANIA

Romania is actively involved but still at the beginning in the transformation of the linear economy into a circular one, based on innovation, through which to ensure competitiveness with the other economies in Europe and to move to the sustainable development solution that takes into account the environment and resources in accordance with the ambitious action plan of the European Union on the circular economy.

Romania's economic growth is not decoupled from waste generation, and waste management lags significantly behind, as landfilling, and often illegal dumping, is still the dominant form of waste management. Performance in terms of circular economy indicators such as resource productivity, eco-innovation, waste generation per gross domestic product, waste treatment and the use of recycled materials in the economy is below the average of EU Member States. There is a low level of involvement of Romanian citizens in circular economy activities, such as using sharing schemes, repairing products, avoiding plastic materials and single-use packaging, or choosing products manufactured locally and/or with a label of environment.

A positive aspect is the fact that Romania has one of the lowest rates of waste per domestic consumption of materials among EU countries and has favourable prospects for improving the country's performance in terms of adopting circular economy practices.

The automotive industry is the second sector with CE potential in Romania, after electrical and electronic equipment (EEE), and followed by food and beverages, potential consisting of CE pillars: extension of useful lifetime and increase of the intensity of use through six KPIs (for example, distribution, sales, useful life, product life extension, repairability, and recycling) [[90]].

The automotive industry has become the most important industry of the country, many foreign investors have chosen Romania due to the relatively cheaper labor force, the high quality of human capital or the competitive tax system. Two car manufacturers, Dacia-Renault and Ford Otosan, operate in Romania, as well as over 500 original equipment manufacturers (OEMs) that supply components and assemblies both at local and global production sites [[91]]. The automotive industry in Romania represents over a quarter of the country's GDP According to the Association of Car Manufacturers in Romania (ACAROM), the automotive industry - the production of vehicles and components - generates approximately 12% of Romania's GDP, which was over 240 of billions of euros in 2021. A considerable number of used cars enter Romania every year, so that 45% of cars registered in Romania are older than 16 years.

In 2020, the age of the car fleet was 16.9 years in Romania in the passenger car category, while the EU average is 11.8 years. There are 2.43 million cars older than 20 years on the road, and they do so in an uncertain technical condition. That is, one third of the car fleet, given that cars under 10 years old do not even make up 20% of the total. In other words, half of the cars in traffic, almost 4 million, are between 10 and 20 years old. Over 50% of these have gasoline engines, 48% have diesel engines, while only 0.6% use electricity, liquefied petroleum gas or natural gas [[92]].

In Romania, cars that reach the end of their life cycle end up either in car dismantling centers or in the so-called ReMat recycling centers. In dismantling centers, priority is given to those parts that can be disassembled and sold as spare parts on the second-hand market. Vehicles dismantled through the national RABLA program usually end up in Remat centers where they are either crushed and exported as such, or shredded. After shredding, metals are separated from non-metals for recycling. However, usually only metals end up being recycled. Other materials such as plastics, textiles or glass, which are often mixed and not easily separated, generally end up in incinerators.

Romania has to deal with a considerable amount of complex waste resulting from scrapped (end-of-life) vehicles. The existing dismantling centers, although numerous, do not have the know-how and technology to recover as large a quantity of components and materials as possible, comparable to the state-of-the-art technology used in other countries such as Germany, Austria, France etc.

The National Circular Economy Strategy was recently approved (through GD no. 1172/2022) [93]. The overall objective of the NSCE is closely linked to the Sustainable Development Goals of the United Nations' 2030 Agenda. An overview of the relevant economic sectors from the point of view of their circularity potential is provided, establishing the general direction of acceleration of the transition from a linear to a circular economic model. The automotive industry is part of these priority areas. As mentioned in NSCE, Romania's vision is to create a stable path to prosperity for the entire society through economic growth that ensures a sustainable environment for future generations.

The Action Plan [94], which will present detailed specific objectives, policy recommendations and concrete actions to be followed, is being developed, to be adopted by the third quarter of 2023. Specific actions and measures for the automotive field included in the CE Action Plan refer to: training engineers in the field of circular economy principles, creation of environmentally friendly dismantling centers, training workers in the field of auto mechanics, implementation of the extended producer responsibility system for used oils and lubricants and removal of abandoned cars on the public domain by strengthening enforcement of relevant legislation, including fines and time limits.

Romania still has important steps to take in the direction of promoting the circular economy, namely a national model of good practice, which should actively contribute to the promotion of new sustainable business models [95]. Despite the difficulties, examples of industrial symbiosis models have begun to emerge in an attempt to identify viable waste management solutions and a more careful approach to competitive advantages is also needed at the national level from the perspective of the circular economy, namely the ability to recycle resources and generate new resources for other industries [96].

