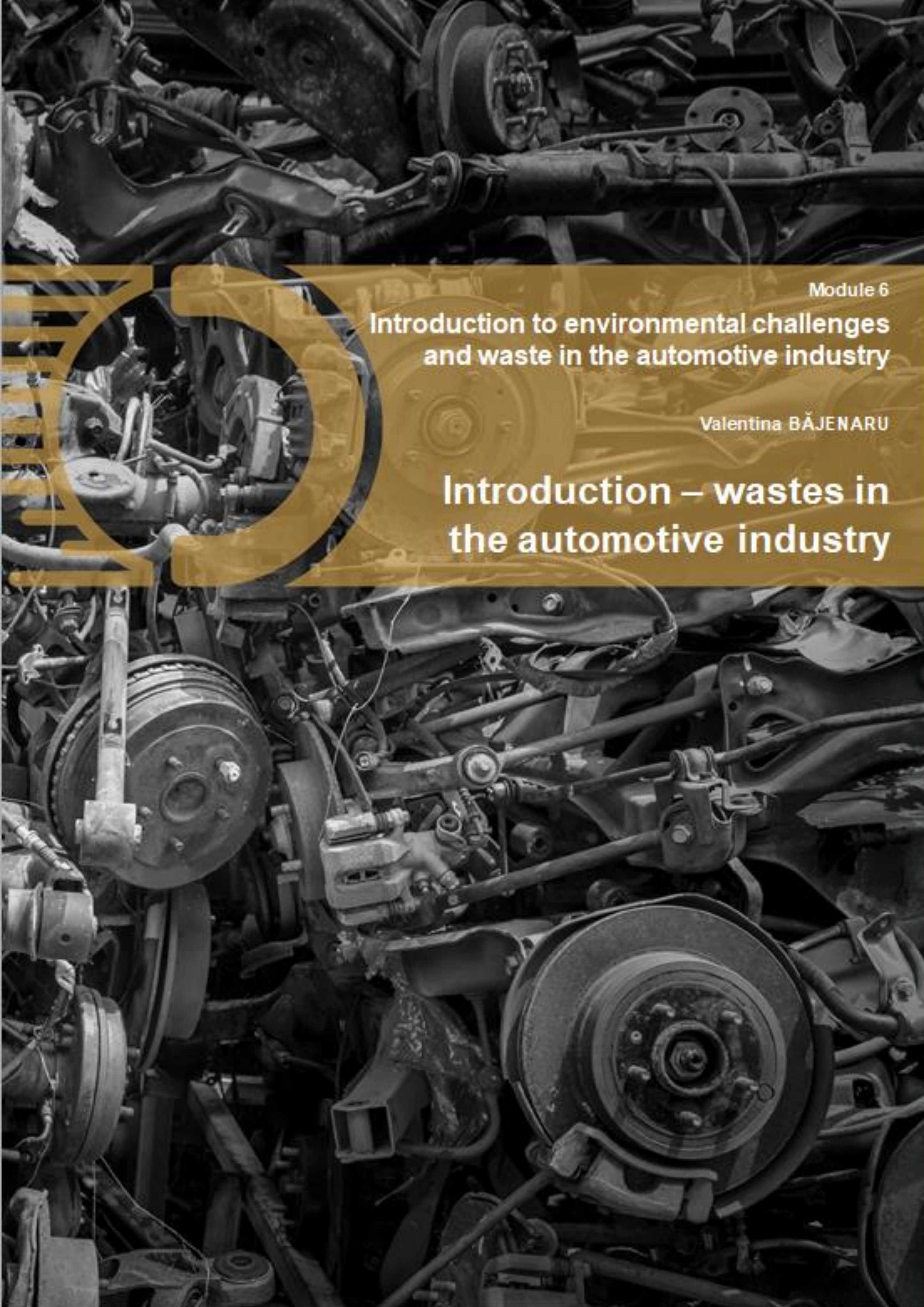

Module 6

Introduction to environmental challenges and waste in the automotive industry

Valentina BĂJENARU

Introduction – wastes in the automotive industry

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DEFINITIONS

In the work on **WASTE FROM THE AUTOMOBILE INDUSTRY**, the following definitions will be used according to GEO no. 78/2000, approved with amendments and additions by Law no. 426/2001:

Vehicle – any vehicle belonging to categories M or N, as well as 3-wheeled vehicles, as defined by Order of the Minister of Public Works, Transport and Housing no. 211/2003, with the exception of motorcycles;

ELV – End of Life Vehicle, become waste;

OEM – original equipment manufacturer, auto parts that are then assembled and installed during the construction of a new vehicle;

Aftermarket parts – are non-OEM auto parts that can successfully replace original parts after the car leaves the factory;

Manufacturer – the vehicle manufacturer or the professional importer of a vehicle;

Individual manufacturer – natural or legal person who produces or imports vehicles, but who does not carry out this activity professionally;

Waste – any substance or object that the owner throws away or has the intention or obligation to throw away;

Hazardous waste– any waste that presents one or more of the hazardous properties listed in annex no. 4 (GEO 92/2021);

Waste generator – "the holder of waste" = "the producer of the waste or the natural or legal person who is in possession of it";

Waste collector– is the economic agent responsible for "waste collection, but also for preliminary storage for transport to a treatment station" (Law 211/2011, Annex 1). Sanitation companies and specialized collectors for picking up various waste;

Prevention – the measures aimed at reducing the quantity and harmfulness for the environment of end-of-life vehicles, of the materials and substances in their composition;

Treatment – any activity carried out for depollution, dismantling, cutting, shredding, recovery or preparation for the disposal of shredded waste, as well as any other operation carried out regarding the recovery and/or elimination of end-of-life vehicles and behaviors;

Competent authorities – the public authorities for environmental protection, respectively the central public authority for environmental protection, the National Agency for Environmental Protection, the county agencies for environmental protection, the "Danube Delta" Biosphere Reserve Administration, as well as other authorities that, according to the legal powers, ensure the regulation and control of activities in the field of waste management;

Disposal – any operation that is not a recovery operation, even if one of its secondary consequences would be the recovery of substances or energy;

Waste management – the collection, transport, recovery (including sorting) and disposal of waste, including the supervision of these operations and the subsequent maintenance of disposal sites, including actions taken as a trader or broker;

Recycling – any recovery operation through which waste is transformed into products, materials or substances to fulfill their original function or for other purposes. This includes the reprocessing of organic materials, but does not include energy recovery and conversion to use the materials as fuel or for filling operations;

Reuses – any operation by which products or components that have not become waste are used again for the same purpose for which they were designed;

Treatment – recovery or disposal operations, including preparation prior to recovery or disposal;

Recovery – any operation that has as its main result the fact that the waste serves a useful purpose by replacing other materials that would have been used for a certain purpose or the fact that the waste is prepared to be able to serve that purpose, in enterprises or in the economy in general;

Traceability – the characteristic of a system to allow the history, use or location of a waste to be traced through recorded identifications.

1. INTRODUCTION

This course includes the regulated system regarding ***WASTES IN THE AUTOMOTIVE INDUSTRY***, the importance and awareness of the problems that arise when disposing of end-of-life vehicles, which includes the system for their collection, sorting and transport, as well as the treatment, disposal, recovery and recycling of this waste. Thus, the work presents an introduction on waste management and covers the vast majority of waste types from the automotive industry.

The preparation of this handbook involved the collection of data from secondary sources, including publications in scientific journals, reports and websites. Thus, a case study approach was adopted to provide examples of recycling solutions and processes so that analytical thinking can be adopted from the design phase of new automotive equipment.

The manual can be used in all countries where projects on the elimination of waste from the automotive industry have been initiated.

The history of the automotive industry spans a relatively short period of time, but it has seen impressive changes, being the field in which technology penetrated the most easily, changing the life and economic structure of the states participating in the effort.[1]

1.1 Automotive Industry

The automotive industry is an important branch of the economy, which includes those activities involved in the design and construction of automobiles.

The automotive industry is an extremely complex activity, which significantly participates in the formation of the gross domestic product of the countries that have developed such an activity. A significant number of companies active in various fields, such as the design of car models, their production and sales to the consumer, contribute to this effort. Much of this industry is owned by a relatively small number of multinational companies, but in addition to these there are tens of thousands of smaller companies that supply various components used in the assembly of automobiles.

1-1. Figure_ Automotive Industry-assembly [www:Dacia.ro]

Over time, the automotive industry has seen continuous development, with various political, economic and even military crises failing to influence production in a significant way. On the contrary, most of the time these moments coincided with additional efforts to produce cars. This economic reality is based on constant demand, with automobiles having a limited lifespan due to physical and moral wear and tear. Moreover, modern life cannot be thought of without the presence of automobiles that are used in all fields of activity, from production, transportation to entertainment.

1.2 Brief History

Automobile industry started in the late 19th century and turned into an important economic activity in the late 20th century.

The father of the automobile industry is considered to be the German engineer Karl Benz, who in 1885 built the first real automobile, equipping it with an internal combustion engine. The discovery was turned into a successful business, Benz being the owner of the first company in the automotive industry that managed to offer a significant number of automobiles to buyers.

The industry became really visible thanks to another German engineer Gottlieb Daimler, who revolutionized the construction of automobiles by creating engines of small dimensions, but with significant power.

The person who managed to transform the automobile from a luxury object to one intended for the masses was Henry Ford, who introduced the technology of the assembly line of automobiles, which allowed them to be produced in a very short time and at prices much more accessible to the general public. Ford's success spurred numerous businessmen around the world to actively participate in the development of the automobile industry, taking advantage of people's growing appetite for automobiles.

The 20th century was a period of development and diversification of the automotive industry, currently reaching the production of thousands of models, from small cars to impressively large trucks intended for heavy transport.

The industry outlook is equally optimistic, given the new technologies that look set to change the industry, namely electric cars and self-driving cars.

Automotive Industry in Romania

The automotive industry in Romania has an appreciable history, in the almost 100 years important progress has been made. The first cars produced here were the ones that left the doors of the Malaxa factory in Reșita. The model was considered quite powerful, with a 30 hp engine, a maximum speed of 120 km/h and a consumption of 11 liters per 100 kilometers.

1-2. Figure_ Robotization of the automotive industry [www:Dacia.ro]

Development of automotive industry in Romania

The automotive industry in Romania remained rather poorly developed until the 60s, the number of cars manufactured being insignificant. Industrialization efforts during the communist regime made the automotive industry increasingly important. In this sense, 3 large car factories were developed in Romania:

1. ***Pitesti factory*** was the most important of all, being the place where the famous Dacia cars were developed and built. During the communist period, several

models were put on the road: Dacia 1100, the first successful model of the factory, followed by Dacia 1300 and Dacia 1310. After the return to democracy, Dacia experienced a rather complicated period, but returned to the ranks of the great manufacturers following the acquisition by the major manufacturer Renault. Today the factories in Pitesti have an appreciable production, the models produced being sold successfully not only in Romania, but also in various countries in Europe or beyond the borders of the continent;

2. ***Craiova factory*** was established in 1976, producing here the well-known Oltcit model inspired by the models of the Citroen company, which was part of the joint venture. In the 90s, the factory was taken over by a Korean company that produced several models. From 2009 until now it is owned by the multinational company Ford, where commercially successful models are produced, including modern, hybrid cars;

3. ***Câmpulung Muscel factory*** was dedicated to the production of off-road vehicles, under the name of ARO. The cars produced here have been recognized as quality, with high performance. Unfortunately, the factory could not keep up with modern economic realities and closed its doors in the 1990s.

Currently, the Romanian Automotive Industry is the most important in the entire economy, representing approximately 28% of GDP. Production is carried out in over 500 companies of various sizes, from the large factories in Craiova and Pitesti to small workshops where various components are produced. Development plans are optimistic, most businessmen saying that in the future they will develop their businesses by implementing appreciable investments.

1.3 Activities & Economic Impact

The modern automotive industry consists of a variety of activities that contribute to a greater or lesser degree to the major economic impact that automobiles have on modern life. These activities are divided into three main categories:

- ***Development of new car models*** is the responsibility of the specialized departments that the big companies own. In the past this activity was done by using sketches on paper and then models made of various materials that imitated reality. Nowadays, much of the development of new models is done with the help of computer technology, which saves time and money and provides much more accurate results;

- ***Cars Manufacturing*** is done in most cases by means of assembly lines. This activity allows significant savings in time and money. Very few models are assembled by hand, these being in the super luxury category, their number being insignificant if we think about production on assembly lines. The trend today is to robotize assembly lines as fully as possible, there are already impressively large factories overseen by a small number of human workers;
- ***Sales and service activity*** is the most visible part, with shops and car workshops being present in most important localities. Most firms of this type are franchises of the manufacturers operating under the brand name they sell, but there are also quite a number of independent firms, particularly in the aftermarket and auto repair business.

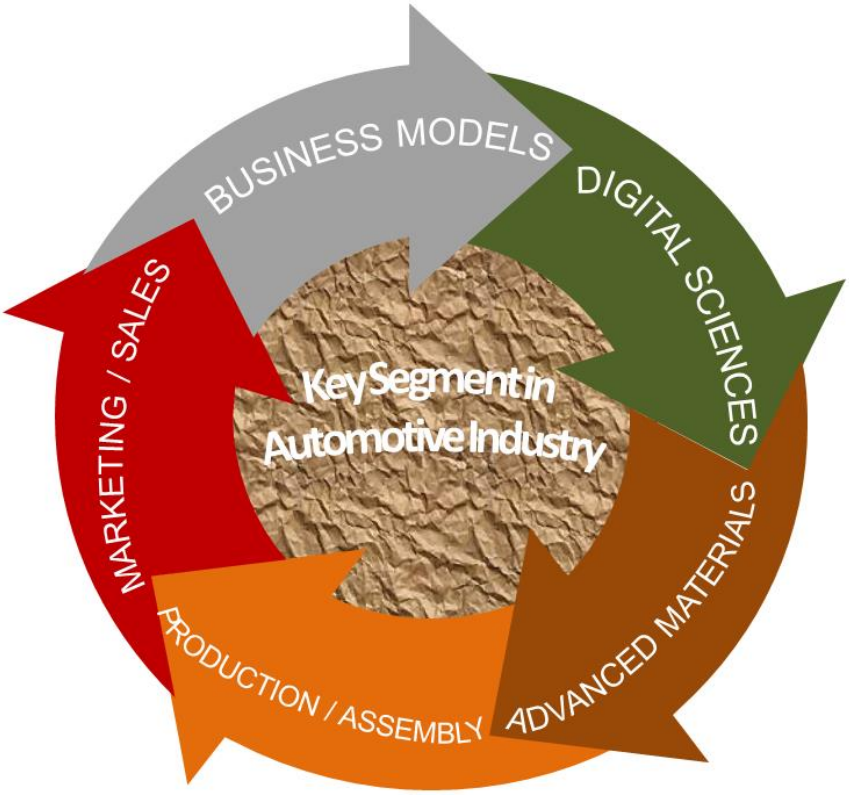
2 STRUCTURE OF THE CAR INDUSTRY

Automotive Industry is an important branch of the economy, it includes research activities in the design and construction of automobiles. Considering the importance of cars, both from the point of view of the economic role and the financial status of the owners, this industry has become one of the most important economic sectors in developed countries. The value is proven by the increasing number of employees working in the various companies involved and by the related activities that they have to gain by participating.

The automotive industry consists of a wide range of organizations and companies with a critical objective of designing, developing, marketing, manufacturing and selling motor vehicles.[2] The industry also does not include companies or organizations dedicated to automotive maintenance, such as gas stations and auto repair and service shops.

The industry consists of manufacturers, but is not limited to original equipment manufacturers (OEMs). Original equipment manufacturers consist of light truck, car, heavy equipment, heavy truck and motorcycle manufacturers. Another category in original equipment manufacturers includes: automotive wholesalers and suppliers, distributors, dealers and importers.

The industry is entering a period of intense change, and the automotive industry would transform into the mobility industry, so the trends in the automotive industry are a result of the combination of business models, digital sciences and new material technologies.



2-1. Figure_ Automotive industry trends

Companies in the automotive industry fall into two categories:

I. car manufacturers and

II. auto parts manufacturers.

Vehicles in the modern world are becoming more complex and involve more electronic parts than in recent years. It therefore increases the number of components manufactured by suppliers rather than manufacturers.

The modern automotive industry is in a constant state of flux. The success of any automotive industry relies on the sales floor as well as the expertise of many different professionals. The sector offers numerous employment opportunities in several positions such as mechanical, sales, assembly, financial, creative, scientific, technical and business position. Other job opportunities in automotive manufacturing plants include quality control workers, safety engineers, managers, supervisors, designers and executives.

The production system in the automotive industry, consisting of the production and processing of materials (metals, plastics, glass, rubber, etc.), the production of parts and assemblies, and the final assembly of vehicles (for example, in the 1920s and 1930s, Ford owned steel companies (no longer the case, but there is still significant vertical integration).

Since the production of cars is expensive, there are a small number of manufacturers in the car industry. Globally, world leaders in the automotive sector include Toyota, Honda, Volkswagen, Nissan Motors and Hyundai. The automobile industry is also an example of mixed oligopoly. It is because it has only a few manufacturers that produce differentiated products.

Key segments

Industry transformation is more about connecting people to automobiles. Change in the automotive sector will involve connectivity, autonomous vehicles, redefined mobility and electrification. The integration of mobile information into the industry would also establish a predictive maintenance path that monitors and alerts consumers to the operational performance of the automobile.

What are the Key Segments in Automotive Industry?

1. Light vehicles
2. Trucks and buses
3. Construction and agriculture
4. Electric and hybrid cars
5. Autonomous vehicles

Light vehicles: These are motorcycles and cars used for business transport involving goods and people (SUVs, passenger cars, minivans and vans);

Trucks and buses: These are mainly commercial vehicles used to transport goods and people (coaches, trailers and light and heavy buses);

Construction and Agriculture: Any industrial machine used for mining, agricultural and construction transport duties (motorcycles and commercial vehicles);

Electric cars and plug-in hybrids: automobiles powered by one or more electric motors. They use electricity stored in rechargeable batteries. Electric motors provide electric cars with instant torque, creating stable and smooth acceleration..

