DRIVEN
EDU-ECO INNOVATION

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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
PSA Peugeot S.A.
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
VW Volkswagen
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].

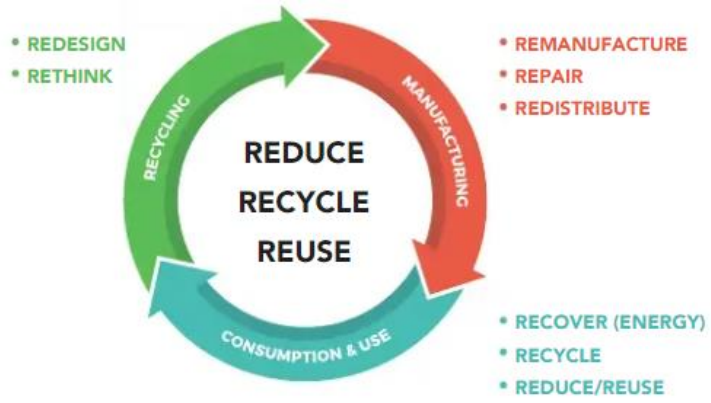
CE is characterized by three key principles:

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.

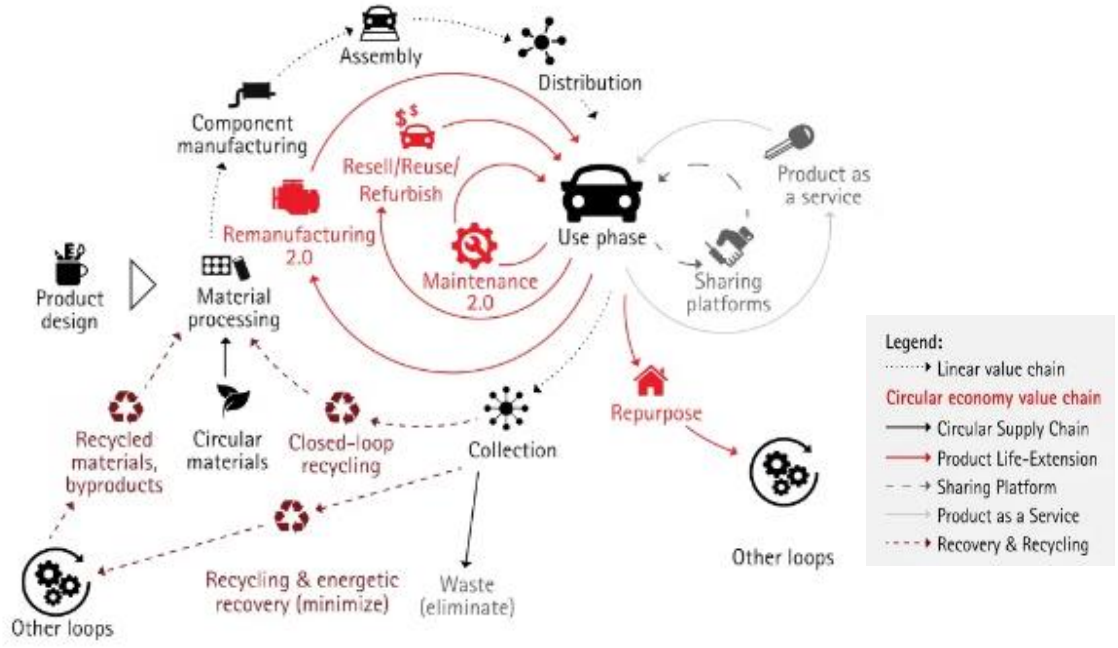
A holistic approach to CE can be broken down into several levels and can be illustrated withdifferent “R” concepts. This “multi-R” approach helps outline the CE structure, as illustrated in 1-1. Figure.



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.

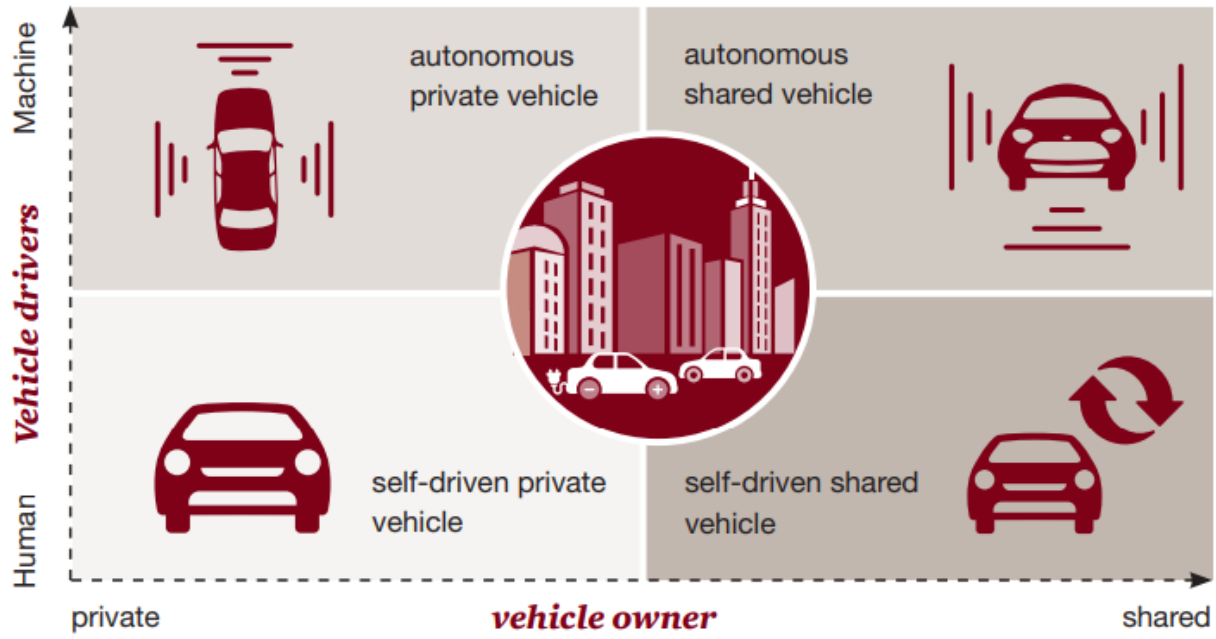
Besides industry-led initiatives, automobile manufacturers also have to adhere to a wide range of existing legislation promoting sustainable production, more efficient vehicles and their proper dismantling. The End-of-Life Vehicles Directive, for example, already sets a

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 below.



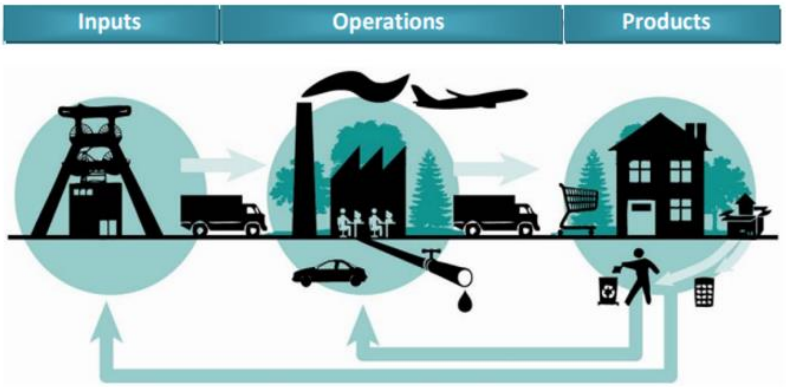
3-1. Figure_ Manifestation of the mobility of the future [https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf]

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 below 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].

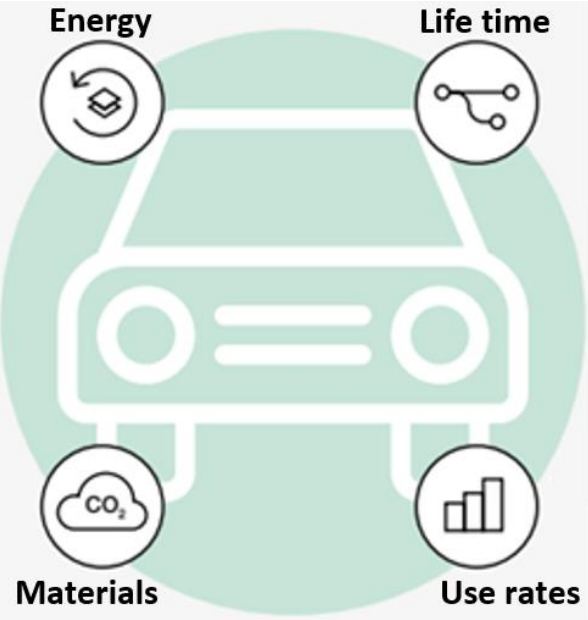
Original equipment manufacturers are heavily investing in electrification, closing material loops, and developing new service offerings and mobility solutions. investors and regulators are pushing to go further.

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].

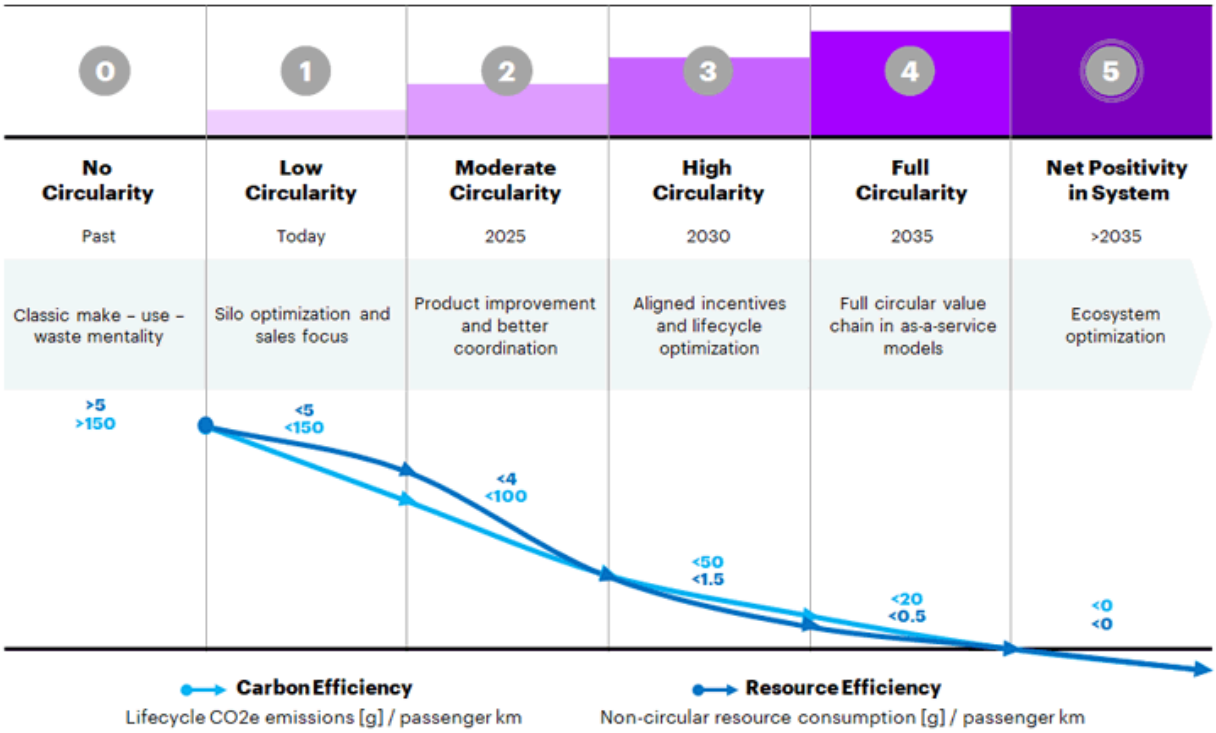
The definition focuses on the relevant variables [122]: energy, materials, lifetime, and use (3-3. Figure). **ENERGY** is used efficiently (per km of movement) and renewable; **LIFETIME** of the vehicle and components is optimized for resource efficiency (by emphasizing efficient design, modularity, 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

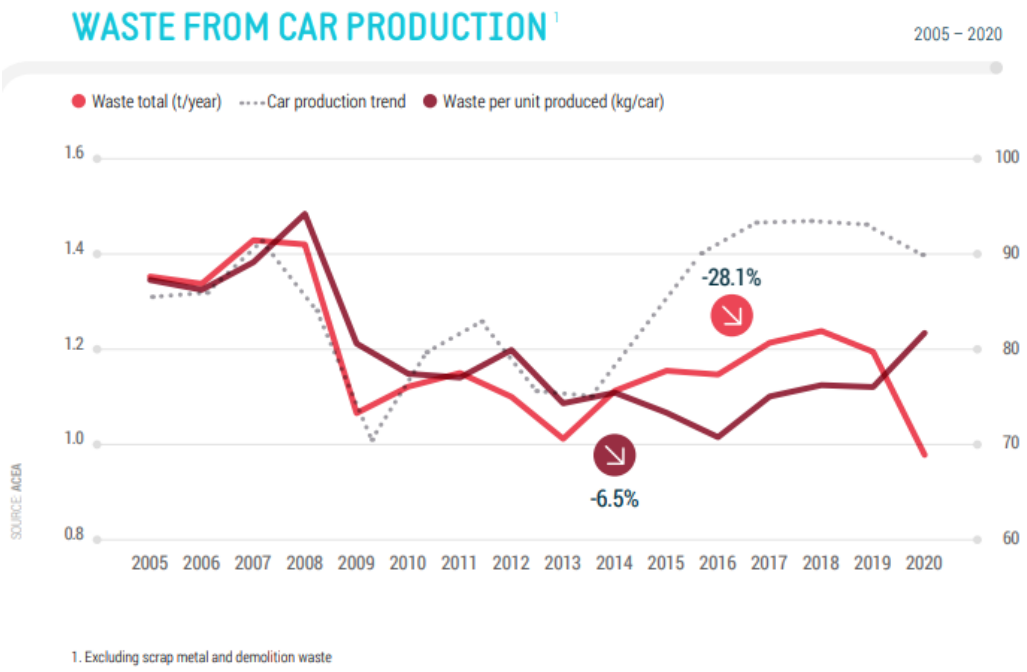
[Source: WEF & Accenture, Raising Ambitions: A new roadmap for the automotive circular economy, 2020]

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].

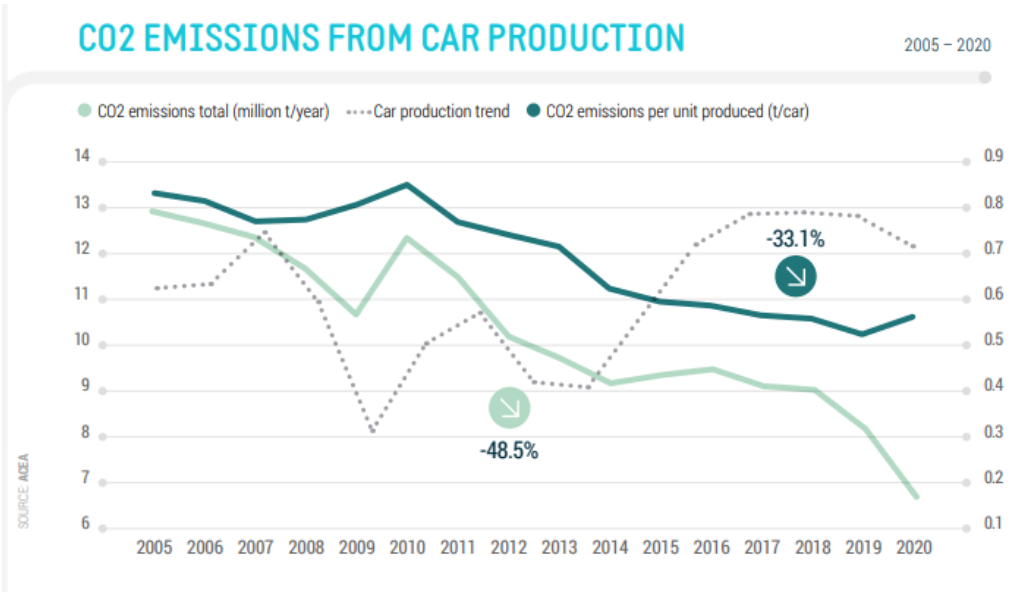
Regarding the localisation of the automotive industry, it is still the case that most production sites are located in the home countries, i.e. the countries where the car manufacturers are based. VW Group has 11 of its 24 factories in Germany, BMW has 4 of its 8 plants in the same country, PSA 5 of 14 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]

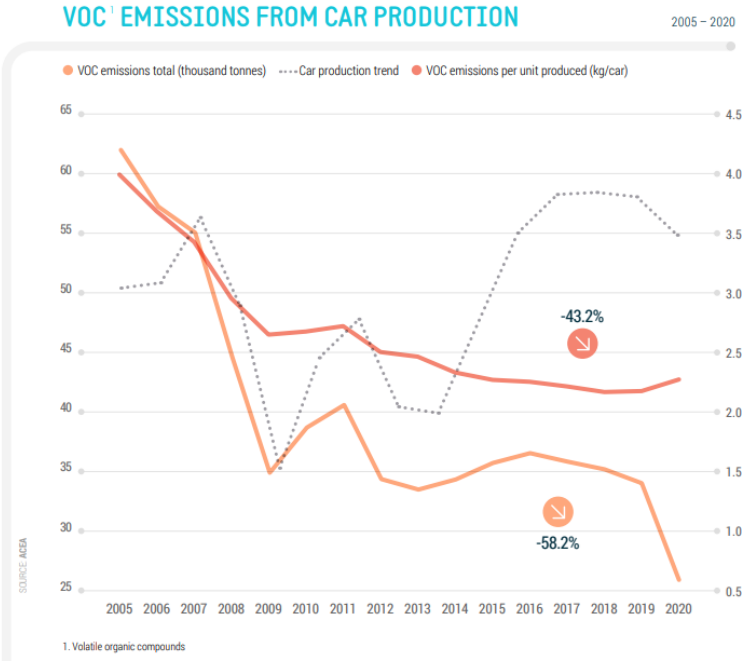
CO_2 emissions from car production have dropped by 48.5% since 2005



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.