5.1.1 RABLA Program

The Car Park Renewal Program so called "Rabla" is a program through which the Romanian government aims to remove old vehicles from the roads. The object of the program is the non-refundable financing from the National Environment Fund, granted in the form of the scrapping premium, for the purchase of new, less polluting vehicles, in exchange for used vehicles given for scrapping.

The program aims to achieve the following environmental protection goals of general interest: reducing the effects of air pollution on the environment and the health of the population, caused by exhaust gas emissions from used vehicles; reducing the effects of soil and water pollution caused by the leakage of hazardous substances from used vehicles; preventing the generation of waste and achieving the objectives regarding the recovery and recovery of waste from end-of-life vehicles.

Two main programs currently operate—"Rabla Clasic" and "Rabla Plus"—which address both individuals and economic agents. Any person with domicile or residence in Romania who owns a car older than 8 years and who has no obligations to the local budget can participate in this program. Old vehicles must have essential parts (engine, wheels, car body, etc.) and be disposed to licensed ELVs operators to receive the vouchers [[97]]. Some comparative aspects regarding these two programs are presented in Table 5.1.

Table 5.1_RABLA Clasic vs RABLA Plus

RABLA CLASIC	RABLA PLUS
For combustion engine vehicles or hybrid without Plug-In	**For 100% electric vehicles, with a hydrogen fuel cell or Plug-in hybrids**
The RABLA CLASIC program is based on awarding a ticket worth 7,000 lei for an old scrapped car, or 10,000 lei for scrapping two used vehicles. The voucher can only be used for the **purchase of a new car with emissions of a maximum of 155g CO2/km** in the WLTP regime. A maximum of 2 RABLA tickets can be used for the purchase of a new car.	For those who opt for a **100% electric car, with a hydrogen fuel cell or plug-in hybrid**, the RABLA Plus Program offers **eco-tickets and old-time eco-bonuses**. Two used vehicles can be scrapped.
Calculation example - the maximum financed value: when purchasing a car with an LPG system that has CO2 emissions lower than or equal to 120g CO2/km (WTLP) by scrapping 2 (two) 15-year-old vehicles with the Euro 3 norm, **can benefit from a total discount of a maximum of 16,000 lei (approx. 3,200 Euros)**: 10,000 lei Rabla ticket (2 scrapped cars), 2 x 1,500 lei (2 cars over 15 years old and Euro 3), 1,500 lei (emission ecobonus), 1,500 lei ecobonus for a vehicle with an LPG system.	**Calculation example** - maximum financed value: when purchasing a 100% electric car and scrapping 2 (two) old cars, **the maximum total amount that can be benefited is 57,000 lei (approx. 11,400 Euro):** 54,000 lei eco-ticket + 2 x 1,500 old-time eco-bonuses.

The positive influence of this program is more significant from 2007 when **REUSE AND RECOVERY** target (85%) and **REUSE AND RECYCLING** (80%) were fulfilled at the national level for 2007–2011, while from 2010 the number of ELVs collected had a sharp increase compared to previous years. Rabla Plus stimulates the transition towards hybrid and electrical vehicles in Romania, but this trend must be strongly supported by the development of specific infrastructure (electrical charging points) across cities and main roads. From 2020, Rabla program vouchers for old vehicles can be used also to buy new motorcycles and through Rabla Plus program is stimulated the transition towards electrical motorcycles.

5.1.2 National IT system for waste traceability

The cross-border waste traceability IT system is a pilot project at the EU level that entered into force on July 1, 2022, Romania being a pioneer in this field [98].

It is developed by the Romanian Administration of the Environmental Fund, in collaboration with the National Environmental Guard from Romania, and involves the enrolment in this system of all companies that have recycling capacities, as well as the correlation of the recycling capacity with the amount of waste brought into the country from other states, regardless of whether they are from the European Union or outside the European Union, the announcement 24 hours before the appearance at the border of each transport, regardless of whether it is by road, sea or rail, reception within 48 hours of crossing the border of the quantity at the destination, mandatory, quantitative reception and approved by the Environmental Guard [99].

The Romanian authorities have limited to 19 the number of border crossing points for waste entering and at these points every shipment announced through the computer system is checked by the commissioners of the Environmental Guard and no unannounced shipment can enter the country. The system allows the monitoring and verification of the correctness of transactions with waste packaging, tires, electrical and electronic equipment, batteries and portable accumulators in the system of extended producer responsibility.