Autonomous vehicles: These are autonomous, driverless or robotic machines that can sense their environment and navigate without human intervention. They use global positioning system, radar and computer vision to detect their surroundings.

2.1 Value chain

The value chain covers all activities from product conception to final delivery in the hands of a customer. In cases where the company involved deals with the production of goods, their value chain starts from the purchase of raw materials to the sale of the product. Processes in the value chain add value to the product until it is ready for sale. Value chain analysis helps to analyze and identify where the problems are in order to make improvements and increase the efficiency of operations. Value chain analysis helps to analyze and identify where the problems are to make improvements and increase the efficiency of operations, so there are two types of activities that businesses/industries are involved in: main/support activities or secondary activities. As for the main activities of this value chain, they are to transform raw materials into products and services that ensure the delivery of the benefits expected by customers.[3]

Automakers' strategies for effectively managing inter-organizational relationships within the production chain is viewed as a key strategic issue for the auto industry...'~ Thus, automobile production should be viewed as taking place in a network of firms. Inter-organizational relationships clearly affect how automotive manufacturing systems operate. If more parts are outsourced, automakers depend on quality control and delivery times. If more subassemblies are assembled involving fewer steps, this leads to the development and use of different joining technologies. If new systems are developed, such as electronic subsystems, external suppliers play an increasingly important role. All external relationships are interconnected in the development of design specifications, which reflect customer demand, manufacturing capacity, retail system and available technology.

A compelling value chain analysis would also help generate a competitive advantage, thus the value chain of the automotive industry starts from:

1. Input logistics
2. Design and manufacture

3. Engineering
4. Quality and warranty
5. Connected Vehicle Services
6. Marketing and Sales
7. Service

Input logistics: it is the initial step in the production line. The action involves receiving raw materials from suppliers located in various locations around the world. After purchasing the raw materials, the industry distributes them among the production units as per the requirement.

Design and Manufacturing: Handles operations. The operations covered the main production stage and were divided into several parts. This step involves the transformation of raw materials into product. Some of the auto manufacturers have their operations and manufacturing facilities scattered around the world, helping them to save on the cost of delivering products to regional markets.

Engineering: In this step, it primarily deals with the flexibility of engineers to manufacture vehicles. It also involves minimizing engineering times by researching and developing solutions. Engineers must also ensure that the production line is more flexible by planning and designing new production processes.

Quality and Warranty: It is an important part that touches all parts of the automotive industry. The agreement among suppliers and industry practitioners in the automotive sector on what any quality and warranty program should entail are:

- managing corrective actions to improve product quality,
- tracking and managing aspects of warranty operations and analyzing contributing factors,
- failures at the cost of the guarantee.

With this, OEMs and suppliers will be on good terms.

Connected vehicle services: These involve services that allow a car to share internet access with other devices. Facilities also consist of specialized technology that accesses the Internet to provide additional benefits to the driver.

Marketing and Sales: It is a critical part of the value chain for vehicle manufacturing companies. This part includes distribution, sales force management, advertising, promotions and customer relationship management. The objective of this step is to ensure that the product reaches the intended consumer segment, as well as to make the target market aware of the products' benefits and features. Marketing and sales focus increases profitability and sales for the automobile company. These automotive companies use online and traditional channels to advertise and market their brands to remain competitive in the industry.

Service: It is the final activity in the automotive industry value chain that adds value to the product. It encompasses customer support after the sale of the product, providing ongoing support relevant to the maintenance of their vehicles. These support activities also ensure customer retention. By providing better customer support, the brand would have a better image and would have a large number of retained customers.

2.2 Resources

Automotive industry resources are also known as support activities that support the primary activities in the value chain. These support activities include:

1. Infrastructure
2. Information technology
3. Finance and Procurement
4. Human resources management

Infrastructure: Organizational structure is the backbone of success in the automotive industry. It encompasses the management of the culture, organizational structure, finances and other resources of the enterprise. With a well-managed infrastructure, the company will have a better chance of creating profits.

Information Technology: Technology plays a vital role in the automotive industry, starting from the first stage of the value chain to the marketing and sales of the final product. With the help of technology, the automotive industry can achieve passenger safety, emission control and vehicle design. Technology has also influenced convenience and customer buying pattern analysis.

Finance and Procurement: Procurement management is an essential support activity in the automotive value chain. It includes the purchase of raw materials from suppliers. Procurement management helps to save costs and ensure the production of reliable and efficient vehicles from quality raw material.

Human Resource Management: Human resource management is a vital area of concern for all vehicle brands. Motivated and well-managed human capital is the key to success in the automotive industry. With human resource management, the company can focus on all parts of HRM, starting from performance control to training and recruitment.

2.3 Key terms

The key terms that define the automotive industry are those advanced systems that provide assistance to the driver, the implementation of new technologies and IoT that perform certain tasks, the monitoring of the vehicle as well as its electrification.

What are the Key Terms in Automotive Industry?

1. **ADAS** - Advanced driver assistance systems
2. **AV** – Autonomous vehicles
3. **IoT** – Internet technology
4. **GPS** – On-board diagnostics
5. **EV** – Electric vehicle
6. **HEV** – Hybrid vehicle
7. **PHEV** - Connected hybrid-electric vehicles
8. **VEB** - Battery electric vehicle

ADAS - Advanced driver assistance systems: Conventionally, ADAS technology allows the car to detect objects, perform the necessary clearances and alert the driver to any dangerous road conditions. In other cases, ADAS technology can slow down or stop the vehicle. It also offers applications such as blind spot monitoring, forward collision warnings and lane change assist.

AV - Autonomous vehicles: They are self-driving vehicles. The technologies used in these vehicles provide significant benefits that reduce accidents, reduce fuel consumption, congestion and increase mobility.

IoT - Internet technology: Technologies in IoT perform various tasks such as connecting to smartphones, recording real-time alerts, providing emergency roadside assistance, among others. The vehicles will also have the ability to send and receive data.

On-board diagnostics: These are methods of monitoring a vehicle by combining a GPS system with on-board diagnostics. Through this combination, one can map and record exactly where a car is and how fast it is moving, as well as how the car behaves inside.

EV - Electric vehicle: is a vehicle powered by one or more electric motors that use energy stored in rechargeable batteries. There are three types of electric vehicles based on the degree of electricity they use. These are:

- ***HEV- Hybrid vehicle***: it generates its energy from both electricity and gasoline. The car's braking system produces its own electricity to recharge the battery.
- ***PHEV - Connected hybrid-electric vehicles***: it generates its energy from both gasoline and electricity. They use plugging into an external charging socket and regenerative braking to recharge their battery.
- ***BEV - Battery electric vehicle***: they are fully electric vehicles and use an external electrical charging socket to charge the battery.

2.4 Production System

The manufacturing plants where assembly takes place are linked to plants where the parts are made. Parts manufacturing may be co-located and owned by the car manufacturer, or parts from suppliers are delivered and stored, or delivered in accordance with just-in-time management objectives. The availability of metal presses, joining equipment and painting technology determines the type of materials that can be combined into product. The space available within the factory, combined with the speed of assembly line and number of production steps, determines the level of integration required in subassemblies.

2-2. Figure_ Dacia automobile production line [www:Dacia.ro]

The pace and costs of the manufacturing plant link various aspects of the supply chain, determining the materials used and the frequency of deliveries to be made. Automobile manufacturers exert some of this influence on the other actors involved through the responsibility they assume for the design of the automobile plant. Changes in their opinion about the optimal production technology thus exert influence on a large number of actors involved in the automation industry, such as material manufacturers, subassembly and system manufacturers.

As a consequence of the amount of capital injected into this system, incremental changes are the rule, radical changes in the system being possible only with the establishment of a new plant. The way in which this system is organized has been widely discussed in the specialized literature on the management of manufacturing companies.

2.5 Sales System

The retail system consists of importers, dealer networks and repair shops. It has both a sales function (new cars and spare parts) and a service and maintenance function.

The dealer network is the link between the car manufacturer and the customer, and the car manufacturer is increasingly trying to tie its customers into a long-term commitment to its products (e.g. conducting home visits, so as Toyota does in Japan).

So, the Competitive Advantage in Automotive Industry are:

1. **Sales** – short time to sell
2. **Quality** – increasing customer satisfaction
3. **Forecast** – predictions about vehicle demand

4. **Inventory** management – inventory update

Sales: In order to remain more competitive, the auto industry must have a short time to sell. Therefore, it would give the company an edge when it comes to innovation, allowing them to reach more customers with new products before their competitors.

Quality: High warranty costs are often an excellent indication that the processes inside are of high quality. Therefore, high quality would translate into an increase in customer satisfaction.

Forecast: It is a vital aspect that addresses the future demand for the car. Predictions based on judgment factors provide information about vehicle demand. Demand forecasting the company could increase the cost of operation in cases where the demand is overloaded.

Inventory management: Warehouses in automotive industries are in different places. Therefore, inventory managers must always update their inventory to help the industry keep up with the mobility that the modern automotive industry requires.

Taking cars back through the dealer network (as proposed by Renault) could be another means of breaking the one-sided relationship between the consumer and the car manufacturer, where the consumer usually takes the initiative.

2-3. Figure_ Dealer Renault

2.6 Present and future automotive industry

The automotive industry is still significant worldwide. Demand for automobiles is high.

However, most specialists expect that the future will offer prospects for increased development. In this sense, several elements are taken into account, such as the increase in the standard of living in countries with a significant population (China, India, Nigeria, Brazil), manifested by the increase in the number of cars driving on the roads of these countries.

Another element that offers optimism is related to the new technologies that will be implemented in the entire automotive industry. The most important so-called "megatrends" are related to the electrification of industry, connectivity through the use of IoT (Internet of Things) technology and autonomous driving of vehicles. These three directions offer advantages in terms of efficiency, reducing pollution and increasing safety.

2.7 Automotive industry challenges

After decades of continuous development, the automotive industry has recently experienced a period of challenges. The companies involved are running into various issues that threaten to derail the progress the industry was used to. Specialists are making huge efforts to find useful solutions to these challenges.

The lack of labor and the impossibility of finding qualified workers willing to work sustainably represents a major challenge for the automotive industry, especially in Eastern European countries and Romania.

Although it makes a significant contribution to the global economy and provides millions of jobs, the automotive industry generates an impressive volume of waste, some of which is very dangerous for the environment. In this sense, the authorities impose strict regulations for their management in order to prevent, reduce and capitalize on them.

In order to reduce the negative effects on the environment and to increase the quality of life, economic agents in the automotive industry have the obligation to ensure proper management of hazardous waste. In addition, this concerns addressing environmental concerns and addressing the issue of natural resource depletion.

3 WASTE IN THE AUTOMOTIVE INDUSTRY

The speed of urban development of localities, imposed an accelerated increase in the sale of automobiles, which characterizes the last decade and have become indispensable in today's modern society. These, in turn, produce a consequence proportional to the increase in waste, thus the problem of waste management manifests itself more and more intensively both at the European level and in Romania.

EU waste policy provides a framework for improving waste management, stimulating innovation in the separate collection and recycling of waste, limiting the use of landfills and creating incentives to change consumer behaviour. It also aims to reduce the actual amount of waste generated and the amount of harmful substances it contains.

EU waste legislation also sets specific targets to increase the recycling of specific waste streams such as electronic equipment, machinery, batteries, construction, demolition, municipal and packaging waste, as well as to reduce the landfilling of biodegradable waste.

3.1 Waste legislation

According to the European Commission, each year ELV generates between 8 and 9 million tonnes of waste in the EU. Thus, Directive 2000/53/EC [4] on "End-of-life Vehicles" establishes measures to prevent and limit waste from ELVs and their components, ensuring their reuse, recycling and recovery. It also aims to improve the environmental performance of all economic operators involved in the life cycle of vehicles. (conf. PNGD)[5]

The key aspects subject to the debate of Directive 2000/53/EC are:

- Vehicle and equipment manufacturers must consider vehicle disassembly, reuse and recovery during product design and construction. They must ensure that the new vehicles are:
    - reusable / recyclable to a minimum of 85% by weight per vehicle;
    - reusable / recoverable to a minimum of 95% of the weight per vehicle.
- They are not allowed to use hazardous substances such as lead, mercury, cadmium and hexavalent chromium.

- Manufacturers, importers and distributors must provide systems for the collection of ELVs and, as far as technically possible, used parts removed when repairing passenger cars.
- Owners of ELV handed over for waste treatment receive a certificate of destruction. This is required for vehicle registration.
- Producers must cover all or most of the costs involved in delivering an ELV to a waste treatment centre. As for the vehicle owner, he should not incur any expenses when delivering an ELV to an authorized waste treatment center, except in rare cases where the engine is missing or the ELV is full of waste.
- Waste treatment centers must apply for a permit or register with the competent authorities of the EU country in which they are located.
- ELVs are dismantled before further processing. Hazardous substances and components are removed and separated. Attention is paid to the potential for reuse, recovery or recycling of waste.
- There are clear quantified targets for annual reporting to the European Commission on the reuse, recycling and recovery of ELV and their respective components. They have become more and more demanding.
- The legislation applies to passenger vehicles and small trucks, but not to large trucks, vintage vehicles, special purpose vehicles and motorcycles.

Every year, millions of vehicles in Europe reach the end of their lives. When end-of-life vehicles (ELVs) are not properly managed, they can cause environmental problems and the European economy loses millions of tonnes of material.

Recycling measures after the abandonment of motor vehicles are the most studied of all, because the most important objectives to be achieved will be:

- The disassembly of the machines should be as easy as possible;
- Development of disassembly companies;
- Components remaining after recycling should be as few as possible;
- Development of own design technologies for car manufacturers.

The End-of-life Vehicles Directive (ELV Directive) sets clear targets for ELVs and their components. It also prohibits the use of hazardous substances in the manufacture of new vehicles (in particular lead, mercury, cadmium and hexavalent chromium), except for defined exemptions when there are no suitable alternatives. The exemptions are listed in Annex II to the directive.

Framework Directive The Waste Directive 2008/98/EC streamlines waste legislation by incorporating rules on a number of issues such as the management of hazardous waste and waste oil.

The year 2023 brings, from the first days, a multitude of news regarding environmental legislation. Against the background of the measures taken at the international level that aim to stop and solve the problems generated by human activities, the Romanian authorities have issued new rules aimed at improving the harmful effects on the environment.

Other EU waste legislation [6]:

- The waste transport regulation aims to ensure the safe transport of all types of waste, including hazardous waste;
- The Packaging and Packaging Waste Directive sets standards for packaging design and sets specific targets for recycling and recovery of packaging waste;
- The EU Landfill Directive and the Waste Incineration Directive set standards and limits for the emission of pollution into the air or groundwater;
- The End-of-life Vehicles Directive sets increasing targets for reuse, recycling and recovery and restricts the use of hazardous substances in both new vehicles and vehicle spare parts;
- The waste electrical and electronic equipment (WEEE) legislation establishes collection, recycling and recovery objectives for electrical goods;
- The Directive on the restriction of hazardous substances in electrical and electronic equipment restricts the use of hazardous substances and substances in electronics;
- The Battery Directive sets collection, recycling and recovery objectives, thus ensuring proper waste management;

- The legislation also targets specific waste streams such as sewage sludge, batteries, polychlorinated biphenyls and polychlorinated terphenyls (PCBs/PCTs)

Source: http://ec.europa.eu/environment/waste/legislation/index.htm

The main normative acts applicable to the Waste Management Plan, from the automotive industry in Romania, are listed in the following table:

Normative act	Description
OUG 92/2021	Emergency Ordinance on waste management (replaces Law 211/2011)
HG 856/2002	Evidence of waste management, including hazardous waste, amended by GD 210/2007
Legea 249/2015	Management of packaging and packaging waste
HG 1132/2008	Regime of batteries and accumulators and battery and accumulator waste
HG 170/2004	Used tire management
HG 1061/2008	The transport of waste on the territory of Romania
Ordonanta 2/2021	Waste storage

The main relevant European Directives and their national equivalent are listed in the following table:

European Directive	Description
Directive (UE) 2018/851	Waste regime
Decision (UE) 2014/955	Establishing the waste list
Regulation (UE) 1013/2006	Waste transfer
Directive (UE) 2018/850	Waste storage
Directive 94/62/CE	Packaging and packaging waste
Directive 2006/66/CE transposed by HG 1132/2008	Regime of batteries and accumulators and battery and accumulator waste

Directive (UE) 2012/19 transposed by OUG 5/2015	Electrical and electronic equipment waste
Directive 849/2018 amending the Directive 2000/53/CE	End-of-life vehicles

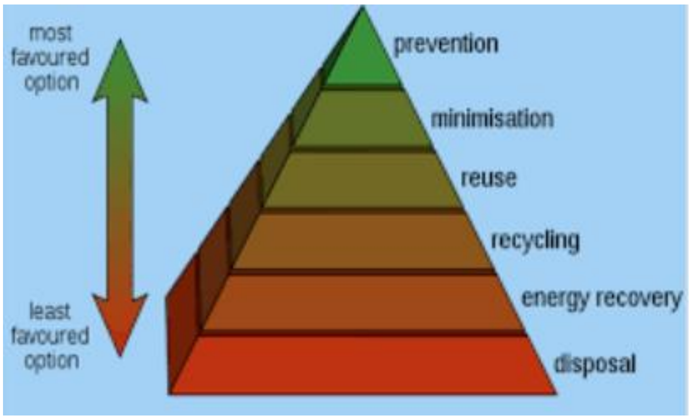
3.2 Management hierarchy

The lack of proper hazardous waste management leads to economic and biological imbalances that diminish the quality of life. That is why, in order to combat the pollution generated by the waste from the automotive industry, the authorities and environmental protection agencies draw attention to the importance of an environmental policy, which primarily aims at selective collection actions. Thus, the management of waste in the automotive industry involves the recycling and reintroduction of some waste (metal, oils, solvents, batteries, plastic and glass). Recycling these materials helps economic operators to address environmental concerns and solve the problem of resource depletion.