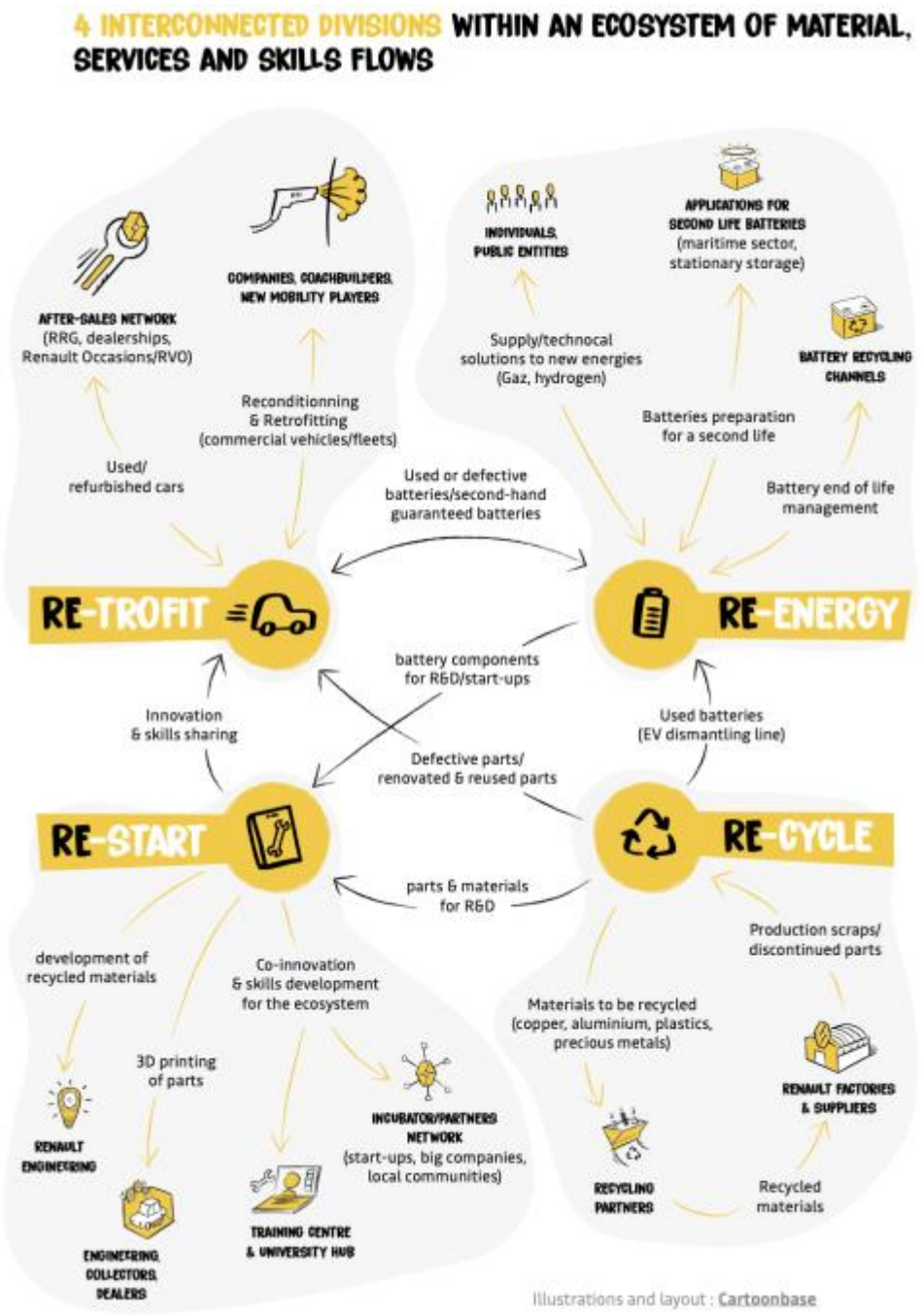
By studying and drawing inspiration from these international good practices, countries and organizations can learn from successful strategies and make progress towards a more sustainable and resource-efficient future.

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.

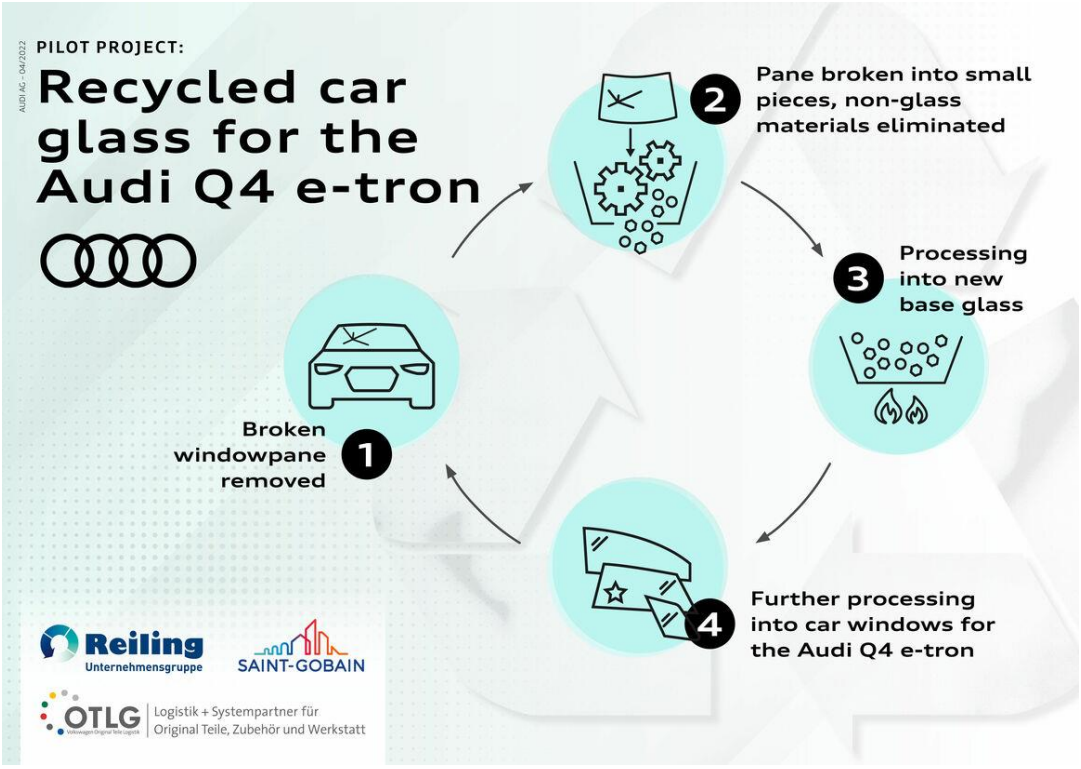
A recent example is the use of PET plastic in the production of the Audi A3 model. PET is a plastic polymer that can be separated from the materials with which it was combined, being therefore easier to recycle.

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.

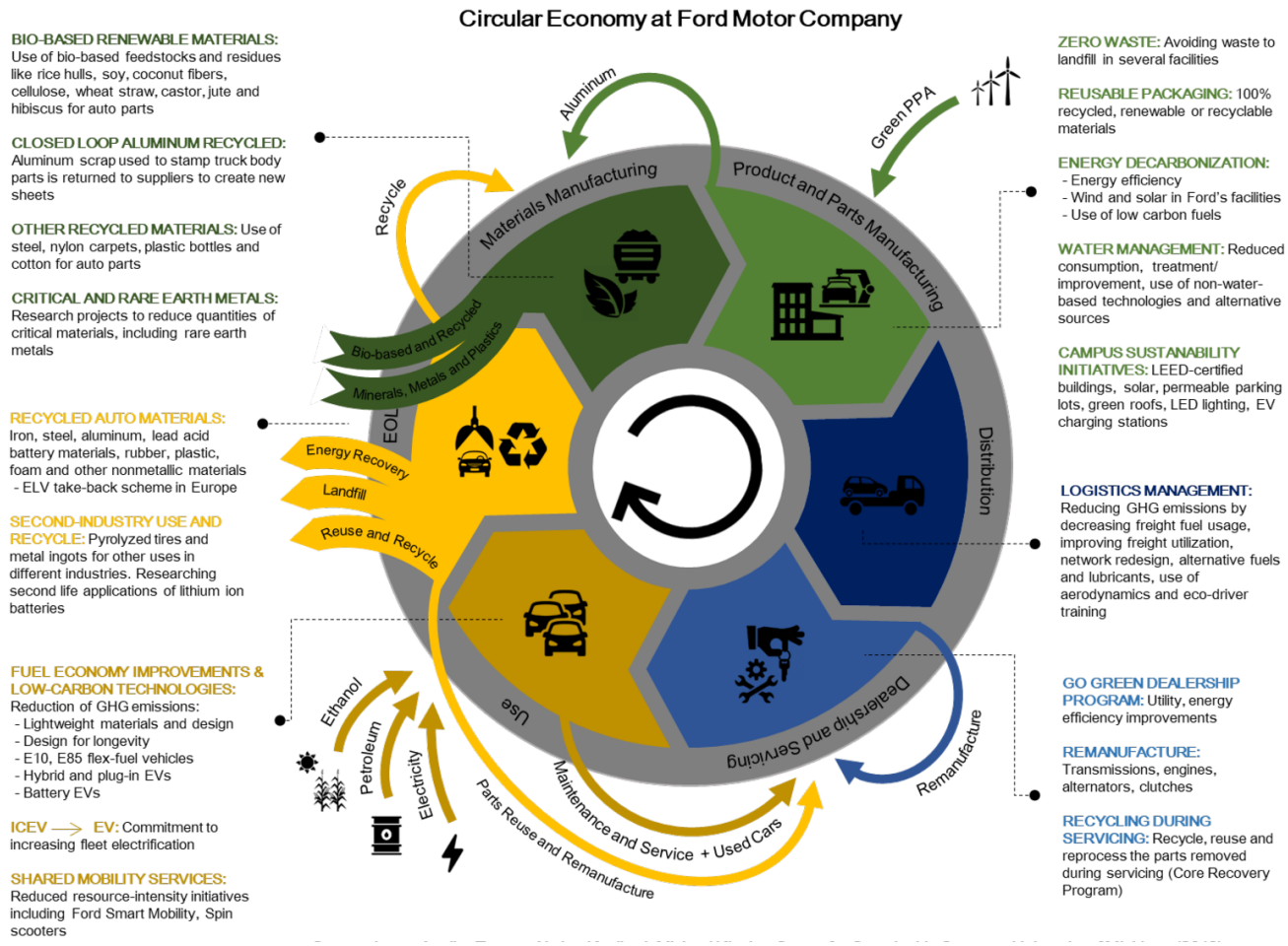
Ford currently recycles up to 20 million pounds of aluminium each month at Dearborn Stamping, Kentucky Truck and Buffalo Stamping facilities. This represents 20-30% of Ford aluminium sheet coil purchases. Making recycled aluminium only takes around 5% of the energy needed to make new aluminium, according 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 CO2 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.



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 [59].

☑ **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 [60].

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 [61].

BMW Group consistently follow the guiding principle of the circular economy: RE:THINK, RE:DUCE, RE:USE and RE:CYCLE [62].

☑ **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. [63].

☑ **RE:CYCLE**

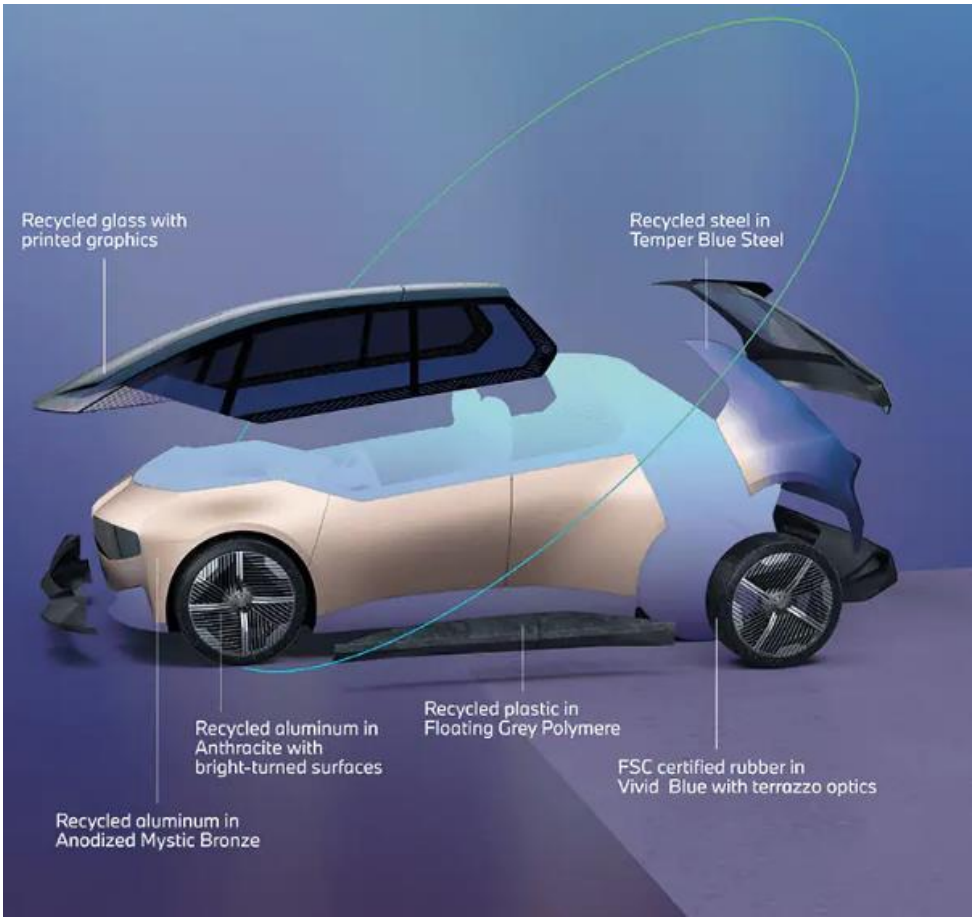
All vehicles launched since 2008 meet global legal requirements for recycling end-of-life vehicles, components and materials. Even today, 95 per cent of vehicles registered in the European Union must be recyclable. BMW Group vehicles are currently made from up to 30 per cent recycled and reused materials. 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** [64].

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 [65].

☑ **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**

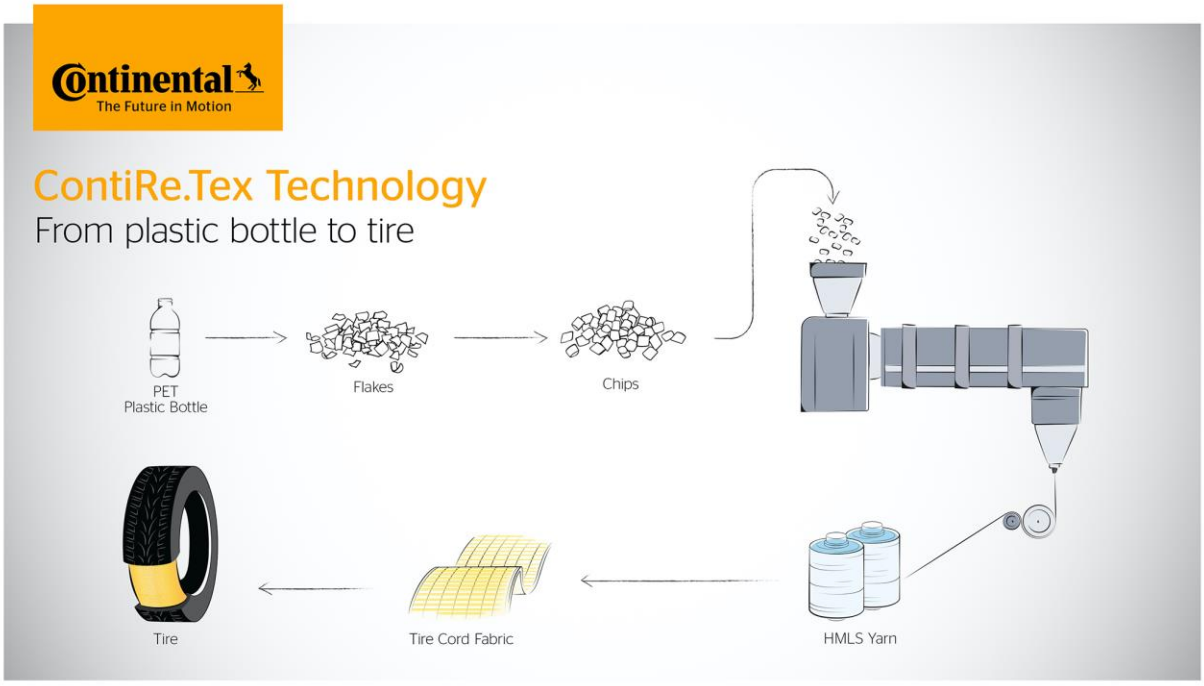
In addition to pyrolysis, Continental also uses the mechanical processing of end-of-life tires. Rubber, steel and textile cables in particular are separated from each other in a highly sophisticated process. The rubber is then prepared to be reused as part of new rubber compounds.

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 [66]. 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 [67].

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.

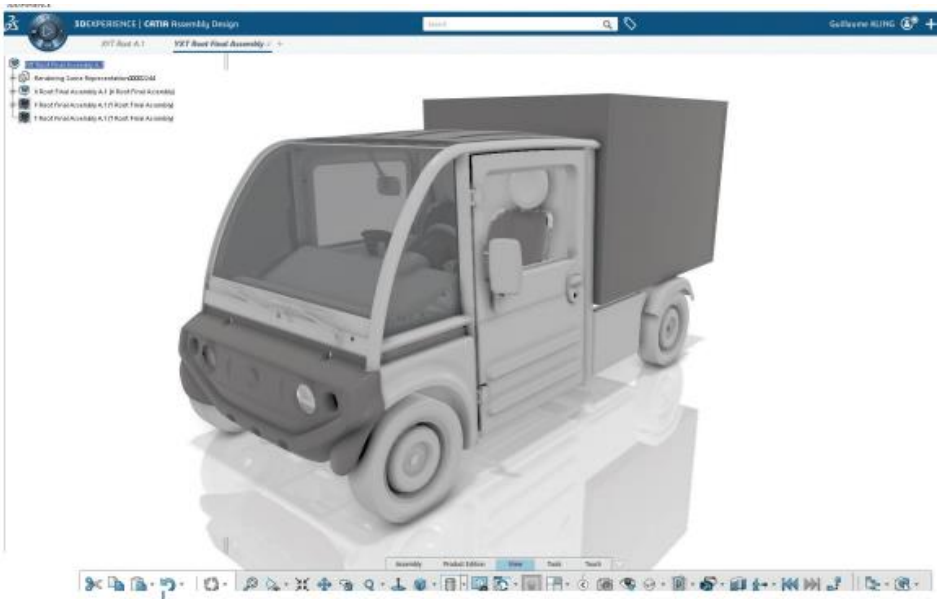
Resins from this production process were further formulated and then supplied to Yanfeng. The parts molded by Yanfeng for demonstration were successfully tested to meet a variety of OEM – Ford, GM, and Stellantis – requirements, thereby demonstrating proof of concept for a truly circular solution.

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 [68].