Traceability is essential for the safety and success of organizations and contributes to [100]:

STREAMLINING THE PROCESS THROUGH TECHNOLOGY: Traceability programs can provide visibility into the entire life cycle of each part and maximize the value of data to quickly identify production issues or trends and make proactive improvements.

SECURE GLOBAL LINKS: Today's supply chain is a highly complex worldwide network that requires synchronized strategic efforts to manage transactions and keep businesses efficient and profitable. To ensure transparency and accountability throughout the supply chain, traceability with direct part marking provides a documented trail of each product, its history, components, quality and safety. This emerging technology proves that products meet certain standards or comply with industry regulations. For example, some car manufacturers must meet traceability standards set by the Automotive Industry Action Group. The group's initiatives work to provide even greater visibility across the entire global supply chain.

EFFECTIVENESS AGAINST COUNTERFEIT GOODS: Another effect of the globalization of industry is the rise of counterfeit goods. As counterfeiters' profit from replicating products, companies lose money and their jobs are put at risk. Counterfeiting also affects consumers. Many counterfeit products do not meet the safety and quality standards of their genuine counterparts, putting end users at high risk. In this case, marking parts with serial numbers is not enough, as criminals can find ways to replicate those symbols.

NONCONFORMING PRODUCT RECALLS: Product recalls affect almost every industry. Full parts traceability is critical to protecting your company from recall liability, as it provides manufacturers with evidence to show that their parts comply with any safety standard. This may reduce the risk of certain products being withdrawn from the market.

Traceability has not always been used, but arose out of the need to manage and track waste as best as possible. In addition, it is carried out according to a legal framework, so that all companies that generate waste follow the rules and comply with the collection, transport, storage, recycling or disposal of the waste generated. The legislative rules regarding traceability are different according to each country, but within the EU, the member states must adhere to the European regulatory framework.

The key to a more sustainable world and the circular economy according to specialists is this complex and efficient chain, called traceability. In this type of economy, the problem of waste must be solved by returning it to the production processes through reporting and valorisation as elements of traceability.

5.1.3 Green number plates for zero-emission cars

On April 27, 2023, the Joint Order of the Minister of Internal Affairs, the Deputy Prime Minister, the Minister of Transport and the Minister of Environment, Water and Forests was approved, which regulates the granting of registration numbers with green letters and numbers, for purely electric or battery-operated cars of hydrogen combustion [[101]].

This includes hydrogen fuel cell vehicles (FCEVs) and battery electric vehicles (BEVs), but does not apply to hybrids.

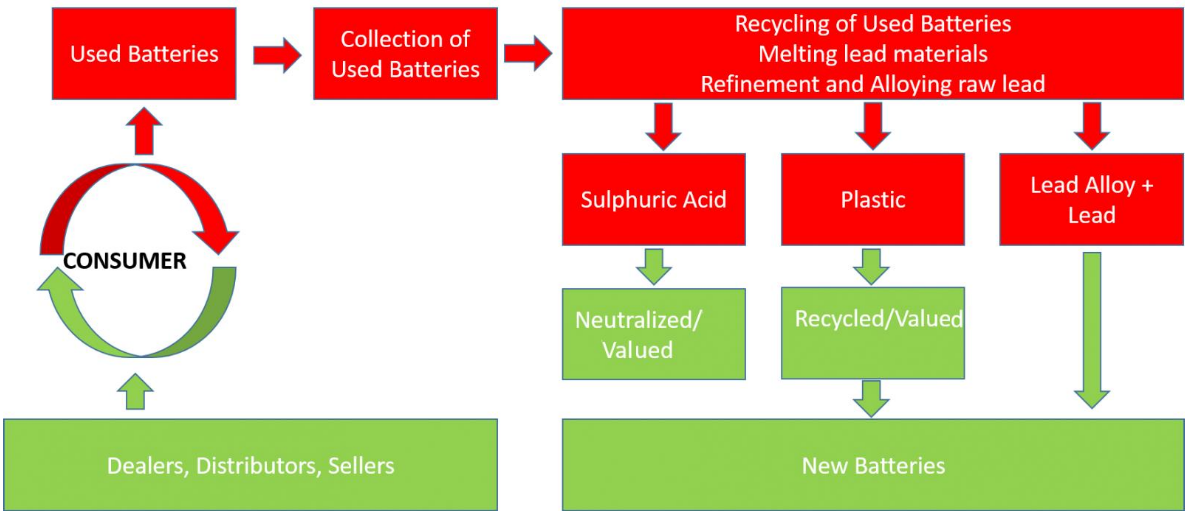
The purpose of this legislative amendment is to ensure the visibility of these categories of vehicles in road traffic, in order to stimulate the introduction of non-polluting transport vehicles on the market, to initiate a legal framework to facilitate their access to the recharging infrastructure with electricity, to establish policies of eco-sustainable transport, designed to cope with heavy traffic, as well as protecting the environment.