The waste management hierarchy is a concept that was developed from Council Directive 75/442/EEC of 15 July 1975 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31975L0442) on waste by the Dutch politician Ad Lansink in 1979, who presented the Dutch parliament with a simple schematic representation that was called "Lansink's Scale", ranking waste management options from the least environmentally desirable options.

To protect the environment and human health, the EU Waste Framework Directive has two key objectives: preventing and reducing negative impacts caused by waste generation and management, and improving resource efficiency.[7]

This defines a "hierarchy" to be applied by EU member states in waste management. Waste prevention and reuse are the most preferred options, followed by recycling (including composting), then energy recovery, while landfill disposal should be the last resort.



3-1. Figure_ Waste hierarchy [8]

The objective of EU waste legislation is to change the perception of waste management within the hierarchy, avoiding disposal and focusing on prevention and reuse.[9]

In other words, any waste management system (and even more so a strategic, national one) must be built prioritizing, in order:

1. preventing the occurrence of waste by minimizing the amount of waste generated,
2. reuse of objects,
3. waste recycling,
4. recovery through energy recovery,
5. final storage (in/on the ground).

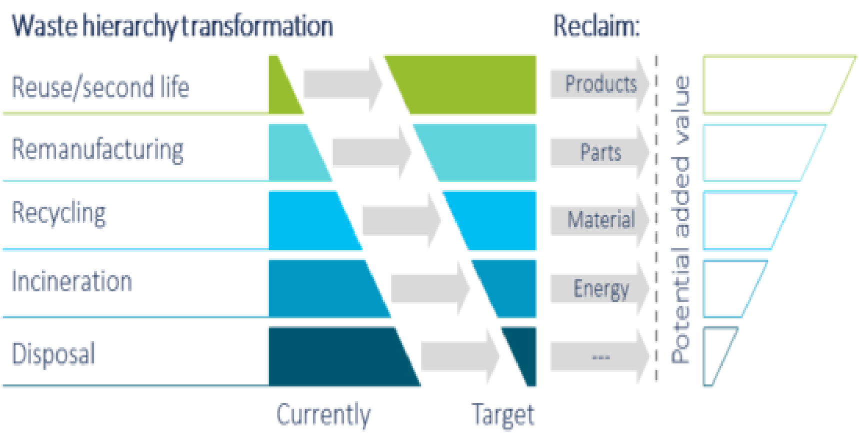
3-2. Figure_ Being wise with waste: the EU's approach to waste management[10]

The lack of proper hazardous waste management leads to economic and biological imbalances that diminish the quality of life. That is why, in order to combat the pollution generated by the waste from the automotive industry, the authorities and environmental protection agencies draw attention to the importance of an environmental policy, which primarily aims at selective collection actions.[11]

Waste management in the automotive industry involves the recycling and reintroduction of some waste (metal, oils, solvents, batteries, plastic and glass). Recycling these materials helps economic operators to address environmental concerns and solve the problem of resource depletion.

3.3 Types of waste

From paint, aerosols, oil-soaked cloths, cardboard and even plastic, the Romanian automotive industry has capacity to manage any waste generated in the automotive industry's production processes. In the case of hazardous waste, special attention is paid to the waste codes regulated according to HG 856/2002 and, depending on the degree of recycling of each material, treatment, decontamination, recycling and neutralization solutions are guaranteed. Special IBC containers are used for liquid management, which also go through a safe and ecological decontamination process. Thus, it is ensured that all waste that can be recycled following decontamination and re-introduced into new production cycles is capitalized, and the risks regarding public health and the environment are eliminated. Next figure illustrates the inverted pyramid described here and the potential value added at different stages.[12]



3-3. Figure_ Waste hierarchy transformation [11]

The waste transformation pyramid is a concept that describes the hierarchy of how waste is handled. From top to bottom, the current total volume of waste increases, while the impact of sustainability measures increases considerably when implemented further up the hierarchy, describing typical strategies for waste prevention and the estimated volume of waste.

Thus, a wide range of waste from the automotive industry can be collected for recovery or disposal. The main types of waste generated by the automotive manufacturing and maintenance industry include:

− liquid waste;

− chemical products, such as antifreeze, refrigerants, battery acid (Lead-acid batteries);

− used washing solutions and emulsions;

− sludges and industrial sludges;

− paint waste, including thinner, varnishes and similar;

− waste with PCB content;

- used solvents;

− used oils, including used oil filters and adsorbents;

− scrap metal, brake pads, bodywork;

− used tires;

- recyclable waste (paper, plastic, metals, rubber, glass, etc.).

Since this waste is characterized by a high content of carcinogenic substances, the management of hazardous waste from the automotive industry becomes an urgent need:

- to prevent environmental contamination;
- to protect people's health (prevention of cancer, respiratory problems or genetic mutations).

Although the list also includes several types of hazardous waste, their improper disposal causes threats to people and the environment.

In addition, storage in unsuitable containers is equally dangerous. Over time, they are subject to decomposition processes, which facilitate the penetration of chemicals into the soil and water, affecting fauna and flora. Also, residues from car batteries can cause fires by releasing toxic substances into the air.

In addition to these aspects, improper management of these wastes can cause risks to employees who come into contact with them. With a high content of carcinogenic substances, hazardous waste from the automotive industry can cause cancer, respiratory problems or lead to long-term genetic mutations.

In this sense, any business in the automotive industry that owns or generates hazardous waste has the responsibility to implement legal measures to manage this waste so that it does not cause any harm.

3.4 Waste management

COLLECTION implies maximum attention and responsibility. Although the list also includes several types of hazardous waste, their improper disposal causes threats to people and the environment.

The novelty in this process is the ability to take over absolutely all types of waste generated and to orient them in a large proportion towards their recycling and valorization and less towards the classic processes of incineration or permanent storage, as follows:

- ***Waste oils***

The process of collecting used oil has become an international concern in recent years, with the goal of responsible management. Care for the environment and a sustainable vision are among the main priorities targeted by the community, as well as by organizations and companies.

More and more companies are implementing policies and actions aimed at reducing the negative impact on the environment. A high amount of used oils is disposed of in the environment, this fact generating consequences that are difficult to remedy. For example, in direct contact with the soil, the oil compromises its quality, having a devastating effect on it.

Also, according to European studies carried out by recycling specialists, one liter of used oil affects 1000 liters of drinking water. Being a liquid that does not mix with water, it forms a film that prevents oxygen from reaching aquatic organisms and plants.

3-4. Figure_ Waste oil
[https://www.dcbusiness.ro/reciclarea-uleiurilor-uzate-care-sunt-pasii-de-urmat_642888.html]

These wastes (used engine and hydraulic oils) are insoluble and can be characterized by a high content of toxic substances and heavy metals. In order to recycle, economic operators in the automotive industry must:

- conclude contracts with companies specialized in the recycling of used oils;
- provide special containers and keep them in good condition;
- label all containers and tanks where used oils will be collected;
- collect and store used oils in specially arranged areas;
- not to mix used oil with other types of waste.

In Romania, the management of used oil is regulated by Government Decision no. 235/2007, which provides for collection actions in order to minimize the harmful consequences on people's health and also on the environment.

According to this law, used oils mean refined oils associated with various additions (additives or other substances) that have become unsuitable for the main purpose, especially oils from combustion engines or those for industrial or hydraulic systems.

Those who generate used oils have the obligation to guarantee the differentiated collection of oils, according to the legal framework. They are also responsible for handing over the used oil to entities authorized to carry out its collection and recycling activities.

Solvents or car parts cleaners

Solvents or cleaning agents are meant to dissolve a substance or material either in the cleaning or degreasing process or in painting. The treatment and disposal of these substances are complex activities, which is why the generators of such waste switch to water-based cleaning or turn to specialized companies to recycle efficiently from the perspective of time and resources.

It is important to remember that in order to recycle, *the collection of this waste must be carried out in special containers in order to prevent mixing with other types of waste.*

Paint

In the first phase, it is identified whether the used paints are oil-based or water-based. It is necessary to know that the chemicals in paints are toxic and can contaminate the environment or create health problems. Also, some types of paints can be flammable or reactive.

Since they are considered hazardous waste, paints should be collected in strong and leak-proof plastic or metal containers. At the same time, they can be eliminated by contacting a company specialized in the elimination of hazardous waste.

Brake pads

Brake pads can be characterized by a high asbestos content. In this sense, they must be collected in such a way as to prevent the risk of contamination.

The need to put used brake pads through a process of packaging, labeling and sealing and storage in special premises is identified. Finally, the disposal is carried out with the help of companies authorized for this purpose.

Used car batteries

Being made of many dangerous materials (acid, nickel, lead), used batteries can contaminate the environment considerably, if not managed properly. That is why it is necessary for the generators of such waste to collect and store them in specially designed units before they reach a specialized recycling center.

Antifreeze

Characterized by a high level of toxicity, antifreeze has the ability to pollute water, generating threats to both human and wildlife health. For this reason, it must not be disposed of on the ground, in the sewer or in water.

Carried out with suitable protective measures (goggles, masks and gloves), the collection of antifreeze is carried out in a sealed plastic container, which is to be transported to an authorized recycling company.

Tires used

Since the volume of used tires is increasing and the materials from which they are made are extremely resistant, the collection and disposal of this waste is particularly critical. In addition, used tires pose a major environmental risk due to the potential for toxic pollution or fire hazards.

Scrap

In the long term, the disposal of metal waste in undeveloped spaces leads to the entry of hazardous chemicals into the soil and water. Most types of metals can be recycled, so generators of hazardous waste from the automotive industry can collect them and hand them over to licensed waste management service companies. However, they must ensure that the metals do not contain liquids or come into contact with other waste.

TRANSPORTATION is carried out by means of vehicles and specialized and authorized personnel for the transport of waste. Any specialized company can serve any request for the transport of waste regardless of its nature, in compliance with the legal regulations in force regarding the transport of waste on the territory of Romania.

STORAGE is done in spaces specially designed for this purpose. Depending on the type and compatibility of the waste, it is temporarily stored to be later sorted, prepared and then processed for recycling or recovery.

PROCESSING is a complex and very important operation in the waste circuit. This consists of a multitude of operations (sorting, packaging, treatment, inerting, neutralization, handling, etc.) that are done depending on the final destination and type of waste.

RECOVERY is perhaps the most important stage in the life of a waste. Once here, a waste can become a source of energy or a raw material for various industrial processes and more.

DISPOSAL applies to waste that could not be utilized in any way, under conditions of maximum safety, by incineration or by final storage in waste depots designed and authorized in this regard.

3.5 Examples of good practices

In accordance with the Environmental Policy, *"Renault Romania Group"* is committed to the prevention and continuous reduction of the environmental footprint by protecting its assets, tangible and intangible, by complying with the following actions:

1. Optimization of energy consumption and atmospheric emissions,
2. Appropriate use of raw materials,
3. Reduction at the source and maximizing the recovery of waste,
4. Prevention of soil and ground water contamination,
5. Controlling water consumption and aqueous discharges into the aquatic environment,
6. Prevention of accidental pollution,
7. Reduction of sound and olfactory nuisances,
8. Keeping chemical risk under control,
9. Implementation of optimal solutions for the transport of employees.

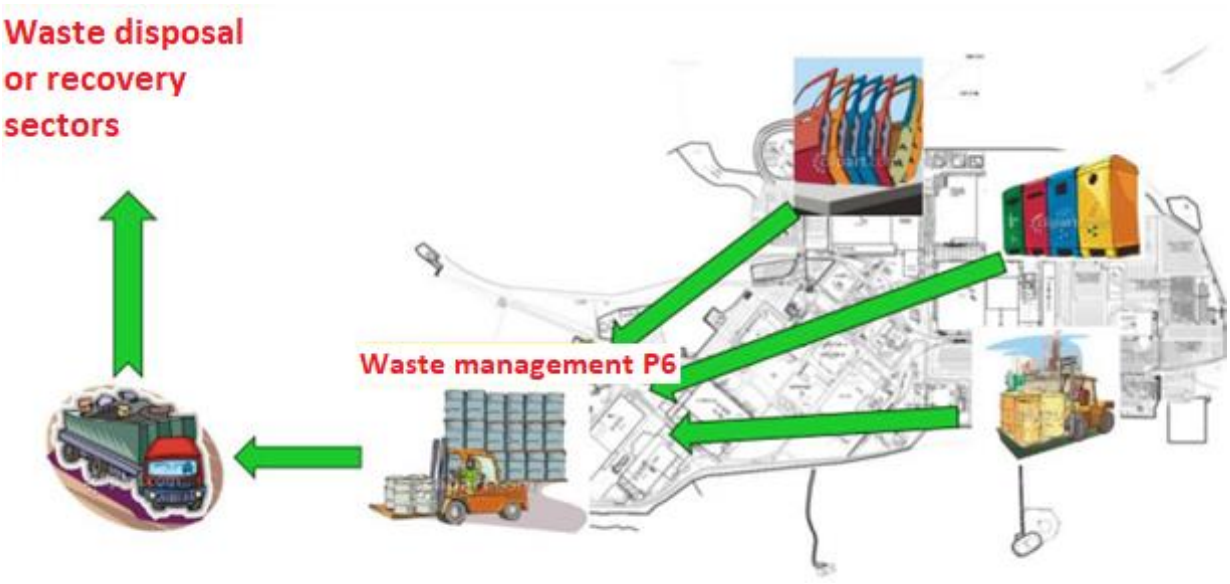
Source: https://www.dacia.ro/brandul-dacia/platforma-mioveni.html

Case example: ***Automobile Dacia industrial platform***

A large part of the waste categories listed in HG 856/2002 or in Decision 2014/955/CE are generated on the Automobile Dacia industrial platform.[13] Thus, the main activities of the Automobile Dacia factory and the categories of waste resulting from them are listed in the table below:

Activity	Location	Generated waste categories
Surface coatings	Paint shop, Chassis (Cataphoresis)	Sludges (fz-ch, phosphating, paint-containing), spent solvents, residual paint.
Embossing, sheet metal cutting	Pressing, Chassis (Welding)	Metal waste (sheet metal)
Machining, cutting parts	Engine, Gearboxes, Chassis (Decks), Aluminum	Chips (steel, cast iron, aluminum), machining sludge, used emulsion, used oil

	(Machining)	
Aluminum casting	aluminum (Foundry)	Used emulsion, aluminum slag, shells and contaminated burrs
Assembly of car parts	ASSEMBLY	Cardboard, plastic film, plastics, wood, mastic, polystyrene, glass
Welding car components	Bodywork, Chassis (Welding)	Metal waste (steel, copper, bronze), mastic
Production of energetic agents	EMPI	Laboratory chemicals, used oil, water treatment sludge
Maintenance	EMPI, local maintenance of all departments	Electrical and electronic waste, metals (steel, cast iron, copper, bronze, aluminum), chipboard (steel, cast iron, copper, bronze)
Constructions and demolitions	The Dacia platform	Soil, concrete, asphalt, conductors (aluminum and copper)
Mold manufacturing	Dacia molds	Steel sheet, tin, polystyrene
Packing, unpacking the piece	AILN, CPS Oarja	Wood, cardboard, foil



3-5. Figure_ Dacia Automobile waste collection flow [14]

4 END-OF-LIFE FOR VEHICLES

VEHICLES at the end of life (ELV), are automotive products that have reached the end of their useful life. Their components are now considered waste and can only be thrown away or used for recycling. End-of-life vehicles generate around 7-8 million tonnes of waste every year in the EU.

ELVs may also be referred to as "junk vehicles" or "salvage vehicles". Thus, there are two categories of ELVs:

- Natural ELVs that have reached the end of their life from a technical or economic point of view;
- Premature ELVs, which are new cars resulting from unwanted events such as accidents.

When end-of-life vehicles are not managed properly, they can cause environmental problems, wasting millions of tons of materials. The End-of-life Vehicle Directive sets clear targets for ELVs and their components and also prohibits the use of hazardous substances when new vehicles are produced, except in defined derogations where there are no alternatives.

The End-of-Life Vehicles (ELV) Directive was introduced to ensure that the waste produced by recycling older vehicles is kept at sustainable levels. First, car recycling should not only help to remove and store potential toxins from ELVs, but should also give new life to used car parts that can be further used on other vehicles.

The ELV Directive sets clear objectives for their reuse, recycling and recovery and aims at the following:

- Collection of waste from end-of-life vehicles and their components;
- Improving the environmental performance of all economic operators involved in the life cycle of vehicles.

Thus, we can say what is the life cycle of ELVs from manufacturing to recycling:

The life cycle of ELVs includes all the necessary steps, from the design phase, vehicle manufacturing, operation and maintenance of the vehicle throughout its life, to scrapping and recycling.