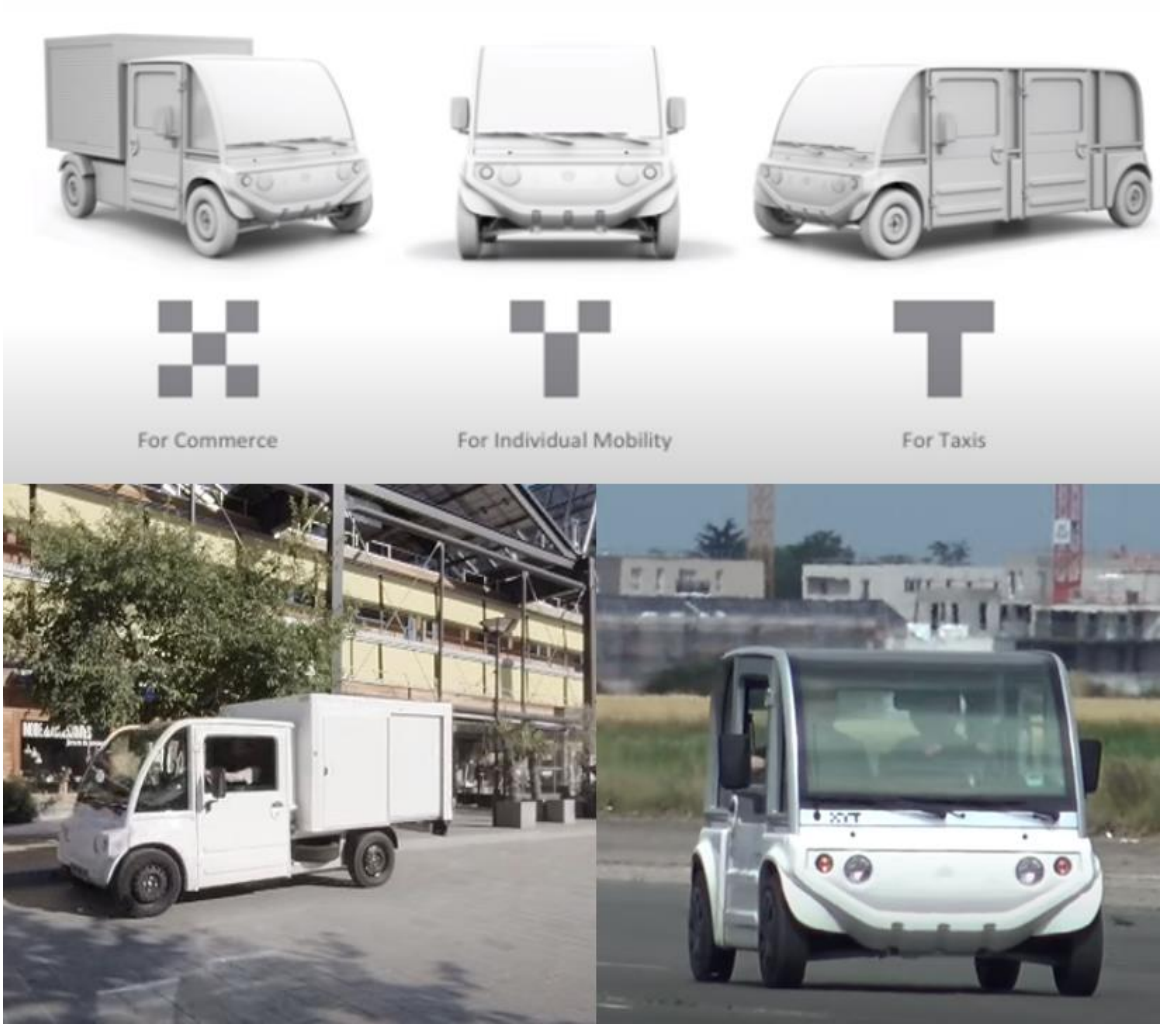
Through the 3DEXPERIENCE Lab program, a Dassault Systèmes' start-up accelerator [69], XYT uses the platform on the cloud with great benefits, as follows: simplify and optimize exchanges throughout the value chain in a collaborative environment; reduce the complexity of design, production and certification; 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 [70, 71].

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 [72].

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% [73 ,74]. 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 [75, 76]. 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 [77].

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 [78]: 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 [79] 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 [80] 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 [81].

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 [82].

IMPACT

- ☑ Significant reduction in incineration of valuable plastic waste approximating over 5 Mt/yr
- ☑ Reduction of almost 1 Mt CO2 eq/yr
- ☑ Job creations from increased recycling facilities.
- ☑ Efficient use of raw materials in EU by implementing Eco-design concept.

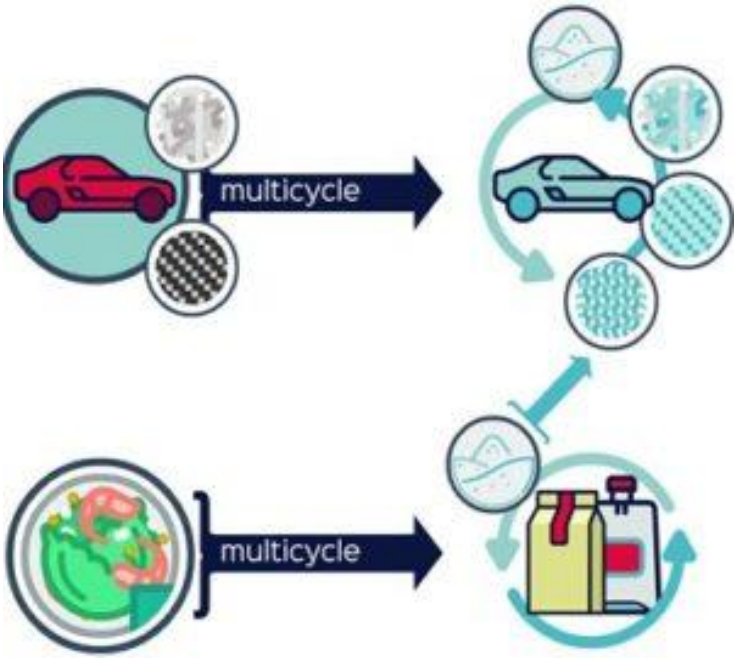
4.10.7 MultiCycle: New collaborative project to pilot selective recovery of pure plastics from multi-materials waste

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 [83].

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 [84].

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 [85].

4.11 GENAN, Denmark: transforming tires into new products

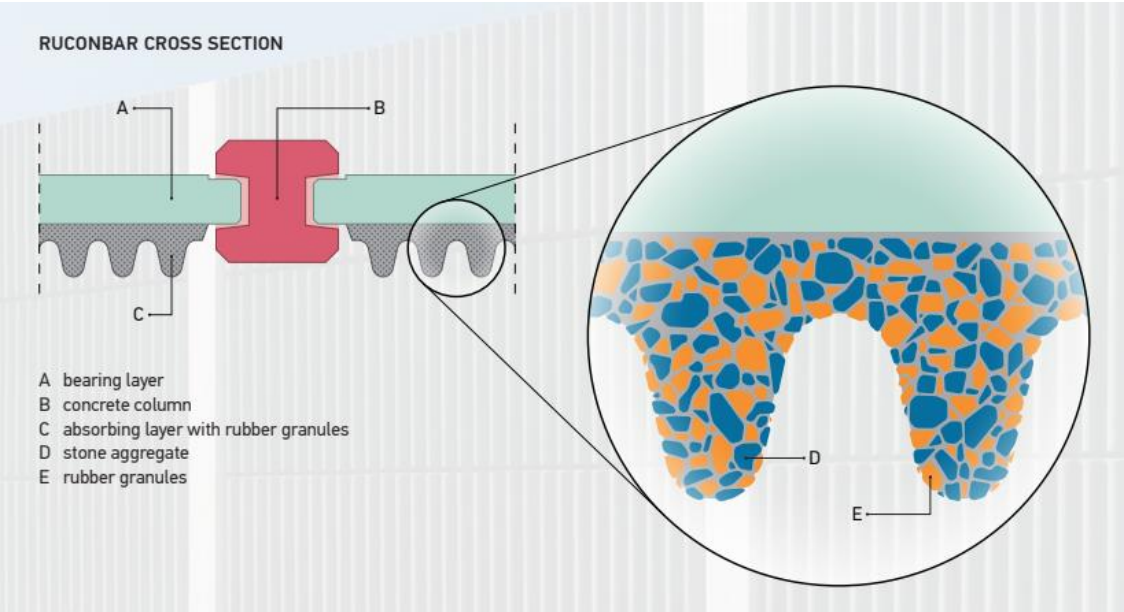
The Danish company Genan recycles 80% of all tires in Denmark. In 2003, Genan built the largest recycling unit in the world in Germany. The company has developed a product made of dust and rubber granules that can be used for the surfaces of athletics fields or as artificial grass on football fields. 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 [86].

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 [87].

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 [88].



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

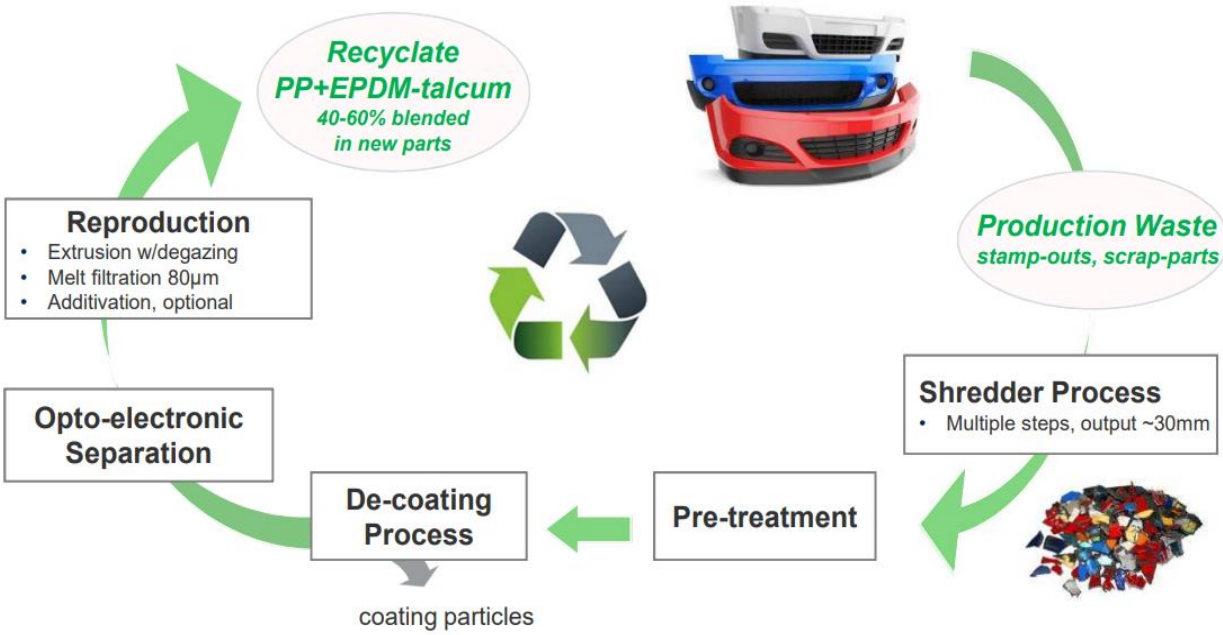
Automotive industry: plastic recyclates offering prime-like performances in new parts.

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. [89]

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 [90].

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.

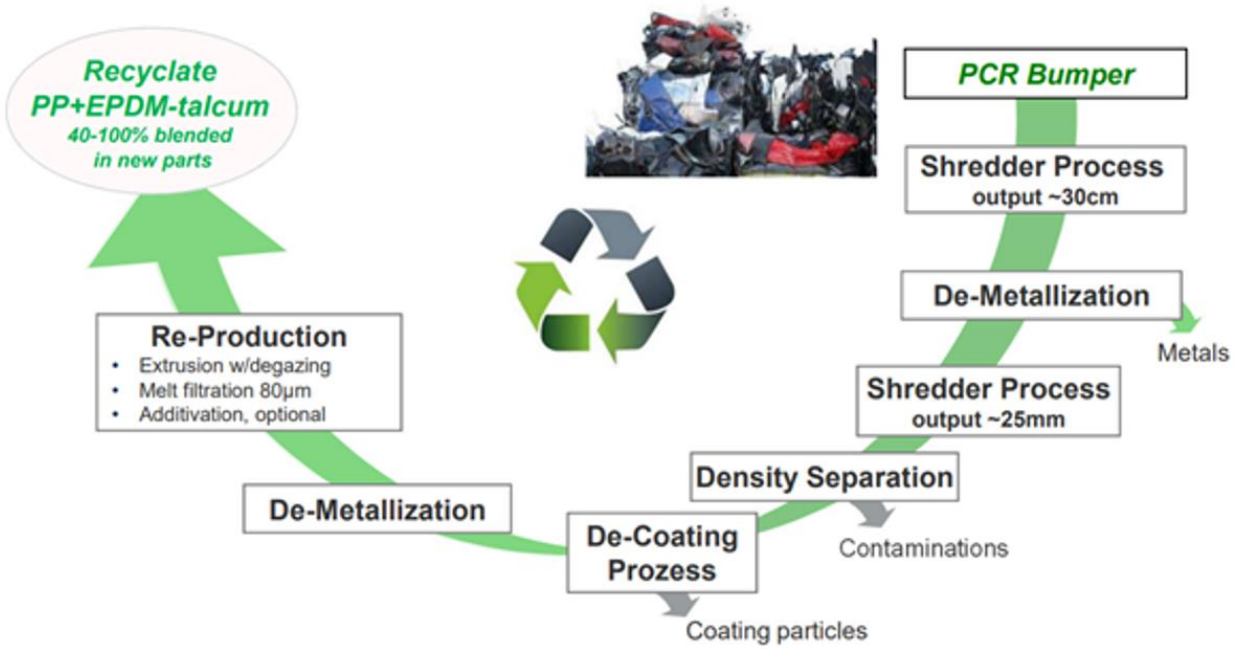
WIPAG – CLOSED LOOP RECYCLING VALUE CHAIN >> BUMPER TO BUMPER (PIR)



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% and 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.

BENEFITS: 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 THE COUNTRIES PARTICIPATING IN DRIVEN PROJECT

5.1 CIRCULAR ECONOMY 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) [91].

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 [92]. 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 [93].

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) [94]. 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 [95], 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 [96]. 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 [97].

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 [98]. 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**	**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

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.	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 [99].

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 [100].

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 [101]:

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 [102].

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

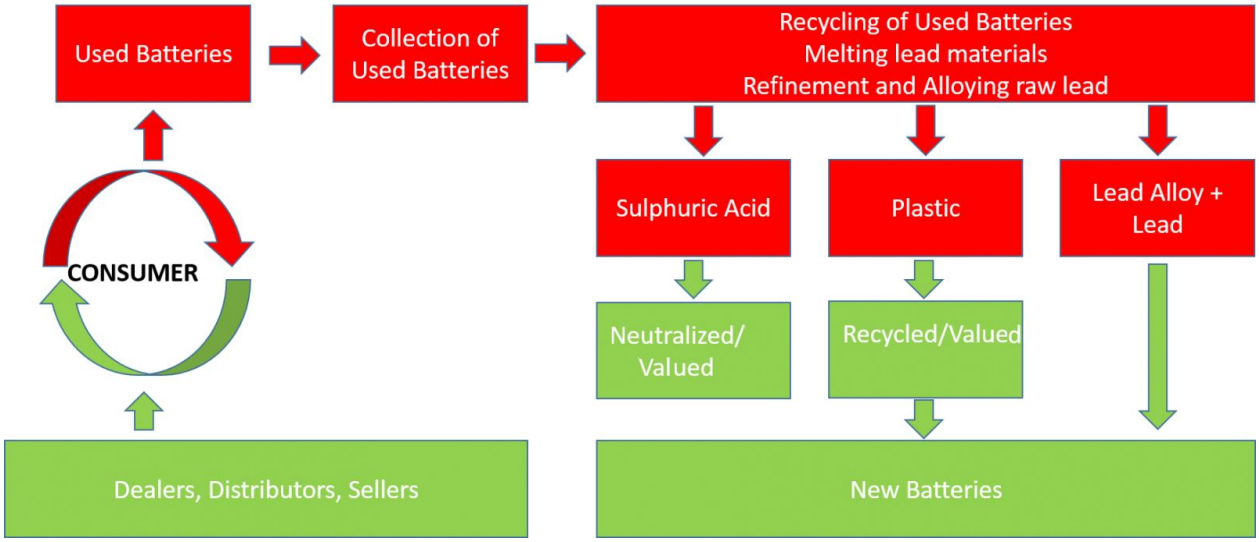
vehicles on the market, to initiate a legal framework to facilitate their access to the recharging infrastructure with electricity, to establish policies of eco-sustainable transport, designed to cope with heavy traffic, as well as protecting the environment.

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 [103]. 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 [104].

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 [105]. 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 [106]. 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 [107]. 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 5.2). 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 [108].

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

TotalREC is an innovative integrated service designed by Indeco [109], 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 [110].

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 [111].

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.

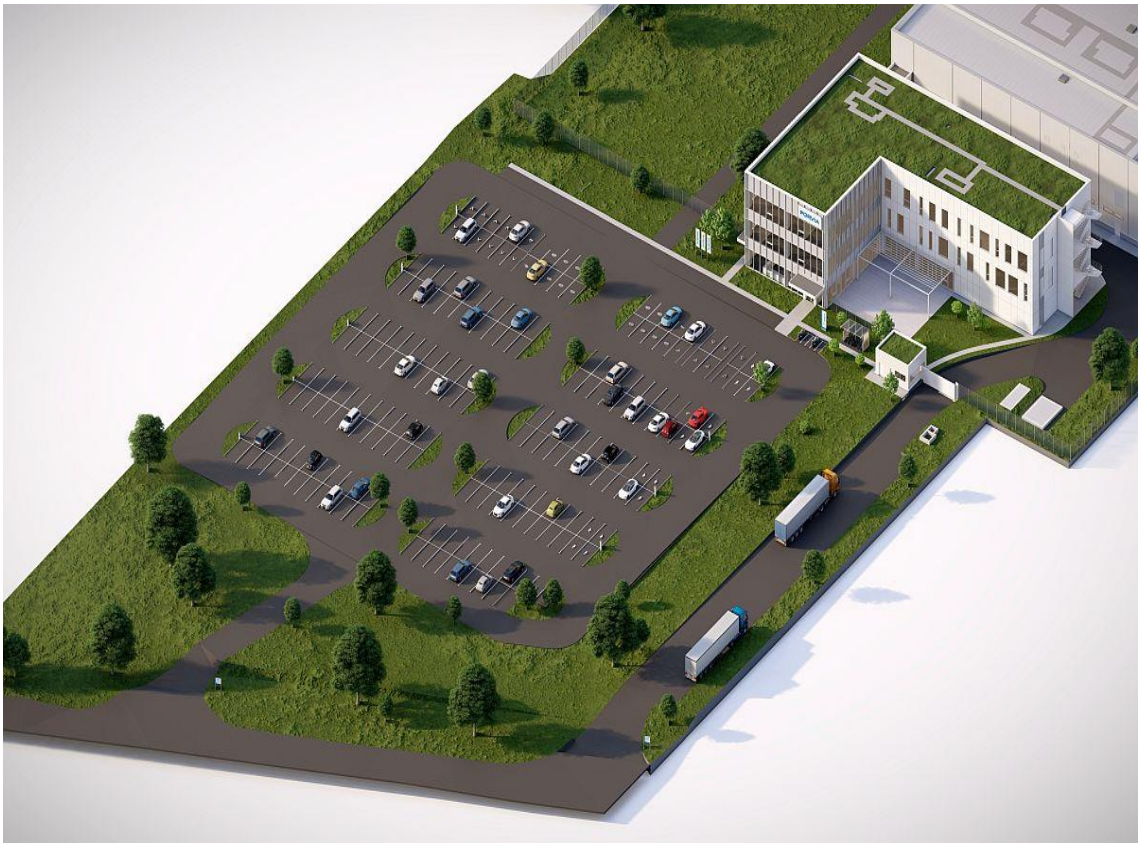


Figure 5-2_HELLA new building, which will be climate neutral by 2025

[source: 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 [112]. 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 [113].

