ECO-INNOVATION AND ECO-DESIGN IN THE CURRENT AUTOMOTIVE INDUSTRY

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Abstract - Current sustainability challenges and the systemic transformation required highlight the need for innovations at multiple levels. The global regulatory framework is driving new environmental design methods and practices. At the European level, based on the European Green Deal, the 8th Environment Action Program (EAP) entered into force on 2 May 2022 as the EU's legally agreed common agenda for environmental policy up to 2030. The EAP forms the EU's basis for achieving the United Nations' 2030 Agenda and its Sustainable Development Goals. In 2020, the European Commission adopted a new Circular Economy Action Plan, which provides measures throughout the product life cycle and aims to prepare the European economy for a green future and strengthen competitiveness, while protecting the environment and giving new rights to consumers. In 2023, the European Council adopted its position on the proposal for a regulation establishing a framework for the stability of eco-design requirements for sustainable products.

The automotive industry is trying to cope with these regulations and at the same time to remain competitive in terms of costs. Also, it is a landmark in forming sectoral models of eco-innovation and eco-design due to its role in modern societies, positively as the main choice of transport but negatively in terms of environmental damage and the intensive use of non-renewable resources.

Keywords: Eco-innovation, Eco-design, Sustainability in automotive industry, Circular economy.

1. Introduction

The current sustainability challenges and the required systemic transformation highlight the need for innovations on multiple levels.

Industrial production processes cannot include an ecological production process without addressing sustainability, societal development and most importantly, a circular economy. Companies can achieve financial and environmental benefits through sustainable production processes.

Eco-design integrates environmental aspects into product and process design to reduce environmental impacts, whereas eco-innovation also concerns nontechnological solutions.

Eco-innovation is viewed as a crucial approach for overcoming challenges to a CE transition where drivers have a significant role to play. To drive the systemic shift to the circular economy, synergies are needed between approaches such as eco-design and eco-innovation, as they focus on product life cycles, process efficiencies, marketing methods and business models, which together promote institutional changes.

Eco-design and eco-innovation complement each other, with the former focusing more on technological improvements and the latter on both nontechnological incremental and radical changes [1]. Eco-design approaches support eco-innovation activities and help companies identify and reduce the negative environmental impact associated with their activities [2].

Leading car manufacturers are adopting responsible trends in the use of resources. For example, over 2021-2025, Ford intends to use 20% sustainable materials in its vehicles [] [3], Volkswagen has committed to halving the carbon emissions per vehicle in all its plants [4], and Toyota [5] has declared that it will seek a 30% reduction in the global average carbon emissions from its new vehicles, compared to 2010 levels. Likewise, over 2026-2030, General Motors [6] has stated that it will use 100% renewable energy for vehicles manufactured in the US and reduce factory greenhouse gas emissions by 31%, even as a raft of automakers, including Honda, Nissan, Toyota, Volvo, and Volkswagen, are working to achieve carbon neutrality by 2031-2050 [7].

2. Sustainable Policies, Regulations and Instruments

The worldwide regulatory framework is pushing new design methods and practices for environmental purposes. Since the Maastricht Treaty was signed on 7 February 1992, institutions and regulatory methods have changed in environmental rulemaking within the European Union.

On 2 May 2022 the 8th **Environment Action Programme** (EAP) entered into force, as the EU's legally agreed common agenda for environment policy until 2030 [8]. The action programme reiterates the EU's long-term vision to 2050 of living well, within planetary boundaries. It sets out priority objectives for 2030 and the conditions needed to achieve these. Growth will be regenerative, climate neutrality will be a reality, and inequalities will have been significantly reduced. Building on the **European Green Deal** [9], the action programme aims to speed up the transition to a climate-neutral, resource-efficient economy, recognizing that human well-being and prosperity depend on healthy ecosystems. The 8TH EAP forms the EU's basis for achieving the United Nation's 2030 Agenda and its Sustainable Development Goals. Among others, it highlights the need for: significantly decreasing the Union's material and consumption footprints; achieving environmental fairness; making use of economic and tax incentives to facilitate the sustainability transition; phasing out fossil fuel subsidies; harnessing the potential of digitalisation; ensuring that policy action is firmly anchored in latest science and knowledge.