In order to make non-polluting vehicles more visible in traffic, the framework is provided to grant these vehicles certain facilities: free parking, access to low-emission areas, tax deductions, especially in large, extended urban areas.

5.1.4 ROMBAT - Recycling batteries to safeguard natural resources

Rombat SA is the largest producer of car batteries in Romania [[102]]. After four decades of activity, Rombat maintains its market leader position at the national level, having a network of over 100 service representatives in Romania. The company is a regional Renault supplier, sole supplier for Dacia since 1996, supplier for PSA Peugeot Slovakia since 2008, and since 2011 for Renault Nissan. Rombat is present both in European countries, such as France, Italy, Germany, Serbia, North Macedonia, Bulgaria, the Republic of Moldova, Greece, Hungary, Russia, Ukraine, Spain, as well as in Asia, Africa and North America [[103]].

Since 2005, the company has been collecting vehicle batteries to extract the lead they contain, recycle them and manufacture new batteries. The batteries are processed at the 3.7 ha Rebat facility in Copșa Mică [[104]]. Over 83% of the battery weight is reused in new processes (5-1. Figure). Rombat encourages owners of used automotive and industrial batteries in ebonite or polypropylene boxes to contact them for collection and cooperation. The company recycles part of the 30 000 tons of batteries that are placed on the market in Romania each year. They distribute batteries in more than 3000 stores across the country, as well as in France and Germany. The company aims to reduce its environmental impact by improving its batteries and enhancing battery recycling services to avoid using up more of Romania's natural resources.



5-1. Figure_ROMBAT Recycling Process of the batteries
[Source: https://www.rombat.ro/en/company/rebat/]

MAIN RESULTS: ROMBAT applies the operating principles of the circular economy, annually managing to recycle 24,000 tons of used batteries, 98 percent of this amount being reintroduced into the production cycle [[105]]. The company extracts around 12 000 tons of lead from old batteries each year, making it one of the leading car battery recyclers in Romania. Over 83% of a battery's weight is reused when it is recycled; lead, lead alloy and plastic are reused in new batteries; the company avoids both further depletion of Romania's natural resources and the pollution caused by discarded batteries; recycling batteries is cost efficient for consumers as the batteries are sold at a lower price.

5.1.5 Eltex Recycling - Integrated recycling group from south-eastern Europe

Eltex Recycling ensures the management of industrial waste and offers **INNOVATIVE IN-HOUSE RECYCLING SOLUTIONS**. Regardless of status, OEM – Original Equipment Manufacturer, or Tier 1 or Tier 2 supplier, smart solutions are needed to manage a varied mix of waste streams, including paints, oils, sludges and coolants, as well as general waste [106]. Eltex analyzes each type of waste, taking into account any space and logistics limitations, then implements the most efficient, ecological and cost-effective solution for each individual waste stream (see Table 5.1). The collection and disposal of all types of waste is ensured, identifying those that can generate cost reductions and that can be reused or recycled. It identifies, collects, separates and safely disposes of all types of automotive waste, including hazardous waste [107].

Table 5.2_ Eltex Recycling Waste management solutions for the automotive industry

PROBLEM	WASTE MANAGEMENT SOLUTION
Mixed packaging, a situation in which very large amounts of mixed packaging are generated, therefore non-recyclable, and high-value packaging is lost.	**Collection at source and compaction in proximity** by collecting waste from production lines.
Large quantities of packaging It is a challenge to accurately determine the quantities of packaging placed on the market in order to report to the AFM.	**Special service** dedicated to determining the precise amount of packaging + Eltex software solution for automated environmental reporting calculations**.**
Industrial Espionage/The Danger of Stealing Components for Industrial Espionage	**On-site destruction:** Controlled scrap destruction services, in the factory yard, through a high safety process that leads to almost total elimination of risks.

Also, the company has dedicated specialists who can provide advice on waste regulation and issues affecting the industry in general and supports educational programs dedicated to the workforce in this industry on the importance and methodology of correct waste separation.

Eltex has the ability to manage any waste generated in the production processes of the automotive industry, from paint to aerosols, oil-soaked rags, cardboard, plastic, etc.