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 [114].

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) [115]. 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) [116] 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.

5.1.12 Key conclusions regarding the automotive industry powered by the circular economy in Romania

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.

5.2 CIRCULAR ECONOMY IN THE SLOVAK AUTOMOTIVE INDUSTRY - REGULATIONS, INITIATIVES AND GOOD PRACTICES IDENTIFIED

5.2.1 Volkswagen Slovakia

The Volkswagen (VW) Group has committed to be carbon neutrality by 2050 as part of its Zero Impact Factory Strategy, including zero emission products, production processes and logistics. In 2020, VW Slovakia committed to improving plant efficiency by 30% and already more than 80% of manufactured vehicles are exported by train. To date, VW has invested some EUR 4.5 billion into Slovakia and now employs 14,800 workers. Production of its subcompact group triplets (VW e-up, Škoda Citigoe iV and Seat Mii Electric) make the VW Bratislava plant the 3rd largest producer of EVs (43,275 units) in Europe. However, production is only committed to 2025, and it is reported that Spain and Germany are in the running for the next contract [117].

The Volkswagen Group is bundling all its measures in environmental protection under the new "goTOzero" environmental mission statement. In its "goTOzero" mission statement, the **VOLKSWAGEN GROUP** concentrates on four main fields of action:

1) CLIMATE CHANGE: Volkswagen is committed to complying with the United Nations' Paris climate protection agreement. The goal is to become a balance-sheet CO_2 -neutral company by 2050. By 2025, the company plans to reduce its total life cycle Greenhouse Gas Emissions of passenger cars and light duty vehicles by 30% compared to 2015. The company actively contributes to the transition towards renewable energies along the entire life cycle.

2) RESOURCES: Volkswagen intends to maximize resource efficiency and promote circular economy approaches in the areas of materials, energy and water. By 2025, the company plans to have reduced the production-related environmental externalities (CO_2, energy, water, waste, volatile organic compounds) by 45% per vehicle compared to 2010.

3) AIR QUALITY: Volkswagen is driving e-mobility forward to improve the local air quality. By 2025, the share of battery electric vehicles in the Group's model portfolio will be between 20 and 25%. The share of electric vehicles in the Group fleet is to rise to at least 40% by 2030.

4) ENVIRONMENTAL COMPLIANCE: In terms of integrity, Volkswagen aims to set an example for a modern, transparent and successful company by installing and monitoring effective management systems that cover the environmental impact of its mobility solutions across all life cycle phases (Volkswagen, 2019).

VOLKSWAGEN SLOVAKIA - THE ALUMINIUM CLOSED LOOP PROJECT

Volkswagen Slovakia is the first of the Group's multi-brand sites to join the Aluminium Closed Loop project. This involves the recycling of aluminium stamping offcuts from the press shop, which are returned to the supplier of the aluminium rolls. The aluminium offcuts are reprocessed at the supplier to enable them to be returned to production without any loss of quality. The use of secondary aluminium saves up to 95 percent of energy compared to primary aluminium. The CO_2 savings and efficient resource management also contribute

to greater sustainability. Among other things, body parts for the Audi Q7 and Q8 models are pressed at the Bratislava plant.

As part of the Group and Volkswagen brand, Volkswagen Slovakia is committed to achieving the environmental goals of the Zero Impact Factory strategy and moving toward climate neutrality. To achieve the best possible results, the company continually uses state-of-the-art technologies and actively participates in projects that have a positive impact on the environment. One of these is Aluminium Closed Loop, which was introduced at Audi's Neckarsulm site in 2017. The project is currently running at four of the Group's sites where press plants with a high proportion of aluminium parts are located (Audi in Neckarsulm, Audi in Ingolstadt, Audi Hungaria in Győr and Volkswagen Slovakia in Bratislava). Further locations will follow. In 2021, the Aluminium Closed Loop project was responsible for a reduction of more than 195,000 tons of CO_2 on balance for the production of Audi models alone. Since its introduction in 2017, these total savings have amounted to more than 725,000 tons of CO_2.

The press shop at the Bratislava site joined the Group's Aluminium Closed Loop project in July 2021. Currently, a large proportion of the parts for the bodies of the SUV models produced in Bratislava (Volkswagen Touareg, Audi Q7, Audi Q8, Porsche Cayenne and Porsche Cayenne Coupé) are pressed here. These include exterior skin parts, roofs, add-on parts, hoods and tailgates, wings, doors, window frames and more.

The Aluminium Closed Loop is a successful example of closed-loop waste recycling that eliminates much of the energy-intensive production of primary aluminium. "The high energy demand can be minimized, among other things, by using recycled materials, thereby contributing to a better environmental balance of our vehicle projects even before our own vehicle production begins," explains Michaela Hletková Ploszeková, Head of the Environmental Department at Volkswagen Slovakia.

The body parts are made from aluminium and steel sheets that are cut from aluminium rolls, otherwise known as coils, at Audi Hungaria's nearby sister plant in Győr, before being formed with pressing tools at the press shop in Bratislava. The aluminium is separated from the other stamping waste resulting from the production of these parts directly on the line.

"Thanks to the separation and cleaning processes in the production process as well as at the recycler, the stamping waste from the press shop for recycling in the Aluminium Closed Loop achieves a purity level of 99.9 per cent. In the pilot year, the company managed to deliver more than 6,600 tons of aluminium offcuts to the Aluminium Closed Loop project despite fluctuating production due to the difficult global situation. We want to continue to gradually increase this share," says Stanislav Novák, Head of the Press Shop Specialist Team [118].

A contracted supplier currently stills transports the separated aluminium waste from the press shop via truck. In the next few years, the plan is to start using alternative environmentally friendly vehicles for this purpose. The waste will then be transported from Slovakia directly to the Group's aluminium supplier so that it can be processed and sent back to the Bratislava press shop as original-quality secondary aluminium or aluminium sheet, where it will then be used again to produce body parts for SUVs [119].

VOLKSWAGEN SLOVAKIA - THE ALUMINIUM CLOSED LOOP PROJECT Volkswagen Group's Slovakia site is one of the first units to enrol in the Aluminium Closed Loop project, which includes recycling aluminium stamping offcuts from press shops that come back to the aluminium roll suppliers [120].

Volkswagen Slovakia sends high-quality aluminium offcuts for re-processing.

When a stamping press cuts and models the sides or roofs of a future SUV out of high-quality aluminium sheets at the biggest automotive plant in Slovakia, the offcuts are sent to a supplier that uses them to produce new sheets.

Volkswagen Slovakia thus saves precious primary raw material and its cars enter the usability phase with greater environmental balance.

The Aluminium Closed Loop project, launched in 2021 in Bratislava, is an example of a circular economy in practice, reducing the energy-intensive production of primary aluminium.

As said Michaela Hletková Ploszeková, head of the environment department at Volkswagen Slovakia: „Using recycled materials to produce the aluminium from which car bodies are made minimises the high energy requirements in the phase before actual vehicle production."

This is one way the plant reduces the overall environmental balance of the vehicles it produces, she added.

Since the launch of the project in July 2021, the carmaker has sent 6,600 tons of high-quality aluminium offcuts for re-processing. The use of secondary aluminium enables energy savings of up to 95 % compared to the production of primary aluminium. The production of CO_2 emissions is reduced as well.

Using the offcuts to produce new sheets minimises the amount of raw materials, in this case bauxite, Hletková Ploszeková noted.

Volkswagen Slovakia opened its €90 million press shop in Bratislava in late 2013. It was one of the most advanced press shops in Europe and its press (91,000 kN) is one of the strongest in the Volkswagen Group. It presses 74 components from aluminium as well as steel sheets for SUV models produced in Bratislava – the Volkswagen Touareg, Audi Q7, Audi Q8, Porsche Cayenne a Porsche Cayenne Coupé. The high usage ratio of aluminium, as much as 96 percent, has made it a suitable place to introduce the Aluminium Closed Loop project.

The Aluminium Closed Loop was first established at the Neckarsulm site in 2017 and then gradually introduced in the Audi in Inglostadt in 2020 and afterwards in Bratislava [121].

Challenges on electrification

At Volkswagen Slovakia, this means shifting from steel to aluminum – which is lighter – and glued rather than welded bodies. The second challenge is how to dispose of the battery. This is particularly the case with lithium-ion batteries, which create new types of waste. Finally, regulations pose a challenge, as they are often contradictory, and simply create a feedback loop. Ms. Ploszeková stressed that Volkswagen Slovakia are committed to covering the entire life cycle of a vehicle, and added that by 2025, the company aims to reduce the environmental burden by 45 percent per vehicle by 2025, compared with 2010 [122].

5.2.2 PSA Slovakia

The Trnava carmaker Groupe PSA Slovakia is a leader in the production of small vehicles of the B-mainstream segment. It currently produces extremely popular Citroën C3 and Peugeot 208 models. In July 2020, the car company already produced the 3.5 millionth vehicle. Serial production at the car company started in 2006 and its products they lead to satisfied customers on almost every continent [123].

In 2019 PSA Group started its first battery production hall in Slovakia, producing 10,250 battery packs and roughly 1 in 5 of its new 208 model are EVs. The majority of cars are petrol (78%) and diesel (20%). The Trnava plant was the eighth largest electric vehicle producer in 2020 (34,300 units) and representatives have hinted at a possible increase in the production of the Peugeot e-208 model [124].

The main aims for PSA Slovakia in the area of circular economy are as follows: (1) Waste treatment at the plant; (2) Reducing the amount of waste and slowing down the emergence of new; (3) Waste disposal; (4) Increasing of environmental awareness of employees and external companies; (5) Communnication with departmens (PSA Annual Report, 2018).

By waste sorting at source – with introducing of operational audits after operations company has reached improvement in sorting, in 2018 the sorting success was 96%. By decreasing the amounth of waste and preventing the emergence of a new one – the produced waste was decreased on 14,7 kg per car; priority has material and energy recccovery – 91% of whole waste produced in company was material and energy elaborated. PSA is increassing invironmental awareness of employees – with system of education and training and by environmental cooperation with external companies, as well as by intensive cooperation with service supliers in the area of waste treatment and by exchange of experiences with French manufacturers inside the PSA Groupe (PSA Annual Report, 2018).

PSA Slovakia is taking circular economy and sustainability seriously. Mr. Peter Švec, Head of External Relations, PSA Groupe Slovakia noted that PSA is firmly committed to sustainability and is the European automotive industry leader in reducing CO_2 emissions. Already 42% of PSA cars sold in Europe emitted less than 100 grams per kilometer of CO_2 in 2016, considerably less than the market average. PSA has ambitious goals for materials, waste materials, hybrid and electric vehicles, mobility services and autonomous cars too (Ministry of Environment of the Slovak Republic, 2017).

5.2.3 KIA Slovakia

Kia Motors Slovakia is the only plant in Slovakia producing engines, shifting from away from diesel to predominately petrol in 2018, accounting for 63% of engines produced. In 2020, demand for petrol engines grew by 68% year- on-year. Compared to VW, Kia is more focused on plug-in hybrid cars than battery electric models, continuing to build small-capacity, high-efficiency, hybrid-compatible gasoline engines at three engine production lines [125].

On 18 March 2004, Kia Motors Corporation officially confirmed the construction of Kia's first European automotive plant in Slovakia Kia Corporation is the 100% owner of Kia Slovakia. Since December 2006, the Company's core business has been the manufacture of motor vehicles and engines. In 2022, the production plant produced the lower mid-range model Kia

Ceed in four body styles as well as the Kia Sportage SUV Mass production of the Sportage in a plug-in hybrid version was successfully launched in early 2022.

At the same time, Kia recently announced plans to start production of a new model electric car at its Žilina plant in 2024 as part of the company's new strategic plan to strengthen the electric car segment. This plan includes 11 new EV models 2025 with a targets of 500,000 sales per year [126].

Kia Motors and SK Innovation join forces to achieve a circular economy of electric vehicle (EV) batteries. This aims to attain the virtuous cycle of the materials of high-voltage batteries for EV and reduce CO_2 through reuse or recycling of batteries after use. Kia Motors and SK Innovation announced on the 29th April 2021 that they had secured the possibility of building an industrial ecosystem that enables eco-friendly handling of EV batteries and technological basis thereof by re-collecting metals such as lithium from used batteries. As a part of the endeavor to reinforce their ESG management, the two companies signed an memorandum of understanding to establish an industrial ecosystem for electric vehicle batteries in March 2020. They have conducted empirical testing for the used battery recycling and subsequently evaluated the possibility of collecting metal within the battery, its effects and efficiency, etc. Under the umbrella of Hyundai Motor Group, Kia Motors evaluates used batteries with a battery performance testing system and reuses those that exhibit good residual battery performance as energy storage systems (ESS) by classifying them into modules or packs. If the residual performance is low, the battery will be decomposed into cell units and the metal is recovered through recycling. After use, the battery contains a lithium electrolyte inside, so it requires a technology that is more difficult than recovering lithium from the waste cathode material generated during battery manufacturing. SK Innovation uses its own technology to recover metal resources such as lithium hydroxide, nickel, and cobalt from the battery after use, and then re-use it to manufacture the cathode materia for batteries (Battery Industry, 2021).

5.2.4 CYRKL

The company Cyrkl focuses on circular economy principles in all its activities. The circular economy is the reason why they were founded as a company and all its activities are aimed at its development, whether in Slovakia or globally. Cyrkl focuses on absolutely all waste, waste materials, by-products, and recyclates. However, the most traded are all types of plastics, paper, cardboard, metals, wood, and construction waste.

Secondary raw materials offered in Cyrkl most often come from industrial production and construction. But also recycling, as recyclers are also on offer. Demand is still the largest for recyclers and processors. However, the manufacturing and construction sectors are also moving forward significantly and their interest in secondary materials is increasing.

Roman Gdovjak, expansion manager from Cyrkl company mentioned, that it is evident, that between firms is a greater effort to produce sustainable products suitable for reprocessing at the end of their life. Many of the companies Cyrkl works with, are seeing an increasing emphasis on eco-design and therefore addressing circularity issues at the very beginning of the lifecycle. Roman Gdovjak believes, that the biggest problems and shortcomings in the implementation of the circular economy oftentimes represent the very mentality and

awareness of companies about these issues. The big issue in Slovakia is, in particular, that landfills are often still the cheapest option. In the case of positive and rare secondary raw materials, companies often do not know their value and do not even look for them.

From the perspective of Cyrkl, the potential of a circular economy is currently mainly in the rising prices of primary raw materials and therefore also in the increasing demand and prices of secondary raw materials. At the same time, various pressures (EU, legislation, public, foreign branches) on the circular economy principles.

Cyrkl is particularly focused on showing companies solutions that combine environmental benefits with financial savings and innovative solutions. By combining these aspects, companies are increasingly motivated. In the future, Cyrkl plans to spread its principles throughout Europe and then throughout the world. This could be achieved by linking the waste market, the waste auctions, and consultancy projects. They are also planning other projects and products that will further develop the circular economy principles, but these are not yet presented.

5.2.5 STERED

PR Krajné, LTD. was established in 2006 with the aim to re-use mixed synthetic textile waste particularly from the automotive industry. Thanks to developing a unique technology, Stered, a comprehensive technological line was assembled, first of its kind not only in EU countries, which is processing the textile material and use it in the production of new products. In PR Krajné, they were looking for an answer to where the border is between real waste and waste as source of secondary raw material. The aim was to turn textile waste into material for new products. Technical textile in a car meets demanding needs of the automotive industry and its life highly exceeds the life of the car itself. When used in a car it is 10 years on average.

Company has focused on a production process in which they transfered as many specific features required by car manufacturers as possible into new product. The period 2007 – 2009 was focused on research and development and production of the product as well as its marketing. A comprehensive processing line is a result of research, development and production of Slovak authors and production companies and it is able to process technological waste from primary production of 1 000 000 new cars or separated waste from 100 000 wehicles after the end of their life. Input waste is supplied by authorized processors of wehicles after the end of their operating life and producers of individual textile parts. A prudent approach to the environment is also proved by the fact that company is revitalized an unused production area for the purpose of construction Mechanical processing with low energy intensity during production of STERED boards is typical for the technological line. Eventually, the technological process has been designed so that not more than 5% of new waste is generated from processing waste – a raw material (Ministry of Environment of the Slovak Republic, 2016).

The main business of PR Krajné is the recovery of mixed waste from synthetic technical textiles from automotive by recycling and incorporating the recycled material into a new product.

By the principles of the circular economy, otherwise unusable waste ends up in landfills or is processed for energy recovery, so the company uses it as a valuable source of raw material. The manufactured products are characterized by longevity and therefore, as construction products they are used in construction applications for a long period of use - delaying the end of the waste state.

The input material consists of synthetic technical textiles used in the automotive industry. These are characterized by a combination of several textile components, fibres, and non-textile materials. The input consists of the technological waste generated in the production of parts for new cars and the separation of textile components from the end-of-life treatment of vehicles. These inputs complement combined and composite textiles also from other sectors, e.g. manufacture of air conditioning and air conditioning filtration fabrics.

A decisive proportion of 80-90% of the input waste, raw materials in PR Krajné are technological waste from the production of parts for new cars. Other inputs include separated parts from end-of-life vehicle processing and other combined and composite textiles - technological waste from industrial production. Waste to the recovery process shall be taken after supporting the material sheet of the product from which the technological waste is generated. In the case of separated textile parts from the processing of ELV, the characteristics declared by the sheets for technological waste are considered to be identical to those of the textile part for a new car. Based on the documented material sheets of the input waste, and raw material, it is possible to confirm the taking over of the basic physical, mechanical and chemical properties of the new product – mechanical and chemical resistance, resistance to neutral leaks to water and air, harmlessness to the environment and the human body, thermal and sound insulating properties, resistance to ultraviolet light, fire, mould, preserving longevity, etc.

Combined and composite textile materials cannot be processed into fibres using standard techniques for the recycling of textiles. Such fabrics are therefore labelled as difficult to fiberize. The unique STERED technology, the only one of its kind, is that it builds the original structure into a clump in the recycling process. In a technological process, recycled material, a clump, is made up of a mixed proportion of different types of combined and composite textiles. The clumps represent the bulk of the original fabric structure, with the fibres partly or completely loose. These protruding fibres from the original fabric structure and free fibres thus create the ability to mechanically bind individual clumps during recycling. Mixed clumps, with the addition of a polyurethane-based binder, are pressed in the form of a finished product, plates. The new product thus assumes all the primary characteristics required by the car industry.

'VERIFIED QUALITY OF AUTOMOTIVE MATERIALS FOR NEW ENVIRONMENTAL QUALITY'. The STERED technology, the method of production of the tuft, the machinery for its production and the tuft itself are the subject of patent protection in the EU, China, Korea and India proceed.

The new product from the recovery of mixed waste from synthetic technical textiles is primarily intended for long-term applications. It is therefore certified as a construction product (30 years or more). Its application is therefore in the area of noise abatement and in particular in retention areas such as green roofs, sidewalks and parking areas. The specific

characteristics of a new product, such as high mechanical resistance, stability, and the ability to repeat the water stress - pouring and evaporation, presuppose this product in the composition of the climate-active area.