Regardless of its age and weight, a vehicle is mostly made of about 75% metal, both ferrous and non-ferrous, while the remaining 25% of the vehicle's weight comes from tires, plastic, rubber, plastic, gases, glass , fabrics, fluids such as oil, antifreeze, lubricants and gasoline/diesel, as well as various electronic components/circuits that have heavy metals and rare metals. Over time, these components degrade and the vehicle becomes unusable, it is said to have reached the end of its useful life. For further clarification, a vehicle can be considered waste in many other scenarios, e.g. discontinuation of a model, accident, breakdown or unavailability of spare parts.[15]

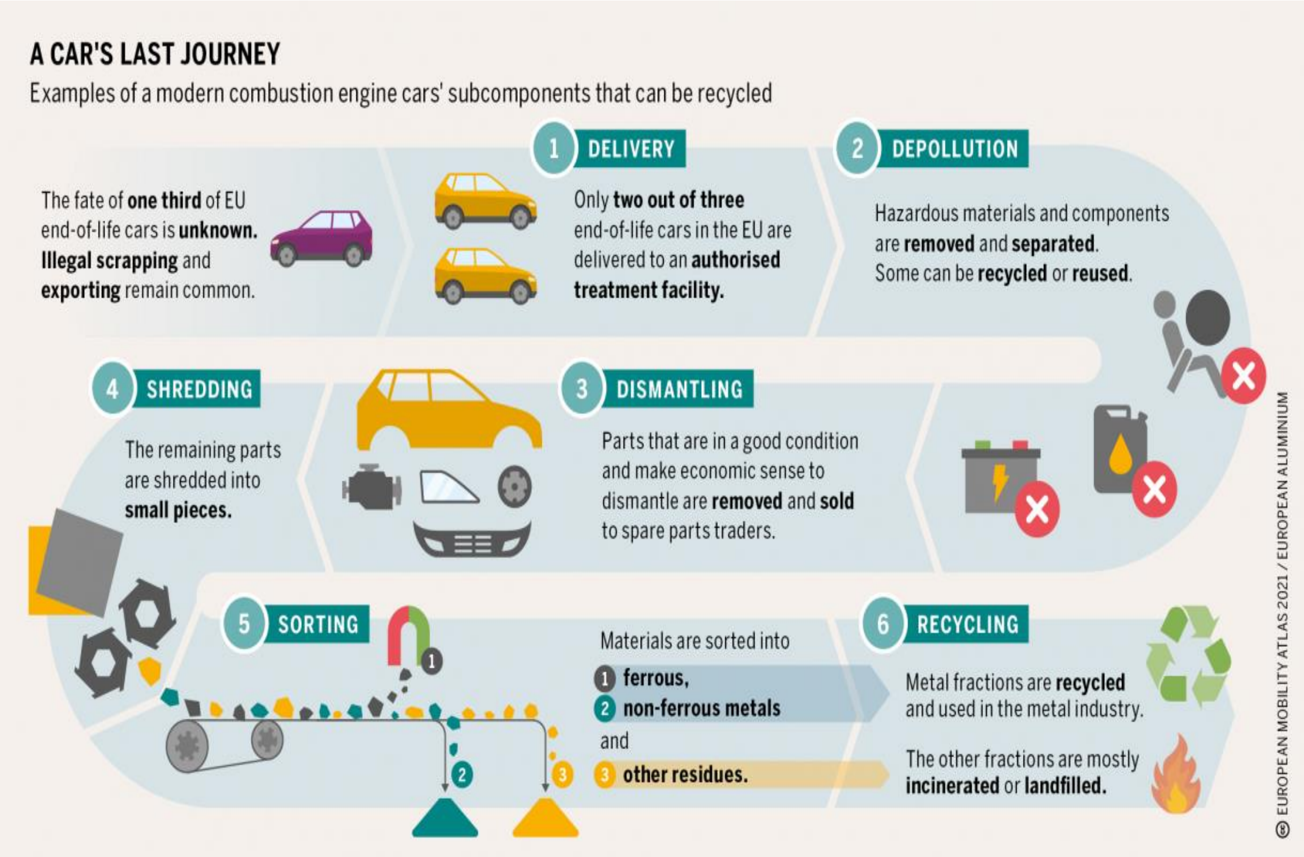
While "scrapping a vehicle" literally means old vehicles have reached their EOL or the vehicle is damaged (accident, natural calamity or any other reason). Such vehicles are prohibited for registration being sold as scrap to car scrap dealers.

Most auto parts can be successfully recycled/repaired/reused if handled carefully, they can be given a new lease of life so that they can either be reused in the aftermarket as spare parts or can be used in different forms and in different applications. Alternatively, they could be recycled into basic raw materials and could be a good base material for the steel, aluminum, plastic, copper and brass manufacturing industry.

Reusable or recyclable parts of a discarded vehicle have value even after the end of the car's life. If in good condition, many engine components and body parts can be salvaged, reconditioned and sold to auto repair shops or individuals who perform auto restoration projects.

End-of-life vehicle recycling phases involves the processing and preparation of used vehicles for disposal which requires six different activities, as shown in the next figure:

1. Delivery and storage of old vehicles for recycling
2. Removal of hazardous fluids and materials from vehicles
3. Dismantling vehicles for usable or recyclable parts
4. Crushing or shredding vehicle bodies
5. Sorting of materials into ferrous materials, non-ferrous materials and other residues
6. Recycling of metal fractions



4-1. Figure_ A car's last journey [16]

4.1 Delivery and Storage

The owner of the used car or cars comes to an authorized scrapping center with the car or cars for scrapping. Following the scrapping process, the certificate of destruction of the old vehicle or vehicles will be obtained.

4-2. Figure_ Storage of vehicles for recycling

The authorized scrapping center's system will determine whether or not the car can be salvaged. Salvage means repairing or removing the useful (functional) parts of the vehicle according to demand and condition. Anything can be recycled from the car depending on its condition. If a car cannot be recovered, it will have to be scrapped and stored in local national depots.

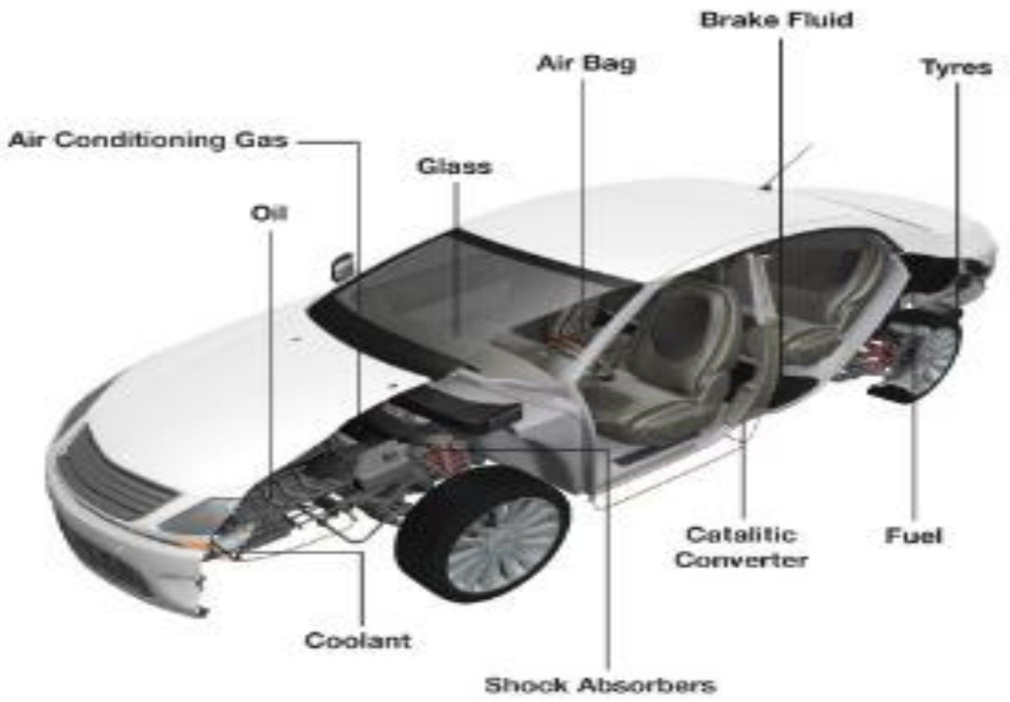
The process of recycling cars is quite complex. All fluids must be drained and removed, the battery, airbags and catalytic converters must be removed, and other valuable parts are manually sorted (main engine, gear, etc.)

4.2 Vehicle depollution

Vehicle depollution is the process of removing hazardous fluids and materials. However, unlike any other old items, these "aged" vehicles have a complex structure of various materials, chemicals, liquids, gases (many of which could be toxic) which, if properly handled, can be recovered effectively from the "scrapped vehicle" and can be recovered and reused.

Once a qualified person has decontaminated a vehicle, the parts will be stored and handed over to specialists who will disassemble them for reuse as something else.

The first step in processing a used vehicle is to remove the battery and drain all hazardous fluids, such as those from fuel tanks, transmissions, radiators and power steering units, to ensure the safe removal of all components for recycling, so:



*4-3. Figure_ **Identification of hazardous fluids and materials [17]***

1. Battery removal

After testing, batteries that are in good condition are sold to customers for reuse, and the rest are sent to an authorized recycling facility to be rebuilt or disassembled for their components. Battery components include; distilled water, silver, lead, acid and plastic and once the ATF has neutralized the acid and purified the water for safe disposal, they will then melt the metals to be reused. Only ATFs can do this, as all hazardous substances must be recycled and disposed of by licensed specialists.

2. Emptying the petrol or diesel tank

Using special equipment, the tanks are emptied and removed. The fuels are used by auto recyclers in their own equipment or sold for reuse.

3. Removal of all hazardous fluids

Fluids such as:• Antifreeze, • Brake fluid, • Engine oil, • Transmission fluid, • Power steering fluid, • Differential fluid (if present), • Windshield washer fluid, etc. are separated and resold on site or sent to reputable recycling facilities to be reprocessed and reused.

4. 4. Freon and other refrigerants

Gases from air conditioning systems are carefully removed by licensed technicians to ensure that none escapes into the atmosphere. The used refrigerant is sold to an authorized buyer for reuse.

5. Oils

Oil is drained from all vehicles, tested and reused for energy recovery in licensed used oil furnaces to heat their buildings. Any excess is sent to recycling facilities to be reprocessed and reused.

6. Removal of hazardous metal

Switch Out is a national program designed to eliminate these hazardous metals such as: • Mercury switches [found in anti-lock brakes (ABS) brakes and comfort lighting], • Lead (battery connectors and wheel weights).

Once all hazardous components are removed, recyclable components are identified and removed.

4.3 Dismantling of vehicles

Over 80% of the weight of the entire vehicle is reused, re-manufactured or recycled. Thus, after the removal of fluids and hazardous materials, the components that can be recycled will be identified:

Bodywork: Vehicle parts and general steel products are obtained

Body and mechanical parts that are in good condition are sold for collision repair and mechanical repair facilities. Unusable parts are recovered as scrap and the metal is recycled.

Glass: raw material for cement

Cables: copper products, motors (cast aluminum armature)

Radiator (Copper and Aluminum): bronze ingots and aluminum products

Engine: Aluminum engines and products

Bumper: interior parts and tool boxes

Catalytic converter: catalytic converters

Transmission: General steel and aluminum products

HEV Engine Magnet: Magnets and Catalysts

Tire: raw material for cement and heat source

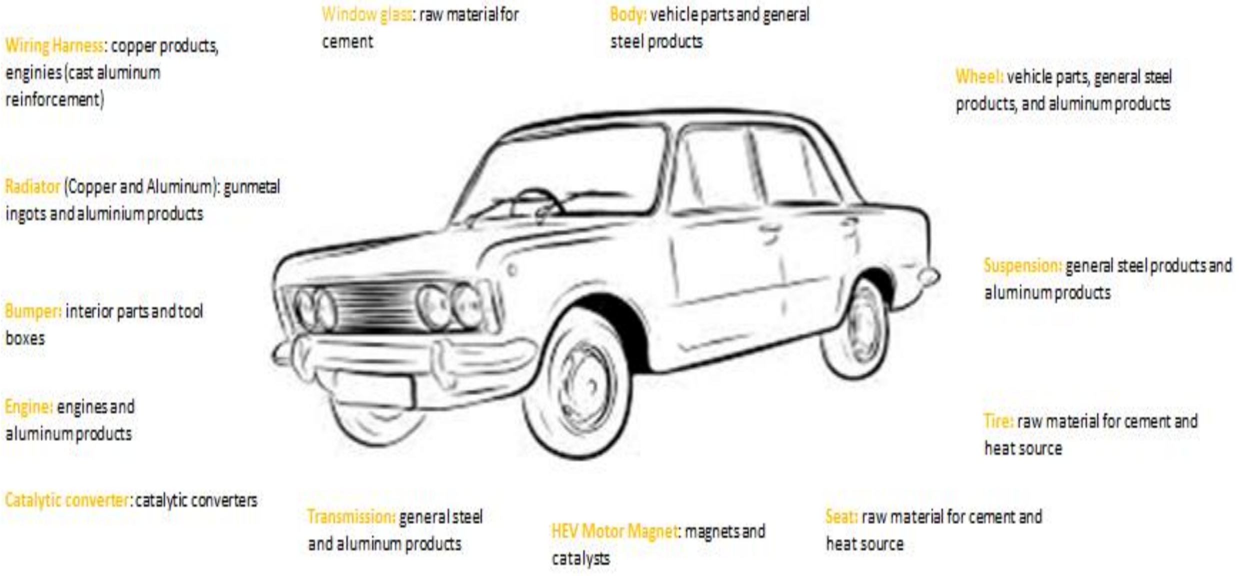
Quality tires with a long life are sold for reuse. Others are sent to tire recyclers and processed to make new products. Thus, tires are often shredded and broken down into pellets before being reused as soccer field flooring or to pave highways.

Wheel: vehicle parts, general steel products and aluminum products

Wheels are sold for reuse. In some cases, they are reconditioned, and the damaged ones are recovered as scrap metal.

Suspension: general steel and aluminum products

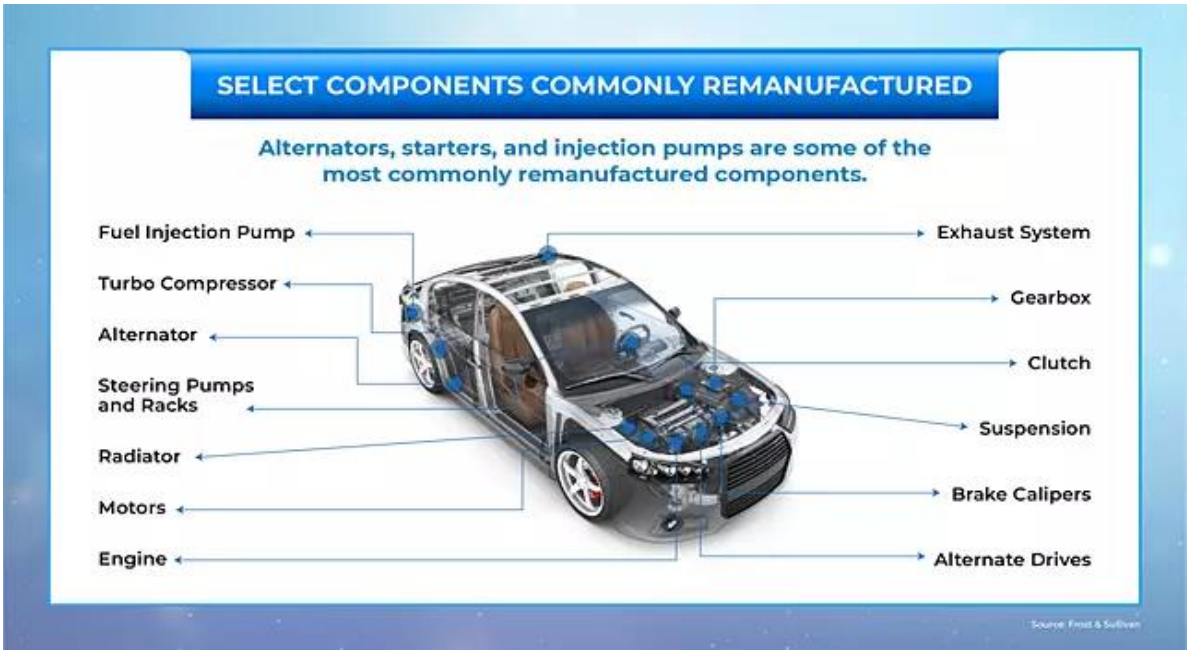
Chair: raw material for cement and heat source



4-4. Figure_Components commonly Recycled from ELVs

From extending tire and battery life to servicing electronics and implementing predictive maintenance systems, the focus is on increasing the useful life of the automotive product.

The primary goals of the vehicle recycling industry are to ***salvage*** as many components as possible from an old, used automobile. Below in the given graph is a rough estimate of the recyclability of an average automobile.



4-5. Figure_Components commonly remanufactured
[https://www.autocar.co.uk/car-news/features/final-destination-one-cars-end-life-journey-scrapheap]

Alternators, starters and injection pumps are some of the most common reconditioned components. Thus, dismantled machines can produce a number of reusable parts. Each of these may still be of value to someone else looking to purchase replacement parts for their own vehicle.

Sometimes it only takes one critical problem to render a machine unusable. The lights, seats, mirrors and other components of a scrapped car might be in perfect working order.

4.4 Conveyors and feeders

After the dismantling process, the parts will use the conveyors and feeders for the recycling and sorting industry, which are of great importance for the recycling and sorting operations.

Conveyor and feeder systems transport materials between two locations and help move and spread heavy materials. They are often used to move materials from one part of the recycling process to another, such as from a sorting station to a baler or compactor.

Conveyors can be designed to handle a variety of materials and can be configured to suit the specific needs of a recycling operation. They can increase efficiency, reduce manual labor and improve safety by reducing the need for workers to manually move materials.[18]

4-6. Figure_ Belt conveyors [18]

Belt conveyors transfer waste from the loading dock to the sorting line and crushers and balers.

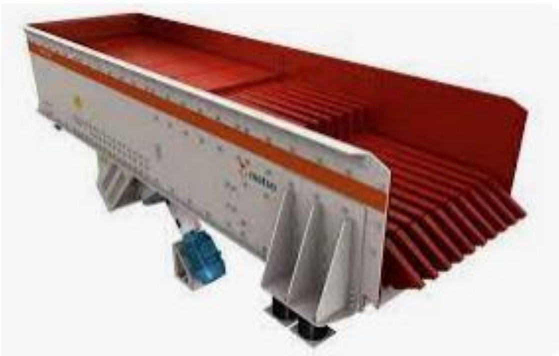
In the process of recycling metal parts, conveyor belts must have a solid top coating and a fabric that can withstand sharp edges.

Feeders are equipment commonly used in recycling operations to control the flow of materials in the recycling process. They are designed to handle a variety of materials such as paper, plastic, glass and metals. Feeders can be used to regulate the amount of material fed into the process, prevent jamming or clogging, and ensure a constant feed rate. They can be automated or manually controlled and can be integrated with other recycling equipment such as shredders, crushers or balers.