5.1.6 TotalREC - Integrated innovative service, addressed especially to workshops and car dealerships

IndECO soluții pentru mediu

TotalREC is an innovative integrated service designed by Indeco [108], addressed especially to workshops and car dealerships, which includes the collection, transport, processing and **recovery in a proportion of over 95% of all waste resulting from the activity of a car service**. The novelty in this package is the ability to take over absolutely all types of generated waste and to orient them in a large proportion towards their recycling and valorization and less towards the classic processes of incineration or permanent storage.

To ensure this service, the INDECO Group has well-developed logistical and technical equipment and a continuously expanding territorial coverage, including:

USED OIL PROCESSING PLANT, furniture that deeply improves the quality of processed used oils, allowing their reintroduction into the industrial circuit or their use as raw material in the petroleum industry. It allows the treatment of a wide range of residual oils, starting from those with a high degree of wear, such as car oils or oils used in thermal treatments, and ending with those that are more easily affected after use, such as hydraulic oils.

PLASTIC WASTE RECYCLING LINE, with state-of-the-art equipment, which ensures the recycling of many categories of waste from the automotive industry that contain various types of plastic (PE, PET, PVC, PP). The processing results in high quality raw material that will be used in the production of an extensive line of plastic objects.

5.1.7 Hella Romania

Hella Romania SRL is part of HELLA Group, one of the top 40 automotive suppliers in the world and one of the 100 largest German industrial companies, that develops and produces electronic components and lighting systems for the automotive industry. HELLA has one of the largest service centers in Europe for spare parts and accessories for vehicles, diagnostic services and support services. It also produces complete modules for vehicles, climate systems and on-board networks. The strategy of the HELLA concern envisages, in the coming years, the development of projects in the electromobility sector by developing solutions and innovations in areas such as Autonomous Driving and Electric Management for the electric car. Hella Romania SRL has five design and development centers, an administrative center and three production units, located in Timișoara, Arad, Lugoj, Craiova, Iași and Oradea, with over 5000 employees [[109]].

Fields of activity: Specialized in the production of electronic control modules, actuators - engine compartment, vacuum pumps, accelerator pedals, power control modules. Competence of D&D centers: mechanical & hardware design, software, system test.

The implementation of the circular economy at Hella Romania is ensured by:

- Optimizing products, technologies and processes to increase performance in environmental protection.
- EcoDesign: Ensures that energy efficiency, recycling requirements and material restrictions are considered in the product development process.
- HELLA products support the electrification of engines and the reduction of CO_2 emissions at all stages. Intelligent battery sensors enable, for example, start-stop functions, while battery management systems ensure the safe and reliable operation of lithium-ion batteries for hybrid and electric vehicles.

- HELLA also contributes to environmental protection by maintaining high environmental standards in development and production, all HELLA production sites being certified according to the ISO 14001 environmental management system.

Hella is expanding the largest factory of the global automotive supplier in Romania, the one in Timișoara, with a new building, which will use sustainable energy solutions, and will be climate neutral by 2025 in the global network [[110]].

A picture of what the factory will mean: production and storage areas, utilities and offices. In total, 13,000 meters where components and electronic equipment for the car of the future will be produced.