The characteristics of the basic structure of a compressed textile pile are essentially unchanged over time in the applications concerned. This makes it possible to confirm the recycling of the recycled product by adding it back to the material recovery process of the new raw material. This applies to all applications from noise abatement applications, and retention solutions, including those where the top layer of the earth's substrate (green roof applications) can be separated. The basis for this premise is a comparison with the input raw material – a clump made up of technological waste from the new fabric and separated parts from the ELV, which has been in use for more than 30 years. An alternative is also energy recovery, e.g., for products that have been contaminated, e.g. by oil and retention materials in parking areas.

Combined and composite fabrics and other automotive fabrics processed in PR Krajné, s.r.o. are divided according to the degree of recyclability into:

FULLY RECYCLABLE

- Textile consists mainly of textile materials and/or added non-textile material is in smaller proportion to the textile part, the textile part is not normally added to other materials in the shaping process, e.g. compacted to hard texture by pressing.
- Recycling results in 5% or less of the newly generated waste.
- In the construction of the car, these textiles make up about 25-35% of the shares in the parts.

RECYCLABLE WITH RESTRICTION

- Textile parts containing a larger proportion of non-textile, non-metallic or textile parts are compressed into a rigid structure.
- The proportion of usable textile parts used for the formation of tufts is 10% of the total volume of material.
- The non-recyclable part is preferably forwarded to energy recovery.
- In the construction of a car, these textiles make up about 35-75% of the shares in the parts.

NON-RECYCLABLE

- The textile part is combined with a non-textile part the processing of which would constitute a hazardous waste from the recycling - a mixture of glass or mineral fibre textile and cotton or the addition of a metal part.
- In the construction of the automobile, these textiles make up about 5-15% of the share of the parts.

At the request of the waste producer, the company PR Krajné, s.r.o. issues a recyclability certificate for the different types of waste.

The separated parts of the processing containing the textile part of an ELV (End-of-Life vehicle) typically consist of 24-35 kg per ELV. Depending on the degree of recyclability, 80-90% of the separated parts can be used. Waste which is contaminated with operational

liquids and other substances for which the waste does not qualify as 'O' and 'non-recyclable' waste shall not be taken over for recycling.

In the process of vehicle recycling presents problems with the textile-component parts, the combination of glass fibre (laminate) components, e.g. roof insulation and combinations with mineral wool or glass wool wadding and addition of the metal part of the aluminium foil - insulation in the motor part.

The executive director of the company, Juraj Plesník, perceives an improvement in the recycling of ELV in the fact that the innovation of each product should start with an end-of-product assessment. By Directive 2005 / 64 / EC of the European Parliament and the Council, every car manufacturer should require the supplier to provide proof of the recyclability certificate - the determination of the technology for the recovery of waste.

This document would form an important part of the implementation of the EP and Council Directive 2000 / 53 / EC on the detection of the use of ELVs as a source of raw materials.

As the biggest problem in implementing a circular economy in the car industry, Juraj Plesník perceives the fact, that in the 'technical textiles' section, this is consistent compliance with the adopted rules under the EP and Council Guidelines 2005 / 64 / EC and EP and Council Guidelines 2000 / 53 / EC. Improving discipline, the demand for the inclusion of technological waste from production for recovery, has, in recent times, indirectly increased the pressure to limit the access of such waste to landfills and the rising costs of receiving waste for energy recovery. However, an important factor in supporting the circular economy is the use of recycled or recycled products on the market, and its support in programmes - the proportion of recycled products - is a criterion.

In particular, in the recycling of complex and difficult-to-break technical textiles used in automotive applications, the emphasis in the design of STERED was, therefore, on linking recycling to the finalisation and incorporation of recycled into a new product.

The product is usable in applications that can bring new applications to the automotive industry itself:

- ☑ Noise reduction in production premises (VW Bratislava, DIPEX, Djong Jing presision…).
- ☑ Reduction of energy consumption in the operation of buildings, combined with rainfall management ('Renewable Energy as an Important Component of Climate-resilient Buildings and the Energy Efficiency of Buildings ') (VW Bratislava, Thyseens Krupp ROTHE Erge, Camfil...).

The new product, the STERED board, is an essential building block of the climate energy active surface. The combination of KEAVS and FVE – the bio solar is now an important tool for the programme Fit for 55.

It is only recently, through the Recovery and Resilience Plan programmes, the Modernisation Fund, and the new Structural Funds that support instruments are being developed to meet the EU's RE Power objectives, opening up the demand for KEAVS applications.

The company PR Krajné has a network of contractual relationships: Waste producers - producers of parts for new cars; Service waste companies that provide comprehensive services in the field of waste management for parts manufacturers and car manufacturers; Authorized processors of old vehicles.

5.2.6 Faureacia Automotive Slovakia

The company manufactures automotive parts, the input parts from which the parts are assembled. In many cases, materials, options, and recyclability percentages are directly prescribed by the manufacturer. Theoretically, Faurecia can find something more recoverable with a longer product life, but without the confirmation of the customer (the car company) itself, they can't use it. Validation tests for a new adhesive to be used in car production, for example, take up to half a year, so they are in many cases limited by the customer. Even though many activities are limited to customer, they are being done also on the level of the subcontractor.

The basic strategic documents of the whole company, not only of Faurecia Slovakia but also of the parent company, already say that the strategies for the new years, for the next periods, must already take into account the circular economy. This applies in particular to new projects. Changing old projects that have been in operation for several years is extremely expensive. Validation tests cost around half a million euros. This applies, for example, to the adhesive used on the dashboard that holds the leather or leatherette part to the plastic base. So there is no return on investment in that. But the new projects that are coming in are being dealt with. Dozens of new projects are coming in every year, as car companies develop new models, as new facelifts are done to old cars, it's always a new project. The whole life cycle of a project is roughly a year to a year and a half of preparation. Followed by the actual production cycle, depending on how the cars are sold. Usually, the first two years it's a huge push, 500, 600, 700 cars a day are produced, and then it gradually goes down as the car stops selling, or a new facelift is created, again the numbers go up, then they start to go down again. It ends up being the end of the life of the project, the project is terminated, and the car company stops making the car. But Faurecia as a supplier is still obliged, depending on the contract with the car company, to be able to produce spare parts for 5, 10, or 15 years.

Just new projects that come in, Faurecia have checklists, AS program checklist, project checklist, and different program checklists, where they are already focusing exactly on material saving, on waste recycling opportunities. Where materials have been used that are recyclable, fewer types of adhesives, and fewer amounts of adhesives have been used. So there is a saving of material in general. This saving in the past started mainly for economic reasons (10 years ago), but more and more economic reasons are no longer key and the ecology, the life cycle of the product, and the carbon footprint are starting to be taken into account.

Forvia Faurecia as a whole has created a new division in the last year to deal with the carbon footprint of all of Faurecia's plants. The division deals with actions to reduce the carbon footprint. For example, at one time a huge percentage of waste was landfilled, then it was realised that it was much more economical and environmentally friendly to burn it, to use energy. In terms of carbon footprint, incineration is the worst way to dispose of waste - it produces the most significant carbon footprint. New ways of recycling waste are therefore being sought.

Prevention of waste products can be selected in Forvia Faurecia into two parts:

THE FIRST PART IS THE PRODUCTION, which is currently in process. In the Košice branch, Faurecia produce doors for passenger cars (Mercedes). These are covered in leather. The leather used to be checked manually, they used to lay out leather cutting templates that cut out the defective leather. The waste/usability of the leather was approx. 50%. Gradually

technology has changed. Brand new technologies have come in where they mark defects on the leather by hand (since leather is a natural material, it has blemishes, wrinkles, insect pinches, etc.). The blemishes are manually marked with different colours and scanned into a pc. The latter evaluates which defects can be visible, which cannot be visible, and which can be visible in which place. The pc itself already creates a pattern, of how the skin can be cut out and the machine cuts it out straight with an electric knife. In this way, the usability of the skin increases from 48-52% to 75-85%.

ANOTHER PART THAT IS DONE IN THIS WAY IS THE PRODUCTION OR COATING OF PLASTICS IN ADDITION TO LEATHER ALSO IN PVC (various artificial types of leather). The plastic is coated into the packaging material, glued and the excess is trimmed off. In the past the excesses were 2-3cm wide, nowadays the excesses are in the order of millimetres. A minimum of excess waste is thrown away/cut.

The main step is therefore to **MINIMIZE THE MATERIAL USED**.

There are many injection moulding machines in Faurecia where plastics are directly injected into moulds. There was a huge amount of waste plastic from these injection moulding machines. When the material or colour was changed, all the excess from the tray of heated plastic was squeezed out and taken to waste. At the moment, production is being set up directly so that there are as few changes or material changes as possible. To use one machine exclusively for only one type of material, one type of paint, to minimize changes. At the same time, new technologies have been introduced where the printed hot plastic (which used to be taken to the landfill or incinerator) is ground after cooling, turned into granulate, and added in certain percentages to the original granulate for reuse. What Faurecia cannot reuse, find companies that know how to reuse it; e.g. surplus plastic from the automotive industry (for quality reasons it is no longer usable in the automotive industry) but it can be used e.g. in the toy industry, bicycle parts, etc.

These are the biggest types of waste that come directly from production.

In addition, Faurecia has a lot of waste that comes indirectly from production (e.g. residues from cleaning spray lines, foaming, various mixtures of water with oil, paint, and glue). Some technologies already recycle all this waste. The water can be purified and reused as technology water. 100% of the water contaminated with glue produces 98% clean water and 2% sludge, which is disposed of. Faurecia has also started to recycle various thinners, and oils that are used indirectly in production.

RECYCLING RATIO AT FAURECIA:

German factories have recycled from 80-95%, Slovak: 40-50%, Czech: approx. 20% of waste. Huge differences can be seen in the approach to recycling. On the other hand, mainly Slovak plants are making huge progress and are looking for ways to recycle more waste. The fact that the individual plants cooperate, the so-called sharing best practices so that other plants can reach the level of the German ones in the share of recycling. Germany is better prepared for recycling. There is a lack of recycling centres in Slovakia, so there is nowhere to recycle.

Currently, the Hlohovec plant is recycling water with sodium hydroxide, which is used to clean the moulds. So far, this has been disposed of as hazardous waste. Faurecia has found a company that can recycle it and processes it further. Tests are underway right now.

The amount of waste is incinerated with energy recovery. However, Faurecia is already trying to avoid this. They protect the environment by not putting it in landfills, but on the other hand, the carbon footprint of such disposal is the highest of all waste disposal options.

As far as Slovakia is concerned, materials such as plastics, and leather are recycled in very large quantities. The problem is that Faurecia can only recycle clean materials.

For example, the dashboard in a car is not a single-species material. There is a mixture of PVC, artificial leather (PU leather), natural leather, and soft plastic. As long as it's still an unfinished part at the level of the individual raw materials, recycling is easy. Separated plastics do not pose a problem in recycling. Once the part is complete and finds out that it cannot be used (the automotive industry has very strict rules for the quality of usability of materials) so to remove non-compliant part there are no recycling companies in Slovakia that can grind the materials from the part, crush them, separate those plastics that are already joined together. Therefore, such parts mostly go to incinerators (unless the percentage of PVC is too high due to the percentage of chlorine that would leak into the air) or to landfill. There is a serious lack of recycling centres in Slovakia that are able to recycle multi-species plastics joined in this way.

The plastic is either reused in the automotive industry (added to the original granulate as regranulate - regrind plastic). The automotive industry already permits what percentage of this regranulate can be used. It is from a safety point of view. The material has to meet strict safety standards. It cannot happen that, because of the use of recyclable material, e.g. an airbag does not fire in the right way or fragments from the dashboard are shattered.

The remaining (unused) regranulate is being further recycled in cooperation with a Cyrkl company. Faurecia is looking for opportunities to use the regranulate. This kind of waste is very popular in Poland, so mostly Polish companies are using plastic regranulates. Recycling is progressing at a better pace in Poland than in Slovakia. So something is reused in different containers, bowls, and toys (less important things from the point of view of safety). In the food industry, regranulate is not used because there are also very strict rules.

As far as the production of leather is concerned, there has been a surplus exported to China and Italy for several years. The leather used in the automotive industry has the highest quality in the world because the individual components have to bear extreme loads. The surplus is therefore bought up and made into, for example, wallets, belts, shoes, and accessories for the clothing industry.

Another part that is generated in large quantities is packaging raw materials. Each part of the car is in separate packaging to protect it from damage. At full production, 500 cars a day are produced, so the packaging stock must be at least at the level of a week's production (that's thousands of packages). When a new project comes along, a new shape of component comes along, and thus the old packaging is no longer usable. This generates a huge amount of waste. Universal packaging cannot be produced yet. However, possibilities are already being looked into for this as well. However, Faurecia has found companies that are buying back the packaging that is not being used. Metal packaging is reprocessed and used in other industries to package other goods. Polystyrene and plastic packaging is also bought back. Plastic packaging is used in other industries (use according to dimensions). Polystyrene packaging is ground and added to new packaging.

There is an increasing emphasis in a company on the circular economy, the reuse of materials, and the recycling of materials.

In August 2022, Faurecia started the cooperation with a Cyrkl company. They found critical wastes for all the plants and the wastes with which they have the biggest costs. They made a selection of what we could recycle or reuse. All the plants prepared an action plan of what

we can do with which waste. They are looking at how to sell it off, and how to get it into circulation. Every month they have an assessment of what has been done.

Faurecia can't very much take steps to allow repair/refurbishment of parts. All parts, procedures, and materials are the property of the owner (a car factory). They cannot input into the process during production. They can input into the process at the beginning of the project. Invariably the customer is the final member who will validate the whole thing. When it comes to validation, specific procedures must be applied during production. No more looking for additional options to facilitate repair/refurbishment of parts. For new projects they have the possibility to enter, e.g. they are currently solving an experiment with glue in Košice. At the moment the adhesive used for gluing parts (leather on the dashboard or on the door panel) is applied from both sides. It is applied to both the door panel and the leather. Tests of the one-part/one-side adhesive are ongoing. So it will take half as much and use less energy, use less machinery to apply and stick the adhesive. It won't directly make it easier to repair or refurbish parts, but it will make it easier to make the parts themselves. It will reduce waste, reduce economic costs, energy, water, and adhesive. It will also reduce the production of spare parts because they will already be produced more simply.

Faurecia cannot extend the life of the products because they have the product prescribed in the specifications from our customers. Customers prescribe them the exact plastic, the exact granulate ratio, the exact adhesive, the working procedures, etc. Faurecia, as a supplier, has no input into this.

Secondary raw materials are not widely used. They are not directly purchased. The only place where secondary raw materials are used in a certain percentage is in granulate for the production of plastic parts. Directly purchased plastic is a certain percentage (each part has a separately specified percentage of regranulate it can contain). E.g. plastic that Faurecia used to buy as 100% PVC granulate, they can currently buy 80% new PVC, 20% regranulate added by the supplier. At the same time, they can reuse all the regranulate that is generated after grinding/granulation into production. This is the most used secondary raw material - plastic from secondary raw materials.

Faurecia also uses **RECYCLED DILUENTS** in their production. They make use of applying adhesives, and paints to plastic parts, so diluents are used extensively. Three **BIG STEPS** have been made in this area:

- ☑ A few years ago they defined which diluents are used in production and set rules to minimize them. For example, diluents (substances containing volatile substances - VOCs) may only be used if they have a direct impact on the quality of the product. That is, they cannot, for example, use them to clean the adhesive warehouse.
- ☑ The most effective diluents have been defined so that they use them as few as possible. In the past, classic acetone was used. Now there are more types of thinners. At a lower price and lower consumption, they have the same effectiveness as acetone thinners.
- ☑ There is a third step going on at the moment where a Faurecia company has found companies that are buying back the used diluent or taking it away for free, cleaning it, and selling the cleaned, recycled diluent back to them at a lower price than new diluent. In Austria, companies have found a use for the surplus sludge after recycling, using it to heat buildings. It goes for incineration. The purified diluent is returned to us for the production process.

In case of the ratio of secondary raw materials in the production process, plastics (plastic granulate) and various fibres are used the most. Within fibres, recycling is very difficult. More or less impossible because different fibre mixtures are used. It is never one material. These are the fibres that are used for carpets, for different upholstery, and so on. They are mixtures of fibres i.e. for example 30% natural fibres, 60% man-made fibres, and 10% glass fibres. While it is all separate, recycling is easy. It is not even recycled at that time as these fibres can be reused. However, once the fibres are mixed and heat-treated, the material is non-recyclable. So far, Faurecia has not been able to find any company within Europe that can recycle these fibres. They are currently experimenting with a Polish and a Spanish company.

As **FOR PLASTIC, IT'S BETTER**. When plastic is mixed from several types, the product is unrecyclable or very poorly recyclable. If it is single-species plastic, recycling is currently at 10-20% depending on the specific plastic (average 15%). This is just one type of production (plastic production on stretch presses). In the others, there is no possibility to use recycled/recyclable raw materials. In most cases, it is e.g. natural leather. There is no natural leather that is recycled.

Various metals, speakers, motors, buttons, etc. are also used, which Faurecia get ready-made. Faurecia does not make these ourselves, so they can't say whether secondary raw materials are used and in what quantities.

They partially produce parts (e.g. dashboards, door panels) that are cast on an injection moulding machine, moulded, trimmed, leather prepared, stitched, and glued together. This is what they produce directly.

Mounting parts, e.g. door wiring harness, and speaker, come in the form of finished or semi-finished products.

According the steps/measures has the company taken so far to enable future recycling of parts at the end of the vehicle's life, at the moment, these options are just getting started, because parts and their features are the property of Faurecia´s customer. Therefore, they cannot interfere much. The department for reducing the carbon footprint also deals with these things, the possibilities of recycling. Faurecia is already starting to actively enter into this process and they are directly suggesting to their customers the materials and the working processes that could be used in the production of their part. At the moment this is only feasible for car parts that are part of new projects. For projects that have been running for several years, it is no longer possible to enter this process. Even car companies in general have become interested in recycling parts, in what they produce. They are able and willing to work with Faurecia to start taking parts recycling more seriously. The communication from the customer (car companies) is starting to happen when they say what they want and they are willing to look for ways to make parts more environmentally friendly, to make them more processable, and recyclable, so there is less waste from them.

Concrete steps are not yet being taken as the whole process is taking quite a long time. Faurecia has started relatively recently with the introduction of a new division in charge of these steps.

In case of the percentage of recyclability, Faurecia cannot exactly say what is the percentage of recyclability, because they take the parts to the car factory, where they are assembled, and the car companies already know the percentage of recyclability. They mostly work with mixtures of plastics and fibers. These mixtures are very difficult to recycle within Slovakia.

It's a bit better within other countries, but it's still a problem. In Czechia and Poland, it is a problem because many parts of the car are made of PVC. During the reprocessing of PVC, free chlorine is produced, which escapes into the environment and therefore the processability of PVC is very limited.