The Eco-innovation Action Plan (EcoAP) COM(2011) 899 [10] was complemented by other Europe 2020 Flagship Initiatives. A major building block for the transition towards a green economy is the "Resource Efficient Europe" Flagship and its roadmap, creating and reinforcing demand for eco-innovation and related investment. The EcoAP focuses on boosting innovation that results in or aims at reducing pressures on the environment and on bridging the gap between innovation and the market. It takes further some actions identified in the Resource Efficiency Roadmap [11].

In 2020, the European Commission adopted a new **Circular Economy Action Plan** [12], that provides the measures throughout the product life cycle and aims to prepare European economy for a green future, strengthen competitiveness, while protecting the environment and give new rights to consumers. The Circular Economy Action Plan, part of the EU Industrial Strategy [13], presents measures to:

Make sustainable products the norm in the EU. Single use will be restricted, premature obsolescence tackled and the destruction of unsold durable goods banned.

Empower Consumers, they will have access to reliable information on issues such as the reparability and durability of products to help them make environmentally sustainable choices.

Focus on the sectors that use the most resources and where the potential for circularity is high. The Commission will launch concrete actions on electronics and ICT, **batteries and vehicles** (new regulatory framework for batteries for enhancing the sustainability and boosting the circular potential of batteries), packaging, plastics, textiles, construction and buildings, food.

Ensure less waste. The focus will be on avoiding waste altogether and transforming it into high-quality secondary resources that benefit from a well-functioning market for secondary raw materials.

In 2023, the European Council has adopted its position on the proposed regulation establishing a framework for setting **ecodesign requirements** for sustainable products [14]. The new regulation [15] will replace the existing 2009 Directive [16] and enlarge the scope to set environmental sustainability requirements for almost all kind of goods placed on the EU market. The current **Ecodesign Directive 2009/125/EC** has established energy efficiency requirements covering 31 product groups. According to the Commission's calculations, this saved EUR 120 billion in energy expenditure and led to a 10% lower annual energy consumption by the products under its scope. The new proposal builds on the existing Ecodesign Directive, but extends it to cover most categories of products (only exempting food, feed, medicine and veterinary products and motor vehicles) and will also include requirements such as product durability, reusability, upgradability, and reparability; presence of substances that inhibit circularity; energy and resource efficiency; recycled content, remanufacturing, and recycling; carbon and environmental footprints and information requirements, including a Digital Product Passport. In March 2022, the European Commission published proposals to extend the scope of eco-design regulations to all physical products on the EU market.

3. Eco-Innovation

3.1 Definitions and Approaches

The idea of eco-innovation is recent, one of the first appearances in the literature was in a 1996 book by Claude Fussler and Peter James [17], and since then definitions and approaches regarding eco-innovation have become intense. In 1997, Peter James defined eco-innovation as "new products and processes that provide customer and business value but significantly reduce environmental impact" [18]. Eco-innovation is defined by the European Commission as "any form of innovation that pursues significant and demonstrable progress towards the objective of sustainable development, by reducing the impact on the environment or achieving a more efficient and responsible use of resources, including both intentional and unintentional environmental impacts, the effects of innovation, as well as not only environmental technology, but also processes, systems and services." The Eco-Innovation Observatory, a three-year initiative funded by the European Commission, defines eco-innovation as: "any innovation that reduces the use of natural resources and lowers the release of harmful substances throughout the entire life cycle." [19].

Eco-innovation influences organizational and consumer practices, based on the basic principle of reducing environmental impact, seeking positive trade-offs between environmental attributes and critical factors in product and process development [20]. Eco-innovation practices have a positive influence on both sustainable performance and business performance in the automotive and auto parts industry [21].

Eco-innovation focuses on developing and implementing new technologies, methods, and practices that contribute to sustainability, resource efficiency, and environmental protection. The different types of eco-innovations can generally be grouped into three main categories: process, product and system innovations [22].

Eco-Innovative Products involves creating new or improved products that are environmentally friendly. These products are designed to have a reduced carbon footprint, consume fewer resources, or be made from recycled or biodegradable materials. Examples include electric vehicles, energy-efficient appliances, and sustainable packaging materials.

Eco-innovation in processes relates to finding new and more sustainable ways to carry out various industrial or business activities. It often involves optimizing resource use, minimizing waste generation, and reducing harmful emissions during manufacturing or production processes. Implementing renewable energy sources, adopting closed-loop production systems, and using water-saving techniques are all examples of eco-innovation in processes.