Examples of feeders in the recycling industry include:

- Apron feeders: Apron feeders are mechanically robust and operationally flexible feeders used in the recycling industry.

- Grizzly Feeders: Grizzly feeders are widely used in waste recycling applications and are suitable for combining large particle scalping and downstream feeding in one operation.



- Tray Feeders: Tray feeders are commonly used in recycling operations prior to secondary and tertiary crushers. The feeders are driven by unbalanced electric motors and compact structures and are easy to install.

4-7. Figure_ Feeder systems [18]

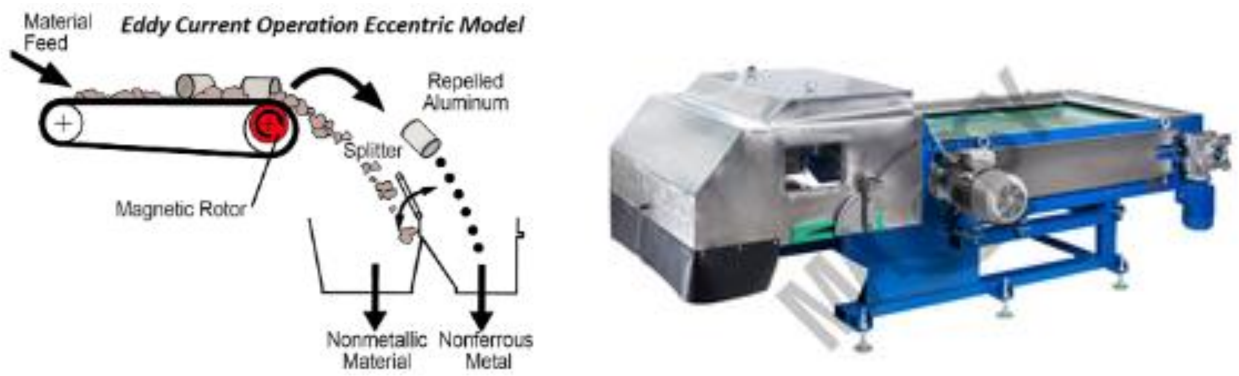
4.5 Metal sorting

When a vehicle is scrapped, before proceeding to the next recycling process the metal fractions must be subjected to a certain pickling and magnetic separation process.

Stripping: Most vehicles have a thin layer of tin over them that prevents the vehicle from rusting. This is great for a car, but not necessary when a vehicle is scrapped and recycled, so the thin layer on the sheet metal is removed. This is done through a process called "pickling" and is done by placing the waste in a hot caustic soda solution that dissolves the tin layer. Once this has been done, the tin can then be recovered in a variety of ways including; evaporation and crystallization using sodium stannate, electrolysis or using hydrated stannic acid and oxide.

The actual recycling process of ferrous metals follows the following steps: sorting the metals into two categories, namely ferrous metals and non-ferrous metals. This step is carried out with the help of magnetic separators of non-magnetic metals (EDDY CURRENT SEPARATOR), then they are categorized according to the material from which the waste is made.

Magnetic separation: Typically, most steel is magnetic and therefore relatively easy to separate from other recyclables such as plastic.



4-8. Figure_ EDDY CURRENT SEPARATOR [19]

The separator is composed of a conveyor at the end of which a magnetic induction cylinder is placed. This cylinder is equipped with very strong NdFeB neodymium magnets. The separation method starts from the different conductivity of each metal.

The next step is crushing and compacting and the result obtained after this action is sent for reuse as secondary raw material for various productions.

4.6 Crushing or shredding (ASR)

The intense concern for both manufacturers and society led to a cooperation between the various disassembly companies.

Once the vehicle has been decontaminated and disassembled, it's time for destruction... Which we mean literally, because once the vehicle has been disassembled, the metal shell of the car will be crushed and sent to the ASR (Automobile Shredder Residue).

10 years ago, the price of scrap metal was so high that the business would have been quite profitable. Now, however, the price of products has fallen so much that it is almost impossible to recover the cost of recycling just by selling scrap metal and other materials.

Solutions to the shredder waste problem are likely to affect both materials and information flows. For governments, recycling is the key word to reduce the amount of shredder waste.

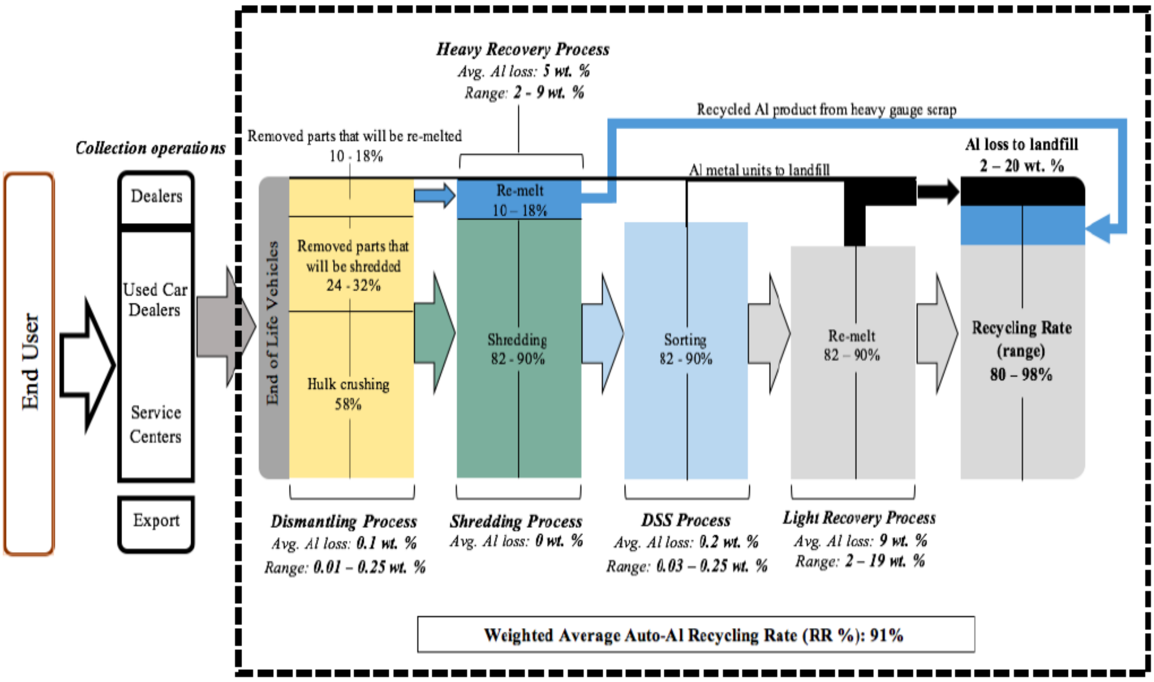
This implies that the flow of materials that are not currently recycled - especially plastics, plastic composites and other non-metals - must be introduced into the production system. Car manufacturers have adopted quite different strategies to manage the shredder waste problem, although through their industry organizations they are trying to find a common solution.

For example, HAMMEL Recyclingtechnik GmbH designed a complete mobile metal processing plant to shred and sort the remaining car body.

4-9. Figure_HAMMEL RECYCLINGTECHNIK [20]

In the first step, the car bodies are shredded using the low-speed HAMMEL shredder. The feeding of the input material is optimal by means of the two counter-rotating special shafts. After shredding, the output material is transported to a mobile metal screen MMS 150 DK. The integrated vibrating screen separates material less than 150 mm. Oversized pieces can be transported back to the chopper. The screened material passes over the vibrating chute to the magnetic drum for the separation of ferrous from non-ferrous materials.

We will show the process material flow diagram summarizing end-of-life auto body processing for aluminum recovery, where each process within the scope of this analysis is within the dotted boundary area, and each material collection and recovery process reports the average and range of losses of aluminum at the landfill.[21]



4-10. Figure_ Process material flow diagram [21]

"Destruction"

When a vehicle is destroyed, it will first go through the processes of: magnetic separation, pickling and melting.

Once the vehicle has been decontaminated, dismantled, sorted it's time for shredding... Which we mean literally, because once the vehicle has been disassembled, the metal body of the car will be crushed and sent to a metal mill for shredding.

5 ELVs RECYCLING PROCESS

Recycling is the introduction of residues or waste into a technological process in order to obtain their reuse and valorization or for ecological purposes. So, we can say that recycling is the process by which "valuable" waste is transformed into secondary raw material for the manufacture of new products.

The ELVs recycling process requires the fulfillment of some minimum technical requirements such as:

1. Storage places (including temporary storage) of end-of-life vehicles before their treatment:

— impervious surfaces for appropriate areas with runoff collection facilities, decanters and cleaning and de-icing solutions;

— water treatment equipment, including rainwater, in compliance with health and environmental regulations.

2. Places of treatment:

— impervious surfaces for appropriate areas, with runoff collection facilities, decanters and cleaning-degreasing agents;

— proper storage of dismantled spare parts, including waterproof storage of oil-contaminated spare parts;

— suitable containers for storage of batteries (with electrolyte neutralization on site or elsewhere), filters and capacitors containing PCB/PCT;

— storage tanks suitable for separate storage of end-of-life vehicle fluids: fuel, engine oil, gearbox oil, transmission oil, hydraulic oil, coolants, antifreeze, brake fluids, battery acids, system fluids of air conditioning and any other fluid contained in the decommissioned vehicle;

— equipment for treating water, including rainwater, in accordance with health and environmental regulations;

— proper storage of used tires, including prevention of fire hazards and overstocking.

3. Treatment operations for the depollution of end-of-life vehicles:

— removal of batteries and LPG tanks;

— removal or neutralization of potentially explosive components (eg airbags);

— removal and separate collection and storage of fuel, engine oil, transmission oil, gear oil, hydraulic oil, coolants, antifreeze, brake fluids, air conditioning system fluids and any other fluid contained in the vehicle removed from use, unless they are necessary for the reuse of the parts in question;

— removal, to the extent possible, of all components identified as containing mercury.

4. Treatment operations to promote recycling:

— removal or catalysts,

— removal of metal components containing copper, aluminum and magnesium, if these metals are not separated in the grinding process;

— removal of tires and large plastic components (bumpers, dashboard, fluid containers, etc.), if these materials are not separated in the shredding process so that they can be efficiently recycled as materials;

— removing the glass.

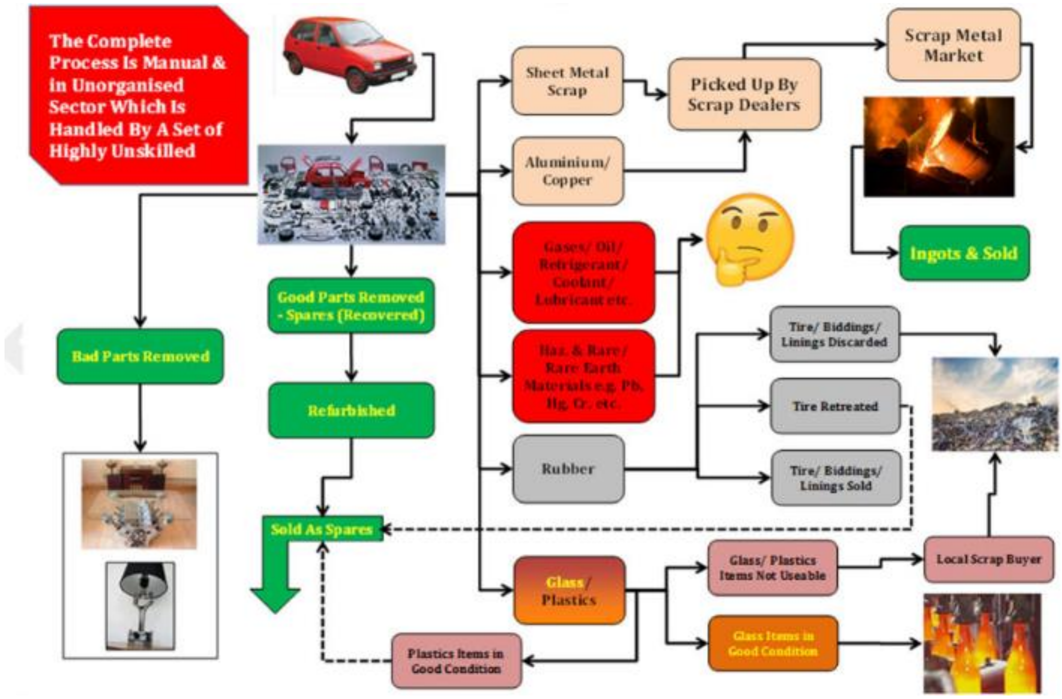
5. Storage operations must be carried out avoiding damage to components containing fluids or recoverable components and spare parts

A production line for recycling waste from the car dismantling process, mainly consists of the mentioned minimum requirements as well as the crushing and separation of iron scrap, steel scrap, aluminum scrap (aluminum baling), engine casing, light melting and the reintroduction of recovered materials into manufacturing.

5.1 Product life extension

If there was a market for used parts, every dismantling company could sell these recycled products and the business would be very profitable. Under these conditions, some of such Romanian companies have developed their outlets in other countries as well.

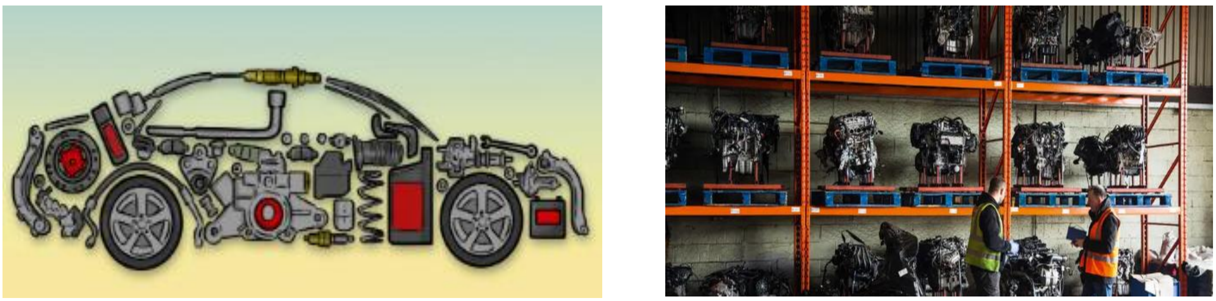
Another serious problem is building a Disassembly Flow, which is quite difficult to achieve.



5-1. Figure_ The recycling flow of a car [22]

Why we should use more dead cars as 'organ donors'?

Once machines have reached EoL and are decommissioned they are stripped piece by piece of all their useful parts and the final step in their journey is disassembly into their base components. It's nice to know that those core components will be reborn in another form, in some cases being parts of a new car.



5-2. Figure_**'Organ donors'** cars from ELVs [23]

The industry believes that increasing the use of recycled parts by 10% could save almost 190,000 tonnes of CO_2 emissions each year in the manufacture of new parts and, if insurers can be persuaded to use them, would help avoid losses and perhaps even reducing the cost of insurance premiums and excesses.

To encourage customers to buy recycled parts, a trade body is developing a certification scheme for vehicle recyclers to ensure greater consistency and reliability of services, including the quality and description of parts, and to enable buyers to distinguish professional sellers from "all the rest". Today, nearly 44 percent of all trucks in North America run on retreaded tires. Retreading can extend tire life by at least 200%, while helping fleets save $3 billion annually in tire costs.

Few people know that the tire factory in Floresti (Romania) has a long tradition, being the first established in South-Eastern Europe in 1939. Initially it was called "Banloc Goodrich", to be renamed "Uzina Chimica Victoria" in 1956. occasion on which the Victoria tire is launched, for the domestic market. Owned by the Michelin group since 2001, the Victoria plant has attracted part of Michelin's investments in Romania. Since the takeover by Michelin, the Floresti plant has undergone many changes and is now in the process of diversifying its product portfolio to serve the American, European and Asian markets, including China. The retreading of truck tires is also carried out at the Victoria plant. The casings used for re-digging in the Floresti unit are collected from Romania. Michelin says that it sells two and a half tires, because actually it is not important to sell the number of tires, but it is important to sell safety per kilometer. For Michelin, in the last two years the retreading market has almost tripled, which proves that there is a market potential, but the retreading profile has also changed.

How electronic equipment recycling could help the automotive industry?

„The lack of raw materials is due the lack of ores such as cobalt, lithium, materials that are increasingly used in the automotive industry. In the absence of these raw materials extracted from the earth, the solution is to procure them from elsewhere, such as from "recycling electrical and electronic waste". Thus, the maintenance of electronic components implies the reduction of electronic waste from landfills.

5.2 Metal fractions recycling

Statistics show that this method of steel recycling uses 75% less energy and resources than producing new steel from iron ore. In fact, recycled metals actually make up about 30% of global metal production! Since 2000, the End-of-life Vehicle Directive has set and met an initial target of recycling 85% of end-of-life vehicles and due to its success, the recycling target has been increased to 95% since last year.

As we find in the name, **ferrous metals contain iron**. Therefore, ferrous metals are magnetic, while non-ferrous metals are not attracted to the magnet, and the sorting is done with the help of large magnetic separators.

It should be noted that electrical and electronic waste (WEEE) contains, in addition to metals (ferrous, non-ferrous) and dangerous substances for the environment, more precisely they contain heavy metals that affect both the ozone layer, fauna, flora and human health.

Therefore, they must be properly handled in specialized WEEE collection centers, where first the harmful substances are extracted, then the metals are recycled in order to reuse them as secondary raw material in the manufacture of other equipment.

Another difference between the two metallic materials is represented by their hardness, more precisely, iron is stronger while non-ferrous metal is more flexible but more resistant to corrosion.

Ferrous metals: wrought iron; steel alloy; stainless steel; cast iron.

Non-ferrous metals: brass; copper; aluminum; silver; gold; magnesium; platinum; zinc; palladium.