Related to steps/measures the company has taken so far to make its production more sustainable, sustainability initially started in the form of looking for ways to reduce costs, gradually it has moved to a phase where cost is not as important as how Faurecia impacts the environment. The main indicator in this at Faurecia is the amount of waste produced and the recycling rate. Another indicator is the amount of energy consumed. And the third indicator is the carbon footprint. In terms of the use of renewable resources in production, they are limited by what the customer dictates (input materials). In terms of the form of energy that goes into production, it's much better there. Faurecia has recently issued a standard for new plants, which talks about renewable sources for new energies. Faurecia is currently investigating the possibility of introducing solar panels at individual plants. This is currently being addressed in Czechia (Mladá Boleslav), Slovakia is a little behind, but it is already starting to be addressed. If new plants are built, it is a standard that renewable energy sources must be included. Germany has a large percentage of company electric vehicles. They are trying to limit their consumption of petroleum products and are switching to electric vehicles.

The home office will be used in the winter period. It has been decided that in all plants, where possible, a home office will be assigned to employees every Friday. This is mainly to reduce energy. From Friday to Sunday the heating may be turned off, and there will be no hot water consumption, no HVAC consumption, etc. However, they have addressed this from the earlier point of view that a gas and energy crisis is coming across Europe. The automotive industry is not considered by the government to be a key industry for the running of the state (such as power stations or bakeries). Faurecia is therefore looking at ways in which they can reduce these energies. For example, they are switching from gas furnaces, burners, and other gas-fired equipment to electricity where possible and, where this is not possible, at least to LPG gas or propane-butane gas. It depends on the possibilities, and what can be used.

Faurecia has also focused on leaks (water, compressed air, and oil from machinery and equipment). Huge amounts of money have been invested. A special gauge was used to look for compressed air leaks and all these were isolated so that the pumps/pressure units did not leak and push air unnecessarily into leaky pipes. As for the streamliners and various large pieces of equipment, light bars were installed underneath these machines so that oil leaks were immediately visible. Various plexiglass walls were installed so that it was possible to see inside the machines where the leaks were. It was not only from an environmental point of view but also from the point of view of the lifetime of the machinery and equipment, this indirectly affects the environment.

In case of the steps/measures does the company plan to take to enable the transition to a circular economy and sustainability, at Faurecia, a division was established that is directly dedicated to ecology and the protection of the environment. It is headquartered in France and falls directly under the President of the company. So it's not just within Slovakia, it's throughout the company. In Slovakia are the first measures, and actions that this division is doing. 10 green attitudes have been launched. These rules refer to the proper management of waste, energy, and environmental protection (water, soil, air). It is a guide for plants from

an ecological point of view. One part of it talks about waste. For new projects, they already have to think together with the customer so that our parts are as ecological as possible and that they can be recycled. This is the main doctrine of the society that is now coming.

In addition, they are talking (largely in connection with the energy crisis) about the possibility of switching to the least energy-intensive production options.

Faurecia also tries to **REUSE** as much waste as possible. What they can use internally they already use internally (regranulates, regrind, and reprocessed materials that Faurecia used to take to the landfill, now it is sorted by parts, colours, and materials and reused in production after milling). What they can't reuse, they are looking through Cyrkl for companies that can use it. It's not just about production, but also about ancillary processes in production (packaging, containers, metal baskets, and general packaging management to make it reusable). They try to dispose of or use as few as possible cartons in packaging. They have thousands of packages. Sometimes it happens that most of the packaging is at the customer's place and Faurecia has nothing to pack the products in. That is when the cardboard is used. They are looking for ways to use some other reusable packaging, not disposable packaging. They would like to get rid of these completely within the next one or two years. In packaging, it's generally using as few disposable pallets as possible. In Faurecia, they are trying to eliminate, if a supplier is providing them with disposable pallets, they are looking for companies that can continue to use them. Those are the different packaging materials.

Two years ago, the branch in Košice launched the **ZERO WASTE PLANT** pilot project. It is related to waste because this is the main thing they can do to have as little waste as possible. There are different sub-processes:

- ☑ E.g. a paperless plant (so that everything is electronic and that everything can be dealt without the need for papers).
- ☑ Plastic-free plant (no use of plastic except in production). Trying to use as little plastic as possible in the offices. No plastic packaging, pens, or markers. All office supplies that are purchased are already made from recycled and recyclable materials.

The impacts of the project on waste, finance, and production, in general, were assessed. From next year Faurecia would like to introduce similar activities at all plants in Slovakia and the Czechia.

5.2.7 WAKIVAKY

As part of its philosophy, Wakivaky applies the principles of the circular economy in several ways. The company started as a school project and gradually gained a spectrum of awards, and created interesting collaborations, which also attracted several major media. Their philosophy is based on the following elements:

A. Locality - focus on local resources and production.
B. The social dimension and inclusion - support for disadvantaged groups.
C. Environmental Dimension - resource use and CO_2 reduction.
D. Fair treatment of employees.

The company is engaged in the production of designer and original bags, rucksacks, packaging for computer equipment, and other accessories.

Specificity is that Wakivaky is literally **"CREATING VALUE FROM WASTE"**, as the main source of material for their products are waste materials, such as the car industry or the furniture industry. All products are made from materials that may have ended up in landfill, so it helps not only in reducing the amount of waste but also CO_2. Furthermore, the waste that is produced is recycled and used, for example, to produce packaging for products or as a filling for products (Hatchai). Wakivaky is trying to spread this whole philosophy through education in the form of workshops for companies or in the form of lectures at various events. Their products and all resources, including material, are of local origin, with people from different social and age groups involved in its production, so Wakivaky is trying to support people from disadvantaged groups. They can also support companies by processing their waste materials, e.g. advertising banners, and develop tailor-made offers to help them utilize their waste management and at the same time support them in their commitment to sustainability (ESG).

Wakivaky uses such raw materials from which it is possible to produce adequate products of their focus (bags, sacks, seating, coolers, notebook covers, and other products). They also evaluate the quality of the waste material into groups and accordingly divide the materials into specific products and parts of products so that they can guarantee the quality of the final products. These are mostly leather or leather scraps, PVC material, but also different types of fabrics, e.g. from tents, or straps that used to be used as seat belts in cars. There are no limits to creativity, but the material should not be dirty and should be safe for health.

All these secondary raw materials (more than 90% of our products are secondary raw materials, the rest are essential haberdashery) mainly come from automotive, furniture, or textile industries but also from company sources (e.g. advertising media).

From the Wakivaky point of view, the problem in the processing of secondary raw materials may be damage to material from which it is no longer possible to produce a product of adequate quality, pollution which cannot be removed, or odour (e.g. from the materials used and from the floors).

Wakivaky believes, that increased attention in the car industry in the context of the circular economy should in particular be on the creation of a system and an obligation to treat waste materials, which generate a high percentage in this industry. As manufacturers are not obliged to do so, the incentives themselves and the reduction of burdens in the form of waste are not sufficient. The capacity of producers or suppliers is severely limited and they are therefore dependent on cooperation with other actors in finding solutions to eliminate these high-quality materials.

Wakivaky is taking materials mainly from nearby sites to maintain CO_2 reduction and gradually expanding the collection according to the planned locations of the production workshops. The forms of cooperation are different. The main philosophy of the company is to absolutely minimize waste, so they are looking for ways to streamline the processes to achieve these objectives. An example is a possibility for customers to send a product that is already at the end of its life. Wakivaky will "dismantle" such a product and use it in production for further production, as well as the waste they generate, for example as a filling in Hatchai's seating product. In the manufacturing process, which is based on recycled

material, the material to be further recycled represents about 30% of the total material used in production.

Moreover, Wakivaky has case studies on the table for further treatment of waste recoverable in the energy or construction industries, which is a very topical issue. They see great potential in this area. The company is also working on creating processes for the so-called basic cell, which can be further expanded by franchising in neighbouring countries while maintaining the same principles. They also have other concepts in the pipeline that can be used, for example, to certify products or companies that meet sustainability standards.

5.2.8 ZF Slovakia

ZF is one of the largest employers and suppliers of the automotive industry in Slovakia. The ZF Group has a history of more than 30 years in Slovakia, with the first plant established in Trnava in 1993. The ZF Group is growing dynamically in Slovakia, and currently employs around 4,100 people [127].

Circular economy is an integral part of achieving our climate goals and decoupling resource consumption from growth.

For ZF Slovakia, the circular economy is a systematic approach in which we use fewer resources for longer and multiple times. Using recycled materials is one key to CO_2 reduction. We are already making an important contribution to resource conservation by constantly increasing the proportion of recycled materials in our products. For example, most of the aluminum housings we use are currently made of recycled aluminum. Its carbon footprint is only 25 percent of that of primary aluminum.[128]

The company ZF Slovakia a.s. declares the values of the circular economy. It is based on the fact that the generated waste is further recycled, or otherwise valued, as far as possible.

In 2020, the company ZF Slovakia a.s. held a tender for waste management companies focused on waste recovery and recycling in addition to a suitable price.

If possible, waste from production is recycled or otherwise evaluated.

Waste from production is subsequently used equally as secondary raw material in industrial production.

The objectives of the ZF Slovakia a.s. also focus on the quality of the production. Therefore the effort of the company is to reduce the wear and tear of our products.

The development department of the company develops new components for cars, focusing on extending these products' life cycle.

In the production process are used secondary raw materials such as paper, wood, and plastics.

The ratio of secondary raw materials in the production process of the company is approximately 30%.

The company ZF Slovakia a.s. has an effort to expand the development department with new people to focus even more on extending the life cycle of their car components.

The percentage of recyclability on average is around 90%.

The company introduces the home office wherever possible to a greater extent, participating in the "Bike to work" campaign, company-wide leaflet promotion of energy saving, and proper waste separation.

ZF Slovakia a.s. needs to follow modern trends in the company that will take them further in the field of circular economy and sustainability.[129]

5.2.9 Key conclusions regarding the automotive industry powered by the circular economy

This global scan of best circular economy practices in the automotive manufacturing sector reveals that many firms and operations are already implementing a wide range of practices that support circular economy objectives and strategies, whether or not these practices have been explicitly identified as circular. However, more wide-spread adoption of such strategies and practices will be key to reducing the sector's resource consumption and greenhouse emissions, and to recovering valuable precious metals and materials at the end-of-life of vehicles.

In case of the current state of use of circular economy aspects in the automotive industry in Slovakia, our initial findings are as follows: (1) In the area of the circular economy in Slovakia we have observed growing environmental awareness in private sector and the consequent willingness to accept relevant measures. The perception of the circular economy between Slovak automotive producers has increased with necessary transition to sustainable economy; (2) In case of practical approaches of circular economy incorporated by Slovak automotive producers, we have selected examples of the main automotive producers in Slovakia (Volkswagen Slovakia, PSA Slovakia, KIA Slovakia), as well as companies across value chain (Cyrkl, STERED, Fauerecia, Wakivaky and ZF Slovakia). VW SK is committed to cover the entire life cycle of a vehicle, and added that by 2025, the company aims to reduce the environmental burden by 45% per vehicle, compared with 2010. Kia Motors join forces to achieve a circular economy of electric vehicle (EV) batteries and reduce CO2 through reuse or recycling of batteries after use. Also PSA Slovakia is taking circular economy and sustainability seriously, the main aims in the area of circular economy are: waste treatment at the plant, reducing the amount of waste, waste disposal and increasing of environmental awareness of employees. The circular economy is perceived not only by main automotive producers in Slovakia, but also by small and medium enterprises that have developed innovative products or offer innovative solutions based on circular economy principles. Companies across value chain, have developed a unique and innovative technologies, as for processing the textile material and use it in the production of new products (PR Krajné), as well have processed of plastics originating from discarded electrical equipment, technological waste and plastics from the automotive industry (ELEKTRO RECYCLING).

In context of circular economy we have found out, Slovakia perceives prospective transition to automotive electrics industry, the introduction of new ones progressive technologies and sophisticated production.

5.3 CIRCULAR ECONOMY IN SERBIA

The Circular Economy Development Programme in the Republic of Serbia for the period 2022 to 2024 was adopted, as a complex and comprehensive document that defines the areas of waste management, water, renewable energy sources and energy efficiency, as well as the priorities for the next three years, and also lays the foundation for the further development of the circular economy and the creation of a stimulating environment for the development of the green transition in Serbia. In this way, it will be possible to further contribute to sustainable development and climate neutrality in order to preserve people's health and raise citizens' awareness of the importance of environmental protection [130].

ROADMAP for circular economy in Serbia [131]: In the 2017 Programme of the Government of the Republic of Serbia, it is said that environmental development will unfold in line with the principles of circular economy applied to the infrastructure projects. Transition to circular economy will keep highlighting the necessity to change the business model of the national industry by promoting eco-sustainable operations. This means introducing and using standards in production process and eco-design, and promoting the new eco-friendly materials and technologies – all in the context of the new market “demands” and needs. However, transition to circular economy must be recognized as a priority strategic goal that shall guide the development of the Republic of Serbia. In addition, it is necessary to harmonize the public policies of the Republic of Serbia and develop indicators modelled after the EU ones, in order to allow the qualitative and quantitative monitoring of the transition process.

5.3.1 Car industry in SERBIA

In recent years, the car industry in Serbia has experienced significant growth and development, positioning itself as a prominent player in the region. The country has successfully attracted numerous international car manufacturers, leading to the establishment of manufacturing plants and increased investments in the sector [132, 133]. This, in turn, has had a positive impact on Serbia's economy, job market, and technological advancements [134].

One of the major contributors to Serbia's car industry is the Fiat Chrysler Automobiles (FCA) Group. FCA operates a production plant in Kragujevac, Serbia, where they manufacture the Fiat 500L model. Since its inception in 2012, the FCA plant in Kragujevac has witnessed a remarkable increase in production and export volumes, significantly bolstering Serbia's position in the global automotive market.

In addition to FCA, there are several car parts manufacturers operating in Serbia (listed are only the most notable examples):

1. **Bosch Serbia**, a division of the globally renowned technology and services supplier Bosch, operates manufacturing facilities in various cities across Serbia, such as Pecinci and Subotica. Specializing in the production of automotive components and systems, Bosch Serbia offers a diverse range of products, including electrical systems, sensors, and automotive electronics.

2. **Brose Serbia**, a branch of the internationally renowned automotive supplier Brose Group, is situated in Pancevo, Serbia. At its manufacturing plant, Brose Serbia focuses on the production of automotive mechatronic systems and electric drives designed for a diverse range of vehicle applications. Among the notable components in its product portfolio are door systems, seat structures, and electric drives for window regulators
3. **ZF Serbia**, a subsidiary of ZF Friedrichshafen AG, is situated in Serbia and serves as a manufacturing and development hub for automotive components and systems. ZF Friedrichshafen AG is a renowned global technology company that specializes in driveline and chassis technology, as well as active and passive safety technology. ZF Serbia's product range encompasses a diverse array of automotive components, including transmissions, clutches, axle drives, and steering systems, among others.
4. **Magna Seating**, a division of Magna International, is a leading automotive seating supplier. They have a manufacturing facility in Odzaci, Serbia, where they produce a range of seating systems for various automotive brands.
5. **Leoni Wiring Systems** is a global provider of wiring systems and electrical components for the automotive industry. They have a production facility in Prokuplje, Serbia, where they manufacture automotive cables and wiring harnesses.
6. **Draexlmaier** is a German automotive supplier specializing in interior components and electrical systems. They have a production plant in Zrenjanin, Serbia, where they manufacture various automotive interior components, including instrument panels, door panels, and center consoles.
7. **Cooper Standard** is a leading global supplier of automotive sealing systems and fluid handling solutions. They have a manufacturing facility in Sremska Mitrovica, Serbia, where they produce rubber and plastic components, such as seals, hoses, and fluid handling systems.

These are just a few examples of car parts manufacturers in Serbia. The country has attracted various international automotive suppliers due to its strategic location, favorable business environment, and skilled workforce. The presence of these manufacturers contributes to the growth of the automotive industry in Serbia and strengthens its position as a key player in the European automotive supply chain. The Serbian government has been actively pursuing policies aimed at attracting foreign investment in the car industry. These policies encompass various incentives, tax breaks, and the development of specialized economic zones, all of which foster a favourable business environment for car manufacturers. The government's commitment to establishing a supportive ecosystem has resulted in increased foreign direct investment and the establishment of new manufacturing facilities. Furthermore, Serbia benefits from its advantageous location and favourable trade agreements. Its proximity to key European markets allows for efficient transportation and access to a vast consumer base. Serbia's membership in the Central European Free Trade Agreement (CEFTA) and its continuous efforts to align with European Union standards have facilitated trade and export opportunities for the car industry.

The growth of the car industry has made a significant impact on Serbia's economy. The sector has emerged as one of the leading contributors to the country's gross domestic product (GDP) and export revenues. The increased production and export volumes of vehicles and automotive components have played a vital role in boosting Serbia's economic performance and generating numerous employment opportunities for the local workforce. Moreover, the development of the car industry has stimulated technological advancements and innovation in Serbia. Collaborative partnerships between international car manufacturers and local suppliers have facilitated the transfer of knowledge and expertise in areas such as advanced manufacturing processes, research and development, and electric vehicle technologies. This exchange of knowledge has contributed to the cultivation of a skilled labor force and the promotion of an innovative culture within the automotive sector. Nevertheless, the car industry in Serbia faces certain challenges. One of the primary hurdles is the need for further investments in research and development to stay abreast of global automotive trends. As the industry shifts toward electric and autonomous vehicles, it is crucial for Serbian car manufacturers and suppliers to invest in advanced technologies to remain competitive in the market. Additionally, the industry must address infrastructure and logistics challenges. Enhancing road networks, transportation systems, and supply chain efficiency will boost the competitiveness of Serbia's car industry, attracting more investment and fostering sustainable growth. Collaborative efforts between the government and industry stakeholders are crucial in addressing these challenges and ensuring the sector's long-term success.

Looking ahead, the future prospects for the car industry in Serbia appear promising. The country's strategic location, favorable trade agreements, and supportive government policies continue to attract foreign direct investment. The expansion of manufacturing capacities, advancements in technology, and the growing emphasis on electric mobility present new opportunities for Serbian car manufacturers.

5.3.2 Bosch Serbia

Bosch, a well-known global supplier of automotive components, has established its presence in Serbia with manufacturing facilities located in various cities, including Pecinci and Subotica. In Serbia, Bosch is a key player in the automotive industry, focusing on the production of a diverse range of high-quality automotive components and systems. Operating with advanced technologies and adhering to rigorous quality standards, Bosch Serbia manufactures a wide array of automotive products, including electrical systems, sensors, and automotive electronics. These components are integral to the optimal functioning, safety, and comfort of modern vehicles [135].

Bosch Serbia's story commenced in 1991 when Bosch Group recognized the untapped potential of the Serbian market and decided to establish its presence in the country. Since then, Bosch Serbia has witnessed remarkable growth, emerging as a prominent player in the Serbian economy and a trusted provider of cutting-edge solutions across diverse sectors. Bosch Serbia boasts a diverse range of operations encompassing various business sectors, including Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and

Building Technology. This diversification empowers Bosch Serbia to cater to a wide array of customer needs and contribute to the advancement of numerous industries in Serbia.

At the heart of Bosch Serbia's operations lie its state-of-the-art manufacturing facilities, adhering to the highest industry standards. These facilities enable the production of a wide range of top-quality products, spanning automotive components, power tools, security systems, and household appliances. Bosch Serbia's unwavering commitment to excellence and precision manufacturing has established its reputation as a reliable provider of innovative solutions. Moreover, Bosch Serbia places immense emphasis on research and development (R&D). The company has established dedicated R&D centers equipped with cutting-edge technologies and staffed by highly skilled engineers and researchers. Through continuous innovation and technological advancements, Bosch Serbia strives to address emerging challenges, meet evolving market demands, and develop sustainable solutions for the future [136].