Organizational eco-innovations change the management or operational structure of a company or organization to promote sustainable practices. It can include adopting environmentally responsible policies, setting up green supply chains, encouraging employee engagement in eco-friendly initiatives, and integrating sustainability into the core values of the organization.

The key mechanisms in eco-innovation are: modification (small adjustments to products and processes); re-design(significant changes to existing products, processes and organisational structures); alternatives (introduction of goods and services that can be used as substitutes for other products); creation (design and introduction of new products, processes, procedures, institutions and organisations).

Eco-innovation is often related to environmental technologies, eco-efficiency, green design, sustainable design or sustainable innovation. While the term "environmental innovation" is used in contexts similar to "eco-innovation", the other terms are mostly used when referring to product or process design and when the focus is more on the technological aspects of eco-innovation than on societal and political aspects. Eco-innovation is also a key enabler in the transition towards Circular Economy and drives the transition towards a circular model by helping to change current business models through product and service design, reconfiguration of value chains, changing how citizens interact with products (ownership, lease, shared use, etc.), and improving value delivery in systems (ecological mobility, smart energy systems, etc.).

3.2 The Eco-innovation Dynamics in the Automotive Sector

The automotive sector is a case to discuss the formation of sectoral patterns of eco-innovation due to its role in modern societies, positively as main transportation choice but negatively due to its enormous costs in terms of environmental harm and intensive use of non-renewable resources. The green product innovations are related mainly to powertrain components that are easily distinguishable from “nongreen” ones.

The automotive value-chain has been dominated by relatively few OEMs, and the technological regime was introduction of incremental innovations (creative accumulation) based on a dominant-design characterized by three fundamental features: internal combustion engines (ICE); all-steel car bodies, multi-purpose character, and fully integrated productive processes. The automobile based on this dominant design became an essential part of modern society, not only because its transportation function but also economically. The performance of ICE has been improved for decades with the incremental development of many sub-systems such as fuel injection, engine cooling, lubrication, exhaustion, transmission etc., as well as other features like weight distribution and organization of the components.

With a growing concern for the environment and the need for sustainable transportation, the automotive industry is now focusing on eco-innovation, by which it tries to respond to the challenges facing the industry, such as rising fuel prices, unpredictable demand, supply chain challenges supply, and growing concerns about air pollution.

4. Eco-Design

4.1 Definitions and Approaches

Eco-design is defined as the integration of environmental aspects in the product design process during its life cycle (Directive 2009/125/EC).

Ecodesign is an approach to include environmental requirements into the product development process. It has the potential to contribute to reductions in greenhouse gas emissions, thus slowing down climate change [23] and can be applied with different goals depending on the product life-cycle stage which must be improved [24]. Eco-design key steps involve selection of low impact materials and reduction of material usage in the production process; product techniques and distribution process optimizations; reduction of product environmental impact while using it; new concept development, i.e., how product can be re-designed at the end of its life; optimization of initial lifetime and end of life considering ways of how the materials can be recovered or re-used [25].

Product design is of crucial importance in the circular economy, as proper design can conserve natural and unused resources, extend product life, and facilitate recycling and remanufacturing. It also sets the preconditions for achieving the full potential of the circular economy in other phases too – production, use and waste management. The implementation of circular economy principles in product design involves the following: the use of easily renewable resources; combining resources in a way that allows for easy separation; maximum efficiency in the use of resources; the minimum amount of waste generated; minimum amount of waste that cannot be reused; the use of waste generated in the remanufacturing process for identical or different products; maximizing the value offered by a product or service; sharing a product or service instead of buying it; the option to repair the product or return it to the market; recycling to bring resources back into the production process and create new values in the most efficient way; and networking between those who generate waste and those who use it as a resource [26].

4.2 Eco Design Strategies

There are many design for excellence - design for X (DfX) approaches, the rules from experience, life cycle thinking, and other potential design for environment (DfE) solutions [27, 28]. Besides environmental impact considerations, structural elements like modularity should be taken into account which has no effect on the environmental impact. Product structure is important for disassembly and in the end for the product lifetime. [29].