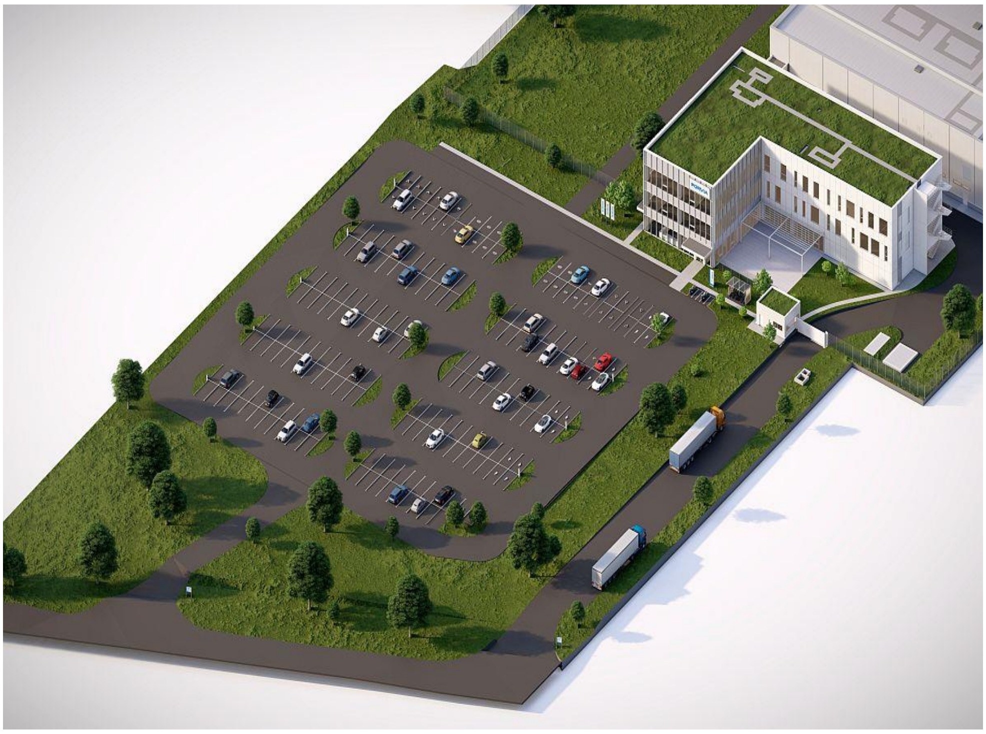


Figure 5-2_HELLA new building, which will be climate neutral by 2025
https://www.pressalert.ro/wp-content/uploads/2022/10/HELLA-PLx-new-factory-640x360.jpg]

A series of sustainable measures will be integrated into the unit, such as a geothermal system for heating and cooling, radiant panels in the office area and photovoltaic panels. In addition, in the office area, the building will have a "green" roof, with vegetation covering the entire area. In HELLA Ghiroda, dozens of types of parts and equipment are produced today, from actuators to complex battery management systems, as well as car computer, pedals or BMS (battery management system) components. The latter will also be produced in the new facility, an increase in volume for the existing factory, but also new products from the BCM (Body Control Module) category. These electronic solutions for cars support the main trends in the field: the electric car and autonomous driving. The components will be manufactured on automatic and semi-automatic pre-assembly and final product assembly lines, with five SMT lines.

5.1.8 Eco Anvelope

ECO ANVELOPE, the only company for managing the flow of used tires in Romania, appeared as a result of the involvement of tire manufacturers and importers in the protection of the environment and in the promotion of sustainable development, they took the decision in 2004 to found ECO ANVELOPE S.A. to respond in an organized and efficient manner to the environmental obligations arising from HG 170/2004 [111]. The founding members of ECO ANVELOPE: CONTINENTAL, GOODYEAR, PIRELLI, MICHELIN.

The company ECO ANVELOPE takes over the collection and recovery obligations of its customers, engaging in a permanent process of protecting the environment.

In the short term, the primary objective is to neutralize the environmental risk that used tires can pose.

In the long term, it acts in the sense of achieving a balanced and structured industrial economy, following three great principles:

EFFECTIVENESS IN ENVIRONMENTAL PROTECTION: Waste tires are completely removed from the environment through technological processes that allow their transformation into new finished products

ECONOMIC BALANCE: The processing of used tire waste paves the way for the development of new investments in the Romanian economy, thus widening the industrial spectrum and creating new jobs

PARTNERSHIP FOR COST OPTIMIZATION: A series of commercial companies are involved in the process of collection and recycling and/or thermo-energy recovery of tire waste, each with a well-defined role in this process. In this way, the costs related to the activities carried out by each commercial company are well calculated and controlled, and finally they are optimized so that each participant in this partnership reaches its proposed level of profitability.

5.1.9 Green Group/ GreenWEEE

Green WEEE is one of the leading Southeastern and Central European players, focused on collection, treatment and recycling of WEEE, cables, batteries, and **AUTOMOTIVE COMPONENTS**. It is the first factory in Europe to receive certification in the pilot audit of the WEEELABEX test, in 2012, having today certificates for 4 treatment streams [112].

The Green WEEE activity is based on three principles of the circular economy:

- ☑ Combating waste and environmental pollution
- ☑ Keeping products and materials in use
- ☑ Reduction of CO_2 emissions.

It is both a recycler and a producer, which contributes to the implementation of the circular economy. As a recycler, it takes waste and transforms it into secondary raw material, and as a manufacturer, it gives waste a new life. Also, after a product's life cycle, it is returned as waste.

"CIRCULAR INNOVATIONS" DIVISION OF GREENGROUP

July 20, 2022, Bucharest - GreenGroup, the leader of the circular economy in Central Europe, acquires SIGAD, a Romanian environmental reporting software developer and launch the "Circular Innovations" division of GreenGroup, which will invest in start-up or scale-up companies with an important contribution to the development of the circular economy in Europe [[113]].