The manufacturing plants in Pecinci and Subotica showcase Bosch's commitment to innovation, research, and development, enabling the company to remain at the forefront of automotive technology. Bosch Serbia's unwavering dedication to continuous improvement and customer satisfaction has earned it a strong reputation within the automotive industry.

The presence of Bosch in Serbia has significant economic benefits, generating employment opportunities and contributing to the development of a skilled workforce. Additionally, the company's operations strengthen the automotive supply chain within the country, attracting other related businesses and fostering collaboration among industry stakeholders. In line with its commitment to sustainability, Bosch Serbia implements energy-efficient technologies and adopts effective waste management systems to minimize its environmental footprint. By prioritizing sustainable practices, Bosch Serbia aligns with the global movement toward a greener and more sustainable automotive industry. Moreover, Bosch Serbia actively engages in research and development endeavors, collaborating with local universities and institutions. These partnerships facilitate the transfer of knowledge and promote the growth of Serbia's technological capabilities in the automotive sector [137].

Overall, Bosch Serbia plays a pivotal role in the automotive sector, manufacturing essential components and systems for vehicles. Through its commitment to innovation, quality, sustainability, and collaboration, Bosch contributes significantly to the growth and advancement of the automotive industry in Serbia.

Bosch Serbia serves as a prominent example of a company dedicated to embracing circular economy principles. Through holistic waste management, product lifecycle management, resource efficiency, packaging optimization, stakeholder collaboration, and employee engagement, Bosch Serbia demonstrates its commitment to waste reduction, resource optimization, and minimizing environmental impact [138].

By implementing listed initiatives and sharing best practices, Bosch Serbia not only contributes to the circular economy within its operations but also inspires and influences other companies and stakeholders in Serbia to embrace sustainable practices and collectively work towards a more sustainable future [139].

The concept of the circular economy has gained global recognition as a sustainable approach to resource management and waste reduction. As a leading global technology and engineering company, Bosch Serbia has actively embraced circular economy principles across its operations worldwide. The initiatives and best practices of Bosch in Serbia, highlighting their dedication to the circular economy and their efforts to minimize environmental impact are [140, 141, 142]:

1. **HOLISTIC WASTE MANAGEMENT**: Bosch Serbia has implemented a comprehensive waste management system aimed at reducing waste generation and promoting recycling and reuse. Through strategic partnerships with specialized waste management companies, Bosch Serbia ensures proper disposal and recycling of various waste streams, including electronic waste, packaging materials, and

production residues. By efficiently sorting and separating waste, Bosch Serbia maximizes resource recovery and recycling, minimizing the need for raw materials and reducing their ecological footprint.

2. **PRODUCT LIFECYCLE MANAGEMENT:** Bosch Serbia places great importance on prolonging the lifespan of its products through effective product lifecycle management. The company designs products with durability and repairability in mind, making it easy to replace or repair components. In Serbia, Bosch actively encourages product maintenance and repair services, enabling customers to extend the lifespan of their products and avoid unnecessary replacements. By prioritizing product longevity, Bosch Serbia reduces waste generation and aligns with the circular economy principles of reuse and resource optimization.
3. **RESOURCE EFFICIENCY AND ENERGY MANAGEMENT:** Bosch Serbia is committed to enhancing resource efficiency and energy management within its operations. Through continuous improvement initiatives, the company optimizes energy consumption, thereby reducing its environmental impact. By investing in energy-efficient technologies like LED lighting and advanced manufacturing processes, Bosch Serbia minimizes energy usage and greenhouse gas emissions. Moreover, the company closely monitors and analyzes resource consumption, identifying areas for improvement and implementing measures to reduce waste and enhance overall efficiency [143].
4. **PACKAGING OPTIMIZATION**: Recognizing the significance of sustainable packaging, Bosch Serbia actively pursues strategies for packaging optimization. The company employs innovative packaging designs that minimize material usage while ensuring product safety and protection. Bosch Serbia promotes the use of recyclable and biodegradable materials in packaging, contributing to waste reduction and a more circular economy. Additionally, the company collaborates with suppliers to implement responsible packaging practices throughout the supply chain, promoting waste reduction and resource conservation.
5. **STAKEHOLDER COLLABORATION**: Bosch Serbia actively engages in collaborative efforts with stakeholders to advance the circular economy. The company participates in industry forums, partnerships, and initiatives that aim to promote sustainability and circular economy practices. By collaborating with suppliers, customers, government agencies, and other stakeholders, Bosch Serbia works towards shared sustainability goals. This collaborative approach facilitates the exchange of ideas and encourages the adoption of circular economy principles across the industry.
6. **EMPLOYEE ENGAGEMENT AND EDUCATION**: Bosch Serbia recognizes the crucial role of employee engagement and education in driving the circular economy. The company conducts internal awareness campaigns and training programs to educate employees about the importance of sustainability and circular economy principles. By fostering a culture of environmental responsibility and equipping employees with the necessary knowledge and tools, Bosch Serbia encourages active participation in waste reduction, resource optimization, and sustainable practices within the workplace.

5.3.3 Brose Serbia

Brose, a global automotive supplier, has established a manufacturing facility in Pancevo, Serbia. The company specializes in the production of automotive mechatronic systems and electric drives for a wide range of vehicle applications [144].

Brose Serbia's production plant in Pancevo is equipped with advanced technologies and operates with a focus on innovation, quality, and sustainability. The facility encompasses various manufacturing processes, including stamping, injection molding, electronics production, and assembly. Brose Serbia produces components such as door systems, seat structures, and electric drives for window regulators, among others. The establishment of Brose Serbia has brought significant benefits to the automotive industry in Serbia. The company has created numerous job opportunities for the local workforce, contributing to employment growth and economic development in the region. Additionally, Brose Serbia's presence has enhanced the country's expertise in automotive mechatronics and electric mobility solutions [145].

Brose is known for its commitment to sustainability and environmental responsibility. The company incorporates eco-friendly practices in its operations, focusing on energy efficiency, waste reduction, and responsible resource management. By implementing these sustainable practices in their Serbian manufacturing plant, Brose contributes to the circular economy and promotes environmentally conscious manufacturing. Moreover, Brose Serbia's presence strengthens the overall supply chain in the Serbian automotive industry. The company collaborates closely with other car manufacturers and suppliers, fostering technological advancements and knowledge transfer within the sector. This collaboration contributes to the growth and competitiveness of the Serbian automotive industry on a global scale.

Brose Serbia has brought economic benefits, job opportunities, technological advancements, and a focus on sustainability. As a prominent player in the automotive industry, Brose Serbia contributes to the growth and development of the sector in Serbia and reinforces the country's position as an attractive destination for automotive investments [146].

Brose Serbia, a subsidiary of Brose Group, has implemented a range of initiatives and embraced good practices in line with the principles of the circular economy. The company is

committed to sustainability and resource efficiency, and has undertaken various measures to promote these values. Here are some noteworthy examples of the circular economy initiatives and good practices implemented by Brose Serbia:

1. **WASTE MANAGEMENT AND RECYCLING**: Brose Serbia has established effective waste management and recycling systems within its operations. The company emphasizes waste reduction, efficient waste sorting, and the recycling of materials. By optimizing material usage and minimizing waste generation, Brose Serbia actively supports the circular economy's aim of reducing resource consumption and promoting responsible waste management.
2. **PRODUCT DESIGN FOR DURABILITY AND REUSABILITY**: Brose Serbia places a strong emphasis on product design that enhances durability and reusability. The company focuses on developing components and systems with extended lifespans and easy maintenance, promoting the circular economy principle of prolonging product life cycles. This approach helps minimize the need for premature replacements and reduces waste generation.
3. **CLOSED-LOOP MATERIAL RECYCLING**: Brose Serbia actively explores opportunities for closed-loop material recycling. The company aims to incorporate recycled materials into its manufacturing processes, reducing dependence on virgin resources. By collaborating with suppliers and adopting innovative recycling technologies, Brose Serbia contributes to a more sustainable and circular supply chain.
4. **COLLABORATION WITHIN THE SUPPLY CHAIN**: Brose Serbia engages in collaborative efforts with suppliers and partners to foster circularity within the supply chain. By encouraging sustainable sourcing practices and promoting the use of recycled materials, the company aims to create a closed-loop system where materials are reused and recycled, thereby minimizing waste and resource depletion.
5. **EMPLOYEE TRAINING AND AWARENESS**: Brose Serbia recognizes the significance of employee training and awareness in driving circular economy practices. The company invests in training programs and awareness campaigns to educate employees about the principles and benefits of the circular economy. By fostering a culture of sustainability, Brose Serbia encourages its workforce to actively contribute to circular economy initiatives.
6. **CONTINUOUS IMPROVEMENT AND INNOVATION**: Brose Serbia fosters a culture of continuous improvement and innovation to advance circular economy practices. The company consistently seeks opportunities to optimize processes, reduce resource consumption, and develop innovative solutions aligned with circular economy principles. This commitment to innovation enables Brose Serbia to remain at the forefront of sustainable manufacturing practices.

Through these initiatives and good practices, Brose Serbia demonstrates its commitment to integrating circular economy principles into its operations. By promoting waste reduction, resource efficiency, and collaboration throughout its supply chain, the company actively contributes to the transition towards a more sustainable and circular automotive industry.

5.3.4 ZF Serbia

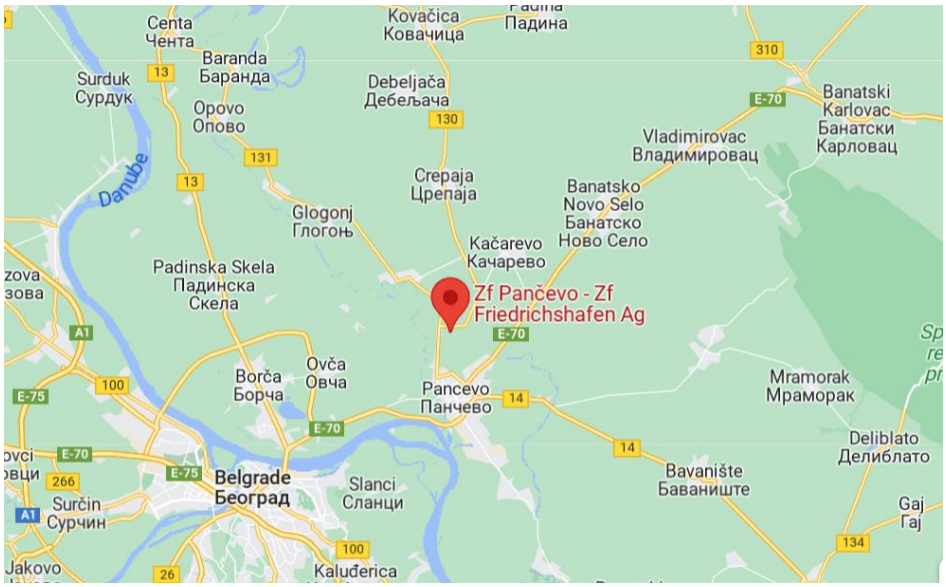
ZF Serbia, a division of ZF Friedrichshafen AG is located in Pancevo (Serbia) and it is a prominent player in the automotive industry, specializing in driveline and chassis technology, as well as active and passive safety systems. With its dedication to innovation, sustainability, and excellence, ZF Serbia has emerged as a significant contributor to the global automotive supply chain. ZF Serbia's origins can be traced back to 1998 when it was established as a joint venture between ZF Friedrichshafen AG and a local partner.

Over the years, the company has experienced substantial growth, expanding its operations and playing a pivotal role in the development of the Serbian automotive industry. Presently, ZF Serbia operates multiple state-of-the-art production facilities and a cutting-edge research and development center, solidifying its position as a leading provider of automotive technology in the region. Leveraging advanced machinery and sophisticated production processes, ZF Serbia possesses a robust manufacturing infrastructure capable of producing a wide array of automotive components and systems. The company specializes in the production of transmissions, clutches, axle drives, steering systems, and other vital automotive components.

Product Portfolio:

- **Transmissions:** ZF Serbia has garnered a strong reputation for its transmission systems, which play a crucial role in transmitting power from the engine to the wheels. The company offers a diverse range of transmission solutions, including manual transmissions, automatic transmissions, and hybrid transmissions. Renowned for their reliability, efficiency, and seamless shifting performance, ZF Serbia's transmissions are highly regarded in the industry.
- **Clutches:** ZF Serbia excels in the production of high-quality clutches, which are essential for transferring torque between the engine and the transmission. The company provides a comprehensive range of clutches, including single-plate, multi-plate, and dual-mass flywheel clutches. These clutches are meticulously designed to ensure smooth engagement, precise control, and enhanced drivability.
- **Axle Drives**: ZF Serbia manufactures axle drive systems that facilitate the transfer of power from the transmission to the vehicle's wheels. These systems encompass drive axles, differential units, and constant velocity joints (CVJs). ZF Serbia's axle drives are engineered to deliver excellent traction, stability, and durability, contributing significantly to overall vehicle performance and safety.
- **Steering Systems:** ZF Serbia's expertise extends to steering systems, which are crucial for vehicle manoeuvrability and control. The company produces hydraulic power steering systems, electric power steering systems, and related components. These systems offer precise steering response, improved fuel efficiency, and advanced driver-assistance features, enhancing both driver comfort and safety.

ZF Serbia is deeply committed to sustainability and environmental responsibility, striving to minimize its ecological impact. The company adopts various strategies and initiatives to promote resource efficiency, waste reduction, and the utilization of environmentally friendly technologies. ZF Serbia actively seeks opportunities to optimize energy consumption, reduce emissions, and implement responsible waste management practices across its operations. Through these efforts, ZF Serbia contributes to a more sustainable automotive industry and fosters a greener future [147].



Innovation serves as the cornerstone of ZF Serbia's operations, driving continuous improvement and technological advancements. The company's dedicated research and development center in Serbia plays a crucial role in developing cutting-edge automotive technologies and solutions. The center focuses on enhancing existing products, exploring new concepts, and collaborating with global research and development teams within the ZF Group.

ZF Serbia has implemented various initiatives and embraced good practices in line with the principles of the circular economy. As a division of ZF Friedrichshafen AG, the company is dedicated to sustainability and has taken significant steps to promote resource efficiency and minimize waste. Here are some key initiatives and practices that highlight ZF Serbia's commitment to the circular economy [148]:

1. **RESOURCE RECYCLING AND REUSE**: ZF Serbia places great emphasis on recycling and reusing materials within its operations. The company has established efficient waste management systems to maximize recycling rates and reduce the disposal of valuable resources. By reintegrating recycled materials into its manufacturing processes, ZF Serbia reduces the need for new resources and fosters a more circular supply chain.
2. **PRODUCT LIFECYCLE OPTIMIZATION**: ZF Serbia focuses on optimizing the lifecycle of its products to prolong their usefulness. Through the use of durable materials, efficient manufacturing techniques, and stringent quality control, the company ensures that its products have an extended lifespan and require minimal maintenance. By designing products with longevity in mind, ZF Serbia minimizes waste generation and enhances the circularity of its offerings.
3. **REMANUFACTURING AND REPAIR SERVICES**: ZF Serbia recognizes the significance of remanufacturing and repair services in the circular economy. The company actively promotes the refurbishment and repair of its products, enabling their continued use. By providing remanufactured components and repair services, ZF Serbia contributes to waste reduction and resource conservation, while also offering cost-effective solutions to customers.
4. **COLLABORATION AND SUPPLIER ENGAGEMENT**: ZF Serbia actively collaborates with suppliers and partners to encourage circular economy practices across the supply chain. The company advocates for sustainable sourcing, including the utilization of recycled materials and responsible manufacturing methods. Through engagement with suppliers, ZF Serbia aims to create a closed-loop system that maximizes resource efficiency and minimizes environmental impact.
5. **EMPLOYEE TRAINING AND AWARENESS**: ZF Serbia places strong emphasis on employee training and awareness regarding the circular economy. The company invests in educational programs and initiatives to enhance employee understanding of circular economy principles and their role in implementing sustainable practices. By empowering employees with knowledge and fostering a culture of sustainability, ZF Serbia drives positive change within the organization.

6. **CONTINUOUS IMPROVEMENT AND INNOVATION**: ZF Serbia constantly strives for improvement and innovation aligned with circular economy principles. The company actively seeks opportunities to optimize processes, reduce waste, and develop innovative solutions that enhance resource efficiency. By embracing new technologies and approaches, ZF Serbia remains at the forefront of sustainable manufacturing practices.

Through these initiatives and practices, ZF Serbia showcases its dedication to integrating circular economy principles into its operations. By promoting resource recycling, optimizing product lifecycles, collaborating with suppliers, and fostering employee awareness, the company actively contributes to a more sustainable and circular automotive industry.

5.3.5 Key conclusions regarding the automotive industry powered by the circular economy in Serbia

The automotive industry in Serbia is embracing the principles of the circular economy, demonstrating a commitment to sustainable practices and reaping numerous benefits. The adoption of circular economy principles has led to improved resource efficiency, reduced waste generation, and increased economic opportunities [149]. Here are the key conclusions regarding the automotive industry powered by the circular economy in Serbia [150, 151, 152]:

- ☑ **ECONOMIC ADVANCEMENTS AND COMPETITIVENESS**: The integration of circular economy principles within Serbia's automotive industry has propelled economic growth and enhanced its competitiveness on the global stage. By prioritizing resource efficiency and sustainable practices, Serbian automotive companies have achieved cost-effectiveness, attracted foreign investments, and created new employment opportunities [153].
- ☑ **SUSTAINABLE RESOURCE MANAGEMENT**: The circular economy approach has enabled the automotive industry in Serbia to adopt more sustainable resource management practices. Through initiatives like recycling, remanufacturing, and waste reduction, companies have reduced their reliance on new materials, thereby lessening the environmental impact associated with resource extraction and disposal [154, 155, 156, 157].
- ☑ **VALUE CREATION AND INNOVATION**: The circular economy has stimulated value creation and fostered innovation within Serbia's automotive industry. Companies are embracing new business models, such as product-as-a-service, which emphasize extending product lifecycles, repairability, and reuse. This transition towards a circular approach has spurred innovation in product design, manufacturing processes, and supply chain management.
- ☑ **COLLABORATION AND PARTNERSHIPS**: The circular economy has promoted collaboration and partnerships among diverse stakeholders in Serbia's automotive industry. Companies are joining forces with suppliers, customers, and other industry players to establish closed-loop systems, optimize resource flows, and enhance overall value chain efficiency. This collaboration encourages the exchange of knowledge, technological advancements, and the sharing of best practices [158].
- ☑ **ENVIRONMENTAL SUSTAINABILITY**: The circular economy within Serbia's automotive industry is actively contributing to environmental sustainability by

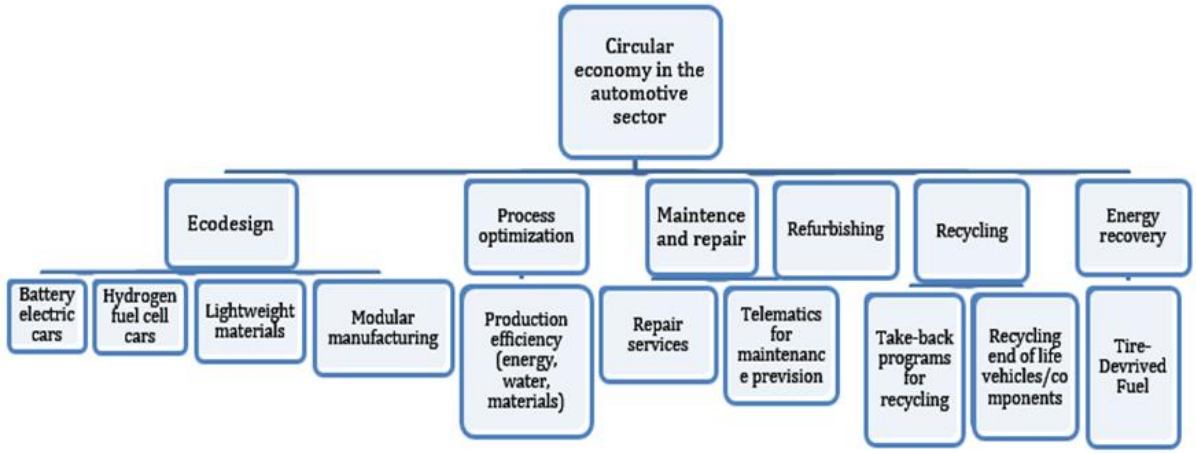
reducing waste, energy consumption, and greenhouse gas emissions. Through initiatives like eco-design, product remanufacturing, and waste recycling, companies are minimizing their environmental footprint and supporting Serbia's commitment to environmental preservation.