4.2.1 Vehicle Design for End-of-Life

The European End-of-life Vehicle Directive (DC, 2002) requires car manufacturers from 2002 onwards to take back all newly registered vehicles that require disposal. The main design consideration at this final stage is to ensure that, whatever disposal method is utilized, the materials in the product do not create a hazard, which means avoiding heavy metals and toxic substances. For example, vehicle airbags are powered by between 50 and 150 grams of sodium acid which converts in to harmless nitrogen gas on impact. The vehicle manufacturer should therefore ensure that the airbags are properly disposed before the vehicle is shredded [27].

4.2.2 Design for Durability

Designing products to last longer reduces both resource use and waste generation. Upgradeability or modular design is a form of product life extension. However, in some cases, if impacts from the complete product lifecycle are considered, increasing durability may have an adverse effect by reducing the adoption of more environmentally beneficial technology with, for example, increased energy efficiency or emission controls.

4.2.3 Design for Recyclability

The use of recycled material can reduce consumption of raw material, energy and water, as well as can reduce waste, consumption of virgin materials, air and water pollution, and energy consumption. Avoiding the mixing of materials in assemblies is one of the important rules of design for recyclability [27].

4.2.4 Design to Minimise Material Usage

Reducing the amount of material used over the product life cycle is an effective method of reducing environmental impact. This strategy can be applied in three areas: reducing the product's physical dimensions, weight reduction, and using alternative materials such as carbon fibre reinforced polymers for car bodies [27].

4.2.5 Selection and Application of Eco Materials

Eco materials have minimal impact on the environment but offer maximum performance for the required design task. Traditionally, designers select materials according to the materials' performance characteristics; physical, chemical and aesthetic properties, as well as by cost and availability. Eco materials and natural fibres are being investigated for automotive components with enhanced environmental performance and comparable technical and economic performance.

4.2.6 Design for Remanufacturing

Remanufacturing to bring components back to a performance level acceptable for reassembly allows materials to be reused in their best condition, thus preventing waste and reducing resource use.

4.2.7 Design for Disassembly

The advancement of automotive technologies towards electronification has created complications for dismantling and accessing parts [30]. The purpose of design for disassembly is to ensure that a product system can be disassembled at minimum cost and effort. Designing to allow disassembly with provision for replacement or reconditioning of worn parts can allow substantial savings, even when the costs of removing and returning the discarded part to the point of remanufacturing are included. Competitive alternatives in the automotive aftermarket are offered by third-party operators who have been remanufacturing auto parts such as alternators, starter motors and water pumps for many years [27].

4.2.8 Design for Energy Efficiency

A major source of environmental impact is the energy consumed by a product during its use. Apart from developing advanced lean-burn combustion systems to improve engine thermal efficiency, the applications of alternative lightweight materials in powertrains and vehicle structures are being investigated to improve fuel economy over the whole life cycle of the product. For example, using aluminium instead of steel in the chassis of a car will ensure greater fuel efficiency by reducing the total energy used over the life cycle of the car [27]. Some representative lightweight materials applicable for different components of automobiles, are light alloys (e.g., aluminum, magnesium, and titanium alloys), HSSs, composites (e.g., CFRP), and advanced materials (e.g., metamaterials). BMW, for example, have increased the proportion of plastics in their vehicle manufacturing to reduce weight and improve fuel economy [31].

4.2.9 Design for Sustainability

Design for high energy efficiency and low power consumption, ease of maintenance and ease of upgradability. The product should be designed with end-of-life in mind, a hierarchical focus on reusability, repurpose, recyclability and finally disposability of any non-recyclable elements. Minimization of impact on the environment through the manufacture of the product, component selection and the long-term operational and environmental resilience of the product [32]. Sustainability enables the application of circularity strategies to extend product life, including reuse, repair, reconditioning and remanufacturing. However, despite the growing trend in sustainability, there is no accurate tracking of the evolution, implementation and potential benefits from the product design stage.

4.3 Data and Digitization in Product Design and Development

The number of sensors and digital systems collecting data on automobiles are rapidly expanding, changing the transportation experience for passengers as well as for those at the controls. Technologies like artificial intelligence and machine learning are transforming the basics of how transportation equipment operates [33]. The customers, recognizing the possibilities, are demanding ever more customized vehicles and intelligent interfaces reflecting the most current capabilities [34]. The new components and technologies are also reshaping the way engineers design and develop the vehicle. These create opportunities that, when used to their full potential, substantially accelerate the incorporation of innovations – allowing manufacturers to better adapt to rapidly changing customer demands.