SIGAD is one of the most important Romanian developers of ERP systems that meet the needs of companies to achieve efficient management of resources and improvement of environmental performance, through a simple and fast solution. The company will benefit from both financial support and the Group's over 20 years of expertise in recycling and capitalizing on waste resources. In addition, synergies with all GreenGroup divisions, networking and good relationship with key industry stakeholders will help accelerate growth. SIGAD will be integrated into the consolidated operations of GreenGroup and is expected to become one of the largest providers of environmental software solutions, non-financial reporting, ESG reporting for large companies and SMEs, in Romania and the Central European region. SIGAD.

The energy and raw material supply crisis, as well as global warming, represent the context that today directs the growth of the economy and underpins the principles of the development of companies on a sustainable basis. It is a favorable time for start-ups, through the opportunities for innovation and flexibility that characterize them and that give them a privileged position in the circular economy.

The integration of start-ups into the GreenGroup ecosystem represents a strategic element in strengthening its position as an integrated player in the circular economy.

5.1.10 The Romanian Circular Economy Stakeholder Platform (ROCESP)

The Romanian Circular Economy Stakeholder Platform (ROCESP) was launched at national level by the Ernest Lupan Institute for Research in Circular Economy and Environment (IRCEM) [[114]]. ROCESP members include local and central government institutions, academic, research and innovation institutions, businesses and civil society representatives. The platform aims to promote and reinforce circular economy measures at national level and to facilitate cross-sectoral dialogue in Romania. It acts through 11 working groups, including Education and training for the circular economy, Mobility and transport.

5.1.11 Circular Economy Coalition (CERC)

Circular Economy Coalition (CERC) [[115]] offers Romania a circular economy platform and promotes the key objectives of the EC Circular Economy Action Plan in Romania, stimulating the development of new markets, business models, and contributing to economic growth and jobs creation. It facilitates activities for its members, becoming a key player for the domestic business community interested in transitioning towards a circular economic ecosystem. CERC monitors national and EU policies, and is actively communicating with Romanian authorities to improve the legislative framework on circular economy. It is open to establishing strategic partnerships with similar local and international organisations and academia. The scope is to develop studies and reports on circularity and to support the implementation of circular economy programmes.

6 CONCLUSIONS

The rising popularity of so-called "circular economy" (CE) models has developed in response to this context of environmental degradation. Definitions regarding the circular economy are focused around key concepts such as: sustainable development, the framework of the 4Rs (Reduce, Reuse, Recycle, Recover), the systemic approach (micro, meso, macro), the waste hierarchy.

By driving circular principles throughout the value chain, automotive players can amplify benefits when it comes to efficiency, revenue and customer loyalty.

A basic component of sustainable development, the circular economy involves, also in automotive industry, several concepts such as sharing, renting, reusing, repairing, reconditioning and recycling materials and products. This approach has the effect of extending the life cycle of products and optimizing the consumption of raw materials and energy, such as minimizing the amount of waste generated, reducing the carbon footprint and a more environmentally friendly approach.

The circular economy aims to decouple economic growth from resource consumption by emphasizing resource efficiency, waste reduction, and the reuse and recycling of materials. To facilitate this transition, the European Union (EU) has implemented a comprehensive array of regulations and directives.

European regulations on the circular economy encompass several overarching objectives. Firstly, they strive to stimulate sustainable economic growth by promoting resource efficiency and waste reduction. By embracing a circular economy, Europe aims to enhance its competitiveness, foster job creation, and minimize its environmental footprint. Secondly, these regulations aim to encourage innovation and the development of sustainable business models. The EU recognizes the potential for industries to innovate and capitalize on the increasing demand for sustainable products and services within the circular economy framework. Lastly, European regulations on the circular economy target the sustainable use of resources, reduction of greenhouse gas emissions, and mitigation of the environmental impacts associated with resource extraction, production, and waste disposal. By optimizing material usage throughout their lifecycle, these regulations aim to minimize Europe's ecological footprint.