- ☑ **REGULATORY FRAMEWORK AND GOVERNMENT SUPPORT**: The Serbian government has played a pivotal role in supporting the circular economy within the automotive industry by implementing favorable policies, regulations, and incentives. The government's dedication to sustainability, coupled with supportive measures, has created an enabling environment for companies to embrace circular practices and drive the transition towards a more sustainable automotive sector [159].
- ☑ **CONSUMER DEMAND AND SOCIAL RESPONSIBILITY**: The circular economy aligns with the increasing consumer demand for sustainable products and services. Serbian consumers are becoming more conscious of the environmental impact of their choices and actively seek products that are produced sustainably, have extended lifecycles, and can be easily repaired or recycled. By embracing circular practices, the automotive industry in Serbia can meet these demands and showcase its commitment to social and environmental responsibility [160].

In conclusion, the automotive industry in Serbia recognizes the potential and benefits of the circular economy. Through the adoption of circular principles, Serbian automotive companies are promoting sustainable resource management, fostering innovation, and contributing to economic growth while reducing their environmental impact. With ongoing government support, stakeholder collaboration, and a focus on consumer demands, Serbia's automotive industry is well-positioned to further embrace the circular economy and contribute to a more sustainable future.

5.4 CIRCULAR ECONOMY OPPORTUNITIES IN HUNGARY

The automotive sector uses a tremendous amount of resources and nowadays, this sector needs to reduce its resource consumption. The figure below presents the circular economy scheme in the automotive sector. Ecodesign reduces consumption for example battery powered cars or using lightweight materials. Process optimization techniques use data and analytics to detect and predict manufacturing flaws to help decreasing the sector's consumption and to create a sustainable supply chains. Extending the life of products is another way to reduce resource use. Car parts removed during servicing can also be repaired and the parts can be sold as remanufactured parts or recycled for use in new applications. Finally, if the car parts for example tires are not useable, companies around the world are using tires from automotive origin to produce tire-derived fuels.



5-3. Figure_ The circular economy scheme in the automotive sector

The transition to a circular economy will be a main pillar of Hungary's Recovery and Resilience Plan with an estimated net budget of EUR 590 million available for two priority areas. EUR 343 million will be devoted to the improvement of the waste management infrastructure, including collection, transportation and sorting capacities. The other area will focus on the development of a smart, innovative and sustainable industry, and the strengthening of the secondary raw material market with an investment of EUR 247 million.

Priority areas when it comes to circular economy opportunities: the Automative battery market, Buildings & Infrastructure, Waste management & Recycling, and Bio-waste Utilization [161, 162]

AUTOMOTIVE BATTERY MARKET The automotive industry is the backbone of the Hungarian economy and the current trends show that the country will play a key role in the emerging EU (and global) battery market. Within the CEE region, preparations for the production of EVs are progressing at the fastest pace in Hungary. Significant electric powertrain-focused developments have been announced by foreign companies that are preparing to invest over EUR 4 billion in the coming years. Due to the current trends of e-mobility uptake and the EU's strengthening battery collection regulations, the battery

industry has significant potential for recycling and reuse. In Hungary, only a few players have competencies for battery component recycling, and several companies export their battery waste for recycling. The same lack of competences apply to services for EV battery reuse. That creates significant opportunities for new businesses, OEMs, utilities and specialized start-ups.

5.4.1 Hungarian good practices in detail

5.4.1.1 Good practices at Kresz & Fiedler Kft.

The 100% Hungarian-owned company profile is plastic injection moulding, which was later supplemented with tool design and production and assembly.

CAD/CAM-based technology is used in tool making, thank to this technology the injection moulding, pressure casting, vacuum and deep drawing tools are made with reliable dimensional accuracy. Kresz & Fiedler Kft., thanks to its own designed tool production and automated production, always successfully undertakes quality-assured, complex component production with guaranteed dimensional accuracy.

5-4. Figure_ Factory Building of Kresz & Fiedler Kft.

[Source: https://www.kresz.hu/hu/fooldal/]

Kresz & Fiedler Kft. operates an integrated quality and environmental management system documented and certified according to ISO 9001 and 14001 standards. Plastic crates are used instead of cardboard boxes for intermediate production processes, material handling, handling and storage of semi-finished products. Kresz & Fiedler discussed with their partners the possibility of using multi-way packaging.

In order to handle oily rags and absorbent mats, the company has entered into a contract with a textile handling company, who will carry out their removal and cleaning professionally. The use of the company management system reduces the amount of paper used.

In the case of scrap production, they strive to recover and reuse metal waste. The tool operation department can therefore create a back-up device. In case of poor quality pad printing, the pad printed parts are washed and painted again.

The waste collection is carried out in a selective manner, in the tool plant a device was also made to help compress plastic bottles. The employees collect the plastic caps for charity, and there is also a designated collection place in the office for used batteries.

A grinder was installed next to the injection-moulding machine for the waste generated during production, so the waste and the residue generated during production are ground back and reused immediately.

Where the customer requests a proposal for a raw material, the most suitable material for the purpose of use is suggested, e.g. glass fiber content against breakage, and UV resistant in the case of parts exposed to sunlight, thereby increasing the life of the products.

Kresz & Fiedler Kft. actively participates in research and development related to recycled raw materials (plastic, wood), so-called re-granulates. In order to facilitate sample production and testing, the company also provides the injection moulding machine, the specialist (technologist) and the know-how. Together with their suitcase-manufacturing partner from Szekszárd, they are testing a plastic material containing wood fibres. The proportion of secondary raw materials used is 20% of the total material requirements.

Thanks to continuous technological upgrades, the company strives to acquire more and more energy-saving machines. Automation (automated production, automatic assembly equipment) and robotization (robot arms, engus removal arms) contribute to increased productivity. Hybrid cars are used for transportation and the employees' bus tickets are 100% reimbursed, promoting lower emissions.

In case of a customer's request to help the transition to a circular economy and sustainability, they undertake the repair and renovation of parts, and provide spare parts for longer than the legal requirement.

5.4.1.2 Good practices in Honsa Kft.

Honsa Kft. was founded in 1999 by the German Koller group. In the past two decades, Honsa Kft. has grown into the leading international car parts manufacturing company not only in Pécs and Hungary, but also in the world.

They produce luggage compartment covers and hat racks, and are direct suppliers to major car brands such as Volkswagen, Audi, Jaguar, Land Rover, Seat and BMW.

For transport within the factory, reusable material storage boxes and pallets are used for packaging materials. This significantly reduces the use of wrapping paper and wrapping film. In addition, rotating packaging materials that can be used several times are also used for deliveries outside the factory, based on an agreement with customers.

In order to prevent the production of waste, the company recycles paper, packaging material, wood, metal and foil. The generated waste is collected selectively and transported anyway. Currently, they are working on optimizing the carpet waste and the carrier frames produced during pressing, and in addition, the resulting waste is also recycled.

The generated metal waste is used by the metal industry, while the generated wood waste is used for energy production by the power plant.

5-5. Figure_ Factory of the Honsa Kft.
[Source: https://www.honsa.hu/rolunk/bemutatkozas]

Another good practice is that PET bottles are used as a secondary raw material for the production of carpets.

Currently, there is a 55 kW solar park on the company's premises, but further development is also planned, as their use of electrical energy is very significant.

In April 2023, they participated in the Recycling active exhibition in Karlsruhe, where they were seeking for new impulses and solutions, so that the current unsolved problems (carpet waste, pressed product waste and paper waste contaminated with glass fibres) can also be solved.

5.4.1.3 Good practices at Harman Hungary

Harman designs and manufactures a wide range of technical solutions for the automotive, consumer electronics and other companies worldwide.

5-6. Figure_ Harman Pécs
[Source: https://madeinpecs.hu/lokal/tovabb-bovit-a-harman]

The company considers the sustainability as a principle of its daily operation. There is a separate company policy dedicated to working, energy and environmental protection. The main area of interest in waste reduction is packaging materials. In many cases multi-way packages are used: in case of TIER2 suppliers (eg. for assembled printed circuit boards) reusable wrapping packaging is used, between the two manufacturing sites in Hungary internal rotating materials are used. Beside these it is under investigation what else could be also reused, like IC-trays, ESD bags, one-way pallets. Above the local measures, the Lifestyle division of the company initiated global actions as well to reduce waste generation. Most of the internally rejected end or intermediate products are repaired instead of scrapping if this is in line with the customer's regulations.

The rate of the recycled materials is 99% in case of the company's products. This is partly recycling of raw materials (87%) and partly utilization for energy production (in the cement factory of Beremend). There is an internal rework workshop for series repairs and modifications where all necessary work can be carried out professionally (eg. software updates). The company has a service centre in Germany where certain segments of the product portfolio are repaired but it is the responsibility of the car manufacturers who are in direct contact with end-users to maintain service background. This is usually done by providing replacement parts for which the necessary buffer is maintained by Harman even years after the production is finished.

The requirements of the automotive industry results in over-calculated lifetime for all parts assembled in a car. This is evaluated by aging tests (temperature cycling tests) which assure that the parts assembled in a car have longer lifetime than the car itself. Primarily in the case of metal components, there is an internal expectation for the use of secondary raw materials. Manufacturers of steel and aluminium housings are required to produce components with a 70% recycled raw material usage ratio.

During the design of the products, the ease of disassembly is taken into consideration, which facilitates recycling at the end of the products' lifespan. At the end of the products' lifespan, it is the responsibility of the final equipment manufacturer (car manufacturer) to recycle the products, but in the case of products supplied by the company, this can - based on estimates - reach up to 90%.

The company rents the Pécs site, but in collaboration with the lessor, they have implemented several energy-saving developments in recent years, such as replacing the air-handling unit, switching to LED lighting, launching an on-site nitrogen production facility, and replacing compressors. In addition, the modernization of the office building's insulation is currently in progress. The company has organized bus services to facilitate the commuting of rural workers, which they plan to expand further in the future. In 2022, they launched a campaign to promote cycling to work, in which valuable gifts were awarded to employees who had proven to have cycled to and from work 20 times.

In case of the purchase of new machines and equipment it is important to find as energy efficient solution as possible.

5.4.1.4 Good practices at Seres Kft.

Seres Kft. is a 100% Hungarian-owned enterprise. The company deals with the production of municipal vehicle superstructures, as well as hydraulics and machine service activities. They have a company management system in accordance with ISO 14001, which aims to minimize the amount of waste generated during production, collect waste selectively, and ensure its proper storage and disposal. They strive to cover as much of their energy consumption as possible with renewable energy sources.

During the cutting of metal materials, the remaining scraps are stored by size and used for further cutting to make smaller parts. The oily rags produced during the manufacturing of hydraulic equipment are also stored and classified according to usability, with only completely worn-out ones being discarded. Leftover electrical materials are also stored systematically and reused until their handling remains reasonable (such as 5-10 meter cable pieces and protective tubes). The metal waste is transported to the steel industry as raw material. The oily rags, used hydraulic oil, and chemical waste generated during painting are transported as hazardous materials. The paper waste is compressed, baled, and transported as raw material for the paper industry.

During the mandatory service checks for vehicles, the list of parts requiring inspection and preventative maintenance is regularly reviewed based on operational and warranty experience. When designing vehicle structures, serviceability is an important consideration to facilitate the replacement of even the smallest components. The service background of electronic units is resolved by a partner, so even malfunctioning electronic devices are repaired rather than replaced as long as possible.

They do not use secondary raw materials directly, only indirectly, in the form of secondary raw materials used in the production of metal raw materials. The most significant part of the weight of the manufactured vehicle structures consists of steel structures, which can be used as raw materials by the metal industry. The dismantling of non-metal components from the metal structures is relatively simple due to the well-thought-out, service-friendly design.

The production halls and office buildings have solar panels installed on the premises to supply electricity. They have switched to LED lamps to make lighting more cost-effective. Heating has been modernized with boiler replacement and the use of solar collectors. They have improved the energy efficiency of the buildings by replacing the windows, insulating the walls, and renovating the roof. They continuously collect data on malfunctions and service needs that occur during the life cycle of vehicles, and based on this, they review preventive maintenance, as well as modify plans and production. They are constantly striving for the most economical use of raw materials and energy.

5.4.1.5 Good practices at Kontakt – Elektro Kft.

Kontakt – Elektro Kft. founded in 1982. The company is a supplier of well-known industrial companies in the fields of industrial electrical control, automation, electrical and sensor technology. The main strategic area of their activities is the design, manufacture and on-site

installation of devices and equipment required for the electrical automation of industrial facilities and equipment.

5-7. Figure_ Kontakt Elektro Kft.'s headquarter, Pécs
[Source: https://www.kontakt-elektro.hu/magunkrol/]

The company's creed includes minimizing the environmental impact of its activities. In addition to being a social interest, this is also often a well-considered financial interest of the company, as it usually correlates with a more energy-efficient and resource-saving material management and operation, resulting in a favourable environmental impact. The packaging materials are reused if they are not damaged and provide adequate protection for the packaged product. Some of the cardboard boxes from suppliers are kept in their original state after being opened, while others are folded and stored after the adhesives are removed. These are then used to package products to be shipped.

During the cutting of cables to size, the pieces that fall off are saved and used for jobs that require shorter cable lengths. In the case of sheet metal cutting, rational-sized pieces are also saved for later use.

Electronics equipment that is deemed faulty and would be installed in control cabinets is not immediately scrapped, but rather the company tries to repair them first with the help of the internal electronics workshop (if the factory warranty is not applicable). The too small cable scraps that are no longer usable are taken over by a contracted partner where they are ground up and the copper material is made recyclable for the metal processing industry through plastic separation. The already unusable sheet metal scraps are also recycled in the metal processing industry. The paper and cardboard waste is selectively collected and becomes a raw material for the paper industry. As the products are usually high-value control devices, whose replacement is very expensive, most of these devices are regularly refurbished. Therefore, ease of assembly is an important factor. One of the most important aspects during production is the focus on quality, which also increases the lifespan of the

products. Complaints related to defective products are always investigated, and the feedback obtained is incorporated back into the manufacturing process.

The metal sheets and cables are partly made of recycled materials at the suppliers. In case of refurbishing of control cabinets the equipment inside the cabinet which are considered good are reused up in the new cabinet.

A 50kWp solar panel system was installed on the roof of the warehouse. The company modernized its heating/cooling system by installing heat pumps with geothermal ground probes, as well as a solar heat collector for producing hot water. Rainwater is stored in tanks and used for flushing toilets. The paint shop switched to using biodegradable degreasing agents and natural cleaning products (e.g. vinegar) during cleaning.

The company has several service apartments on site for accommodating some of its employees, which reduces the environmental impact caused by commuting. In addition, they are planning to purchase electric company cars.

They have set up an internal energy monitoring system that allows them to track the energy consumption of individual departments, machines, and building sections. Based on this, they have already carried out several optimizations and plan to take further steps.

5.4.2 Brief description of other Hungarian good practices

Mercedes-Benz has been the world's most innovative brand for 130 years. The owners of the brand decided in 2008 to build a factory in Kecskemét, which employs 4,000 people by now, and construction works of a second factory have also begun. In recent years, several developments have been carried out in the factory, primarily taking sustainability aspects into account. Electricity demand has been reduced due to the modernisation of lighting systems and the automatic timed switching of each zone according to needs. The new measures introduced have achieved savings of more than 1000 MWh/year.

At the beginning of 2021, the drying cooling zone for topcoat was rebuilt in the polishing plant. The implementation of this reconstruction saved approximately 1000 MWh of thermal energy per year. The dining room and kitchen ventilation system in the main office building was adjusted to the opening hours, which also saved more than 100 MWh/year.

For the treatment of contaminated material generated in the dry separators of the surface treatment plant, a technology has been found in which the waste can be used in its original state, so its use as a by-product has been approved by the Environmental Protection Authority. As a result, in December 2021, the amount of waste in 2021 was already reduced by 18 tons for saturated limestone flour, which is waste generated during the dry separation of painting technology [163].

Kauffmann Technische Federn is a recognized international expert in the development and production of high-quality technical springs, bent and pressed elements. Multi-way packaging materials are used, which also contain secondary raw materials. Waste from production generated in the factory is sold as secondary raw materials. They are also thinking about solar panel development.

Technoplast Kft. manufactures components. The waste generated from chipping is valued as a secondary raw material. The energy used by the plant is covered by solar panels.

Trocellen manufactures air ducts for the automotive industry. During production, 10-30% waste is generated from the raw material. Heat insulating material is made from the generated wastes.

HAJDU Autotechnika Zrt. is primarily a manufacturer of automotive and other parts produced by sheet metal processing. The waste from production is transported by the contracting partner and sold as secondary raw materials. The factory has its own solar park. Employees get to work with the company's bus.

ACPS Automotive Kft. deals with the production of towbars. Metal shavings formed during production are used as secondary raw materials. If the given product fails the quality control, there are cases when the product is repaired. The company's new factory building will have solar panels. There is selective waste collection throughout the factory. The company helps employees get to work with private buses.

Bebusch Hungária Kft. deals with injection moulding and automation. The remaining plastic from production is sorted into 6 categories and sold as secondary raw materials. They try to use electricity consciously, for each of their machines they measure the current consumption and register the data with the help of a software. The waste heat from one of the machines is used for heating. They are thinking about a solar park because of the high electricity consumption. Employees are taken to work by their own bus service.

The **Salesianer** company deals with work and protective clothing. They also have clothes made from 100% recycled materials. Clothes are cleaned in individual washing machines that use less water.

Büttner Kft. deals with the CNC production of tool steel and aluminium sheets. Steel and aluminium shavings generated during production are collected and sold separately. Part of the energy used for production is provided by solar cells.

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.

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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