When a vehicle is destroyed, it will go to the last process of recycling the metal fractions, sorting them and then melting them:

Melting: Once the steel has been separated and the layer of tin removed, the steel is placed in a furnace to be melted. Once this is done, the steel will be cast into wheels and rolled into new flat steel sheets.

This process can be carried out repeatedly without the steel losing its strength, and when the steel is reused in flat sheets, it can be reused again in many things, including building cars, but also as building materials for strengthening and framing concrete structures.

Ferrous metal recycling

The extraction of iron from ore requires a very large amount of energy and we must take into account the fact that metal deposits are non-renewable resources, continuously exploited until they are exhausted.

Therefore, from an ecological point of view, we must take into account the saving of natural resources by recycling and valorizing the resulting ferrous and non-ferrous waste that serves as secondary raw material in other productions.

Also, iron that reaches the natural environment does not degrade completely, it has resistance over time, which leads to the degradation of the ozone layer.

Another *benefit of metal recycling is represented by the reduction of costs and the increase of the economy* within the various companies that deal with production.

Recycling of non-ferrous metals

The procedure for recycling non-ferrous materials falls into the category of recovery of ferrous and non-ferrous waste.

Copper is part of the category of non-ferrous metals and is one of the most common materials. End-of-life automotive waste is a valuable source of copper scrap.

Among the properties of copper, we mention electrical conductivity, so the production of electricity is due to copper, which is found in wires, cables, pipes and other components for electrical equipment. Also, copper is found in lighting devices, displays, telephones, refrigerators, on-board computers, and almost in all automotive electrical equipment.

Copper, as well as the other materials of which it belongs, can be recycled infinitely, so it is a valuable metal and its recycling is an efficient method of reintroducing it into the economy and into other productions.

At the collection center, the metals are brought either separately or in structures that must be dismantled in order to separate the ferrous from the non-ferrous. In this case, from a metallic structure, the metals containing iron are extracted with the help of magnets, while the copper and other non-ferrous metals remain behind.

Aluminum is a malleable material, it can be bent easily. As a rule, it has a silver color, but most of the time it is painted white. Aluminum is often found in the radiator, engine, cables, but also in other car parts. The most valuable scrap aluminum is unpainted or damaged.

Aluminum recycling begins with the removal of other components such as screws, plastic or any other ferrous or non-ferrous elements and then follows the actual recycling process which is similar to the other non-ferrous ones.

Silver and gold belong to the category of precious non-ferrous metals. The recycling of these two materials is made from PCB (Printed Circuit Board) waste from control systems that can be melted and the result is used as secondary raw material.

PCBs have complex copper in their content through the manufacturing process. In addition, there is nickel plating, gold plating, tin plating and lead plating in PCB production, so these heavy metals are also contained.

5.3 Glass recycling

Glass is a material that can be recycled infinitely. This means that it does not lose its properties during the recycling process and does not need to be combined with virgin material.

Before we explain how glass is recycled, it's important to talk about why this process is useful. Making glass requires sand, limestone, dolomite and calcium carbonate, which are fused and mixed. The next step is modeling, and finally the material is cooled.

Thus, every time we produce new bottles, virgin materials are needed. In coastal areas, soil erosion is a real problem. The more we produce new items, the more sand we take from these areas. Therefore, one method by which we can contribute to protecting the environment is to reuse materials, through recycling.[24]

Once at the recycling center, the waste is sorted by color, then broken and ground, when any impurities are removed. The result is melted and transformed into granules, which will be used in making new products.

Recycling is a process that allows us to save natural resources and energy. At the same time, through it we can better manage greenhouse gas emissions that cause global warming. Keep in mind the tips above to recycle glass correctly.

5.4 Catalytic converter recycling

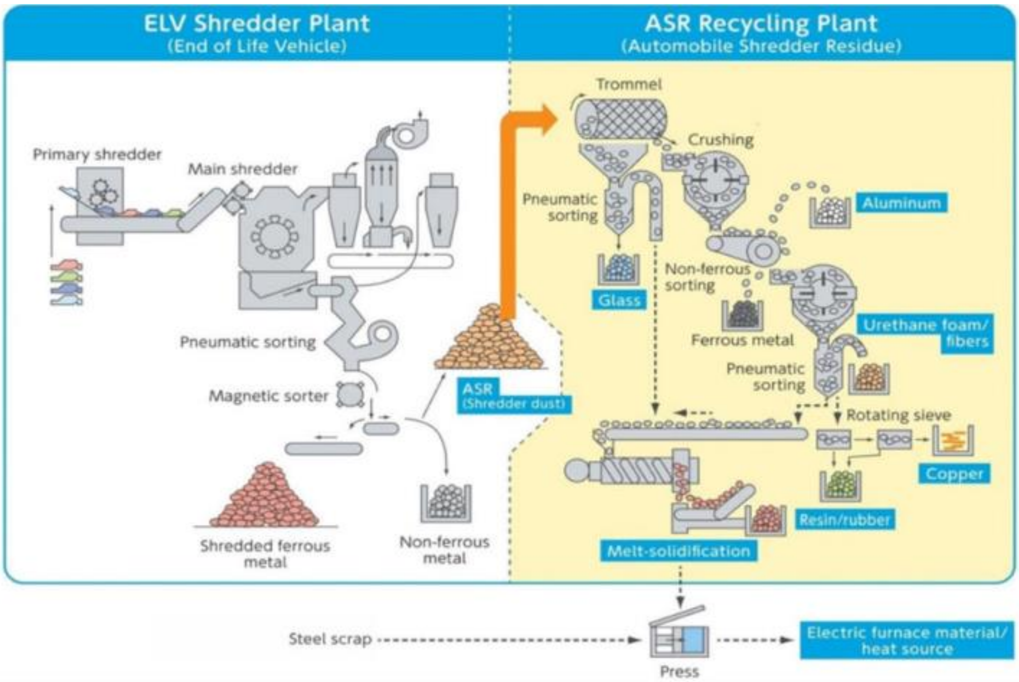
Palladium, Rhodium and Platinum are just a few of the precious metals found in catalytic converters. These metals are removed and reused in various pharmaceuticals, electronics and even jewelry – including wedding rings! Alternatively, they can be reused in the production of new catalytic converters. However, regardless of what the catalytic converter is reused for, it should only be recycled by a qualified professional, as once the ceramic interior is opened and exposed to air, it is considered hazardous waste.

5-3. Figure_ Catalytic converter recycling [25]

5.5 Car body recycling

In order to recycle the car body, metal recycling companies require that all plastic and upholstery components be removed before shredding or crushing the vehicle body.

After third-stage dismantling, the vehicle must be sent to a recycler or a shredding facility known as an ASR (Automobile Shredder Residue). These intensive factories have complex material separation operations. The shredder pulverizes the vehicle, which is then sent by conveyors to sophisticated metal separation technologies, including magnetic, eddy current, laser and infrared separation systems. Such recovery facilities then become feedstock for steel mills, electric arc furnaces, aluminum and other non-ferrous metal smelters. A simple diagram of them is shown below:



5-4. Figure_ Recycling chart [15]

Once all salvageable parts and hazardous materials are removed, the vehicle body can be crushed to reduce its bulk for shipping. However, removing non-hazardous non-metallic components reduces the volume of material to be crushed and could increase the scrap value of the vehicle body. Crushing consists of flattening—that is, compressing the carcass into a rectangular cube.

5-5. Figure_ Casing compression

5.6 Used tires recycling

Among the waste that can be found all around are used car tires. Fortunately, however, used tires represent a type of reusable waste, because the material from which they are made is resistant and can be transformed into other objects by different methods. Thus, many of the used tires are recovered. In this way nature is successfully protected and becomes much cleaner and healthier for everyone.

What are used tires and how can they be recycled?

Used tires are car tires that have reached the end of their life, which can no longer fulfill the purpose for which they were manufactured. The material from which they are made is very robust, resistant to different environmental conditions, durable over time, so their removal will be very difficult.

Car tires are indispensable for people in transport activities, but their disposal can bring with it various problems that will have an impact on the environment.[26]

Flow of used tires

1. ***DELIVERY*** - Natural and legal persons, vulcanizers, services, dealers, shops, have the obligation to hand over used tires free of charge to the authorized companies in order to collect and valorize them.

2. ***COLLECTION*** - The collectors carry out the action of taking the tires from the owners and transferring them to the regrouping platforms. The collection process is done on the basis of an order and a shipping notice (issued by the holder), without claiming the value of this service to the holder.

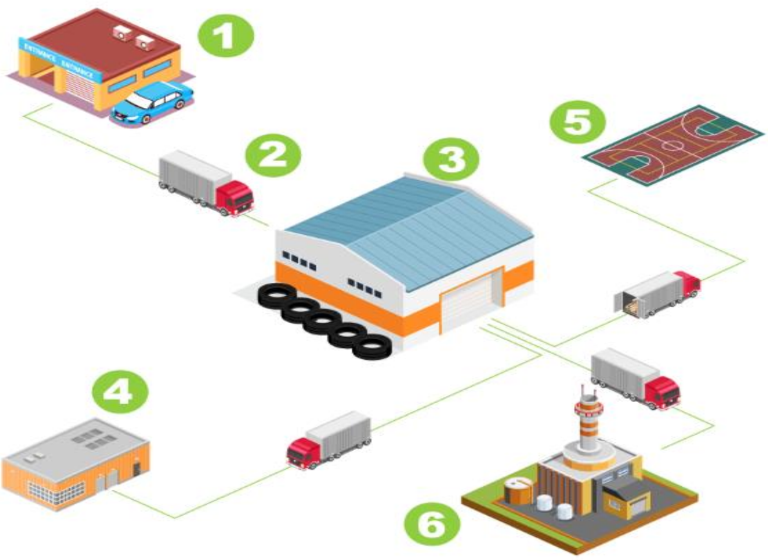
3. ***SORTING*** - The platform is an authorized space where tires are regrouped, sorted into reusable used tires and non-reusable used tires as well as loading for shipment to recyclers.

4. ***USED REUSABLE TIRES*** - Used tires that can be reused will be sent for re-etching or retreading to specialized companies.

Tire retreading is a cheaper option that drivers turn to when they want to save on the purchase of new tires. This process involves the reconditioning of old tires with the aim of reducing the carbon footprint of tire production and the use of raw materials. Also, retreaded tires undergo performance and safety tests before they are sold.

5. ***MATERIAL RECOVERY*** - The methods of material recovery of non-recoverable used tires are multiple, from backfill for roads to carpets for covering gymnasiums and playgrounds.

6. ***ENERGY RECOVERY*** - Energy recovery is possible due to the calorific power of the tire (24-28 MJ/kg). Thanks to this quality, used tires can be used as an alternative fuel.



5-6. Figure_ Waste tire flow [27]

5.7 Recycling used batteries

The global need to reduce greenhouse gas (GHG) emissions and the growing need for individual and sustainable mobility are just a few examples of the phenomena that are creating challenges for the automotive industry.[28]

Due to these changes, automotive OEMs and first-tier suppliers will face a major transformation from the conventional combustion engine to other technologies to protect their businesses. One approach to overcoming these obstacles is to reduce the emissions of the engine used. **Battery electric vehicles (BEVs), fuel cells (FCs) and power-to-gas** are some popular technologies that could help achieve this goal.

Current developments, with a particular focus on BEVs, and one of the biggest barriers for electric vehicles is the life cycle of batteries in terms of energy storage.

Current developments in transport to reduce greenhouse gases

In recent decades, a number of measures have been established to increase the efficiency of traditional internal combustion engine (ICE) vehicles. However, the rate at which efficiency is increasing is decreasing more and more, and there are no longer expectations of major gains in propulsion system development. In addition to this improvement, there was also new legislation for ICEs and a demand to reduce GHG emissions, paving the way for the emergence of new technologies in recent decades.

There are currently **three promising technologies** worth noting that will significantly increase sustainability in private car transport and truck and bus transport and logistics:

1. ***Battery electric vehicles***: a method of using batteries, generally lithium-ion batteries, to store electrical energy, which powers electric motors.
2. ***Fuel Cell Electric Vehicles* (FCEV)**: A method that uses electrochemical processes to convert a continuously fed fuel into electricity in a galvanic cell. Hydrogen (H2) is usually used for these types of engines.
3. ***Power-to-gas* (P2G or PtG)**: a method by which electricity from sustainable sources is converted into combustible gases, such as methane or hydrogen, using electrochemical processes, in turn powering internal combustion engines or fuel cells combustible.

Hydrogen can be used in fuel cells as well as in power-to-gas engines. They offer a variety of technological benefits, and some key OEMs such as BMW and Hyundai are investing in research and development and manufacturing facilities. Hyundai expects H2 fuel cell vehicles to be on par with BEV prices in 2030.

The potential being explored for electrification is in the main heavy propulsion applications such as trucks, buses, trains, aircraft and ships and not in the automotive industry. Although there are some advantages in using fuel cells or hydrogen-based power-to-gas engines, there are some (technological) barriers (eg vehicle production cost, technological maturity, fuel cost and profitability) to overcome. A detailed description of additional barriers can be found in Trencher et. al. 2021 (pdf)[29].

5-7. Figure_ vehicul cu celule de combustie H_2 Hyundai [30]

Challenges for bevs and the value chain of their components

Customers in the automotive industry are used to the widespread availability of gas stations and fast refueling times. Therefore, the potential range and availability of fast-charging energy is an important issue for the success of alternative propulsion systems.

From a customer perspective, there are three major challenges that can be identified that interfere with BEVs becoming competitive with ICE vehicles in the near term:

- ***Charging infrastructure*** (ie, number of fast/turbo charging stations, power line capacity)
- ***Range*** when not charged
- ***Competitive prices*** for BEVs

Although the complexity of a BEV powertrain is lower compared to an ICE powertrain and the key elements (e.g. gearbox and shifter) of an ICE are not required, production of BEVs is still expensive today compared to vehicles with combustion engine.

This mainly results from the costs of extracting and processing raw materials and the total production costs for energy storage. Since, relatively speaking, the interior and body of the cars remain the same, the focus is on gaining a competitive advantage by producing affordable batteries with increasing capacity and reducing emissions during the production steps for the final product and the necessary materials.

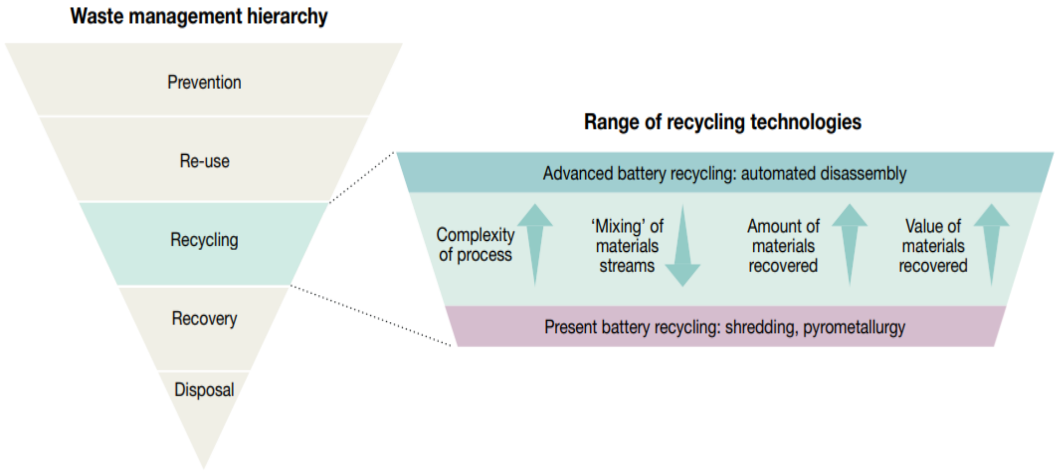
One way to reduce the total GHG emissions of a powertrain during the use phase is to extend the life of the battery. This in turn shifts the focus to aftermarket and product maintainability. Compared to ICE-powered vehicles, the BEV value chain is becoming more complex, as the reuse of components and raw materials is of increasing importance. In the past, old ICE cars were serviced and resold if possible before being scrapped for parts and low value resources.

At this point, the market for used BEVs is just starting to emerge. The resource value in BEVs is significantly higher and more difficult to recover than in ICE vehicles. Consequently, recycling requires special capabilities and significant effort and lengthens the value chain. Therefore, the recyclability of BEV components is an important feature to consider.

In the BEV aftermarket, there is huge potential to add value and unlock new market segments, while significantly increasing the overall sustainability of the industry. A shift from ICE components to more complex battery systems is challenging the current structure and capabilities of the aftermarket.[31]

Due to the growing demand for BEVs, there will be many batteries reaching the end of their (prime) life in the next decade and by extension coming to market with significantly reduced power/productivity. Because the technology is relatively early in its maturity curve compared to ICEs, there are few approaches available to extend component life, recycle battery cells, or even prevent disposal altogether.

The **"BEV Waste Hierarchy Pyramid"** provides an approach to better understand the effects of waste prevention and measures that extend the life of products and parts.



5-8. Figure_ BEV Waste Hierarchy Pyramid [24]

Here, that hierarchy is extended to consider the range of battery recycling technologies[32]:

"Prevention" means that LIBs are designed to use less critical materials (high economic importance but risk of insufficient supply) and that EVs should be lighter and have smaller batteries.

"Reuse" means that electric vehicle batteries should have a second use.

Reuse/second life of batteries outside of a BEV is a promising way to generate profit. Due to the high technical requirements imposed on vehicle batteries in relation to their possible charging and discharging currents and their capacity, the batteries can only be used in a single vehicle for a limited period of time. They typically reach end of life (EoL) at 80% SOH (usually referring to first life).

Applications in which these batteries can be used after passing this mark:

- the use inside the storage house of batteries for energy from solar systems or other renewable energy sources;
- the use of batteries for energy storage within enterprises to allow more flexible reactions to volatile energy prices. During periods of high energy prices, such storage can be used as a buffer for production demand.