5. Innovative Environmental Technologies in Automotive Industry

Environmental technologies refer to process technologies (including energy conversion technologies) and measurement technologies used for environmental purposes (to measure pollution or to identify toxics). Some examples: pollution control technologies and cleaning technologies that treat pollution released into the environment; cleaner process technologies: new manufacturing processes that are less polluting and/or more resource-efficient; waste management equipment; environmental monitoring and instrumentation; green energy technologies. The automotive industry has developed a variety of green technologies to ensure sustainability and to lower the negative effects of the industry on the environment [35].

5.1 Green Technology from Tesla

Innovative green technology is associated with Tesla, which is the accelerating transition to sustainable energy. After launching the first electric car, Roadster, in 2008 [36], Tesla officially presented its cutting-edge battery technology and electric powertrain. Toyota Industries establishes on-board battery production line at its new Ishihama Plant, increasing production of bipolar nickel-hydrogen batteries for hybrid vehicles.

5.2 Bipolar Nickel-hydrogen Battery

Toyota Industries developed its **bipolar nickel-hydrogen battery** jointly with Toyota Motor Corporation and was used first in the world as the electric drive battery for electrified vehicles in the Toyota Aqua, launched in July 2021. In this **innovative battery**, a cathode is applied to one side of a metal component called a current collector and an anode to the other.

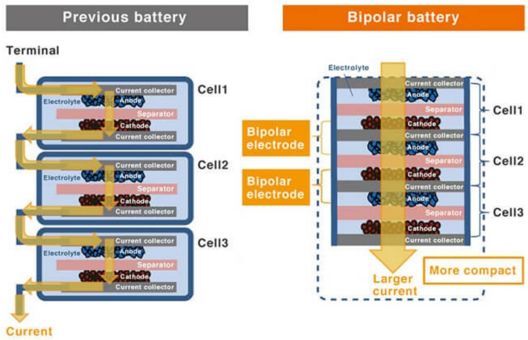

Figure 1: The bipolar nickel-hydrogen battery
[Source: https://www.toyota-industries.com/products/automobile/battery/]

Several of these structures, which are known as "bipolar electrodes," are stacked together to form a battery. By having cathode and anode together in the current collector, batteries can be made smaller as they require fewer parts. In addition, the wider electrical path and simple structure reduce resistance within the battery, allowing large currents to flow quickly. This means that they can produce higher outputs compared to conventional nickel-metal hydride batteries [37]. In bipolar nickel-hydrogen batteries, a cathode is applied to one side of a metal component called a current collector and an anode to the other; several of these structures, which are known as “bipolar electrodes,” are stacked together to form a battery. As the term “bipolar” indicates, the current collector can be shared by a cathode and an anode. This technique reduces the number of parts and thus enables the battery to be made more compact. It is also possible to stack a larger number of cells. In addition, since bipolar batteries have a wider electrical path and a simpler construction, there is lower resistance within the battery itself. This enables the flow of larger currents, achieving approximately twice the output of the conventional nickel-hydrogen battery equipped in the previous-generation Aqua.

5.3 Pioneering Use of Biosynthetic Rubber in Engine and Drive System Hoses

Toyota became the world's first automaker to use biohydrin rubber, jointly developed with Zeon Corporation and Sumitomo Riko Co., Ltd., in vacuum sensing hoses (engine and drive system hoses). Biohydrin rubber is manufactured using plant-derived bio-materials instead of epichlorohydrin, a commonly-used epoxy compound. Since plants absorb CO_2 from the atmosphere during their lifespan, such bio-materials achieve an estimated 20 percent reduction in material lifecycle carbon emissions compared to conventional petroleum-based hydrin rubber [38]. As biodiesel fuel is produced by chemical processing on oil palm, the raw material of palm oil, bio glycerin is generated as a by-product. Bio glycerin can be used to manufacture bio epichlorohydrin. (Roundtable on Sustainable Biomaterials certification as a plant-derived raw material has been confirmed.)

Figure 2: Toyota became the world's first automaker to use biohydrin rubber
[https://global.toyota/pages/global_toyota/sustainability/report/kururisa_en.pdf]

5.4 3D Printing for the Automotive Industry

Additive manufacturing is a specific 3D printing process. This process builds parts layer by layer by depositing material according to digital 3D design data, so that, instead of milling a workpiece from a solid block, additive manufacturing builds the part up layer by layer from material supplied as a fine powder. Various metals, plastics and composite materials can be used.