In order to incorporate the circular economy in their business strategies, companies in the automotive industry have different visions, as follows:

- Designing sustainable vehicles from recycled and recoverable materials is at the core of Renault Group. Its activity is also based on reconditioning spare parts, re-using batteries from electric-vehicle, or providing ever cleaner and more sustainable car-sharing services.
- The Volkswagen Group created concepts for the reconditioning and recycling of vehicle components early on. One important driver of the circular economy is the

ongoing decarbonization of the Volkswagen Group. The growing use of secondary materials and the establishment of closed loops of materials help to significantly reduce the CO_2 emissions. Fundamentally, VW pursue four lines of action at Group level in the area of circular economy: First, efforts are already intensifying to use recyclable and reusable materials in vehicle designs – for example, from production waste; VW wants to further improve the supply of circular materials, i.e., secondary materials and renewable raw materials – for example by buying back end-of-life vehicles – and thus bring valuable materials back into the loop; another approach is to preserve recyclable materials through reuse and repurposing – for example, in the recycling of high-voltage vehicle batteries in Salzgitter; VW are also working intensively on developing business models that simplify the recovery of raw materials from their products.

- Skoda perceives the circular economy based on the following concepts: minimizing negative impacts on the environment, input resources and the loss of these resources, and conversely maximizing the circulation of resources.
- With the "MaterialLoop" project, Audi closes several material cycles in the automotive industry. Together with 15 partners from the research, recycling and supplier sectors, AUDI looks at the reuse of so-called post-consumer materials, which are taken from customers' vehicles at the end of their life cycle, from the automotive industry and uses them for the production of new cars, as part of Audi's circular economy strategy.
- Ford has set an target of using 20% recycled and renewable plastics in new vehicle designs by 2025 at its factories in North America and Europe and a 10% target for its factories in China and Turkey. Ford also uses a closed-loop system to manufacture its F-series trucks and is the largest closed-loop aluminium recycling automaker in the world, according to its 2022 sustainability reports. In the Integrated Sustainability and Financial Report, 2023 FORD sets also the ambitious sustainability aspirations, as follows: achieve carbon neutrality no later than 2050, use 100 percent carbon-free electricity in all manufacturing by 2035, use only recycled or renewable content in vehicle plastics, attain zero emissions from our vehicles and facilities, make zero water withdrawals for manufacturing processes and use freshwater only for human consumption, reach true zero waste to landfill across our operations, eliminate single-use plastics from their operations by 2030.
- The BMW vision of the circular economy is established on protecting and preserving the environment, reusing valuable resources several times, and ensuring that nothing ends up going to waste.
- Continental is constantly optimizing tires in the direction of increased sustainability. Proposed objective by 2050 at the latest: tires made entirely from sustainable materials.

The European automotive industry pays increased attention to compliance with national and European environmental policies. To this end, sustained efforts have been made to reduce the amount of greenhouse gas emissions by creating engines with low fuel consumption, in parallel with increasing the technical performance of new vehicles and by developing electric vehicles. These technological developments have been made possible thanks to the considerable investments in research-development-innovation made by the major European companies in the automotive sector.

The automotive industry has certainly been part of the problem of pollution and resource depletion, but today it can also be part of the solution, considering that: the vast majority of companies in the automotive industry consider the circular economy to be an important topic and apply the principles of the circular economy; all major car manufacturers have ecological car models in their portfolio, made from recyclable materials; the crisis in petrol and diesel prices will make people more interested in purchasing electric cars.

ROMANIA is actively involved but still at the beginning in the transformation of the linear economy into a circular one. Given the need to decarbonize the economy, to conserve and use resources as efficiently as possible to minimize the impact of production and consumption activities on the environment, it is necessary for this trend to adopt circular economy practices to accelerate. These practices must also be extended to smaller companies (SMEs), obviously also supported by comprehensive and effective policies adopted by state institutions and by appropriate financing and implementation support mechanisms.

Romania’s automotive industry has good potential in the CE pillars: extension of useful lifetime and increase of the intensity of use through six KPIs (for example, distribution, sales, useful life, product life extension, repairability, and recycling).

For the successful transition from the linear economy to the circular economy, it is necessary to move from the waste management policy to the resource management policy, respecting in practice the hierarchy of solutions for circularity (extending the life of products through reinvention/repurposing, the second-hand market, repair, reuse of components and, only as a last step, recycling).

Also, to stimulate the development of this model, it is necessary to increase "green" skills. Currently, in Romania there are universities, national R-D institutes, research stations and competitiveness clusters / poles with a profile for applications in the circular economy.

Synergies are needed between all relevant parties, namely authorities, social partners, economic and academic environment, to ensure the full circularity of the automotive industry in Romania.

The Good Practices Guide in the automotive industry, complemented by the other intellectual results of the DRIVEN Project, is a useful tool to create synergies between all relevant parties – economic and academic environment, authorities and social partners, to develop an ecosystem for the circular economy, products with a long lifespan, waste to become raw material for other products, and environmental pollution to be reduced.

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