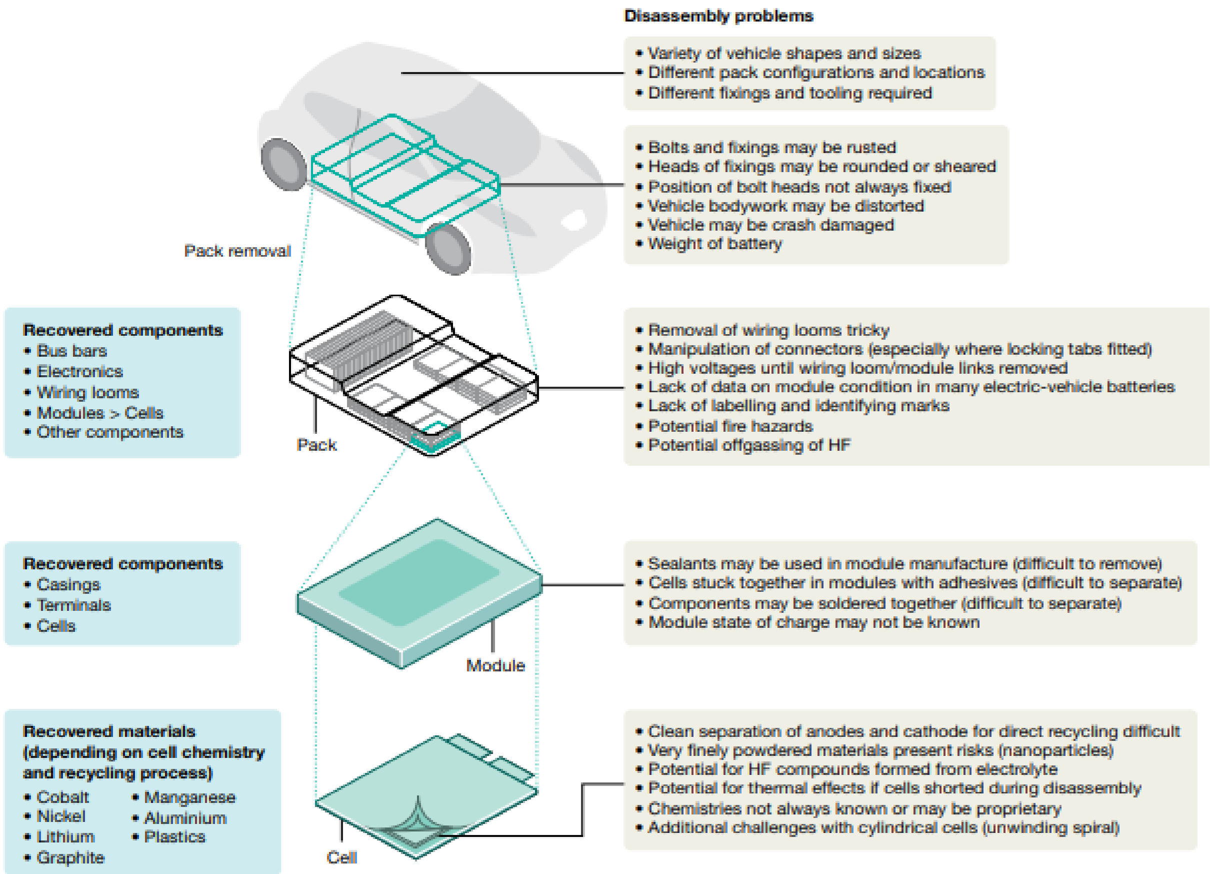
"Recycling" means that batteries must be recycled, recovering as much material as possible and retaining any structural value and quality (eg prevention of contamination).

"Recovery" means the use of battery materials as energy for processes such as pyrometallurgical fuel. Battery cells age unevenly and a single defective battery cell affects the SOH of the entire battery.[28]**Error! Bookmark not defined.** Minor defects can render BEVs inoperable even though they still offer great potential value.

Reuse or a second life is an option for a battery, so remanufacturing battery packs promises a high added value potential compared to recycling or incineration. Typical use cases are replacing insufficient battery cells or modules or even other battery parts. Keeping these highly engineered products in use significantly increases customer value.

Consequently, finding remanufacturing strategies will be a key focus for the near future, offering great potential for the automotive industry and automotive suppliers.

Thus, there are a lot of challenges regarding the disassembly of these batteries such as:



5-9. Figure_ Diagram showing the takedown challenges at different levels of scale [32]

"Disposal" means that no value is recovered and the waste goes to landfill.

Based on these applications, new business models can be developed to manage the different battery life cycles. Scientific studies estimate an available range of 112 to 275 GWh per year by 2030. [28]

6 ELECTRIC VEHICLES VERSUS INTERNAL COMBUSTION VEHICLES

We are accelerating towards an ***electric future***, but do we really understand the ***consequences of replacing the conventional motor***?

Electric vehicles (EVs) represent the future of the automotive industry in terms of reducing greenhouse gas emissions, air pollution and a better level of living comfort around the world. This phenomenon is fueled by the emission targets set by the European Commission, which estimates that by 2030, there should be at least 30 million electric cars on the roads of EU countries, not including hybrid ones.[33]

The bodies of millions of clean electric cars that will be on the world's roads in the coming years will hide a "dirty" battery, because the lithium-ion batteries that equip the vehicles are produced in some of the most polluted places in the world.

Research shows that even though electric vehicles have no CO2 emissions on the road, they are responsible for more carbon dioxide than conventional cars.

To build a car battery - which weighs 500 kilograms - CO2 emissions are 74% higher than in the case of producing a conventional efficient car, if it is manufactured in a factory powered by fossil fuel energy (according to Berylls' conclusions).

In addition, regulators have not set clear guidelines on acceptable life-cycle carbon emissions for electric vehicles, even as China, France and the UK move toward outright bans on combustion engines. "Inevitably they will end up in where the battery is built, how it's made and even where we get the electricity from," says Henrik Fisker, chief executive and chairman of California-based electric car developer Fisker Inc.[34]

It is known that every new technology comes with an additional cost that must be feasible in relation to current trends.

Currently, manufacturing an electric car pumps out "significantly" more climate-warming gases than a conventional car, which at this stage emits only a fifth of the carbon dioxide it emits over its lifetime, the department estimates integration of the Mercedes-Benz electrical system.

Thus, with the adoption of electric vehicles, we get a reduction in greenhouse gas (GHG) emissions, but we will have a significant increase in the level of human toxicity due to the greater use of metals, chemicals and energy to produce the powertrain and of high voltage batteries. And in terms of cost, higher initial cost at the time of purchase due to the higher price of the battery.[35]

6.1 Carbon footprint of electric vehicle

At least one thing is certain: if an electric car is charged with green electricity, it does not produce climate-damaging carbon dioxide emissions during operation. But an electric car's carbon footprint doesn't just start when the proud new owner pushes the start button for the first time. This footprint already starts in the production process.

Based on the Paris climate target, Volkswagen [36], has set itself the goal of being CO2 neutral as a company in balance sheet terms by 2050; by 2025, the carbon footprint of the fleet of cars and light commercial vehicles is to be reduced by 30% in balance terms compared to 2015. Emissions from the entire life cycle are taken into account, including the entire production value chain, the use of the vehicle by customers and recycling. The e-mobility strategy is the core technology for achieving these goals.

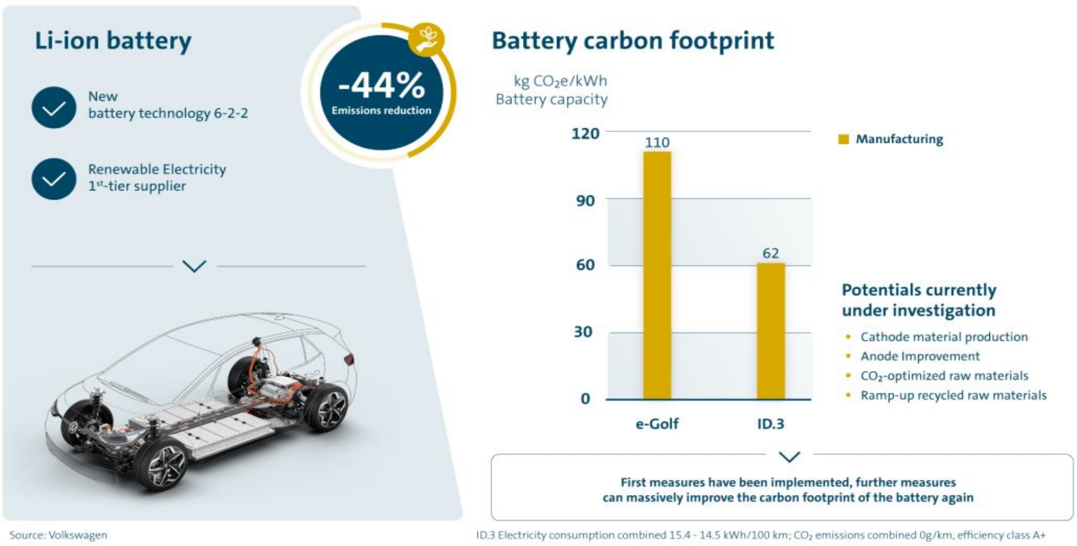
The methodology for calculating life cycle assessments – and as part of this, CO2 balances (greenhouse gas balances) – is based on the globally valid ISO 14040 standard for life cycle assessment (LCA).

6.2 The electric vehicle already has a superior equivalent

Using current models in the compact class, we have created TÜV certified balance sheets to compare an electric vehicle (Battery Electric Vehicle – BEV) with a modern petrol and diesel model respectively. To ensure a fair comparison, the models have been selected so that equipment and performance are as similar as possible.

Compared to the battery used in the e-Golf03, the new generation of batteries in the ID.3 marks a huge advance. With the new cathode material (6-2-2), the battery capacity has been increased at the same material cost compared to the previous generation (1-1-1). At the same time, we have agreed with our battery cell supplier to use electricity from renewable energies.

These two measures reduced the specific carbon footprint from 110 kg CO2/kWh to only 62 kg CO2/kWh.

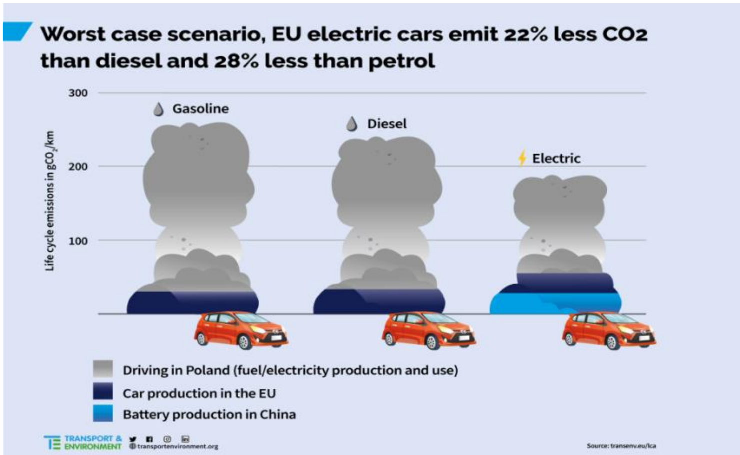


6-1. Figure_ Specific carbon footprint [37]

There is also great potential for reduction in the rest of the value chain, for example in the production of cathode material or anode graphite. In addition to the potential in the battery supply chain, measures are currently being considered for other hot spots such as steel and aluminum.

Vehicle emissions compared to conventional vehicles

Electric cars in Europe emit almost **three times less CO_2** on average than equivalent petrol or diesel cars. That's according to a new online tool developed by T&E that allows the public to compare the lifecycle emissions of an electric vehicle with fossil fuel vehicles.



6-2. Figure_ Scenario Electric cars than diesel [37]

7 AUTOMOTIVE SUSTAINABILITY

Sustainability in the automotive industry covers everything from research and development and engineering to supply chains and supporting a circular economy. Although sustainability has been on the industry agenda for some time, today it has taken on new urgency and importance. This is because in recent years there has been an increase in public awareness and concern about sustainability in the car and truck industry.[38]

For example, around 80% of a vehicle is now recyclable. The remaining 20% were usually sent to landfills. Experts agree that reusing and reselling these non-recyclable materials should be a key sustainability goal for manufacturers. With customers demanding environmental and social sustainability from the brands they support, the automotive industry has increasingly moved to adopt sustainable practices that meet these expectations.

This return to zero-waste production is supported by the use of materials that can be recycled and reused over and over again.

UBQ™ material helps automakers achieve zero-waste technology and achieve their sustainability goals. For example, the company has already partnered with vehicle manufacturer Daimler to partially replace traditional plastics such as polypropylene with the climate-positive thermoplastic UBQ by early next year.

7.1 Asustainable future

As consumer preferences and advanced technologies make sustainability and zero waste more accessible to the automotive industry, UBQ Material helps manufacturers meet the challenge of rethinking and redesigning production processes while reducing waste and investing in materials that encourage continuous reuse..

Can zero waste be achieved in the automotive industry?

Yes, but all stakeholders need to be involved, so UBQ Material plays a role in supporting car manufacturers as they become more environmentally conscious and work towards their sustainability goals.

Due to its properties, plastic is irreplaceable in the automotive industry, it has eliminated metal, contributed to the reduction of car weights and the reduction of CO_2 production and fuel consumption..

Incorporating recycled materials into the car interior is a more complicated step due to strict emissions and odor requirements. PET recycling technologies have proven successful in the production of mats and flooring. Recycled textiles are used for cushioning the floor.

Other possibilities are being developed, such as fibers obtained from unused portions of coconut, flax, beet or coffee that would serve as plastic filling materials. All this occurs to conserve natural resources and use waste.

7-1. Figure_ Recyclable materials model SKODA SCALA [39]

The production of plastic parts generates unusable parts and items that have been thrown away in the past. Today, they are used to produce recycled materials. They have an advantage due to their quality, being able to be used completely from scratch.

7.2 10R of automotive industry

Automotive waste management through different types of circular economy strategies based on the 10R framework (i.e. recover, recycle, reuse, remanufacture, refurbish, repair, reuse, reduce, rethink, refuse).[40]

The data were organized according to the framework by Potting et al., where the 10Rs are structured into three groups:

a) useful application of materials;

b) extend the life of the products and their parts; and

c) smarter manufacturing and use of products

Smarter product use and manufacture	R0	Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1	Rethink	Make product use more intensive (e.g. through sharing products or by putting multi-functional products on market).
	R2	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources
Extend lifespan of product and its parts	R3	Reuse	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function
	R4	Repair	Repair and maintenance of defective product so it can be used with its original function
	R5	Refurbish	Restore an old product and bring it up to date
	R6	Remanufacture	Use parts of discarded product in a new product with the same function
	R7	Repurpose	Use discarded products or its part in a new product with a different function
Useful application of materials	R8	Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9	Recovery	Incineration of material with energy recovery

7-2. Figure_ CE strategies, from Potting et al. (2017)

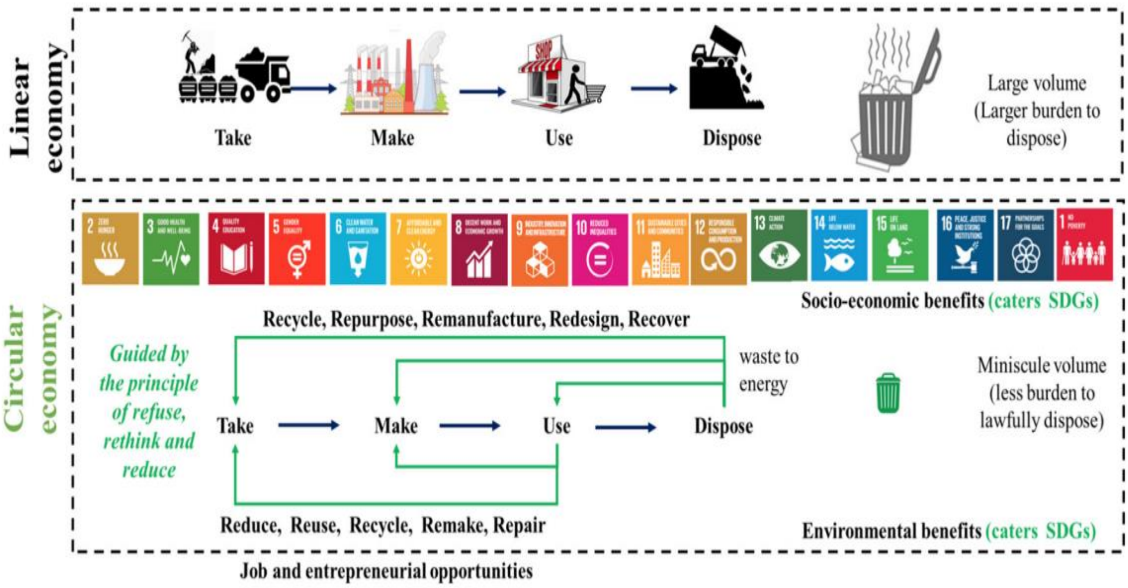
7.3 Vision of a circular economy

EV implementation is a sustainable solution for the automotive industry to respond to the degradation of the Earth. Originally, sustainability meant meeting the needs of the present without compromising the ability of future generations to meet theirs.[41]

Our growing economic system operates within a parent system (Nature) that was fixed/constant and is now shrinking and an economic system that continues to grow. A linear flow of materials and energy is not feasible to maintain if industries are to be sustainable, as the circular model focuses on the economy and the environment and its benefits over the linear system. In comparison, sustainability focuses on the social aspects of society – the circular economy is thus a framework in which the fundamental aspects of sustainability are achievable.