3D printing or additive manufacturing is a technology that has revolutionized the automotive industry. Significant advances in the field over the last decade have transformed the design, development, production and distribution processes in the sector. They have given way to new models, lighter and safer products, shorter delivery times and lower costs, increasing the functionality and value of existing products. The concept seems new, but it has been around for over 30 years. It involves a process in which the 3D design data described in a digital file is used to develop a component by depositing materials in layers. The materials used in 3D printing include a wide range of metals, plastics and composites [39].

Bugatti's eight-piston monobloc brake caliper is a key example. Bugatti favors titanium for certain components due to the material's high-performance characteristics but processing the metal with conventional methods is costly and challenging. The use of 3D printing not only enabled Bugatti to produce the caliper at the required scale but also took its performance potential even higher, massively reducing the weight of the component while making it considerably stiffer and stronger than the conventional production alternative (aluminum).

Figure 3: Bugatti's eight-piston monobloc brake caliper is the world's largest functional titanium 3D printed car part.
[https://www.bugatti.com/media/news/2018/world-premiere-brake-caliper-from-3-d-printer/]

Another example [40, 41] is the 3D printed **Czinger 21C**. In the next figure is represented a view inside the engine bay of the Czinger 21C, clearly showing how the potential of metal Additive Manufacturing has been heavily leveraged throughout the car, from the vehicle's chassis to brake, suspension and exhaust components.

Figure 4: View inside the engine bay of the Czinger 21C
[Source: Czinger Vehicles]

A great example is the 3D printed Light Cocoon by EDAG. This project started in 2015 and they successfully put together a few 3D printed concept cars [42].

Figure 5: The EDAG Light Cocoon
https://www.digitalengineering247.com/article/edags-light-cocoon-is-a-metamorphosis-for-car-design

It's impressive how light the car is. A thin layer covers the lattice-like skeleton of the car which is only possible with 3D printing technology. The EDAG Light Cocoon combines 3D printed vehicle structure with a weatherproof textile outer skin panel [43]. The current vehicle design and production model calls for cars to be developed with an outer metal structure that's integral to load-bearing requirements. Taking inspiration from natural elements like plant leaves, EDAG reimagined the relationship, bringing the functionality from the outer metal skin layer into a skeletal bone structure with the capacity to withstand forces. The Light Cocoon's design resulted in a spider-like, hollow structure that accommodates the assembly of aluminum profiles of different thicknesses. Stability requirements were met and the EDAG team achieved weight savings of approximately 25% thanks to the approach.

5.5 Mercedes-Benz AG for CO2-free Manufacturing Technology

Stuttgart, Germany, May 24, 2021 – Mercedes-Benz AG is the first automaker to take a stake in Swedish start-up H2 Green Steel (H2GS) as a way to introduce CO2-free steel into series production. Together with its steel suppliers, the company is restructuring its supply chain to focus on preventing and reducing CO_2 emissions rather than offsetting them. The partnership with HSGS is another step towards CO_2 neutrality, which Mercedes-Benz is pursuing as part of Ambition 2039, its goal of achieving a fully connected and CO2-neutral vehicle fleet in 2039 – 11 years earlier than the legislation requires EU [44]. By using a new, innovate manufacturing process, the production of steel at the supplier level is CO_2 free. By contrast, steel produced using a classic blast furnace emits an average of more than two tons of CO_2 per ton. In the new process, the supplier uses hydrogen and electricity from 100 % renewable energy sources instead of coking coal in steel production. The hydrogen serves as a reduction gas, which releases and binds the oxygen from the iron ore. Unlike the use of coking coal, this does not produce CO2, but water. The supplier uses electricity from 100% renewable sources for the energy requirements generated in the manufacturing process.

5.6 ŠKODA - Use of Renewable Raw Materials

ŠKODA, in collaboration with the Technical University of Liberec and the supplier, has developed a sustainable, ecological material made from sugar beet pulp which can be used in dyed form in the interior of vehicles to create certain design accents. In addition, ŠKODA is working on another material based on the miscanthus reed which will also be used in the interior of models in the future [45]. The use of rice husks, hemp, cork and coconut fibres is also being researched. ŠKODA is deploying used high-voltage batteries from electric vehicles in stationary energy storage systems before they are recycled. This second life cycle effectively reduces the batteries' CO2 footprint. The VW Group is investigating the use of other ecologically sourced materials, such as materials based on cellulose. One flagship project is cooperation with a recycling company. As part of this, a process has been developed to turn painted bumpers into granules. These can then be used for new bumpers.

5.7 AUDI's Sustenability

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

Audi and its suppliers managed to recover aluminium waste and bring it to the level of new product quality, thus avoiding, in 2019 alone, approximately 150,000 metric tons of CO_2 entering the the environmental balance sheet [46]. Audi and THINKTANK at KIT are working on a special method of recycling plastics used in the automotive industry that will create intelligent circular systems in supply chains and use resources efficiently [47]. Launch of the pilot project: chemical recycling enables the creation of a closed circuit for plastics in the automotive industry. Recycled plastic waste is turned into pyrolysis oil, which can then be used to create new components.

5.8 Ford' s Closed Loop

Ford has set an target of using 20% recycled and renewable plastics in new vehicle designs by 2025 at its factories in North America and Europe and a 10% target for its factories in China and Turkey. Ford also uses a closed-loop system to manufacture its F-series trucks and is the largest closed-loop aluminium recycling automaker in the world, according to its 2022 sustainability reports [48]. In the Integrated Sustainability and Financial Report, 2023 [49] FORD sets also the ambitious sustainability aspirations, as follows: achieve carbon neutrality no later than 2050, use 100 percent carbon-free electricity in all manufacturing by 2035, use only recycled or renewable content in vehicle plastics, attain zero emissions from our vehicles and facilities, make zero water withdrawals for manufacturing processes and use freshwater only for human consumption, reach true zero waste to landfill across the operations, eliminate single-use plastics from their operations by 2030.

5.9 BMW i Vision Circular

The BMW i Vision Circular is a vision vehicle from the automobile manufacturer BMW and gives a foretaste of the year 2040. The car was presented to the public at the IAA 2021.

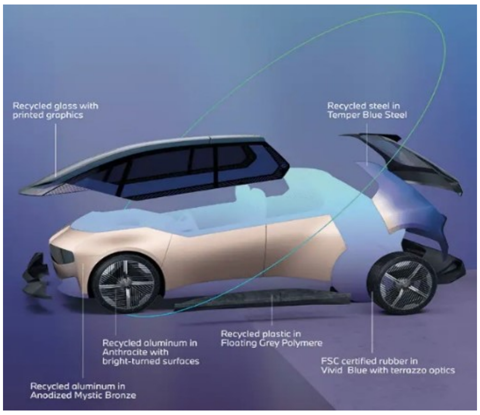

Figure 6: BMW i Vision Circular [https://www.bmw.com/en/events/iaa2021/bmw-i-vision-circular-domagoj-dukec-first-look.html]

The focus of this concept car is on sustainability and luxury. It consistently followed circular economy principles in its design with the intent to reduce CO2 emissions.

6. Conclusions

The automotive industry is one of the most important and rapidly growing sectors of the global economy and has been playing a vital role in shaping the future of transportation. Environmental protection is one of the basic pillars of the carmaker's sustainability and the automotive industry could shape this fundamental restructuring.

By fostering creativity and the adoption of more sustainable practices, eco-innovation contributes to the transition towards a greener economy and a more resilient and environmentally conscious society. Governments, businesses, and individuals all play essential roles in driving eco-innovation and creating a positive impact on the planet. Eco-innovation is also a key enabler in the transition towards Circular Economy and drives the transition towards a circular model. Product design is also of crucial importance in the circular economy, as proper design can conserve natural and unused resources, extend product life, and facilitate recycling and remanufacturing. It also sets the preconditions for achieving the full potential of the circular economy in other phases too – production, use and waste management. Eco-innovation is often related to environmental technologies, eco-efficiency, eco-design, sustainable design or sustainable innovation. Ecodesign and eco-innovation complement each other. Eco-design approaches support eco-innovation activities and help companies identify and reduce the negative environmental impact associated with their activities.

Leading car manufacturers are adopting responsible trends in the use of resources and permanently offer solutions for the implementation of sustainable strategies through eco-innovation and eco-design, applied both at the institutional scale, to production processes as well as to cars and subassemblies.

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