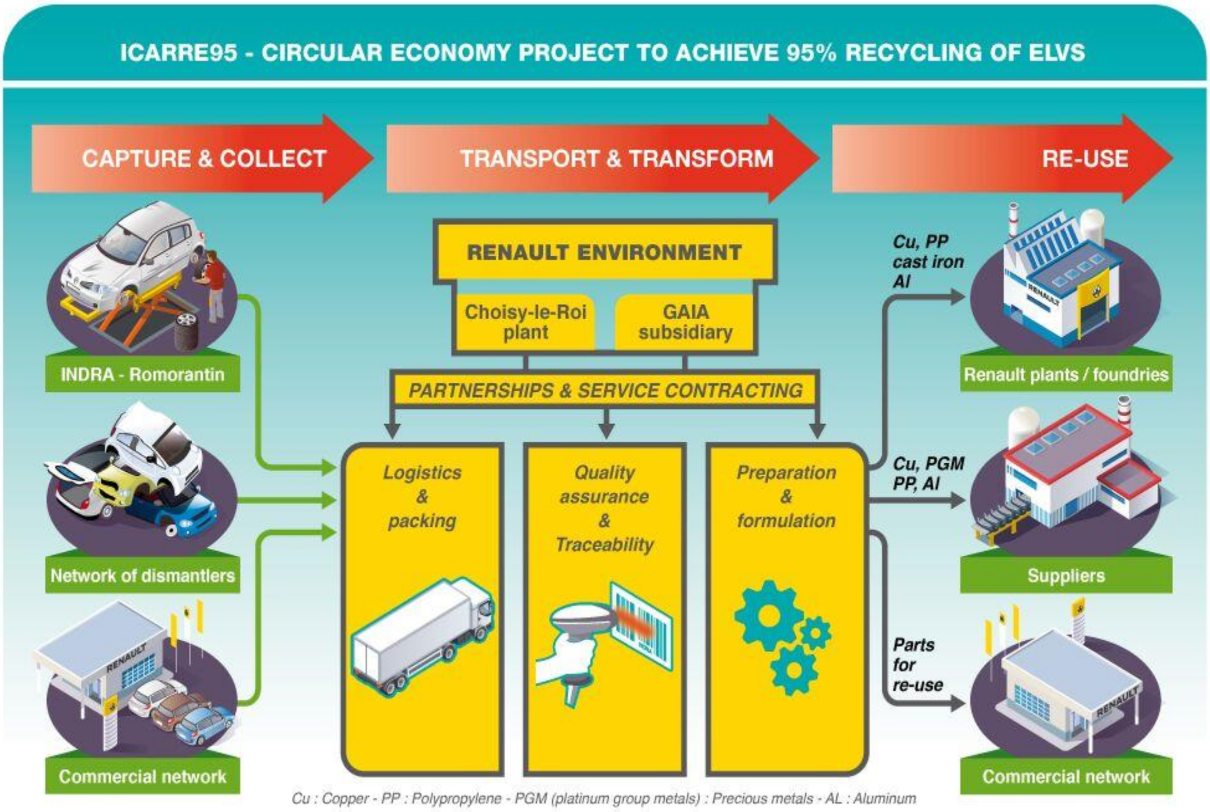
The concept behind the circular economy is a collection of ideas from a number of scientific fields, including industrial ecology, industrial ecosystems, industrial symbiosis, cleaner production, production systems, product-service systems, eco-efficiency, cradle-to-cradle design cradle, biomimicry, resilience of social-ecological systems, performance economics, natural capitalism and the concept of zero emissions, among others.

The aim of the circular economy is to preserve the value of products and materials for as long as possible.



7-3. Figure_ The difference between the linear and circular economy shows ways to achieve the SDGs.[42]

For example, one of Renault's circular economy objectives was to ensure the recycling of materials within the same branch ("closed loops"). The ICARRE95 project offered RENAULT (through its subsidiary Gaïa) the opportunity to develop new activities in the field of material collection and recycling in collaboration with an entity specialized in material recycling (SYNOVA for plastic, MTB for copper...).



7-4. Figure_ Circular by design – Products in the circular economy [43]

In the first phase of the project, the objectives were to increase the volumes collected and establish quality standards for recycling operations to avoid cross-contamination.

The second phase was to favor the reuse of these materials by preparing them for a new life and reusing them in production processes.

During the Icarre95 project (2011-2015), Gaia served as the "interface" for all project members, enabling traceability of materials, contractual arrangements and invoicing. Since then, it ensures the operational feasibility of the closed recycling loops developed within the Icarre95 project.

Until the end of 2015, the Renault group could rely on five closed loops, operated by GAIA or other affiliates:

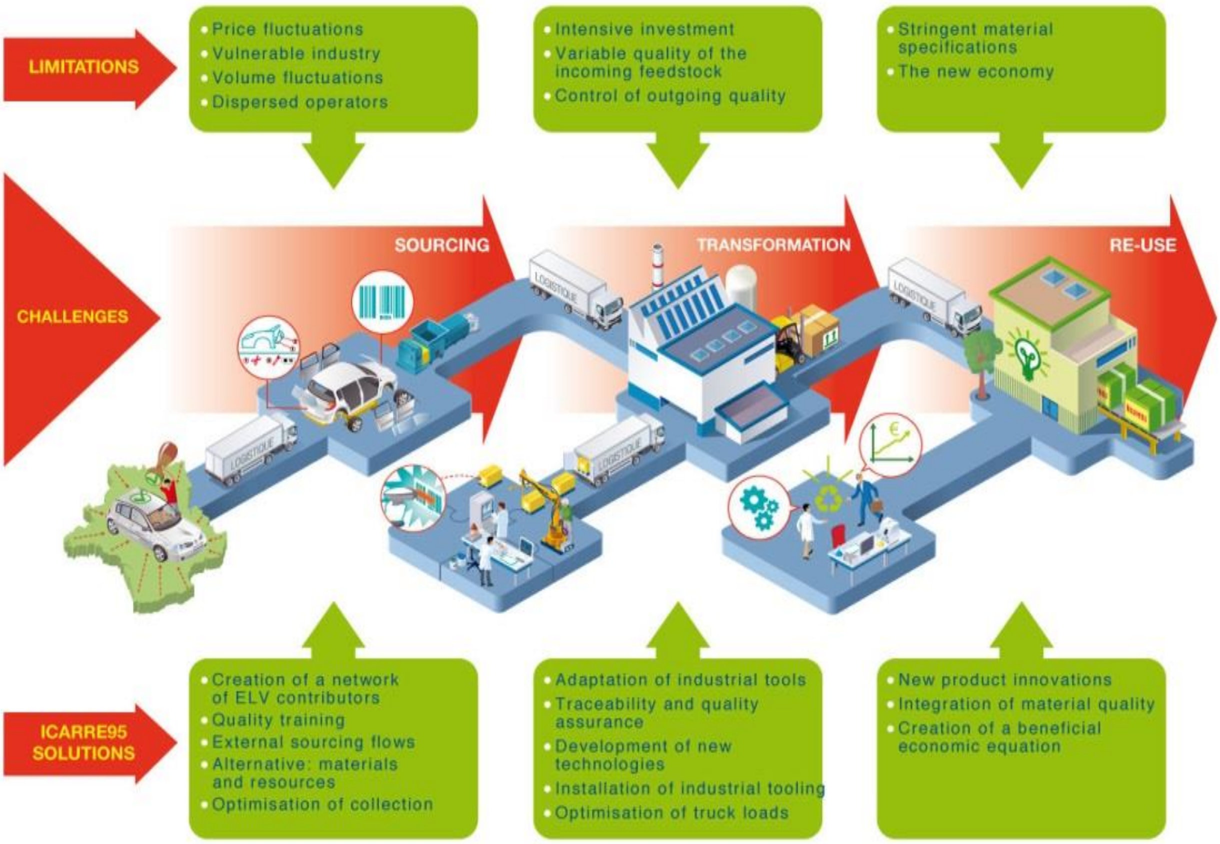
1 The recycling of metal parts from the maintenance and service networks are sent to foundries.

2 Copper recycling: wiring harnesses bought from scrap yards are turned into high-quality recycled copper.

3 Recycling of polypropylene (from bumpers).

4 Recycling of metals from the Platinoid group (from used catalytic converters).

5 Recycling of metal waste from production processes.



7-5. Figure_Renault circulary economy [44]

Earth's resources are limited. So using them effectively is essential. "Closing material cycles can decouple economic growth and resource consumption, as well as reduce dependencies," says circular economy expert Dennis Christian Meinen. The aim of the circular economy is to preserve the value of products and materials for as long as possible.

8 QUIZ

1. What is the automotive industry?

   The automotive industry is an important branch of the economy, which includes those activities involved in the design and construction of automobiles.

2. What are the Key Segments in Automotive Industry?
   a) Light vehicles
   b) Trucks and buses
   c) Construction and agriculture
   d) Electric and hybrid cars
   e) Autonomous vehicles

3. What is the Automotive Industry Value Chain?
   a) Input logistics
   b) Design and manufacture
   c) Engineering
   d) Quality and warranty
   e) Connected Vehicle Services
   f) Marketing and Sales
   g) Service

4. What are the Automotive Industry Resources?
   a) Infrastructure
   b) Information technology
   c) Finance and Procurement
   d) Human resources management

5. What are the Key Terms in Automotive Industry?
   a) ADAS - Advanced driver assistance systems

b) AV – Autonomous vehicles

c) IoT – Internet technology

d) GPS – On-board diagnostics

e) EV – Electric vehicle

f) HEV – Hybrid vehicle

g) PHEV - Connected hybrid-electric vehicles

h) VEB - Battery electric vehicle

6. What are the Competitive Advantage in Automotive Industry?

   a) Sales – short time to sell

   b) Quality – increasing customer satisfaction

   c) Forecast – predictions about vehicle demand

   d) Inventory management – inventory update

7. What are the so-called megatrends in the automotive industry?

   a) electrification of industry,

   b) connectivity through the use of IoT (Internet of Things) technology and

   c) autonomous driving of vehicles.

8. What are the challenges of automotive industry?

   The lack of labor and the impossibility of finding qualified workers

9. What ELV Directive prohibits?

   Prohibits the use of hazardous substances in the manufacture of new vehicles (in particular lead, mercury, cadmium and hexavalent chromium),

10. What is the management hierarchy regarding the disposal of car waste?

    a) preventing the occurrence of waste by minimizing the amount of waste generated,

    b) reuse of objects,

    c) waste recycling,

d) recovery through energy recovery,

e) final storage (in/on the ground).

11. What are the types of waste?

a) liquid waste;

b) chemical products, such as antifreeze, refrigerants, battery acid (Lead-acid batteries);

c) used washing solutions and emulsions;

d) sludges and industrial sludges;

e) paint waste, including thinner, varnishes and similar;

f) waste with PCB content;

g) used solvents;

h) used oils, including used oil filters and adsorbents;

i) scrap metal, brake pads, bodywork;

j) used tires;

k) recyclable waste (paper, plastic, metals, rubber, glass, etc.).

12. What are ELVs called?

"junk vehicles" or "rescue vehicles"

13. How many categories of ELVs are?

a) Natural ELVs that have reached the end of their life from a technical or economic point of view;

b) Premature ELVs, which are new cars resulting from unwanted events such as accidents.

14. What is the cradle to cradle life cycle?

From the design phase, vehicle manufacturing, operation and maintenance of the vehicle throughout its life, to scrapping and recycling.

15. What are the recycling operations of old vehicles?

a) Delivery and storage of old vehicles for recycling

b) Removal of fluids and hazardous materials from vehicles

c) Dismantling vehicles for usable or recyclable parts

d) Crushing or shredding vehicle bodies

e) Sorting of materials into ferrous materials, non-ferrous materials / other residues

f) Recycling of metal fractions

16. How is metal sorting done?

    Sorting is done with the help of large magnetic separators.

17. How is recycled glass?

    The waste is sorted by color, then broken and ground, when any impurities are removed.

18. What is obtained by recycling catalytic converters?

    Palladium, Rhodium and Platinum.

19. What are used tires and how can they be recycled?

    Are car tires that have reached the end of their life, they can be recycled by Retreading.

20. What are the Challenges for BEV?

    a) *Charging infrastructure* (ie, number of fast/turbo charging stations, power line capacity)

    b) Range when not charged

    c) *Competitive prices for BEVs*

9 REFERENCE

[1]. https://work-finder.eu/automotive-prezentul-si-viitorul-industriei-auto-in-romania/

[2]. https://www.predictiveanalyticstoday.com/what-is-automotive-industry-top-software-in-automotive-industry/

[3]. Istriteanu S. and Gheorghe G, Research on the Value Chain as a Strategic Management Tool for the Digital Enterprise, International Journal of Modeling and Optimization, Vol. 11, No. 4, November 2021;

[4]. https://eur-lex.europa.eu/legal-content/RO/TXT/?uri=celex%3A32000L0053

[5]. http://www.anpm.ro/documents/16755/42624324/Planul+National+de+Gestionare+a+Deseurilor.pdf/49fb72f1-81e2-4892-b0a9-669c74ce95e4

[6]. https://environment.ec.europa.eu/topics/waste-and-recycling/waste-law_en

[7]. https://ec.europa.eu/environment/green-growth/waste-prevention-and-management/index_en.htm

[8]. https://ecoteca.ro/ue-ro-ierarhia.html

[9]. Being wise with waste: the EU's approach to waste management, Publications Office of the European Union, 2010, ISBN 978-92-79-14297-0, doi 10.2779/93543

[10]. https://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf

[11]. https://www.indecogrup.ro/colectare-deseuri-periculoase-din-industria-auto/.

[12]. https://blog.camelot-group.com/2021/12/circular-economy-automotive-industry-challenges-for-sustainable-value-chain-transformation/

[13]. https://cdn.group.renault.com/dac/ro/plan-de-gestionare-a-deseurilor/plan-gestionare-deseuri-Dacia.pdf

[14]. DACIA automotive waste management plan and work points, 2022 - 2025

[15]. https://www.motorindiaonline.in/vehicle-scrapping-or-recycling-an-indian-perspective/

[16]. https://eu.boell.org/en/end-of-life-vehicles-final-destination

[17]. https://autodrain.net/

[18]. https://recyclinginside.com/recycling-technology/conveying-and-feeding/

[19]. https://www.magsy.ro/

[20]. ecovery-worldwide.com/en/artikel/hammel-recyclingtechnik-gmbh-25-years-revolution-3624270.html

[21]. Sean Kelly and Diran Apelian, Automotive aluminum recycling at end of life: a grave-to-gate analysis

[22]. https://evreporter.com/vehicle-scrapping-or-recycling-indian-perspective/

[23]. https://www.autocar.co.uk/car-news/features/final-destination-one-cars-end-life-journey-scrapheap

[24]. https://marathonepr.ro/blog/reciclarea-sticlei

[25]. https://www.livepr.ro/ce-este-un-convertor-catalitic/

[26]. https://stratos.ro/reciclarea-cauciucurilor-uzate-informatii-utile-pentru-protejarea-mediului-inconjurator/

[27]. https://ecoanvelope.ro/fluxul-anvelopelor/

[28]. https://blog.camelot-group.com/2021/12/circular-economy-automotive-industry-challenges-for-sustainable-value-chain-transformation/

[29]. Trencher, G.; Edianto, A. Drivers and Barriers to the Adoption of Fuel Cell Passenger Vehicles and Buses in Germany. Energies 2021, 14, 833. https://doi.org/10.3390/en1404 0833

[30]. https://driving.ca/features/feature-story/motor-mouth-batteries-and-hydrogen-are-like-milk-and-cheese

[31]. D. Parker et al. 2015, Remanufacturing Market Study

[32]. Harper, G., Sommerville, R., Kendrick, E., Driscoll, L., Slater, P., Stolkin, R., Walton, A., Christensen, P., Heidrich, O., Lambert, S., Abbott, A., Ryder, K., Gaines, L., & Anderson, P. (2019). Recycling lithium-ion batteries from electric vehicles. Nature, 575(7781), 75-86. https://doi.org/10.1038/s41586-019-1682-5

[33]. https://republica.ro/acceleram-catre-un-viitor-electric-dar-intelegem-cu-adevarat-toate-consecintele-inlocuirii-motorului-conventional

[34]. https://www.zf.ro/auto/murdaria-curatelor-masini-electrice-17560077

[35]. Shrey Verma, Gaurav Dwivedi, Puneet Verma, Life cycle assessment of electric vehicles in comparison to combustion engine vehicles: A review, Materials Today: Proceedings, Volume 49, Part 2, 2022, Pages 217-222, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2021.01.666. (https://www.sciencedirect.com/science/article/pii/S221478532100763X)

[36]. https://www.volkswagenag.com/en/news/stories/2021/02/e-mobility-is-already-this-much-more-climate-neutral-today.html#

[37]. https://www.transportenvironment.org/discover/does-electric-vehicle-emit-less-petrol-or-diesel/

[38]. https://www.ubqmaterials.com/blog-post/zero-waste-in-automotive-industry/

[39]. https://www.automotoinvest.ro/utilizarea-materialelor-reciclate-in-masinile-skoda-niciun-plastic-nu-se-pierde-1

[40]. Piero Morseletto, Targets for a circular economy,Resources, Conservation and Recycling,Volume 153,2020,104553,ISSN 0921-3449,https://doi.org/10.1016/j.resconrec.2019.104553. (https://www.sciencedirect.com/science/article/pii/S0921344919304598)

[41]. WCED, 1987. World commission on environment and development. Our Common Future 17 (1), 1–91. https://sustainabledevelopment.un.org/content/documents/5987ourcommon-future.pdf.

[42]. Hari Bhakta Sharma, Kumar Raja Vanapalli, Biswajit Samal, V.R. Sankar Cheela, Brajesh K. Dubey, Jayanta Bhattacharya, Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery, Science of The Total Environment, Volume 800, 2021, 149605, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2021.149605. (https://www.sciencedirect.com/science/article/pii/S0048969721046805)

[43]. Halia M. Valladares Montemayor, Rayyan Hamza Chanda, Automotive industry's circularity applications and industry 4.0, Environmental Challenges, Volume 12, 2023, 100725, ISSN 2667-0100, https://doi.org/10.1016/j.envc.2023.100725. (https://www.sciencedirect.com/science/article/pii/S2667010023000495)

[44]. http://www.circulary.eu/project/renault-closed-loop/

Module 6

Introduction to environmental challenges and waste in the automotive industry

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Introduction – wastes in the automotive industry

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